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Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors

November 2015

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EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments 2007 - 2013

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Romania Climate Change and Low Carbon Green Growth Program

Output C1.1
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THE WORLD BANK
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This report corresponds to “Output C1.1: Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors” in the Advisory Services Agreement on “Romania: Climate Change and Low Carbon Green Growth Program” signed between the Ministry of Environment and Climate Change[1] and the International Bank for Reconstruction and Development on July 23, 2013. This report includes seven sectoral technical reports:

1. Agriculture Sector Technical Report
2. Energy Sector Demand Technical Report: Long-Term End-Use Service Demand Analysis (ESDA) In Romania
3. Energy Sector Supply Technical Report: Achieving Mitigation of Emissions from Energy Supply using a TIMES-MARKAL Model for Romania
4. Forestry Sector Technical Report: Opportunities for Mitigation and Adaptation through Forests
5. Transport Sector Technical Report Urban Sector Technical Report: A Technical Assessment of the Energy and Emission Impacts of Alternative Development Patterns in the Bucharest-Ilfov Region
6. Urban Sector Technical Report: A Technical Assessment of the Energy and Emission Impacts of Alternative Development Patterns in the Bucharest-Ilfov Region
7. Water Sector Technical Report

[1] Now, Ministry of Environment, Waters and Forests

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AGRICULTURE SECTOR TECHNICAL REPORT

November 2015

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Contents

Abbreviations and Acronyms

ARD	Agriculture and Rural Development
CAP	EU Common Agricultural Policy
CCA	Climate Change Action
CH4	Methane
CO2	Carbon Dioxide
EAFRD	European Agricultural Fund for Rural Development
EC	European Commission
EIP	European Innovation Partnership
EPIC	Environmental Policy Integrated Climate (EPIC) Model
ESU	Economic Size Unit
EU	European Union
EU-15	The 15 Member States of the European Union prior to enlargement in 2004 and 2007
EU-27	The 27 Member States of the European Union (now actually 28 since Croatia acceded in July 2013)
GCM	Global Circulation model
GDP	Gross Domestic Product
GHG	Greenhouse gas
GVA	Gross Value Added
HNV	High Nature Value
ICAS	Institute of Forest Research and Management
ICPA	National Research and Development Institute for Soil Science, Agro-chemistry and Environment
INHGA	National Institute for Hydrology and Water Management
IPCC	Inter-governmental Panel on Climate Change
MECC	Ministry of Environment and Climate Change
MARD	Ministry of Agriculture and Rural Development
N	Nitrogen
N2O	Nitrous Oxide
NIS	National Institute of Statistics
NMA	National Meteorological Administration
NMS	New Member States
NRDP	National Rural Development Program
RAS	Reimbursable Advisory Service
UAA	Utilized Agricultural Area
WUO	Water User Organization

AGRICULTURE SECTOR

A. Sector Background

1. **Agriculture plays an important role in the Romanian economy, but in spite of its considerable potential, productivity lags behind EU average.** Romania is among the best endowed European countries in terms of its agricultural land, fertile *chernozem* soils and water resources. Agricultural land occupies almost 62% of Romania's total area and nearly two-thirds of the 13.3 million hectares are considered as highly-productive arable land mainly used for maize and wheat production[2]. But average crop yields in Romania are 30-50% lower than the EU average, pointing to a much less than optimal use of these production factors. While agriculture has been traditionally the backbone of the Romanian economy, the share of agriculture in the total gross value added (GVA) decreased over the last decade by more than 50%, due to growth of other sectors. But the Romanian primary sector still has a share of 6% of GVA, which places agriculture far ahead of the other EU member states, averaging 1.8% (Figure 1)[3]. With a total agricultural output of Euro 15.48 billion in 2014, Romania ranks eighth in the European Union[4]. While on average, 52% of the EU member states agricultural output derives from crop production and 43% from livestock production, Romania ranks first in the EU-28 with 73% share of the agriculture output deriving from crop production.

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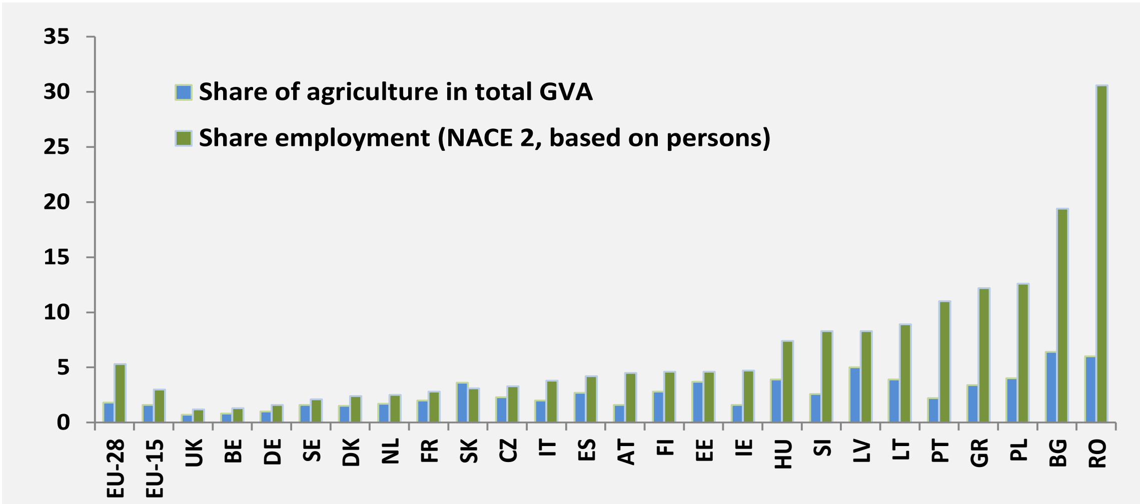
[2] Eurostat. Agricultural Census 2010.

[3] Gross Value Added (GVA) is a baseline context indicator for the structure of the economy that is calculated by Eurostat for all EU Member States - it is defined as the value of output (at basic prices) less the value of intermediate consumption (at purchasers prices)

[4] Eurostat. Agriculture, forestry and fishery statistics. 2014 edition.

Figure 1: Importance of agriculture in the Romanian economy (percentage in total GVA and percentage in total employment, by NACE categories, 2012)



Source: ARD Strategy, using data from Eurostat

2. **The Romanian agricultural sector has more weight within the EU because of its size of the rural population and contribution to the overall workforce.** With over 45% of Romania's population living in rural areas (compared to 24% in the other EU member states), nearly half of the population plays a vital role for maintaining Romania's rich biodiversity and ensuring sustainable management of natural resources[5]. Still, more than 70% of Romania's poor live in rural areas, as the high share of the population living in rural areas, contribute relatively little to economic growth. While the agriculture share in total employment dropped by over 25% in the last decade, agricultural employment still constitutes 28.6% of Romania's total employment (Figure 1), compared to an average of 5.3% in the EU-28. Benchmarking also shows that the labor productivity in Romanian agriculture is the second lowest in the EU. The Romanian labor productivity per full time equivalent in farming is four times lower than the EU-28 average.

3. **Romania also stands out by its high number of agriculture holdings and unique dualistic farm structures.** Romania accounts for over 30.3% of the EU total 12.2 million farms, and with 3.4 ha, has the lowest average farm size in the EU, only ahead of Malta and Cyprus[6]. Among all EU member states, Romania suffers from one of the most pronounced structural divisions and also stands out with the missing the "golden middle". Following the collapse of the socialist regime and the redistribution of agriculture land, more than 93% of the 3.7 million Romanian holdings are still engaged in (semi-)subsistence farming, which manage just over 40% of the utilized agriculture area (UAA)[7]. While less than 0.4% of the Romanian agriculture holdings are

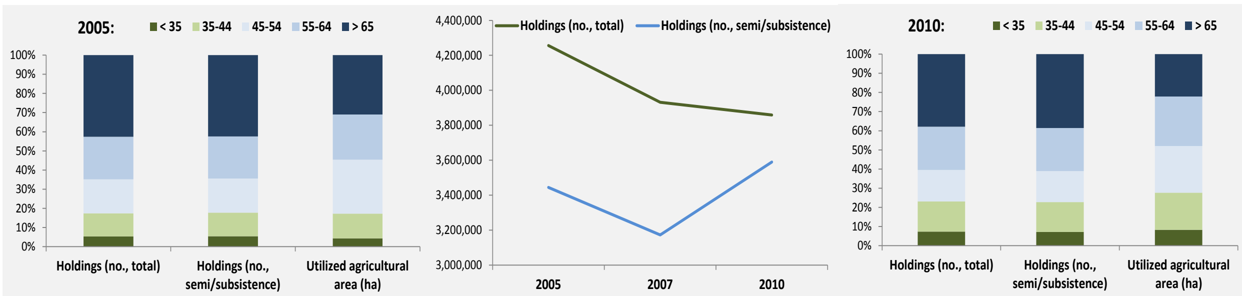
[5] Romania: Reviving Romania's Growth and Convergence Challenges and Opportunities. A Country Economic Memorandum. World Bank. 2013.

[6] Eurostat. Agriculture, forestry and fishery statistics. 2014 edition.

[7] Eurostat. Agriculture, forestry and fishery statistics. 2014 edition.

categorized as large-scale commercial units averaging over 421 ha. These farms manage nearly half of the utilized agriculture area.

Figure 2: Farm structure and land utilization in Romania by age of holder (2005 - 2010)



Source: ARD Strategy, using data from Eurostat

4. **The ageing farm population and emigration of the younger generation could lead to a significant demographic shift in the next 15 years.** Today, already 40% of the farm population is 65 and older and by 2030, this share will grow to 60% (Figure 2). Even though the population density in rural areas is 71.6 inhabitants / km^2, compared to 48.3 inhabitants / km^2 in the EU-28, At the same time it is estimated (2011) that the population of rural areas in Romania is declining by an average of 4.5% / year with population declines in individual counties varying from 1.0 - 11.6% / year[8]. Within the next 15-20 years, over 2 million Romanian farmers managing 75% of the utilized agricultural area will be subject to inter-generational transfer. Considering the high rate of depopulation from rural areas and overall emigration by the younger generation, the gradual departure of retiring farmers could accelerate the transformational process leading to more market viable farms. As larger agriculture holdings have better access to public support schemes and also to capital, this demographic shift should promote much needed investments for modernizing the Romanian agriculture sector.

5. **Managing the demographic transition without jeopardizing the agricultural productive potential and ensuring social equity will be key concern for policy-makers in decades to come.** Policy-makers are challenged by ensuring a smooth transfer of farm assets, expanding opportunities for in-coming young farmers, and providing viable and equitable options for retiring/departing farmers. Effective policies will be essential to address the risk of land abandonment and counter further land fragmentation. The incomplete land reform is a major hindrance and transaction costs for land registration an almost impossible hurdle to overcome. Policy-makers will be challenged to tailor the various instruments under the Common Agricultural Policy (CAP), as to promote the transformational process without negative social impacts.

6. **Romania's agriculture political agenda is mainly driven by the Common Agricultural Policy (CAP) of the EU, as its accession opened tremendous financial opportunities for the**

[8] National Institute of Statistics. Statistical Yearbook 2011. http://www.insse.ro/cms/files/Annuar%20statistic/14/14%20Agricultura%20silvicultura_ro.pdf.

Romanian ARD sector. During the first programming cycle of implementing the EU Common Agricultural Policy (CAP), Romania was entitled to receive Euro 13.7 billion, of which Euro 5.6 billion were primarily used to support farmers by means of direct payments (Pillar I of CAP) and Euro 8.1 billion Euro for the co-financed national rural development program (NRDP 2007-13). For the current programming cycle 2014-20, the financial allocation increased to Euro 19.8 billion (2011 constant prices)[9].

7. **The CAP provides an ideal framework mainstreaming climate change mitigation and adaptation activities, but the structural duality in Romanian agriculture also mirrors the distribution of direct payments.** Following the most recent reform of the CAP 2013, climate change mitigation and adaptation has become one of the cross-cutting objectives to be pursued horizontally by all member states through all agricultural support measures. The new direct payment scheme under Pillar I of the CAP obliges member states to spend a minimum of 30% of their national envelope for "greening" activities and within for rural development measures (Pillar II of the CAP), Romania also has to earmark minimum 30% of their expenditure on measures that help curb GHG emissions and adapt to climate change[10]. The National Rural Development Program (NRDP 2014-20) was approved by the European Commission in June 2015. While addressing its environmental challenges, Romania needs to take full account of the financial opportunities by the CAP. But due to the weight of subsistence farming and stringent eligibility criteria (minimum size of farm is 1 ha or minimum size of crop parcel is 0.3 ha), over 70% of the farms do not qualify for direct payments[11]. Furthermore, of those who do qualify, 99% secured only 46% of the national financial envelope. While direct payments under Pillar I favor larger commercial farms, the support schemes under the NRDP (Pillar II) are more oriented towards the smaller- and medium-sized producers.

8. **The National Rural Development Program 2014-20 is a comprehensive suite of mitigation and adaptation measures eligible for co-financing under the European Agricultural Fund for Rural Development (EAFRD).** The main entry point for climate actions in the NRDP 2014-20 is under priority 5 of the new EU rural development regulation, namely "*promoting resource efficiency and supporting the shift towards a low carbon and climate resilient economy in the agriculture, food and forestry sectors*". But since climate change mitigation and adaptation are also cross-cutting objectives for the EAFRD, climate actions should also be introduced under other priorities.

[9] European Commission. Multiannual Financial Framework 2014-20.

[10] European Commission. Overview of CAP Reform 2014-20. December 2013.

[11] Out of 3.7 million farmers, only about 1.1 million were registered with the Paying and Intervention Agency in Agriculture (APIA) in 2010.

B. Impact of Climate Change

9. Climate change will be the greatest environmental factor affecting future agriculture and the farming sector is one of the most vulnerable sectors in the Romanian economy. Although Romania is one of the best-endowed European countries in terms of the resources, its agricultural production is heavily dependent on the climatic conditions during the vegetation period of the crops. The annual average temperature is projected to rise by up to 1,5^{o}C in the next 15 years and by the end of the century, the temperature is expected to rise up to 5,0^{o}C while the total amount in mean annual precipitation is projected to decrease by 10-20%[12]. The impacts of climate change may be positive or negative, but those currently encountered by the agriculture sector in Romania are predominantly negative, leading from increased incidences of floods, more frequent and longer sustaining droughts, to increased risk of soil erosion and desertification.

10. The impact of climate change on the Romanian agriculture and rural development sector is particularly crucial, as the majority of rural population depends on agriculture either directly or indirectly on agriculture for their livelihoods. The agriculture and rural development sector is highly vulnerable to the impacts of climate change, as provider of adequate food, deliver ecosystem services, support economic growth, and provide safe living environment for rural communities. It is evident that climate change will have an impact on the whole agriculture sector and on the individual household. With agriculture contributing to nearly 30% of the total workforce and the vulnerability of the sector, it is expected that the livelihoods of many people living in rural Romania will be increasingly affected by climate conditions.

11. The extent of vulnerability also depends on the dualistic farm structures, as large-scale commercial holdings facing different challenges from climate change compared to the very small-scale subsistence farmers. It is expected that climate change will have impact on the aggregated agriculture and individual farmers in the south and south-eastern region of Romania. As large-scale farms commonly have very specialized production, like cereals and oilseeds, they are highly vulnerable to the impact of frequent and long periods of drought, which impact crop yields and farm profits. But they are well-informed professionals with good technical and financial resources and have a good capacity and many options to adapt their farming systems, which help them better adapt by means of new technologies and use of irrigation. Small-scale subsistence farmers are socially and economically very vulnerable to adverse climate events with farming directly engaging around one-third of the working population. In some cases individual farmers are also highly specialized in the production of specific crops, such as onions or potatoes, which further increases their vulnerability. In other cases some intrinsic resilience can be found within communities of small farmers due to their low inputs and recycling of resources, existing

[12] European Commission. Agriculture and climate change. http://ec.europa.eu/agriculture/climate-change/index_en.htm

low carbon economies, diversity of production, strong social relations and (in some regions) alternative sources of off-farm income. The resilience and adaptive capacity of these more diverse communities has the potential to be further developed if obstacles such as low educational standards, geographical / social isolation and lack of access to investment capital can be overcome.

12. The vulnerability of Romanian agriculture to climate change is strengthened by lacking agricultural extension and inadequate information flow from results of research. The dissolution of the National Agency for Agricultural Consultancy (ANCA) has disabled the effective delivery of advisory services. This deprived the ARD administration of its most important information dissemination instrument, while farmers lost access to knowledge and support services. Especially the subsistence farmers should be object of policy focus that entitles their fullest attention and continuous communication. In addition, farmers benefit only marginally from the results of research, due to deficiencies in advisory services, which increases their vulnerability. One response by government has been the county chambers of agriculture, coordinated by MARD, and local centers for agricultural consultancy which provide some training and information programs for producers.[13]

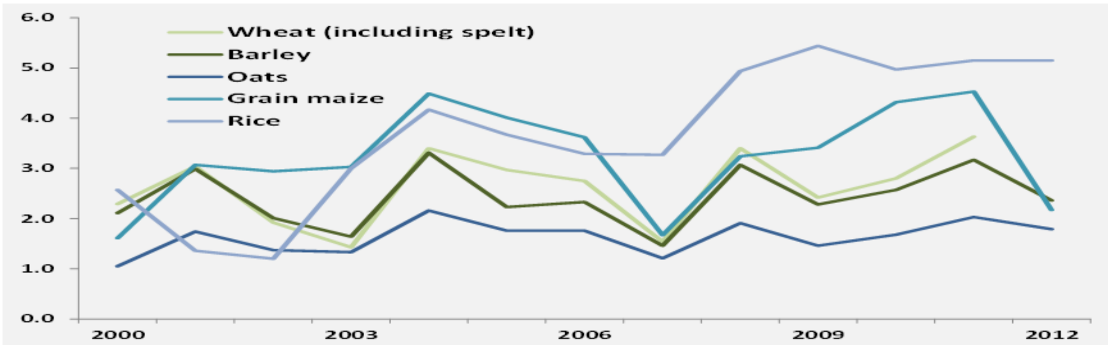
13. The crops that experience the most severe impacts are typically rain-fed crops grown in the traditional summer season, such as maize, sunflower, fruits and vegetables. For maize, Romania could see a 9% decrease in its maize output by 2030 under the above temperature and precipitation projections[14]. For sunflower, Romania should expect a decrease in its total sunflower production of about 14% by 2030. On the other hand, some crops may benefit from the direct effects of climate change (as well as elevated CO_2 levels) – notably those that will benefit from a longer, warmer growing seasons such as autumn-sown winter wheat or pastures (grassland respectively fodder). Romanian wheat could be positively affected from climate change, as a 7% increase of the wheat production is projected. Overall, the potential impacts of

[13] In accordance with the legal framework on the organization and operation of the county chambers of agriculture (CCA), there are 31 CCAs subordinated to the County Councils which are being coordinated from the technical and methodological perspective by MARD. At the same time, there are 500 local centers for agricultural consultancy which are subordinated to the county chambers of agriculture. The general objectives of the activity consists of ensuring the consultancy capacity of the farmers, especially for the subsistence farms, young farmers, small and medium farms. The specific objectives focus on developing training and vocational training programs designed for agricultural producers in accordance with the EU requirements and norms, as well as in accordance with the priority objectives of MARD on the development of agriculture for the medium and long term; promoting the programs and measures of financial support from European and national sources granted to agricultural producers; organizing an efficient information system based on free of charge promotional activities for agricultural producers (fairs, exhibitions, competitions, festivals, symposiums, debates, meetings, round tables, radio-TV shows), specialized technical assistance, development, editing, multiplication and distribution of specialized materials (guidelines, fliers, brochures, posters, etc.) with useful information for the aforementioned.

[14] European Commission – Joint Research Center. Assessing Agriculture Vulnerabilities for the design of Effective Measures for Adaptation to Climate Change (AVEMAC Project). 2012.

climate change in Romania are likely to increase the risk of crop failure and reduce the financial security of farmers in many areas, especially the south and south-east of the country.

Figure 3: Yields of main cereals in Romania in 2000-12 (tons/ha)



Source: ARD Strategy, using data from Eurostat

14. Agriculture productivity is closely tied to climatic adverse events like droughts and floods, making this sector to one of the most climate-sensitive of the economy. While vagaries of the weather, like droughts, may last few weeks or several months, they affect the outcomes of the entire agricultural production year. The crop year 2007 was considered one of the driest years in Romanian agriculture, leading to one of the lowest performances compared to 2011 (Figures 3). In 2011, average yields were 1.5-3 times higher compared to 2007. Flooding is another recurring problem affecting Romanian agriculture. Be it after snow melt or heavy torrential rains, the number of floods has increased over the last few decades due to climate change.

15. From 1980 to 2011, Romania suffered average annual weather related losses of $US 8,452 million, or 0.26% of GDP, of which 34% was linked to drought.[15] Climate modeling suggests that such trends will increase in the future. The warmer, drier and more variable climate and a higher likelihood of extreme events will seriously affect the sector. During the last 20 years the occurrence of severe floods increased and the projections show that this trend will continue into the future, as a result of climate change. An additional factor of flooding in Romania is the over-exploitation of forests and modification of local hydrology. The impact of flooding is exacerbated by the lack of a modern and well-maintained flood prevention infrastructure. Increased intensity and frequency of drought, which comes as a result of a combined effect of reduced precipitation and rising temperatures, especially in the south and south-east of the country. Since 1901, Romania has seen one to four extremely droughty and/or extremely rainy

[15] McCallum *et al.,* 2013.

years in each decade, but the number of droughts has been increasing after 1981. Within 12 years 2000-12, there were 6 years with a large rainfall deficit and a significant drop in crop yields due to drought.

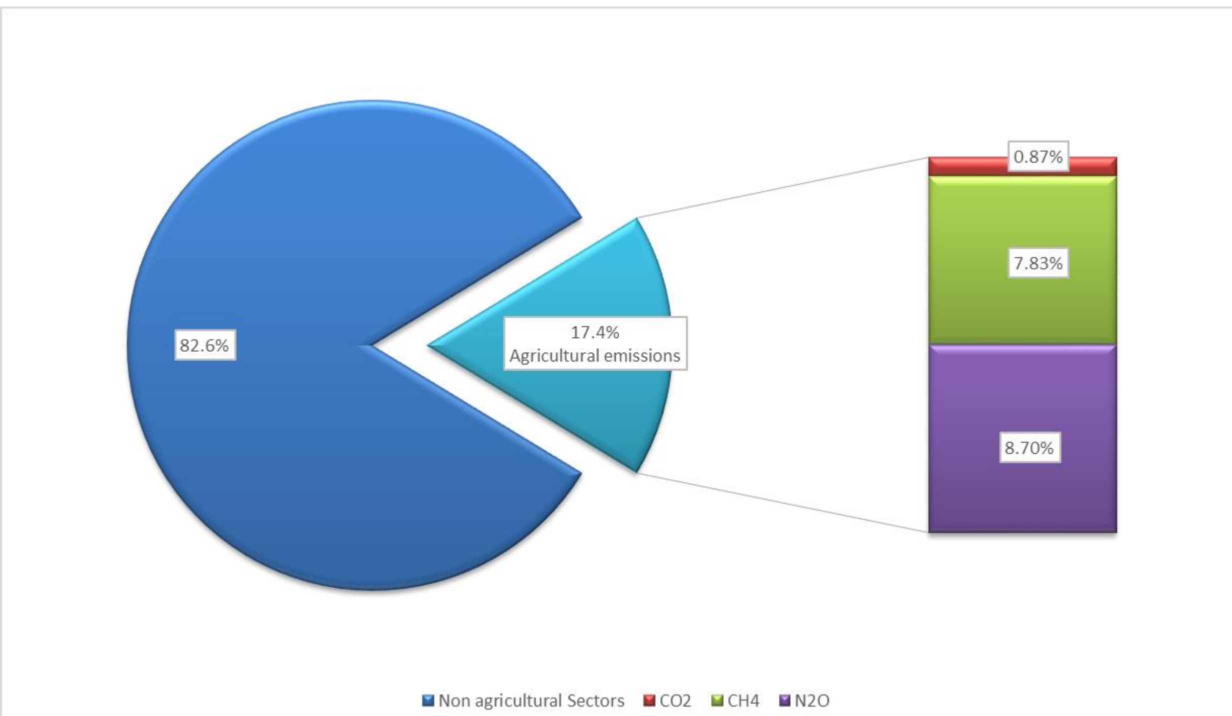
Box 1. The impacts of climate change on the Romanian agriculture sector are projected to include:

- **Damage to land and infrastructure due to the increased incidence of flooding:** an estimated 1.3 million hectares of land are at risk. In 2005-10, there was a total of €6 billion loss from damages to real estate, land and roads with 27,000 houses affected, thousands of km of national roads destroyed, and hundreds of thousands of hectares of land inundated.
- **Soil erosion and degradation** will come as a result of more frequent and intense drought, as well as of intense rainfall. Draught, together with hot winds, will increase soil evaporation and create a risk of soil degradation, marginalization and abandonment of agricultural land in the areas where soils are most light and vulnerable to erosion, particularly in the south, south-east and east of Romania. Increased incidence of heavy rain storms, with high intensity and short duration, will generate increased short-term surface runoff and the risk of increased soil erosion by water on sloping land - particularly in areas with the most vulnerable soil types.
- **Yields of grain and other crops are projected to decrease** across the southern and south eastern part of Romania due to increased frequency of drought. Perennial crops (orchards and vineyards) are also very vulnerable with partial or total loss of crop and premature ageing of plantations.
- **The productivity, conception rates and health of farm animals will decrease** as a result of the increased heat stress, water shortage, and a reduction in grassland / forage productivity (due to drought).
- **The productivity of the small scale hydro plants**, which generate 36 percent of electricity in rural areas, will be negatively affected by drought and declining river flows.
- **Water supply will be further decreased by the lowering of the groundwater table in the summer**, due to reductions in the surface flow regime.
- **The demand for irrigation water will further increase** due to higher summer temperatures and the subsequent evapotranspiration.
- **More frequent forest fires** will become a new risk due to the drought; this will negatively impact the availability of wood for fuel and construction;
- **The quality of rural roads will further deteriorate** with the heavier rainfall and flooding; this will affect dirt and gravel roads more than the paved ones.
- **Ecosystems' capacity to deliver essential services**, such as climate regulation, food, clean air and water, and to control the floods or erosion will deteriorate.

C. Challenges of Adaptation and Mitigation

16. Romanian agriculture is not emission-intensive, even though it is a significant contributor to overall GHG emissions. Romania's contribution to global emissions is insignificant: its share of the world's GHG-emissions amounts to only 0.3% and it is responsible for less than 3% of the EU overall emissions. With 17.4% of the total GHG emissions in 2012, the agricultural sector is the third biggest source from the Romanian economy, and this percentage exceeds regional and EU-28 averages (10%)[16]. But the relative high contribution of agriculture to the overall GHG-emissions of Romania is based on other industries of the economy, which release less emissions compared to the EU-28 average. The type and significance of agricultural emissions are closely connected with farm management of soils, livestock numbers and farming practices of biomass. For Romania, the main agricultural sources of GHG-emissions are nitrous oxide (N_2O) based on soil nitrification and manure management, methane (CH_4) from enteric fermentation by ruminants, above all cattle, and carbon dioxide (CO_2) from energy/fuel used in buildings and machinery. 50% of the agricultural emissions are nitrous oxide followed by 45% methane and just 5% based on carbon dioxide (Figure 4).

Figure 4: Breakdown of GHG emissions from Romanian agriculture

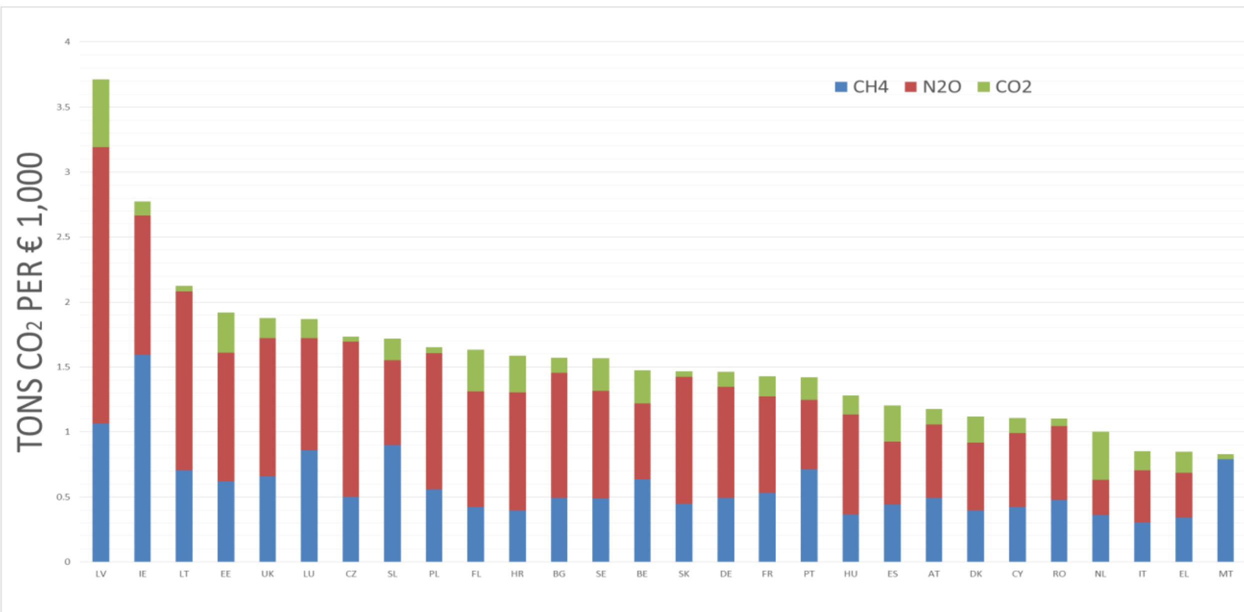


[16] Eurostat. Agriculture – greenhouse gas emission statistics. October 2013.

Source: European Environmental Agency

17. The emission intensity of Romanian agriculture (Mt CO_2 equivalence per 1,000 Euro of agriculture value added) belongs to the lowest within the EU-28. Within the EU-28, Romania produces the fifth lowest GHG emissions in percentage to the agriculture output (Figure 5), both overall and by its major components – methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). This is mainly based on the high share in subsistence farming following the redistribution of farmland and ownership after the collapse of the socialistic regime. Due to financial constraints, these subsistence farmers are challenged in their effort in mechanization. But also, due to low share of livestock production, reduced area of rice cultivation (both sources for CH_4), and the minimal use of inorganic nitrogen fertilizers, hamper chances to increase productivity in agriculture.

Figure 5: GHG emissions from agriculture as percent of agriculture value added



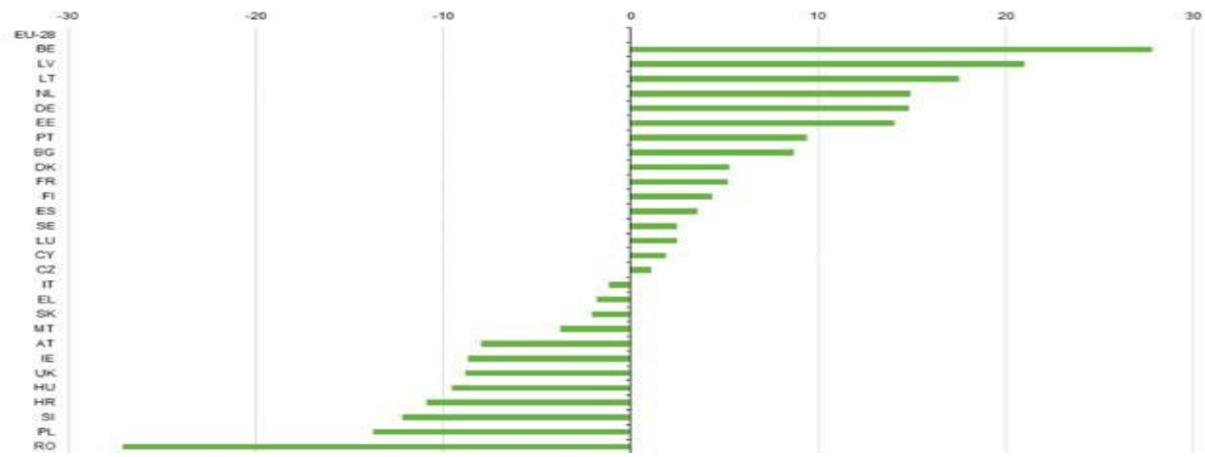
Source: World Bank own calculations using data from European Environmental Agency and Eurostat

18. Within the EU, Romania recorded the largest overall decline in agricultural GHG-emissions over the period 1990 to 2011. While the GHG-emissions from agriculture in the EU-28 have declined by nearly 25% since 1990[17], the agriculture sector reduced its emissions faster than

[17] Eurostat. Agriculture - greenhouse gas emission statistics. October 2013.

overall GHG-emissions. The reduction in agriculture emissions within the EU-28 is mainly attributed to reduction in livestock numbers, improvements in good farming practices, decreased application of nitrogen-based fertilizers as well as, improvements in manure management. During the timeframe 1990 to 2011, Romania recorded the highest decrease in agriculture emissions within the EU (Figure 6). While the animal output still contributed with 44% to the overall agricultural production 15 years ago, the collapse of the socialist regime and challenges in complying with EU standards have impacted the Romanian livestock sector. While GHG emissions from agriculture have dropped by over 53% since 1989, the correlation between the decline of the livestock sector and development of GHG emissions has stopped and the levels of GHG emissions have stagnated since the mid-nineties.

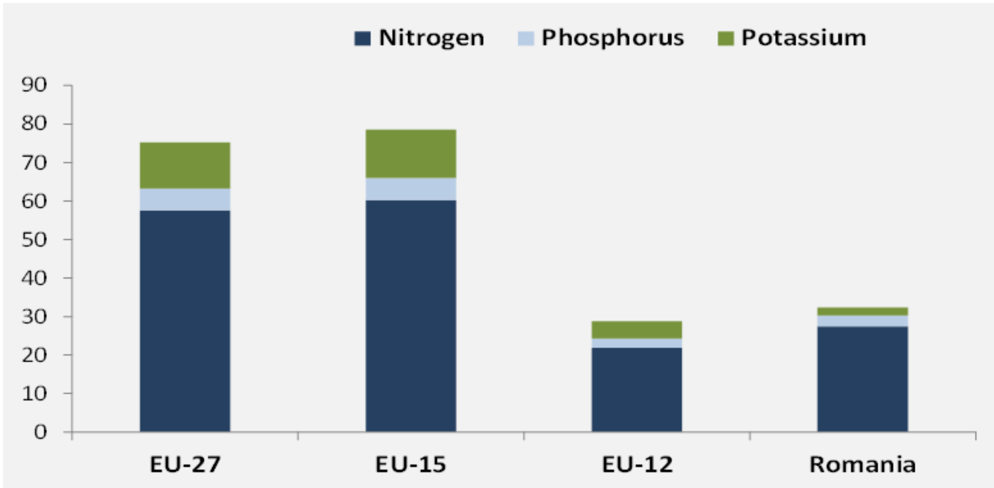
Figure 6: Change in aggregated emissions of methane and nitrous oxide from agriculture (1990-2011)



Source: European Environmental Agency

19. Romania's green growth agenda is also challenged by the worsening of soil degradation and water quality. Benchmarking shows that soil degradation and water quality in Romania is worse compared to the EU-28, and due to the poor quality in soil, expressed in nitrogen, has even led to a deficit several years back and seriously affect agricultural productivity. Although Romania uses low levels of manufactured fertilizers compared to the EU-28, the appearances of nitrates in groundwater is a serious environmental concern (Figure 7). Romanian farmers rely heavily on organic fertilizers, of which the majority derives from individual households. Improper animal waste management, mainly in subsistence farms, coupled with sparse wastewater treatment stations in rural municipalities contribute to this environmental impact. Under the NRDP 2014-20, measures for modern manure management practices (i.e. capturing, storing, treating and applying) are financially supported and could contribute significantly decrease the environmental impact.

Figure 7: Use of manufactured fertilizers in Romania compared to the EU (kg/ha of UAA)

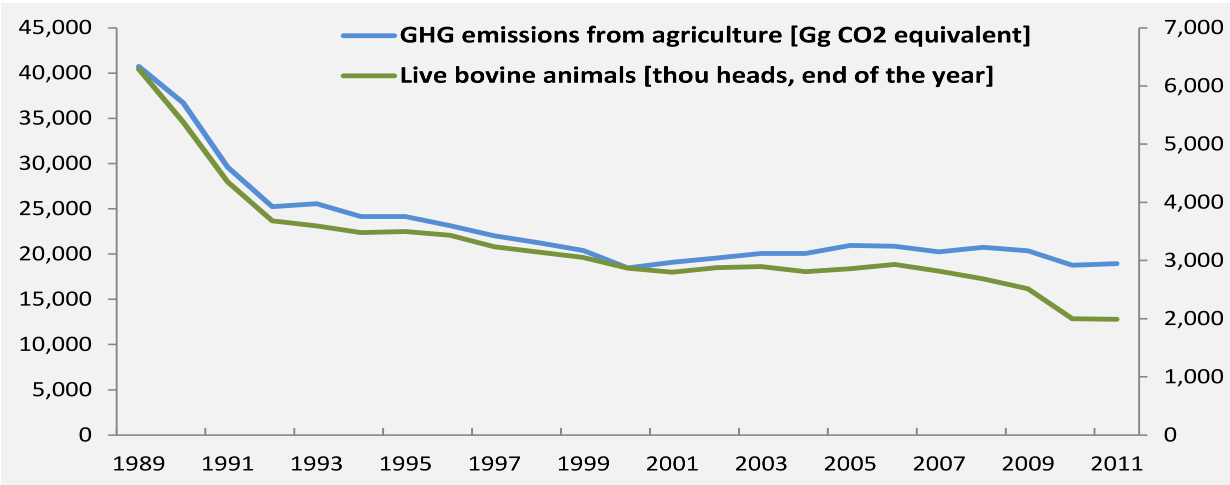


Source: ARD Strategy, using data from Eurostat (2011)

20. Decreasing livestock numbers show strong correlation with reductions in agricultural GHG-emissions. While GHG emissions from agriculture have dropped by over 53% since 1989, there had been a strong correlation between the decline of the livestock numbers and development of GHG emissions (Figure 8). This decline in livestock numbers can be explained by the on-going transformational process promoting the dualistic farm structures, as traditionally the livestock farmers had been middle-sized holdings, a farm-size category, which is continuously depleting. In addition and especially since accession to the EU, the meat industry has declined due to challenges complying with EU hygiene standards. Following the projections by the National Research and Development Institute for Soil Sciences, the cattle numbers will continue to decline for the next 10 years, while the other ruminants (sheep and goat herds) have recovered from their all-time low in 2005 and are slowly picking up again[18]. So, even though livestock numbers are projected to continue falling during the next decade, this stagnation in the correlation (Figure 8) also highlights the realistic scenario that agricultural GHG emissions will increase again, as the Ministry of Agriculture and Rural Development's vision for a competitive, export-driven, climate-resilient agriculture is fully implemented and thereby the farming economy improves, especially livestock number increase and crop production becomes more intensive again. But changes in feed could counteract growing livestock numbers in the future.

[18] Expert opinion of Dr. Catalin Simota,.National Research and Development Institute for Soil Science, Agro-chemistry and Environment, Bucharest, Romania.

Figure 8: GHG emissions from agriculture and evolution of animal stock (1989-2011)



Source: ARD Strategy, using data from Eurostat

21. The agriculture sector in Romania has made advances towards reducing its carbon footprint over the last decades, however improvements in the agricultural economy and intensification of the sector are likely to lead to a turnaround. Romania's demographic shift will be the factor with the most impact for greener growth. Within the next 15-20 years, over 2 million Romanian farmers, which manage 75% of the utilized agricultural area (UAA) will be subject to inter-generational transfer, based on the current age-structure. Considering the high rate of depopulation of rural areas and overall emigration by the younger generation, the gradual exit of elderly farmers for the agriculture sector the demographic shift could lead to an acceleration of more market viable farms. As these larger entities have the ability to better absorb funds from the Common Agriculture Policy (CAP), the availability of capital will promote much needed investments for modern farming practices. Overall, the financial liquidity and profitability of larger farms has improved their access to financial resources in the last decade, and due to this demographic shift, is expected to continue and increase. Increased access to capital will lead to increased investment in machinery, improved farming practices and above all, higher productivity. By means of land consolidation, farmers will also have more access to financial resources, as to modernize agricultural holdings, which should have a positive impact on mainstreaming climate change mitigation and adaptation activities.[19]

[19] McCallum, S., Dworak, T., Prutsch, A., *et. al.* (2013): Support to the development of the EU Strategy for Adaptation to Climate Change: Background report to the Impact Assessment, Part I Problem definition, policy context and assessment of policy options. Environment Agency Austria, Vienna.
http://ec.europa.eu/clima/policies/adaptation/what/docs/background_report_part1_en.pdf.

22. Irrigation infrastructure is old and only infrastructure owned by the water users' organizations (WUO) were recently partially rehabilitated. The irrigation infrastructure was built in the pre-transition years for the non-market rural economy based on large state owned farms and is not fully relevant for today's irrigation demand and farm structure. Irrigated area has declined since the collapse of the socialist regime from 3.2 million ha, in particular due to much higher prices charged to farmers for electricity and for irrigation. Today, around 1.5 million ha (11.3% of the total UAA) is covered theoretically with economically-viable irrigation infrastructure but only 820,000 ha are currently functioning. Since most irrigation in Romania is supplementary, the actual uptake in irrigation varies from year to year depending upon not only annual rainfall is dependable not only on many factors. Following cuts in subsidies in 2010, the irrigated area dropped from 294,000 ha to 75,000 ha. A governmental emergency decree in 2013, led to an increase of irrigated area to 180,900 ha.[20] The main challenges of irrigation lie in the electricity costs for pumping water from the Danube River, high water tariffs, and low hydraulic efficiency. The affordability of irrigation favors mainly large commercial farmers and is financially less attractive for small farmers. While the current draft NRDP 2014-20 earmarks Euro 400 million to support "off-farm" investments in irrigation infrastructure, policy reforms are needed to develop programs which will be evaluated against EU standards for programming and prioritization.[21],[22]

23. **The EU Common Agricultural Policy (CAP) plays an important role in supporting appropriate climate actions in the Romanian agriculture and rural development sector.** Following the most recent reform of the CAP in 2013, climate change mitigation and adaptation has become one of the cross-cutting objectives of the new CAP to be pursued horizontally through both pillars of the CAP. 30% of the financial envelope for direct payments within Pillar I will be linked to "greening activities" (crop diversification, maintaining permanent grassland and maintaining of ecological focus areas), which are all relevant to climate action. In addition, in its new rural development policy, two out the six rural development priorities and minimum 30% of the funding for the National Rural Development Program (NRDP) 2014-20 is also earmarked for climate change mitigation and adaptation, as well as, land management activities. The current draft NRDP 2014-20 includes a series of measures and criteria to limit or help reduce GHG emissions, like afforestation, no tillage, crop rotation, manure management (incl. composting

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[20] Government Emergency Ordinance No.79/2013 by means of which the National Agency for Land Improvements (NALI) and the organizations and federations of the users of water for irrigations (OUAI/FOUAI) can carry supply electricity in accordance with the legal provisions in force.

[21] McCallum, S., Dworak, T., Prutsch, A., *et. al.* (2013): Support to the development of the EU Strategy for Adaptation to Climate Change: Background report to the Impact Assessment, Part I – Problem definition, policy context and assessment of policy options. Environment Agency Austria, Vienna.
http://ec.europa.eu/clima/policies/adaptation/what/docs/background_report_part1_en.pdf.

[22] Measure 4.3 for off-farm investment support. Information provided by MARD Managing Authority, DG Mihai Herciu. February 2015.

and storage), organic farming, and the promotion of renewable energy sources. In addition, financial support for the rehabilitation of irrigation infrastructure and risk management instruments facilitate farmers adapting to climate change. More thorough analysis on the NRDP has been provided in the "Agriculture and Rural Development Rapid Assessment" in January 2014.

D. Recommendations for Adaptation and Mitigation

24. The long-term vision for a competitive, export-driven agriculture sector that aligns rural living conditions more closely to urban areas will only be possible, if adequate climate-resilient policies and investments are implemented and adaptation measures taken. The Ministry of Agriculture and Rural Development (MARD) has incorporated the promotion of climate-resilience in their draft medium- and long-term vision for the agriculture and rural development sector (horizon 2020/2030), as to limit the carbon footprint of agriculture. To reduce the effects of extreme weather conditions like droughts and floods, improvements of land and water management practices are needed, together with the rehabilitation and modernization of irrigation and drainage services. Besides investment on irrigation, also new varieties can positively impact crop yields in the future. But also improvements in good farming practices, like manure management and minimizing erosion through afforestation can reduce vulnerabilities. Other measures would bring important benefits on limiting GHG emissions, like promoting organic farming and renewable energy from biomass. In helping farmers and rural communities adapt to climate change, improving awareness and better management of risks in the agriculture sector would complement the key investments on adaptation. There are priority directions that Romania needs to pursue in the medium- and long-term in terms of including the agriculture and rural development sector in their green growth agenda. The Ministry of Agriculture and Rural Development (MARD) has a draft medium- and long-term vision for the agriculture and rural development sector posted on their website, which promotes climate-resilience and addresses key issues limiting the carbon footprint of agriculture. Some of the following critical interventions are incorporated in MARD's long-term vision and could address the climate change mitigation and adaptation challenges, while also remediating current ARD inefficiencies:

a) **Rehabilitation and modernization of irrigation**: Investments in irrigation while targeting water efficiencies can lead to significant water savings. The rehabilitation should be prioritized according to the farmers demand, past irrigation experience and investments should include farmers co-financing, as to create ownership and responsibility.
b) **Encourage windbreaks and soil management to reduce soil erosion**: Limiting the losses of *chernozem* soils is crucial, due to their positive impact on crop productivity. The creation of windbreaks (greenbelts) should be protect against erosion. Improved farming practices (e.g. contour tillage, grass strips) could also protect against water-runoffs on slopes.
c) **Promoting renewable energy sources:** While Romania is well on the way to reach its overall renewable energy targets defined in the Europe 2020 strategy (22% based on hydro- and wind-power), the contribution of agriculture (biomass) is less than 2%, a share,

which sits well below the EU-28 average. In promoting bioenergy, incl. biofuels, the risks associated with the indirect land-use should be taken into account.

d) **Promoting organic farming:** Even though organic farming has been slow in Romania (2.1% of UAA), the low levels of fertilizer used could be beneficial, and while reducing the environmental impact, this niche production contributes to growth of the agriculture sector and provides new employment opportunities.

e) **Improving good farming practices:** Modern manure management (capturing, storage, treatment and application) can significantly decrease GHG emissions from agriculture, as CH_4 and NO_2 emissions from the livestock sector are the major reasons behind agriculture-related GHG emissions. Animal waste can further be used as an alternative form of on-farm energy production (biogas). But good farming practices, like minimum tillage and using drought-resistant crop varieties are ideal adaptation measures, as to improve water conservation.

f) **Improving awareness of climate change and the need for adaptation:** Using existing institutional capacity (e.g. agricultural chambers) to collect from, disseminate information and raise awareness to farmers on requirements to adapt to climate change. Farmers need to be encouraged to increasingly use the various options offered under the risk management framework in agriculture. Besides agricultural insurance, the NRDP foresees the possible participation under the mutual fund for income stabilization in case of natural disasters or sanitary issues.

25. Strengthening policy and institutional capacity is vital to support the recommended interventions. The capacity of the current research and development should be broadened, as to strengthen applied sciences on new climate-resilient crop varieties, but also to improve systematic monitoring of soil, surface, groundwater and overall biodiversity. The EU- and national funded support schemes should be revisited, as to improve the uptake of all farmers participating in climate change mitigation and adaptation measures.

EUROPEAN UNION

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Romania Climate Change and Low Carbon Green Growth Program

Output C1.1
Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors

ENERGY SECTOR DEMAND TECHNICAL REPORT: LONG-TERM END-USE SERVICE DEMAND ANALYSIS (ESDA) IN ROMANIA

November 2015

THE WORLD BANK
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This report corresponds to Output C1.1: "Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors" in the Advisory Services Agreement on "Romania: Climate Change and Low Carbon Green Growth Program" signed between the Ministry of Environment and Climate Change[1] and the International Bank for Reconstruction and Development on July 23, 2013.

[1] Now, the Ministry of Environment, Waters and Forests

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List of Acronyms and Abbreviations

AIM	Asia-pacific integrated model
ASIF	activity-structure-intensity-fuel
ESDA	end-use service demand analysis
EU	European Union
FE	final energy
FEC	final energy consumption
Gcal	giga (billion) calorie
GDP	gross domestic product
GHG	greenhouse gas
GWh	giga (billion) watt-hour
IEA	International Energy Agency
INS	National Institute of Statistics
ISIC	international standard industrial classification
kgoe	kilogram of oil equivalent
ktoe	kilo ton (metric) of oil equivalent
LCS	Low carbon scenario
LEAP	long-range energy alternatives planning
LULUCF	land use, land-use change and forestry
m^3	cubic meter
MAED	model for analysis of energy demand
MARKAL	market allocation
MBtu	million British thermal unit
MJ	mega (million) joule
Mtoe	million ton (metric) of oil equivalent
NC6	sixth national communication
NEMS	national energy modeling system
pkm	passenger kilometer
PPP	purchasing power parity
TJ	tera (trillion) joule
tkm	ton (metric) kilometer
UE	useful energy
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

After the collapse of the Ceauşescu regime in 1989 and its recent entry to the European Union (EU) in 2007, Romania has experienced an impressive economic growth over the past decade. For example, Romania's gross domestic product (GDP) and GDP per capita (in real terms) during 2004−2013 grew by annual average of 3.5% and 4.3% respectively, well above the rate of EU as a whole (World Bank, 2014a).[2] Based on International Monetary Fund (IMF) projection, Romania's real GDP will continue to grow by an average of 3% per year from 2014 to 2019 (IMF, 2014). As the Romanian economy expands and households' incomes rise, they are likely to get access to reliable electricity and good transportation infrastructure, and purchase energy-using household appliances and motor vehicles. More energy is likely needed to satisfy these growing demand for energy-using household durables and energy services in the long term. For example, between 2003 and 2012, average monthly household expenditure in Romania increased by 3 times, while household ownership of electric appliances (e.g., TV sets and washing machines) and passenger cars increased by 1.5 times (INS, 2014). If no action is taken, increasing demand for energy will also have substantial consequences for greenhouse gas (GHG) emissions for some time.

Energy planning is key to sustainable energy development for every nation. Formulating energy plans and policies, and establishing goals, such as energy efficiency targets, renewable energy action plan and reduction of GHG emissions, require a clear understanding of the development of future energy demand. In the literature, a wide variety of methods are used for energy demand forecasting. These methods can be classified in several different ways such as top-down vs bottom-up, static vs dynamic, statistical vs accounting, univariate vs multivariate, and time-series vs regression.[3] However, understanding of these methods and their relevance in different contexts is quite important for energy demand projection and analysis. For instance, a sophisticated model with extensive input data and assumptions may not always be appropriate compared to simple model with limited input data. This is particularly true for many emerging economies such as Romania, where necessary detailed input data and appropriate models are lacking. More specifically, a simple flexible framework for projecting energy demand that is disaggregated into larger number of end-use categories under each energy-consuming sectors of the economy is desirable for Romania.

The EU is looking at cost-effective ways to make the European economy more climate-friendly and less energy consuming. To achieve this goal, EU has set short− and long−term quantitative climate and energy targets for its member countries. For example, "20−20−20" targets require 20% reduction in GHG emission, 20% reduction in energy consumption and 20% improvement in energy efficiency by 2020 across the EU from 1990 levels. Likewise, the EU's "2030 framework for climate and energy policies" require at least 40% reduction in domestic GHG emissions, increasing the share of EU's renewable energy to at least 27% and increasing energy efficiency by at least 27% in 2030 from 1990 level. The long−term EU strategy, "roadmap for moving to a low carbon economy in 2050", requires 80% GHG emissions

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[2] Despite a major slump in economic growth in 2009 (−6.8%) and 2010 (−0.9%) due to global economic and financial crisis, Romania's real GDP grew by an average 7.3% per year during 2004−2008 and by 2.1% per year during 2011−2013.

[3] For comprehensive review of different energy demand models, see Pandey (2002), Nakata (2004), Jebaraj and Iniyan (2006), Bhattacharyya and Timilsina (2010), and Suganthi and Samuel (2012).

reduction by 2050 from 1990 level. As part of the broader EU energy and climate strategies and policies, Romania is committed to energy security, energy efficiency and competitive energy market improvement, renewable energy promotion and low carbon green growth development.

Based on the assessment of the 2014 national reform and convergence programs for Romania, EU commission recommended programs that focuses on improving efficiency of industries, thermal insulation of buildings and the rehabilitation of district heating systems (EU, 2014a). However, addressing these energy strategies require clear understanding of end-use service demand evolution over the long-term. There are only handful of empirical research studies that examine future energy demand in Romania. A recent synthesis report by World Bank (2014b) finds that a significant increase in final energy demand is expected, particularly in transportation and services sectors, and that country still lags significantly behind most EU countries in energy efficiency measure. Bianco et al. (2010) analyzed non-residential electricity consumption in Romania up to year 2020 using econometric techniques. Based on the calculations of energy demand by sectors and corresponding emission factors, MMSC (2013) projected energy-related GHG emissions up to 2030 under different scenarios. This sixth national communication (NC6) study[4] uses a physical accounting technique, Model for Analysis of Energy Demand (MAED), for evaluating future demand for energy by sectors in Romania based on the macro-economic indicators evolution. However, the method used and the assumptions made in evaluating energy demand in the NC6 study are not clear. Using PRIMES model, EU (2014b) projected energy trends by sector and by fuel to 2050 of EU countries, including Romania. However, the results of this study are at aggregated level and the results presented for passenger transport activity for Romania are questionable. To authors' knowledge, there are no existing studies on long-term sectoral end-use service demand analysis (ESDA) in Romania.

In this study, we develop a simple modeling framework for evaluating long-term ESDA at sub-sector and end-use levels. We then use this model to assess ESDA in Romania from 2010 to 2050. The contribution from this study is three-folds. First, it develops a simplified modeling framework for projecting long-term end-use service demand with special emphasis on Romania. Second, using this method, the study analyzes sectoral end-use service demand evolution in Romania under baseline and low carbon scenarios. The low carbon scenario involves energy efficiency measures at different end-use levels in households, services and industries. To understand how different countries in the EU compare to Romania, this study also analyzes selected energy-related indicators. Third, this study also develops a marginal abatement cost (MAC) curve for Romania based on serctoral level end-use energy efficiency improvement. This study can provide useful information for policy makers involved in Romania's long-term energy and climate policies development.

[4] Romania is included in the Annex I Parties to the 1992 UN Framework Convention on Climate Change (UNFCCC). Under this convention, Romania is required to submit national communications in every 4-5 years which contain information on national GHG emissions, climate-related policies and measures, GHG projections, vulnerability and adaptation to climate change, financial assistance and technology transfer to non-Annex I Parties, and actions on raising public awareness on climate change. In 2013, Romania submitted its sixth national communication (NC6).

2. Overview of socio-economic and energy demand sectors in Romania

Numerous energy policy reforms over the last two decades have shifted Romania's energy sector from a predominantly carbon-intensive state-owned system towards a low-carbon market based system. Broadly, these reforms can be grouped into two categories. First category is the energy sector market reforms that include diminishing energy subsidies, aligning domestic fuel prices with the international market, restructuring of energy-intensive industry sector, and making administrative processes easier and more efficient. In 2011, the Romanian government removed subsidies for central district heating which covers about 20% of the population mainly in urban areas (World Bank, 2013a, pp 101). However, despite the government's commitment to address energy price reform, gas and electricity prices are still regulated in the country. Both household and industrial electricity and natural gas prices expressed in Euros in the country have actually declined since 2008 mainly due to falling energy and supply costs. For example, over the 2008-2012 period, household and industrial electricity prices decreased by 2.5% and 7.5% respectively, while gas prices decreased significantly by 18.5% for households and by 1.8% for industries (EU, 2014c). Natural gas is consumed by households mainly for heating and represents more than a quarter of household spending in Romania. On the contrary, prices of gasoline and diesel, mainly used for transportation, are among the highest in the EU because of higher fuel excise tax. For example, in 2012, the pump prices of gasoline (US$ 1.70 per liter) and diesel (US$ 1.73 per liter) in Romania are comparable to the EU average prices but they are much higher compared to the world average prices (World Bank, 2014a). Between 1992 and 2012, final energy demand by industries fell by 50%, an equivalent of 7 Mtoe (Eurostat, 2014a). The decline in energy demand in industries is mainly attributed to technology upgrading and restructuring of the energy-intensive industries (Popovici, 2011).

Second category is the setting of medium-term Romania 20/20/20 climate and energy targets as part of the EU commitments under the Kyoto Protocol. These targets include reducing GHG emissions by 20% compared to 1990, increasing renewable energy contribution to 24% of final energy consumption, and increasing energy efficiency by reducing primary energy consumption from the baseline by 19%. Based on the annual submission of GHG inventory data to UNFCCC secretariat, Romania's GHG emissions, without land use, land-use change and forestry (LULUCF), decreased by 50% between 1990 (base year) and 2011 which is far below its 2020 reduction target (UNFCCC, 2014). Likewise, Romania is on track for meeting the other two targets as well. For example, in 2012, the share of renewable energy in gross final energy consumption reached 22.9% close to the 2020 objective (Eurostat, 2014a). Also, Romanian energy savings target of 2020 is 19% (10.07 Mtoe) reduction of primary energy consumption from the baseline of the PRIMES model, is expected to be achievable (World Bank, 2013b).

In terms of purchasing power parity (PPP), with constant 2011 US$ 358.2 billion, Romania is the eleventh largest economy among the EU-28 countries in 2013. Between 1995 and 2013, Romania's per capita income increased by 73%, faster than Germany (28%) and EU-28 average (30%) (Table 1). However, Romania's real per capita income measured in PPP of US$ 17941 in 2013 remained much lower than other large economies in the region. For example, it is less than half of Germany's per capita income of US$ 42045 in 2013 (Table 1). Despite more Romanians live in urban areas now than in the past, the proportion of urban population remains the same at 54% (Table 1), mainly due to decline in total population.

In 2012, Romania had the thirteenth largest final energy consumption in the region. More than half of this consumption is coming from petroleum products and natural gas mainly in transport and household sectors (Eurostat, 2014a). In per capita terms, both electricity consumption and final energy consumption (FEC) in Romania is still at a much lower level than many countries in the region. For example, in 2012, Romanians consumed only 30% of electricity to that of Germans and about 36% to that of EU-average (Table 1). Likewise, its per capita FEC excluding electricity (892 kgoe/capita) is less than half of Germany (2088 kgoe/capita) and of EU-28 average (1706 kgoe/capita) in 2012. However, note that between 1992 and 2012, the total FEC per capita in the country decreased by 11% mainly due to the decline of population, and the structural adjustments and significant energy efficiency improvements in industries. The low per capita electricity consumption and FEC levels indicates that Romania's energy demand still has a long way to reach the levels of high-income countries in the region. In addition, the number of passenger cars per thousand people in Romania reached 203 in 2012, an increase of 46% from 1992, but this figure remain much lower compared to Germany (531) and the EU average (477) in the same year (Table 1). As economy grows and income rises, it is more likely that the number of passenger cars and transport energy demand will also increase in the foreseeable future.

At the sector level, between 1992 and 2012, FEC by industry decreased significantly by 42%, while it is increased in residential (57%), transport (60%) and services (300%) sectors (Table 1). There is strong correlation between high levels of sectoral FEC with high levels of income. For instance, in per capita terms, FEC of both residential and transport sectors, and income in Romania is much lower compared to industrialized countries like Germany and the EU average over the 1992-2012 period (Figure 1, left). Similarly, there is a close correlation between income and sectoral final energy intensity. In particular, final energy intensity of industry sector relative to GDP per capita is declining in Romania, Germany and the EU average over the 1992-2012 period (Figure 1, right). In contrast, correlation between energy intensity of services sector relative to GDP per capita is about the same during the same period. However, these sectoral intensities are relatively much higher in low-income countries like Romania when compared with high-income countries like Germany and the EU average. More specifically, aveDrage final energy intensity of industry sector in the country declined significantly by 70% during the same period. Despite this improvement, Romania's final energy intensity of industry sector (137 kgoe per 1000 US$ in 2005 prices) is more than twice the German average and roughly 70% higher than the EU average in 2012 (Table 1).

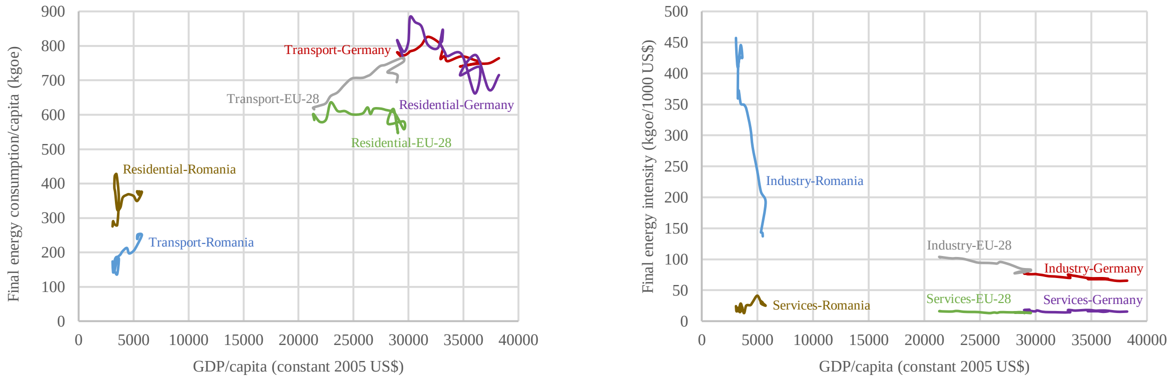

Fig. 1. Relation between income and final energy consumption by sector in per capita terms (left) and relation between income per capita and final energy intensity by sector (right) in Romania, Germany and EU-28 for the period 1992-2012.
Sources: World Bank (2014), Eurostat (2014a) and INS (2014).

Table 1

Overview of selected historical socio-economic and final energy consumption indicators in Romania, Germany and EU-28

	Romania			Germany			EU-28		
	1992	2012	% change 92–12	1992	2012	% change 92–12	1992	2012	% change 92–12
GDP per capita (PPP, constant 2011 US$)	10366 [a]	17941 [b]	73% [c]	32919 [a]	42045 [b]	28% [c]	25603 [a]	33261 [b]	30% [c]
Urban population (% of total)	54	54	0%	73	75	3%	71	74	4%
Electricity consumption per capita (kWh)	1816	1985	9%	5593	6538	17%	4524	5534	22%
Final energy consumption (FEC) per capita (kgoe)	1192	1063	-11%	2741	2650	-3%	2210	2182	-1%
Industry, FEC (% of total)	52	30	-42%	29	29	0%	31	26	-16%
Residential, FEC (% of total)	23	36	57%	28	27	-4%	26	26	0%
Transport, FEC (% of total)	15	24	60%	28	29	4%	28	32	14%
Services, FEC (% of total)	2	8	300%	13	15	15%	11	13	18%
Others, FEC (% of total)	8	2	-75%	2	<1	-100%	4	3	-25%
Total, FE intensity (PPP, kgoe per 1000 2011 US$)	110 [a]	63	-43%	82 [a]	63	-23%	87 [a]	67	-23%
Industry, FE intensity (PPP, kgoe per 1000 2011 US$))	145 [a]	45	-69%	69 [a]	59	-14%	89 [a]	70	-21%
Services, FE intensity (PPP, kgoe per 1000 2011 US$)	6 [a]	10	67%	14 [a]	14	0%	14 [a]	12	-14%
Passenger cars per 1000 people	139 [d]	203 [e]	46% [f]	515 [d]	531 [e]	3% [f]	415 [d]	477 [e]	15% [f]

Notes: [a] Data from 1995; [b] data from 2013; [c] data for 1995-2013; [d] data from 2000; [e] data from 2011; [f] data for 2000–2011.

Sources: INS (2014), World Bank (2014), and Eurostat (2014a).

3. Methodology

In the literature, various modeling techniques are used for analyzing end-use energy demand of different energy sectors of the economy. These techniques vary from a complex mathematical programming with extensive input data to a simple modeling framework with limited input data.[5] However, it is important to understand these techniques and their relevance in different contexts. We develop a simple bottom-up accounting framework model, ESDA, for evaluating medium and long-term end-use service demand at sub-sector and end-use levels. The framework is based on three-factor (activity, structure and intensity) decomposition analysis. The ESDA is a tool to model energy demand by various types of energy consuming services and aggregate the results to the end use or sector level. We follow this approach for three reasons. First, necessary detailed energy-related dataset are often lacking or they not readily available in Romania. Second, skill as well as programming and computing requirements can be quite challenging in Romania where both financial and skilled human resources may be limited. Third, most of the available models are commercial in nature and they require substantial amount of time for compiling initial dataset and computing. The ESDA model is built using Microsoft Excel and its most important features include transparency, flexibility and easy to use.

The ESDA model also relies on the scenario approach to develop a consistent storyline of the possible paths of energy demand evolution. However, this model does not optimize or simulate but uses accounting approach to provide answers to “what-if” type of analysis under alternative possible development scenarios. In this model, scenario is viewed as a consistent description of a possible future direction of governmental socio-economic plans and polices of a country. To make the model simple and easy to use but flexible enough to consider detailed analysis of service demand analysis, the supply-side of the energy system is excluded.

The ESDA model structure specifies total energy consumption to be a sum of terms, where each term represents an end-use component. The end-use components can be individually calculated, yielding the desired disaggregation of total fuel consumption by end-use. The four major energy consuming sectors considered in model are residential, services, industry and transport. The industry sector is further divided into four sub-sectors: agriculture, construction, mining and quarrying, and manufacturing. Depending on the nature of the analysis and the country, these sectors/sub-sectors are further divided into several end-use categories (Figure 2). The energy demand for each end-use categories is driven by one or several demographic, socio-economic and technological parameters, whose values are given as part of the scenarios.

[5] Different modeling techniques include mathematical programming, econometrics, statistical and accounting methods, and network analysis. The Long-range Energy Alternatives Planning system (LEAP), the Asia-Pacific Integrated Model (AIM)/Enduse, TIMES/MARKAL, National Energy Modeling System (NEMS), ODYSSEE-MURE and Model for Analysis of Energy Demand (MAED) are some of the commonly used end-use energy demand models.

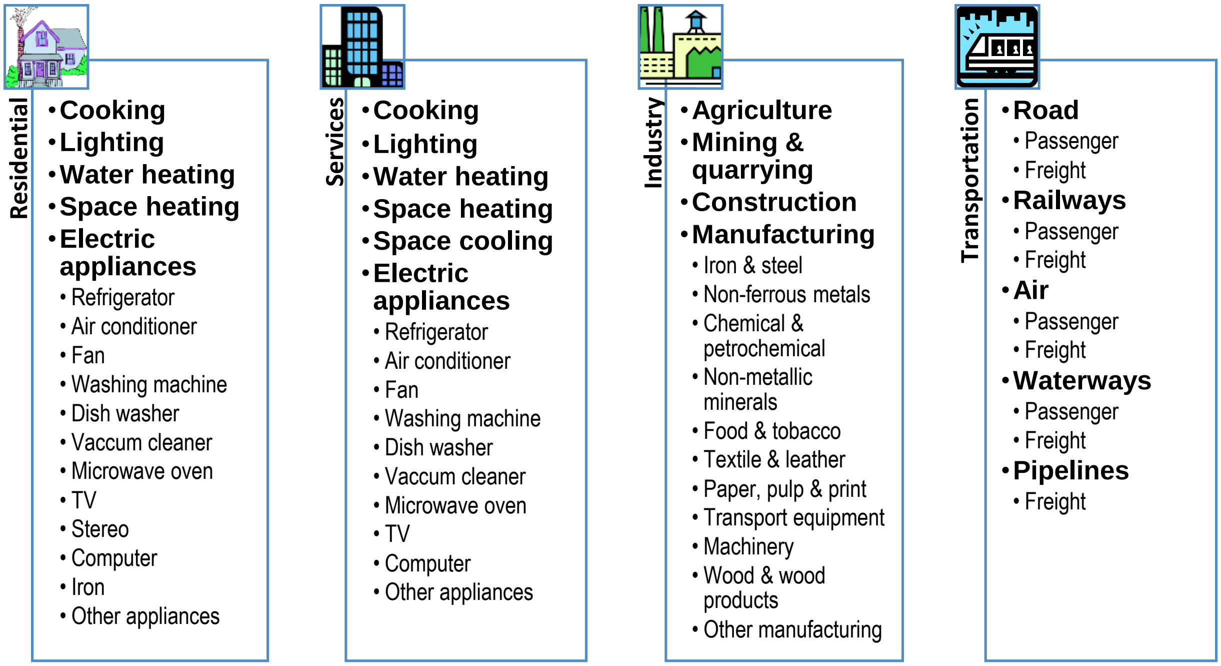

Fig. 2. Simplified general energy consuming sector/sub-sector and end-use service classification.

In ESDA modeling framework, the energy demand of each end-use for energy consuming sectors and subs-sectors is projected using a decomposition approach. Decomposition analysis quantifies the impact of different driving forces or factors on energy consumption. Decomposition of energy end-use trends often distinguishes among three main components (activity, structure and energy intensity) affecting energy consumption. Demand of energy use by each end-uses and by sub-sectors is calculated using the following general equations:

$$E_X(t) = \sum_x E_{x,X}(t) = \sum_y E_{y,x,X}(t), \quad x \in X \qquad (1)$$

$$E_{y,x}(t) = A_{y,x}(t) \cdot S_{y,x}(t) \cdot EI_{y,x}(t) \qquad (2)$$

where E_X is the total energy demand for sector X, A is the activity level, S is the structure and EI is the energy intensity. The small cap subscripts x and y represent sub-sector and end-uses respectively. For example, activity level may value-added for manufacturing industries and services, population and living floor area in the residential sector, or passenger kilometer or ton-kilometer for transportation. Likewise, sectoral structure is the mix of activities within a sector and sub-sectors such as share of value added in manufacturing industries, and energy intensity is the energy use per unit of activity such as energy use per unit of value added for manufacturing industries. In the case of Romania, 4 energy consuming sectors are considered. Depending on data availability, breakdowns of energy demand by sub-sectors and end-uses for each sector are different.

3.1 Residential sector end-use service demand

The energy consumption in residential sector includes all energy-using activities related to private dwellings but excludes energy used for personal transportation. Depending on the purpose of the study and the availability of data, the residential sector can be disaggregated into sub-sectors by geography (e.g., north, south, east and west, or urban and rural) or by income levels (e.g., low, medium and high) without changing the structure of the equation. Energy demand for each of these sub-sectors can be further classified into different end-uses. Common end-uses associated with this sector include space heating, water heating, cooking, lighting, air-conditioning, refrigeration and running a variety of electric and non-electric appliances. For example, space heating may be the most important end-use in a cold country, while it could be cooling in a warm country. The future energy consumption trends in the residential sector and the different end-uses are driven by wide range of driving factors, including changes in population, urbanization rates, household income, dwelling size and type, dwelling floor area, energy-mix, energy efficiency of appliances, appliances diffusion rate and standards, and household preferences and behaviors.

The overall energy demand in the residential sector is the sum of energy demand of various sub-sectors and end-uses (Equation 1). The projection of energy demand trends by end-uses and by sub-sectors is done using a decomposition approach (Equation 2). In the equation, activity may refers to population or number of occupied dwelling or number of refrigerators and structure may refers to dwelling size (number of inhabitants per dwelling) or average dwelling floor area or appliances ownership. The residential energy intensity[6], a proxy for energy efficiency, is the amount of energy consumed per activity for sub-sectors and end-uses. Altogether, 6 different end-uses (space heating, water heating, air-conditioning, cooking, lighting and use of electric appliances) are considered. There is no residential sub-sectors. The mathematical formulation used for projecting energy demand for each of these end-uses are explained in Annex A.

3.2 Services sector end-use service demand

The services sector, also referred to as commercial or tertiary sector, consists of service-providing facilities or businesses and other private and public organizations. Similar to residential sector, the common uses of energy associated with this sector include space heating, water heating, space cooling, lighting, refrigeration, cooking, and uses of a wide variety of appliances. However, energy consumption for commercial transportation and for electricity or heat generation are excluded from the sector.

The structure of the equations (Equations 1 and 2) used for calculating services sector end-use energy demand is similar to residential sector. However, unlike residential sector, the Romania's services sector is further divided into five sub-sectors: offices, hospitals, hotels, sport facilities and others (non-specified). Five different services end-uses (space heating, space cooling, water heating, lighting and others) for each of these sub-sectors are considered. The main driving factor affecting energy consumption in the services

[6] Energy intensity is determined by many factors, including energy efficiency, structure of the economy, the exchange rate, size, geography and climate of a country, and consumer behavior. Using energy intensity at the aggregate level (e.g., energy consumption per unit of GDP or value added) as a proxy for energy efficiency is sometimes misleading and often generate misleading results. However, in decomposition analysis, energy intensity is used as a proxy for energy efficiency because the activities for sub-sectors or end-uses are measured either in physical metrics (e.g., ton of steel or floor area) or in value (e.g., dollars) (IEA, 2014).

sector is the level of economic activity represented by value-added output of the sector. In general, higher economic activity leads to increases in commercial activities and that in turn leads to an increase demand for energy services. In addition to economic activities, the trends in services energy demand is also influenced by floor area, age and type of the commercial buildings, climatic conditions and energy efficiency improvements. The mathematical formulation used for projecting energy demand for each of these end-uses are explained in Annex B.

3.3 Industry sector end-use service demand

Among different energy consuming sectors of the economy, the industry sector is heterogeneous and quite complex. In general, the industry sector consists of all facilities and equipment used for producing, processing, or assembling goods. For the purpose of energy demand analysis, the industry sub-sectors can be classified according to International Standard Industrial Classification (ISIC)[7] that represents a standard format based on economic activities (UN, 2008). Energy use in this sector is mainly used for process heat and cooling, and powering machines, and in lesser amounts for space heating and cooling, water heating and lighting.

The Romania's industry sector is divided into 4 sub-sectors (agriculture, manufacturing, mining and quarrying, and construction). The manufacturing sub-sector is further sub-divided into 10 energy-intensive categories and they are iron and steel, chemical and petro-chemicals, non-metallic minerals, food and tobacco products, pulp and paper, textile and leather, transport equipment, machinery, wood and wood products, and other manufacturing (non-specified). For each of these industry sub-sectors, including 10 categories, energy demand is calculated separately for 3 end-uses. These 3 end-uses include electricity for specific uses (e.g., lighting, motive power and electrolysis), thermal uses (e.g., space and water heating, steam generation, furnace and direct heat) and motor fuels (e.g., gasoline and diesel). Depending upon the nature of heat (temperature) requirements, the thermal end-use is further sub-divided into 3 categories and they are furnace and direct heat (high temperature), steam generation (medium temperature) and space and water heating (low temperature). The structure of the equations is similar to Equations 3.1 and 3.2 and the mathematical formulation used for projecting energy demand for each of these end-uses are explained in Annex C.

3.4 Transportation sector travel demand

Transport sector consists of all motorized and non-motorized vehicles whose primary purpose is transporting people and goods from one physical location to another. Energy use in this sector is mainly used for running the motors. A wide range of transportation modes can be grouped into three broad categories based on the medium they use: land, water and air. Each transportation modes can be further sub-divided into several branches either separately or combination of ownership, type, activity, location and category. For example, in the case of Romania, land transport includes road, rail and pipeline, water transport includes maritime and inland waterways, and air transport includes aircrafts. Excluding pipeline,

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[7] In industry sector, the individual aggregated categories include 4 sections of ISIC and they are agriculture, forestry and fishing (Section A), mining and quarrying (Section B), manufacturing (Section C) and construction (Section F). Depending upon energy requirements, these 4 sections can be grouped into two sub-sectors: energy-intensive manufacturing (i.e., Section C) and non-energy-intensive non-manufacturing sub-sectors (i.e., Sections A, B and F).

each of these transport modes are further sub-divided by activity (e.g., passenger and freight). Since road transport dominates Romania's transportation system, it is further sub-divided by vehicle type (e.g., motor cycle, car, bus, lorry and truck).

For simplicity, the transport module of ESDA model follows commonly used activity-structure-intensity-fuel (ASIF) framework approach. The following equations are used in estimating motorized travel demand and its associated energy use.

$$TD_{k,r,T}(t) = \sum_i \sum_j N_{i,j,k,r}(t) \cdot OF_{i,j,k,r}(t) \cdot VKT_{i,j,k,r}(t) \cdot LF_{i,j,k,r}(t), \quad r \in T \tag{3}$$

$$E_{k,r,T}(t) = \sum_j N_{i,j,k,r}(t) \cdot OF_{i,j,k,r}(t) \cdot VKT_{i,j,k,r}(t) \cdot EI_{i,j,k,r}(t) \tag{4}$$

$$TD_{k,nr,T}(t) = \sum_j TD_{j,k,nr,T}(t) = TD_{j,k,nr,T}(t-n) \cdot DRVI_{j,k,nr,T}(t), \qquad nr \in T, nr \neq r \tag{5}$$

$$E_{k,nr,T}(t) = \sum_j TD_{j,k,nr,T}(t) / LF_{j,k,nr,T}(t) \cdot \left\{ EI_{j,k,nr,T}(t) \right\} \tag{6}$$

where *TD* is travel demand, *N* is number of road vehicle, *OF* is operational factor, *VKT* is vehicle kilometer travelled, *LF* is load factor, *E* is energy demand, *EI* is energy intensity (fuel economy), *DRVI* is driving variable (index), *T* is transport sector, *t* is time period and *n* is number of period. The small cap subscripts *i*, *j*, *k*, *r* and *nr* represent fuel type, transport mode, activity type, road transport and non-road (rail, air, water and pipeline) transport respectively. In this framework, transportation travel demand is a function of mode, technology choice, total distance traveled, driving style and vehicle occupancy, and transport energy use is a function of travel demand and fuel efficiency (Equations 3 and 4). However, in this analysis, travel demand for all modes of transportation (road, rail, air, water and pipeline) in Romania is calculated as a function of historical value of travel demand and corresponding driving variables (Equation 5), mainly due to data limitation. Travel demand for passenger transportation is measured in passenger-kilometer (pkm) or number of passengers, and travel demand for freight transportation is measured in ton-kilometer (tkm) or ton. Although the energy demand by different transportation modes are not reported in the study, it can be calculated using Equation 6. Note that this is the simplest method to calculate travel demand where reliable data are limited. The total travel demand for non-road transportation of passengers (passenger-kilometers and freight (ton-kilometers) is calculated as a function of population or GDP or the combination of both. For simplicity, we exclude non-motorized mode of transportation such as human-powered (bicycles) and animal-powered transport.

4. Data and scenarios assumptions

The ESDA approach requires gathering of wide range of statistics. Broadly, these dataset can be grouped under three categories and they are energy demand data, socio-economic and demographic data, and technological data. For Romania case study, these data are compiled from several national, regional and international publications. In particular, Romania's National Institute of Statistics (INS), EU's Eurostat and the World Bank's World Development Indicators are the primary sources of data. However, none of these publications provide complete dataset. Therefore, data used in calibrating base year (2010) and the activity parameters used in projecting future sectoral end-use service demand are compiled from various sources (Annex D). The activity parameters, exogenous inputs to the model, are used to estimate the future end-use service demand. While these sources report data on different energy sources in different measurement units, all values are converted to the common energy unit of kilo ton of oil equivalent (ktoe) using caloric and other conversion factors (Annex F). The choice of base year as 2010 is constrained by the availability of data. The projections of end-use service demand are made through the year 2050 with 5 years of interval.

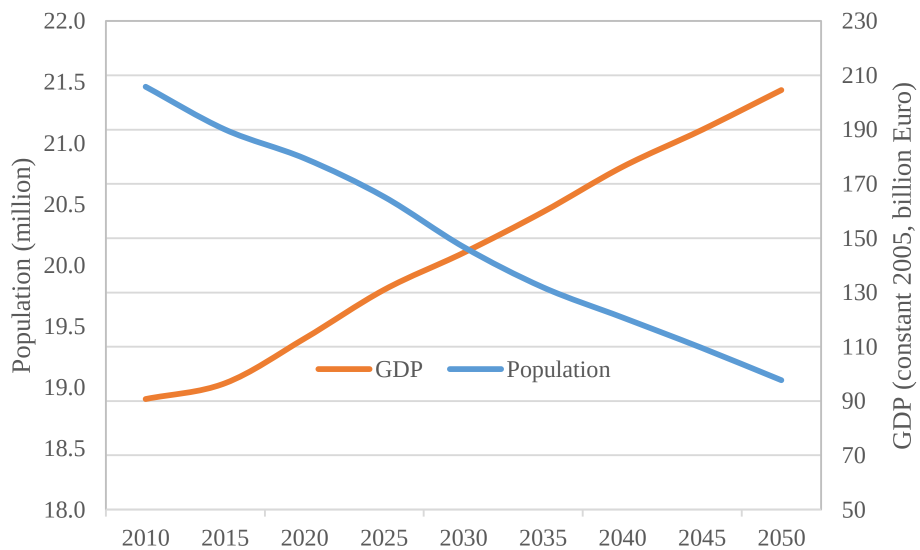

Fig. 3. Projections of population and GDP for Romania, 2010-2050.

In the ESDA model, projections of end-use service demand are based on scenario-driven analysis. This study covers the development of baseline and low carbon scenarios for end-use service demand in Romania. The baseline scenario provides a useful point of comparison for the impacts of choices or changes in alternative low carbon policies. The baseline scenario is not necessarily the most likely of possible scenarios but it reflects a moderate view of future energy demand given a continuation of current trends. The population and economic assumptions associated with the baseline scenario projections for Romania is shown in Figure 3. Population and the economic growth are key driving factors that influence the outlook of energy demand for end-use services. The other major driving factors that influence baseline energy demand outlook, their data sources and assumptions made are summarized in Annex E.

In the alternative low carbon scenario (LCS), Romania is committed to EU's energy and climate strategies including 2030 framework for climate and energy policies and the roadmap for moving to a low carbon economy in 2050. In particular, this study covers the end-use energy efficiency measures in residential, services and industry sectors. Major energy efficiency improvement measures include use of more efficient lighting and electric appliances in households and services, retrofitting buildings with wall, window and roof insulation, heating system improvement, and use of efficient electric motor and thermal energy equipment in industry sector. To reflect EU's energy and climate strategies, the LCS scenario that extends from 2010 to 2050 is analyzed in two phases. The first phase is LCS 2030 scenario that follows the EU 2030 Framework and runs from 2010 to 2030. The second phase is LCS2050 that follows EU's 2050 roadmap to low carbon economy and runs from 2010-2050. The assumptions made under these two LCS scenarios are summarized in Annex G.

5. Results and discussions

In this analysis, useful energy demand for end-use services includes energy used in three sectors: residential, services and industrial. End-use energy demand excludes the energy used to generate electricity. The remainder of this section focuses on the results of sectoral energy demand by end-use services under the baseline and LCS scenarios in Romania. Note that we exclude transport sector analysis in this report as this sector is covered in detail elsewhere.

5.1 Residential sector

The residential sector is Romania's largest energy consumer. Romanian households spend more than 13% of their income on energy, one of the highest rates in the EU (EU, 2014a). In 2010, this sector accounted for 36% of total final energy demand, using solid biomass and natural gas as the major fuels. The baseline scenario projects that Romania's useful energy demand for end-use services will continue to grow at an average annual rate of 0.8% from 2010 to 2050 to reach 7324 ktoe (Table 2). While, electricity demand for appliances is projected to grow relatively at higher rate, 1% per year, during 2010−2050 period under baseline scenario.

Table 2

Residential sector useful energy demand by end-use, 2010−2050 (ktoe)

	2010	Baseline scenario							
		2015	2020	2025	2030	2035	2040	2045	2050
Space heating (climate corrected)	2669	3420	3610	3811	4023	4133	4247	4364	4484
Air conditioning	25	38	49	62	74	87	101	114	128
Water heating	779	770	759	744	729	718	707	697	686
Cooking	1011	1000	985	965	946	932	918	905	891
Lighting	155	199	210	222	234	241	247	254	261
Electric appliances	592	667	694	720	748	783	813	843	874
Refrigerator/freezer	250	268	276	285	295	307	319	331	342
Washing machine	120	130	138	145	152	159	166	174	184
Television	167	197	203	208	212	217	221	224	227
Computer	23	38	43	48	54	66	72	79	86
Other appliances	32	33	34	34	35	35	35	35	35
Total	5233	6094	6307	6523	6754	6894	7033	7176	7324

Within residential end-uses, space heating is projected to account for more than half of all useful energy consumption under baseline scenario during 2010−2050 period (Figure 4). The highest share of space heating in the country is mainly due to long cold winter with higher heating degree days. Apart from outdoor temperature, many other factors influence energy demand for space heating including the size and type of dwellings, and the efficiency of the heating system and equipment. Space heating therefore represents the largest opportunity to reduce residential energy demand by increasing energy efficiency of the heating equipment and by changing energy-mix. Solid biomass fuels is commonly used for space heating in many rural Romanian households. Although, the share of energy demand for air cooling and lighting combined in total useful energy demand is relatively small, in the range of 3% in 2010 to 6% in 2050, energy demand for these end-uses is projected to grow at much higher rate. For example, energy demand for air cooling and lighting is projected to increase at an average annual rate of 4% and 1.3% per year, respectively during 2010−2050 period. In contrast, energy demand for water heating and cooking is projected to slightly decline from 2010 to 2050 (− 0.3% per year), mainly due to decline in country's population during 2010−2050 period.

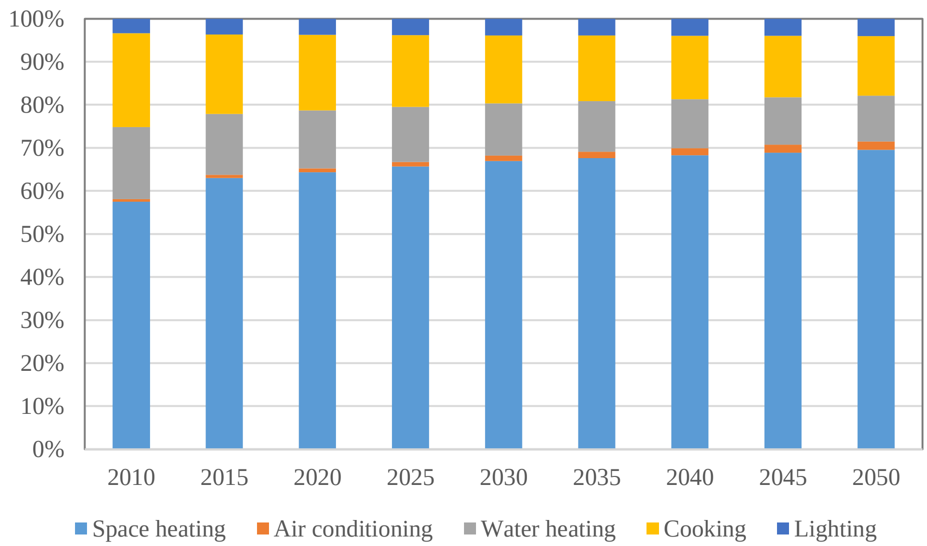

Fig. 4. Percentage share of end-uses in total residential useful energy demand during 2010−2050.

As economy grows and income rises, the use of household electrical appliances and demand for electricity are also projected to increase. For example, electricity demand by appliances is projected to increase from 592 ktoe in 2010 to 874 ktoe in 2050. In particular, residential use of refrigerator, washing machine and television combined is responsible for about 90% of total electricity demand by the appliances under baseline scenario during 2010−2050 period.

Under LCS, the residential useful energy demand is estimated to decline compared to baseline scenario during 2010−2050 period. Due to energy efficiency measures under LCS, energy demand for lighting is projected decline by 51%, followed by air conditioning (33%), electric appliances (21%) and cooking (9%) in 2030 compared to baseline scenario (Figure 5). However, in absolute terms, about 60% (853 ktoe) of total residential demand energy reduction in 2030 is projected to come from space heating alone. It follows similar trends in 2050 under LCS. For example, about 29% (2154 ktoe) of total residential energy demand reduction is projected in 2050 under LCS when compared to baseline scenario. Space heating, cooking and lighting are the major end-uses responsible for the energy demand reduction in 2050. Detailed results of LCS are summarized in Annex I.

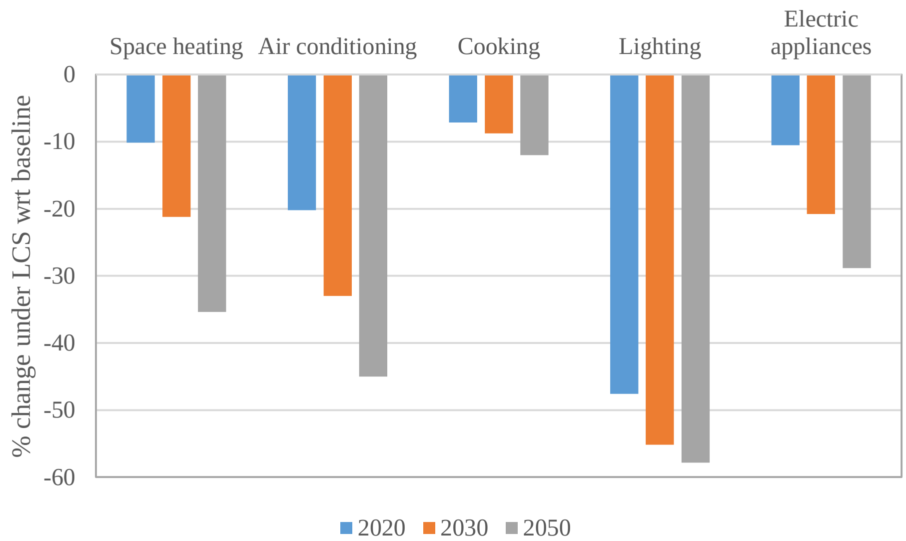

Fig. 5. Percent change in residential useful energy demand by end-uses under LCS wrt baseline scenario.

5.2 Services sector

In 2010, service sector accounted for more than half of the country's GDP and about 10% of total final energy consumption (INS, 2014). The services sector is the most heterogeneous sector of the economy that includes wide range of energy consumers. In this analysis, services sector is sub-dived into four categories: offices, hospitals, hotels and restaurants, sport facilities and others (institutional buildings, retail stores, warehouses and other service industries).

Table 3

Services sector useful energy demand by sub-sector and by end-use, 2010-2050 (ktoe)

	2010	Baseline scenario							
		2015	2020	2025	2030	2035	2040	2045	2050
Space heating	665	768	909	1037	1152	1299	1434	1573	1701
Office	108	126	149	171	192	215	236	258	278
Hospital	92	96	110	121	130	136	141	145	149
Hotel/restaurant	51	62	74	86	98	111	124	137	149
Sport facilities	47	49	56	62	66	69	72	74	76
Others[a]	367	436	519	597	666	768	861	959	1050
Space cooling	98	113	134	153	170	192	212	232	251
Office	16	19	22	25	28	32	35	38	41
Hospital	14	14	16	18	19	20	21	21	22
Hotel/restaurant	8	9	11	13	14	16	18	20	22
Sport facilities	7	7	8	9	10	10	11	11	11
Others[a]	54	64	77	88	98	113	127	142	155

Water heating	71	83	98	111	124	139	154	169	183
Office	12	14	16	18	21	23	25	28	30
Hospital	10	10	12	13	14	15	15	16	16
Hotel/restaurant	5	7	8	9	10	12	13	15	16
Sport facilities	5	5	6	7	7	7	8	8	8
Others[a]	39	47	56	64	71	83	92	103	113
Lighting	154	190	225	256	284	320	353	387	418
Office	14	16	20	22	25	28	31	34	36
Hospital	24	38	43	48	51	53	55	57	58
Hotel/restaurant	13	16	19	22	26	29	32	36	39
Sport facilities	6	6	7	8	9	9	9	10	10
Others	96	114	136	156	174	201	225	251	274
Others[b]	251	287	332	372	404	447	484	520	551

Notes: [a] includes institutional buildings, retail stores, warehouses and other non-specified service industries. [b] includes cooking and electric appliances measures in final energy. Cooking is the major part of energy consumption in hotels and restaurants.

On average, energy demand in services sector in the baseline scenario is projected to grow at much higher rate than other energy consuming sectors. Services sector useful energy demand by end-uses, excluding cooking and use of electric appliances, is projected to double from 988 ktoe in 2010 to 2553 ktoe in 2050, at an annual average growth rate of 2.4% (Table 3). Similar to household sector, space heating is projected to account for most of the energy demand in the services sector. For example, in 2050, the share of space heating in total useful energy demand ranges from 61% in hospitals to 72% in hotels/restaurants and sport facilities (Figure 6). This is followed by lighting, in the range of 9% (offices and sports facilities) to 24% hospitals), and space cooling, in the range of 9% (hospitals) to 11% (offices and sport facilities) in 2050 (Figure 6). The share of lighting in total useful energy demand is projected to be relatively small.

Overall, about two-third of the total useful energy demand is projected to be used for space heating, followed by lighting (16%), space cooling (10%) and water heating (7%) in 2050.
District heat and natural gas are the most commonly used energy sources for space heating in the country. In 2010, district heat alone supplied for more than 11% of total energy demand in the services sector, mainly used for space and water heating. Final energy demand for cooking and electricity use for appliances combined is projected to increase as well but at a lower average annual rate of 2% over the study period (Table 3). Offices, public and private combined, is the largest sub-sector in terms of energy consumption in the country. By 2050, about 40% of total services useful energy demand is projected to be used by offices, followed by hospitals (26%), hotels and restaurants (24%) and sport facilities (11%) (Table 3).

Under LCS, the services useful energy demand is estimated to decline compared to baseline scenario during 2010−2050 period. Due to energy efficiency measures under this scenario, energy demand for space cooling is projected decline by 35%, followed by space heating (30%) in 2030 when compared to baseline scenario (Figure 7). In absolute terms, space heating is responsible for 346 Mtoe total services energy demand reduction while space cooling is responsible for 59 ktoe of total services energy demand reduction in 2030 under LCS when compared to baseline scenario. Under LCS in 2050, both space heating and space cooling are responsible for about 45% reduction in services energy demand (Figure 7). In absolute terms, it follows similar trends as in 2030 in 2050 under LCS. For example, about 87% (744 ktoe) of total residential energy demand reduction is projected to come from space heating in 2050 under LCS when compared to baseline scenario.

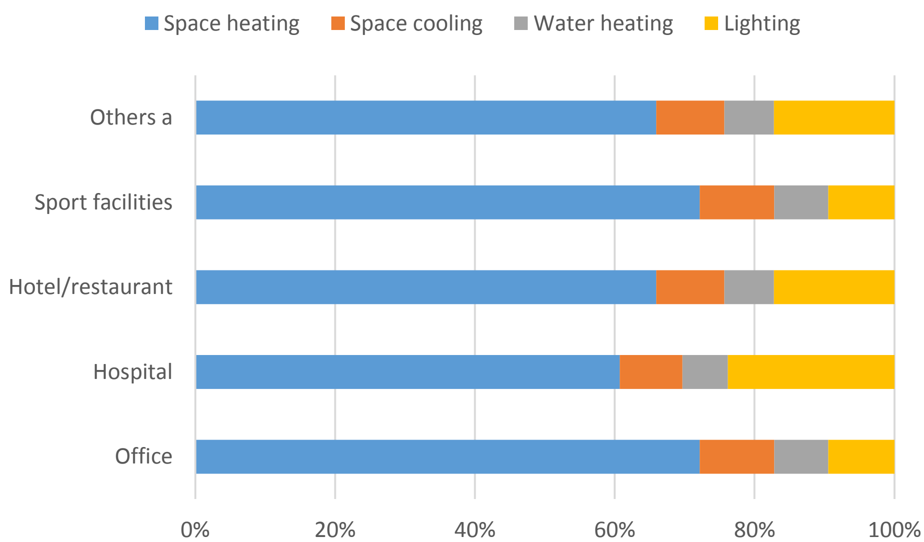

Fig. 6. Services sector useful energy demand by sub-sector and by end-use, 2050.
Note: [a] includes institutional buildings, retail stores, warehouses and other non-specified service industries.

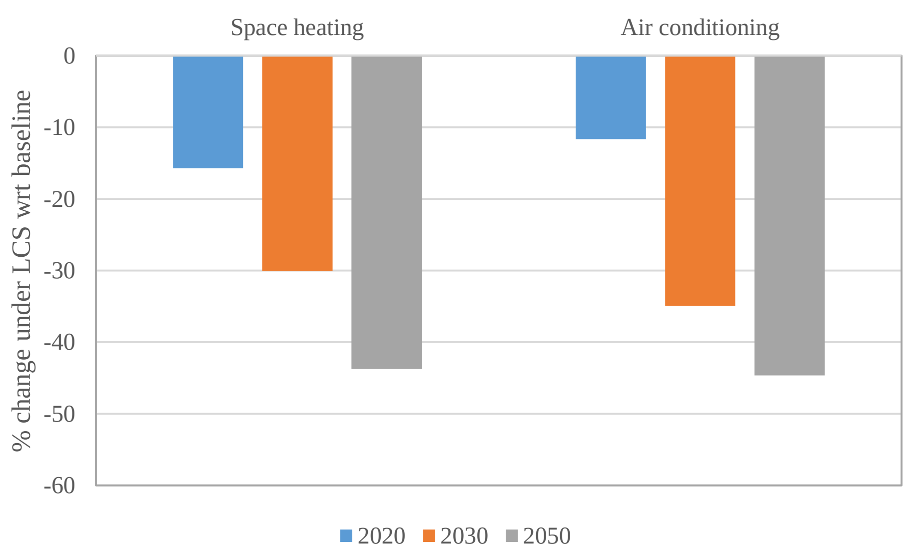

Fig. 7. Percent change in services useful energy demand by end-uses under LCS wrt baseline scenario.

5.3 Industry sector

In this study, the Romanian industry sector is sub-divided into 4 broad categories: agriculture, manufacturing, mining and quarrying, and construction. Manufacturing is further sub-divided into 10 energy intensive and non-intensive industries. In 2010, about 88% of total industrial final energy is consumed by manufacturing industries. In the same year, close to two-thirds of total manufacturing energy demand is consumed by a handful of energy intensive industries such as iron and steel, and chemical and petrochemical industries (Eurostat, 2014a). In terms of energy types, coke, natural gas and electricity are mainly used in iron and steel industry, while oven coke, while natural gas, electricity and refinery gas is mainly used in chemical and petrochemical industries.

The total industrial sector useful thermal energy demand is projected to grow at an annual average rate of 1.3% from 2010 to 2050 to reach 5197 ktoe (Table 4). In this study, in order to describe the quality of thermal energy demanded by the manufacturing industries, three temperature intervals are considered. The low temperature (less than 100 °C) corresponds to processes as washing, rinsing, and water and space heating of the industrial facilities, the medium temperature (100 °C to 400 °C) corresponds to steam generation, and the high temperature (more than 400 °C) corresponds to furnace and direct heat. The thermal energy use for agriculture, mining and quarrying, and construction industrial sub-sectors is relatively small mainly used for processes such as washing, rinsing and space heating. In 2050, the share of these three sub-sectors combined in total thermal energy demand is projected to be only 5.8%, about 302 ktoe (Table 4).

Table 4

Industry sector useful thermal energy demand by sub-sector, 2010-2050 (ktoe)

	2010	Baseline							
		2015	2020	2025	2030	2035	2040	2045	2050
Agriculture	40	41	42	44	45	45	45	45	44
Manufacturing	2990	3164	3417	3679	3946	4208	4489	4718	4895
Furnace and direct heat	1859	1856	1952	2064	2173	2271	2376	2450	2498
Steam generation	487	556	618	677	741	808	879	941	993
Space and water heating	644	753	847	938	1032	1129	1233	1326	1405
Mining and quarrying	4	4	4	4	5	5	5	5	5
Construction	113	101	128	152	174	195	216	236	253

Within the industrial manufacturing sub-sector, total thermal energy demand for chemical and petrochemical is projected to be the highest (50%), followed by iron and steel (19%), non-metallic minerals (10%) and the rest of manufacturing industries (22%) in 2050 (Annex H). More specifically, in 2050, furnace and direct heat (high temperature) thermal energy demand is projected to be concentrated mainly in iron and steel, non-metallic minerals and chemical and petrochemical manufacturing industries, while steam generation (medium temperature) thermal energy demand is projected to be concentrated in textile and leather, food and tobacco, and other manufacturing industries, and space and water heating (low temperature) is projected to be concentrated in wood and wood products, machinery, transport equipment and food and tobacco (Figure 8).

Apart from thermal energy use, demand for electricity for electric motor and others (motor fuels and electricity for non-electric purposes) are also projected to grow at an annual average rate of 1.6% and 1.5% respectively, from 2010 to 2050 (Table 6). Between 2010 and 2050, demand for electricity for electric motors by manufacturing industries is projected to double. Although small in absolute values, growth in energy demand for construction sub-sector is projected to be quite high at average annual rate of about 2.2% for electric motor and others end-uses. More than 92% of total electricity demand for electric motors in 2050, mainly used for refrigeration, air conditioning and lighting, is projected to be concentrated in manufacturing industries (Table 6).

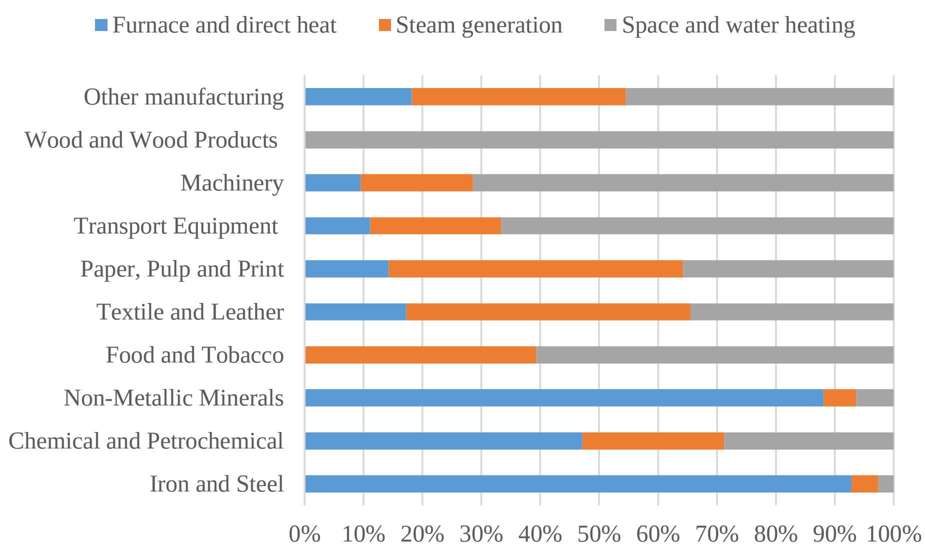

Fig. 8. Useful thermal energy demand by manufacturing sub-sector, 2050.

Table 6

Useful energy demand by industrial end-uses, 2010–2050 (ktoe)

	2010	Baseline scenario							
		2015	2020	2025	2030	2035	2040	2045	2050
Electric motor	1074	1156	1282	1421	1549	1667	1798	1914	2014
Agriculture	38	40	41	43	45	46	47	47	47
Manufacturing	981	1066	1179	1307	1425	1533	1655	1762	1856
Mining and quarrying	14	15	16	17	18	19	20	21	22
Construction	40	36	45	54	61	69	76	83	89
Others[a]	904	939	1056	1172	1280	1379	1485	1578	1658
Agriculture	218	226	238	250	260	267	273	277	280
Manufacturing	486	533	591	655	713	769	831	885	933
Mining and quarrying	20	21	23	25	27	28	30	31	32
Construction	179	160	204	243	280	315	351	384	414

Note: [a] includes motor fuels and electricity for non-electric motor purposes.

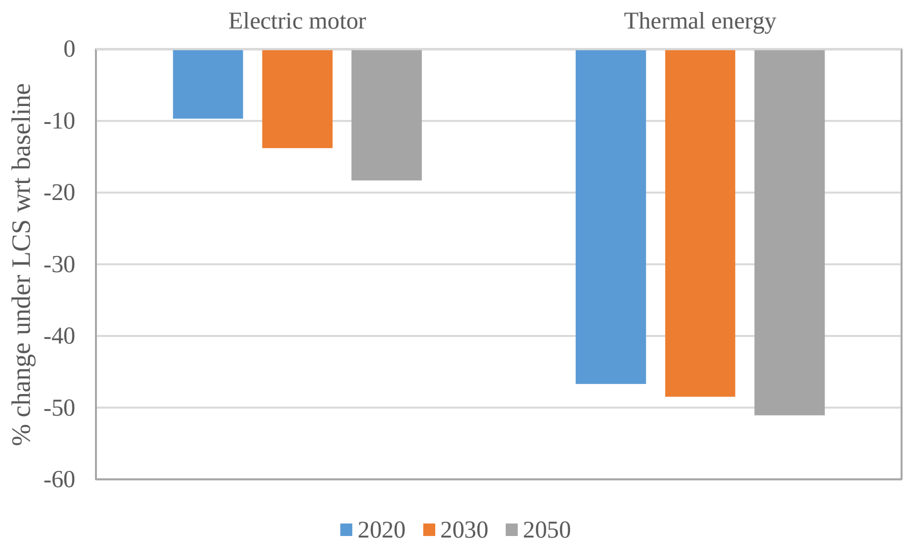

Fig. 9. Percent change in industry useful energy demand by end-uses under LCS wrt baseline scenario.

The industry useful energy demand is estimated to decline under LCS when compared to baseline scenario during 2010–2050 period. Due to energy efficiency measures under LCS scenario, demand for thermal energy is projected decline by 48% and demand for electricity for electric motors is projected decline by 14% in 2030 when compared to baseline scenario (Figure 9). In absolute terms, these two end-uses are responsible for 2326 ktoe of total industry energy demand reduction in 2030 under LCS when compared to baseline scenario. Under LCS in 2050, thermal energy and electric motors are responsible for 51% and 18% reduction, respectively, in total industry energy demand (Figure 9). In absolute terms, electric motors are responsible for 527 ktoe of industry energy reduction, while thermal energy is responsible for 2653 ktoe of industry energy reduction in 2050 under LCS.

6. Concluding remarks

This study provides a projection of energy demand by end-use services for residential, services and industry sectors and travel demand different transportation modes in Romania to the year 2050. The projections employ currently available information, trends and plausible assumptions to form a view of the Romanian end-use service demand by energy consuming sectors over the next 40 years. The projections made in this study is considered under baseline and alternative low carbon scenarios.

Although there is considerable variation in the growth of between end-use sectors, the total Romanian end-use demand is projected to increase from 2010 to 2050. The results of the baseline scenario imply that most of these end-use energy demand is coming from residential and industrial sectors. In the residential sector, total useful energy demand is projected to grow at an average annual rate of 0.8% from 2010 to 2050. Demand for electricity by electric appliances in the residential sector is projected to grow at slightly higher rate, 1% per year during 2010−2050 period. Despite the population of Romania is projected to decline over the study period, rising incomes and increasing dwelling area (living floor space) are responsible for growing end-use energy demand in the residential sector. In particular, demand for climate-corrected space heating is projected to be the dominant end-use service demand in residential sector during 2010-2050, accounting for more than 50% of total residential useful energy demand. Space heating therefore represents the largest opportunity to reduce residential energy demand by increasing energy efficiency of the heating equipment and by changing energy-mix.

In industry sector, electricity demand for electric motors is projected to grow at an annual average of 1.6% between 2010 and 2050 under the baseline scenario. Likewise, total thermal (heat) energy demand, measured in useful energy demand, is projected to grow at an average annual rate of 1.3% between 2010 and 2050, mainly due to growing economy and strong growth in energy-intensive manufacturing industries. In particular, manufacturing industries such as iron and steel, chemical and petro-chemicals, and non-metallic minerals, dominate total thermal energy demand.

Although services sector’s share in total final energy demand is relatively small, end-use energy demand in this sector is projected to grow at much higher rate than other energy consuming sectors. Services sector useful energy demand by end-uses, excluding cooking and use of electric appliances, is projected to double from 2010 to 2050, at an annual average growth rate of 2.3% under the baseline scenario. Similar to household sector, space heating is projected to account for most of the energy demand in the services sector.

The low carbon scenario (LCS) involves energy efficiency measures at different end-use levels in households, services and industries. In 2030, these three sectors together are responsible for 3.2 Mtoe (25%) of useful energy demand reduction due to energy efficiency measures. Likewise, these sectors together are responsible for 6.2 Mtoe (32%) of useful energy demand reduction due to energy efficiency measures in 2050. Insulating buildings, both residential and services, will likely reduce total useful energy demand by 52% (1.2 Mtoe) in 2030 and 38% (2.3 Mtoe) in 2050. The other major effective measures include increasing efficiency for thermal energy use in industries and efficient lighting in households.

To summarize, energy demand by end-use services in Romania are expected to increase in the long-term. A reliable and adequate supply of modern and clean energy is needed to meet these demand. There is a great potential in reducing energy demand for space heating in buildings in the country by improving energy efficiency of heating equipment and by renovating buildings.

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Glossary

EU-28	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, Sweden, United Kingdom
Energy intensity	Energy intensity is determined by many factors, including energy efficiency, structure of the economy, the exchange rate, size, geography and climate of a country, and consumer behavior. Using energy intensity at the aggregate level (e.g., energy consumption per unit of GDP or value added) as a proxy for energy efficiency is sometimes misleading and often generate misleading results. However, in decomposition analysis, energy intensity is used as a proxy for energy efficiency because the activities for sub-sectors or end-uses are measured either in physical metrics (e.g., ton of steel or floor area) or in value (e.g., dollars).
Energy system	An energy system comprises an energy supply and end-use sector.
Energy supply sector	The supply sector consists of processes for extracting, converting and delivering energy resources into more desirable and sustainable forms to end users.
End-use sector	The end-use sector provides services such as cooking, lighting, heating, cooling and mobility.
Service demand	Service demand refers to the quantified demand created by a service. Service outputs from devices satisfy service demands. Examples include finished steel products, person-km traveled by road and heat energy for raising steam.
Useful energy	Useful energy is the energy that is actually converted into useful heat or work obtained by final energy users from the primary and secondary energy sources delivered to them, with a given stock of energy-using equipment, appliances and processes and a given mode of operation of these facilities. Examples include the work obtained from a motor car, or the light obtained from a filament bulb or a fluorescent tube, or the heat obtained in the steam produced by burning fossil fuel beneath a boiler.
Final energy	Final energy refers to all fuel and energy that is delivered to users for both their energy and non-energy uses not involving transformation process.

Sources: IEA (2005, 2014); UN (1982, 2011).

Annex A

Annex A.1: Set of equations for calculating final and useful residential energy demand and input parameters

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$$E_R(t) = \sum_r E_{r,R}(t) = \sum_j E_{j,r,R}(t), \quad j = \{sh, wh, ck, li, ac\}, \quad r \in R \qquad 3.1$$

$$E_{ck,r}(t) = POP_r(\mathrm{t}) \cdot SEC_{ck,r}(t) \qquad 3.2$$

$$E_{li,r}(t) = DWT_r(t) \cdot APDW_r(t) \cdot \{LIDW_r(\mathrm{t})/100\} \cdot SEC_{li,r}(t) \cdot 1825 \cdot (25/1500) \qquad 3.3$$

$$E_{wh,r}(t) = DWT_r(\mathrm{t}) \cdot PPDW_r(\mathrm{t}) \cdot \{WHDW_r(\mathrm{t})/100\} \cdot SEC_{wh,r}(t) \qquad 3.4$$

$$E_{sh,r}(t) = DWT_r(t) \cdot APDW_r(t) \cdot \{SHDW_r(\mathrm{t})/100\} \cdot HLR_r(t) \cdot HDD_r(t) \cdot ORDW_r(t) \cdot 24 \qquad 3.5$$

$$E_{ac,r}(t) = DWT_r(t) \cdot \{ACDW_r(\mathrm{t})/100\} \cdot SEC_{ac,r}(t) \qquad 3.6$$

$$\left. \begin{aligned} E_{ea,r} &= DWT_r(t) \cdot \left\{ \sum_{ea} DIEA_{ea,r}(t) \cdot UEC_{ea,r}(t) \right\} \\ &= DWT_r(t) \cdot UEC_{ot,r}(t) \end{aligned} \right] \quad , \quad ea = \{rf, wm, tv, ct, ac\}, ot \qquad 3.7$$

$$POP_r(t) = POP_r(t-n) \cdot \{1 + (GPOP_r(t)/100)\}^n \qquad 3.8$$

$$PPDW_r(t) = POP_r(t) / DWT_r(\mathrm{t}) \qquad 3.9$$

$$UEC_{ea,r}(t) = UEC_{ea,r}(t-n) \cdot \{1 + (AEEI_{ea,r}(t)/100)\} \qquad 3.10$$

Annex A.2: List of indices, and input and derived variables used in residential module

Index/variable	Definition	Measuring unit
ac	Air conditioner	
ap	Appliances (electric and non-electric)	
ck	Cooking	
ct	Computer	
ea	Electric appliances	
j	End-use type	
li	Lighting	
n	Number of periods	
ot	Other electric appliances	
r	Residential sub-sector	
rf	Refrigerator	
sh	Space heating	
t	Time period	
tv	Television	
wh	Water heating	
wm	Washing machine	
ACDW	Share of dwellings with air conditioning	%
AEEI	Autonomous energy efficiency improvement	%
APDW	Dwelling area (living floor space) per dwelling	square meter / square feet
DWA	Dwelling area (total)	square meter / square feet
DIEA	Diffusion of electric appliances per dwelling	unit
DRDW	Dwelling demolition rate	%
DWT	Dwelling stock	unit
E	Energy demand	GWh (ktoe)
GPOP	Average annual population growth rate	%

HDD	Heating degree days	Days °C
HLR	Average dwelling heat loss rate	Wh/sqm/days °C/year
LIDW	Share of dwelling with access to electricity	%
ORDW	Dwelling occupancy rate	%
POP	Population	person
PPDW	Dwelling (population) size	person
R	Residential sector	
SEC	Specific energy consumption	kWh (kgoe)
SHDW	Share of dwelling with space heating	%
UEC	Unit energy consumption	kWh (kgoe)
WHDW	Share of dwelling with water heating	%

Annex B

Annex B.1: Set of equations for calculating final and useful services energy demand and input parameters

$$E_S(t) = \sum_s E_{s,S}(t) = \sum_j E_{j,s,S}(t), \quad j = \{sh, sc, li\}, \quad s \in S \qquad 4.1$$

$$E_s(t) = \sum_j E_{j.s}(t) = SERA(t) \cdot \sum_j \{SHSER_{j,s}(t)/100\} \cdot SEC_{j,s}(t) \qquad 4.2$$

$$E_{ot}(t) = \sum_s E_{ot,s}(t) = SERA(t) \cdot \sum_s \{SHSER_{ot,s}(\mathrm{t})/100\} \cdot UEC_{ot,s}(t) \qquad 4.3$$

$$UEC_{ot,s}(t) = UEC_{ot,s}(t-n) \cdot \{1 + (AEEI_{ot,s}(t)/100)\} \qquad 4.4$$

$$SERA(t) = \left[SERAT(t-n) \cdot \{1 + (GSERA(t)/100)\}^n \right] \cdot \{DRS(t)/100\} \qquad 4.5$$

$$\sum_j \sum_s \{SHSER_{j,s}(t)\}/100 = 1 \qquad 4.6$$

Annex B.2: List of indices, and input and derived variables used in services module

Index/variable	Definition	Measuring unit
j	End-use type	

li	Lighting	
n	Number of periods	
ot	Others (end-use)	
s	Services sub-sector	
sh	Space heating	
sc	Space cooling	
t	Time period	
wh	Water heating	
DRS	Services floor area demolition rate	%
E	Energy demand	GWh (ktoe)
GSERA	Growth rate of floor area of services	%
S	Services sector	
SEC	Specific energy consumption	kWh (kgoe)
SERA	Floor area of services (effective)	square meter / square feet
SHSER	Share of total services floor area	%
UEC	Unit energy consumption	kWh (ktoe)

Annex C

Annex C.1: Set of equations for calculating final and useful industry energy demand and input parameters

$E_{i,I}(t) = \sum_j E_{j,i,I}(t), \quad j = \{ht, mt, lt\}, \quad i \in I$	5.1
$E_i(t) = \sum_j E_{j,i}(t) = IVA(t) \cdot \sum_j \{SHIVA_{j,i}(t)/100\} \cdot SEC_{j,i}(t)$	5.2
$E_{k,i}(t) = IVA(t) \cdot SHIVA_{k,i} \cdot UEC_{k,i}(t), \quad k = \{el, mf\}, \quad i \in I$	5.3
$UEC_{k,i}(t) = UEC_{k,i}(t-n) \cdot \{1 + (AEEI_{k,i}(t)/100)\}$	5.4
$IVA(t) = \sum_i IVA_i(t); \quad \sum_i \{SHIVA_i(t)\}/100 = 1$	5.5

$$IVA_i(t) = IVA_i(t-n) \cdot \{1 + GIVA_i(t)/100\}^n \qquad 5.6$$

Annex C.2: List of indices, and input and derived variables used in industry module

Index/variable	Definition	Measuring unit
el	Electricity use for specific purpose (end-use)	
i	Industry sub-sector	
j	End-use type	
lf, mt, ht	Low (l), medium (m) and high (h) temperature	
mf	Motor fuels (end-use)	
n	Number of periods	
t	Time period	
E	Energy demand	GWh (ktoe)
I	Industry sector	
IVA	Industrial value added	Currency (e.g., US$)
SEC	Specific energy consumption	kWh (kgoe)
SHIVA	Share of industrial value added	%
GIVA	Growth rate of industrial value added	%
UEC	Unit energy consumption	kWh (ktoe)

Annex D

End-use Energy Demand Drivers

Annex D.1: Residential sector

	Base year (2010)	Future source/assumptions
Average HDD	Eurostat (1980-2009)	Assumed same value (i.e., 3092) for 2010 and for future years
No. of households/ Dwelling stock (*DWT*)	NIS	$DWT(t+1) = DWT(t) \cdot (1 + r/100)^n \cdot (1 - DRDW/100)$ where *DWT* is dwelling stock, *r* is annual dwelling

		growth rate and *DRDW* is dwelling demolition rate. Here, *r* is assumed at 0.7% per year for 2015-2050, DRDW for 2015-2030 is based on MMSC (2013) and DRDW for 2035-250 is authors' assumption.
Floor area (*DWA*)	NIS	*DWA = APDW / DWT*
Floor area/dwelling (*APDW*)	Calculated *DWA / DWT*	$\mathrm{APDW(t+1)} = APDW(t) \cdot (1+r)^n$ Where APDW is dwelling area per dwelling and r is annual growth APDW growth rate. Here, *r* is assumed at 0.5% in every 5 years for 2015-2040 and 0.4% every 5 years for 2040-2050.
Population (*POP*)	INS (2014)	Eurostat (2014b) (main scenario)
Household size (*PPDW*)	Calculated *PPDW = POP / DWT*	Calculated *PPDW = POP / DWT*
Dwelling occupancy rate	BPIE (2014)	
Appliances ownership (i.e., refrigerator, washing machine, TV, computer per dwelling)	INS (2014)	Appliances ownership for 2050 is authors' assumption. Figures for 2015-2045 is interpolation of 2010 (actual) and 2050 (assumed) values.
Specific energy consumption (SEC) for space heating, air cooling and water heating	EU (2012)	
SEC for cooking	Sanga and Jannuzzi (2005)	
SEC for lighting		SEC for lighting (150 lux); 5 hours per day and 25/1500 W/lm based on 25 W CFL.
Share of dwelling with air cooling	ENTRANZE (2014)	
Unit energy consumption (UEC) for appliances and AEEI	EU (2014c)	Based on autonomous scenario. Data for 2035-2050 is authors' assumption.

Annex D.2: Services sector

	Base year (2010)	Future source/assumptions
	Source	Assumptions
Floor area by services types	BPIE (2014) Floor area for 2010 is assumed based on 2009 value (i.e., 67.2 m sqm) and average growth of service sector GVA of 2.3% between 2009 and 2010. However, the share of sub-sectors in total floor area for 2010 is assumed same as that of 2009.	Future growth rate of floor area of services for 2010-2030 are based on MMSC (2013); and for 2030-2050) are based on authors' assumption. Demolition rate (2015-2030) is based on MMSC (2013) and for 2030-2050 is based on authors' assumption. Share of total floor area by services types for future years are authors' assumption.
Specific energy consumption (SEC) for space heating and cooling, and water heating	EU (2012)	SEC for SH, WH and SC is calculated as UE for each end use divided floor space for each end uses.
SEC for lighting	Same as residential	
SEC for others	Atanasiu et al. (2012)	SEC for others (in FE) for future is based on AEEI of 1%/5yr from 2010 to 2030 and 0.5%/5yr from 2030 to 2050.

Annex D.3: Industry sector

	Base year (2010)	Future source/assumptions
GDP, GVA and growth rate	Eurostat (2014c)	2015-2030 MMSC (2013) 2030-2050 authors' assumption
Energy intensity (EI) for thermal energy use by types	EU (2012)	EI for SH, WH and SC is calculated as UE for each end use divided VA.
EI for motor fuels and electricity	Eurostat (20014a,c)	Motor fuels are not used for thermal energy requirements. * Electricity for thermal energy use is assumed 5% of total electricity use for agriculture and manufacturing. However, it is assumed 0% for mining and quarrying and construction. AEEI is assumed 0.5% in every five years for the period of 2010-2050 for motor fuels. For electricity use for non-thermal purposes, AEEI is assumed 1% in every five years from 2010 to 2050.

		About 60% of total electricity use in industry are used by electric motor systems based on EU (2009).

Annex D.4: Transport sector

	Base year (2010)	Future source/assumptions
GDP, GVA and growth rate	Eurostat (2014c)	2015-2030 **MMSC (2014)** 2030-2050 authors' assumption
No. of vehicles, VKT, LF, OF	INS (2014), Eurostat (2014a)	EI for SH, WH and SC is calculated as UE for each end use divided VA.

Annex E

Annex E.1.1: Residential sector

	BASIC DATASET FOR RESIDENTIAL SECTOR	Code	Unit	2010	2015	2020	2025	2030	2035	2040	2045	2050
	Demography and dwellings data											
	Population (resident as of July 1st)- total	[*POP*]	[million]	22.5	22.2	21.9	21.5	21.0	20.7	20.4	20.1	19.8
	Dwellings stock - total	[*DWT*]	[million]	8.43	8.88	9.08	9.27	9.45	9.62	9.79	9.94	10.09
	Dwellings occupancy rate	[OR*DW*]	[%]	88.5	88.5	88.5	88.5	88.5	88.5	88.5	88.5	88.5
	Dwellings stock - effective	[*DRDW*]	[million]	7.46	7.86	8.04	8.20	8.36	8.51	8.66	8.80	8.93
	Dwellings (population) size - effective	[*PPDW*]	[person]	3.02	2.83	2.73	2.62	2.52	2.43	2.36	2.29	2.22
	Dwelling area (living floor space) - total	[*DWA*]	[million sqm]	330	423	446	471	497	511	525	539	554
	Dwelling area (living floor space) per dwelling -effective	[*APDW*]	[sqm]	44.2	53.8	55.5	57.4	59.5	60.0	60.6	61.3	62.1
I.	**Factors for space heating**											
	Share of dwellings with space heating	[*SHDW*]	[%]	100	100	100	100	100	100	100	100	100
	Mean annual heating degree-days (1980-2009)	[*HDD*]	[days °C]	3092	3092	3092	3092	3092	3092	3092	3092	3092
	SEC for heating per floor area (climate corrected)	[$SEC_{sh,R}$]	[kWh/sqm/yr]	142	142	142	142	142	142	142	142	142
II.	**Factors for air conditioning**											
	Share of dwellings with air conditioning	[*ACDW*]	[%]	5	7	9	11	13	15	17	19	21
	SEC for cooling per dwelling	[$SEC_{ac,R}$]	[kWh/dw/yr]	795	795	795	795	795	795	795	795	795
III.	**Factors for water heating**											
	Share of dwellings with water heating facilities	[*WHDW*]	[%]	100	100	100	100	100	100	100	100	100
	SEC for water heating per person	[$SEC_{wh,R}$]	[kWh/person/yr]	403	403	403	403	403	403	403	403	403
IV.	**Factor for cooking**											
	SEC for cooking per person	[$SEC_{ck,R}$]	[kWh/person/yr]	523	523	523	523	523	523	523	523	523
V.	**Factors for lighting**											
	Share of dewellings with access to electricity	[*LIDW*]	[%]	100	100	100	100	100	100	100	100	100
	SEC for lighting per dwelling area	[$SEC_{li,R}$]	[lumen/sqm/yr]	150	150	150	150	150	150	150	150	150
VI.	**Factors for electric appliances**											
	UEC of refrigerator/freezer	[$UEC_{rf,R}$]	[*kWh/unit/yr*]	325	319	313	308	305	302	299	298	297
	UEC of washing machine	[$UEC_{wm,R}$]	[*kWh/unit/yr*]	250	247	246	245	243	241	240	239	239
	UEC of television	[$UEC_{tv,R}$]	[*kWh/unit/yr*]	200	201	202	201	201	200	199	198	197
	UEC of computer	[$UEC_{ct,R}$]	[*kWh/unit/yr*]	78	76	75	75	75	75	75	75	74
	UEC of other electric appliances	[$UEC_{ot,R}$]	[*kWh/dw/yr*]	50	50	49	49	48	48	47	47	46

Annex E.1.2: Electric appliances diffusion rate

ELECTRIC APPLIANCES DATA	Code	Unit	2010	2015	2020	2025	2030	2035	2040	2045	2050
Appliances diffusion											
Refrigerator/freezer	[$DIEA_{rf,R}$]	[unit/dw]	1.20	1.24	1.28	1.31	1.35	1.39	1.43	1.47	1.50
Washing machine	[$DIEA_{wm,R}$]		0.75	0.78	0.81	0.84	0.87	0.90	0.93	0.96	1.00
Television	[$DIEA_{tv,R}$]		1.30	1.45	1.46	1.46	1.47	1.48	1.49	1.49	1.5
Computer	[$DIEA_{ct,R}$]		0.46	0.74	0.82	0.90	1.00	1.20	1.30	1.40	1.50

Annex E.2: Services sector

BASIC DATASET FOR SERVICES SECTOR	Code	Unit	2010	2015	2020	2025	2030	2035	2040	2045	2050
Buildings data											
Floor area of services - total	[*SERAT*]	[million sqm]	61.1	71.3	84.5	96.8	108.2	121.2	133.4	145.9	157.0
Future floor area growth rate of services sector	[*GSERA*]	[%]		3.1	3.5	2.7	2.3	2.3	1.9	1.8	1.5
Demolition rate	[*DRS*]	[%]	0.0	1.0	1.3	1.6	2.3	1.6	1.3	1.0	0.5
Occupancy rate		[%]	85	85	85	85	85	85	85	85	85
Floor area of services -effective (demolition and occupancy r	[*SERA*]	[million sqm]	51.9	60.0	70.9	81.0	89.9	101.4	111.9	122.8	132.8
Offices (public and private)	[*SHOF*]		8.5	9.8	11.7	13.4	15.0	16.7	18.4	20.1	21.7
Hospitals	[*SHHO*]		7.2	7.5	8.6	9.5	10.1	10.6	11.0	11.3	11.6
Hotels and restaurants	[*SHHR*]		4.0	4.8	5.8	6.7	7.6	8.6	9.7	10.7	11.6
Sport facilities	[*SHSF*]		3.6	3.8	4.4	4.8	5.1	5.4	5.6	5.8	5.9
Others (educational, wholesale/retail trade, and other non-r	[*SHOT*]		28.7	34.1	40.5	46.6	52.0	60.0	67.2	74.9	81.9
Value added											
Total services GVA (in chain linked volumes b.€ 2010)	[*Y*]	[billion Euro]	58.8	68.1	80.6	92.5	103.6	116.1	127.9	140.0	150.9
Market and non market services GVA (excl transport)		[billion Euro]	49.7	57.9	68.7	78.7	88.0	98.6	108.5	118.6	127.7
Factors for space heating											
SEC for space heating per office floor area	$[SEC_{sh,of,S}]$	[kWh/sqm/yr]	149	149	149	149	149	149	149	149	149
SEC for space heating per hospital floor area	$[SEC_{sh,ho,S}]$		149	149	149	149	149	149	149	149	149
SEC for space heating per hotel/resturant floor area	$[SEC_{sh,hr,S}]$		149	149	149	149	149	149	149	149	149
SEC for space heating per sport facility floor area	$[SEC_{sh,sf,S}]$		149	149	149	149	149	149	149	149	149
SEC for space heating per others floor area	$[SEC_{sh,ot,S}]$		149	149	149	149	149	149	149	149	149
Mean annual heating degree-days (1980-2009)	[*HDD*]	[days °C]	3092	3092	3092	3092	3092	3092	3092	3092	3092
Factors for space cooling											
SEC for space cooling per office floor area	$[SEC_{sc,of,S}]$	[kWh/sqm/yr]	22	22	22	22	22	22	22	22	22
SEC for space cooling per hospital floor area	$[SEC_{sc,ho,S}]$		22	22	22	22	22	22	22	22	22
SEC for space cooling per hotel/resturant floor area	$[SEC_{sc,hr,S}]$		22	22	22	22	22	22	22	22	22
SEC for space cooling per sport facility floor area	$[SEC_{sc,sf,S}]$		22	22	22	22	22	22	22	22	22
SEC for space cooling per others floor area	$[SEC_{sc,ot,S}]$		22	22	22	22	22	22	22	22	22
Factors for water heating											
SEC for water heating per office floor area	$[SEC_{wh,of,S}]$	[kWh/sqm/yr]	16	16	16	16	16	16	16	16	16
SEC for water heating per hospital floor area	$[SEC_{wh,ho,S}]$		16	16	16	16	16	16	16	16	16
SEC for water heating per hotel/resturant floor area	$[SEC_{wh,hr,S}]$		16	16	16	16	16	16	16	16	16
SEC for water heating per sport facility floor area	$[SEC_{wh,sf,S}]$		16	16	16	16	16	16	16	16	16
SEC for water heating per others floor area	$[SEC_{wh,ot,S}]$		16	16	16	16	16	16	16	16	16
Factors for lighitng											
SEC for lighting per office floor area	$[SEC_{li,of,S}]$	[lumen/sqm/yr]	400	400	400	400	400	400	400	400	400
SEC for lighting per hospital floor area	$[SEC_{li,ho,S}]$		400	400	400	400	400	400	400	400	400
SEC for lighting per hotel/resturant floor area	$[SEC_{li,hr,S}]$		400	400	400	400	400	400	400	400	400
SEC for lighting per sport facility floor area	$[SEC_{li,sf,S}]$		400	400	400	400	400	400	400	400	400
SEC for lighting per others floor area	$[SEC_{li,ot,S}]$		400	400	400	400	400	400	400	400	400
Factors for others											
SEC for others per services floor area	$[UEC_{ot,S}]$	[kWh/sqm/yr]	56	56	54	53	52	51	50	49	48

Annex E.3.1: Industry sector

ECONOMIC DATA	Code	Unit	2010	2015	2020	2025	2030	2035	2040	2045	2050
GDP											
GDP -total (in billion € 2010)	[Y]	[billion Euro]	124	139	163	187	209	233	256	279	300
GDP index (2010=100)	[IY]	[index]	100	112	132	151	169	187	206	224	241
GVA											
GVA - total (in billion € 2010)	[GVA_j]	[billion Euro]	111	124	146	167	187	207	228	248	267
Of which:											
Agriculture			7.1	7.4	7.8	8.3	8.6	8.9	9.2	9.3	9.5
Manufacturing			31.5	36.3	41.9	48.0	53.5	58.8	64.7	70.5	75.9
Iron and Steel			1.6	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6
Chemical and Petrochemical			1.4	1.8	2.0	2.3	2.7	3.1	3.5	3.9	4.3
Non-Metallic Minerals			0.6	0.6	0.7	0.8	0.9	0.9	1.0	1.0	1.0
Food and Tobacco			6.9	8.3	9.4	10.2	11.0	12.0	13.1	13.9	14.6
Textile and Leather			2.6	3.2	3.6	3.9	4.2	4.6	5.0	5.3	5.6
Paper, Pulp and Print			0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8
Transport Equipment			4.0	4.9	6.0	7.6	8.8	9.9	11.1	12.5	13.9
Machinery			2.4	2.9	3.7	4.7	5.5	6.2	7.1	8.0	8.9
Wood and Wood Products			1.2	1.4	1.6	1.7	1.9	2.0	2.2	2.4	2.5
Other manufacturing (n.e.c.)			10.1	11.1	12.6	14.6	16.3	17.7	19.4	21.1	22.7
Mining and Quarrying			2.1	2.2	2.4	2.5	2.7	2.9	3.1	3.3	3.4
Construction			11.3	10.2	13.0	15.6	18.1	20.5	23.0	25.3	27.4
Services			58.8	68.1	80.6	92.5	103.6	116.1	127.9	140.0	150.9

Annex E.3.2: Dataset for industry sector

ENERGY INTENSITY FOR INDUSTI	Code	Unit	2010	2015	2020	2025	2030	2035	2040	2045	2050
Motor fuels											
Gasoline											
Agriculture	$[EI_{g,j}]$	[Wh/Euro]	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.5
Manufacturing											
Iron and Steel			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemical and Petrochemical			42.3	42.1	41.9	41.7	41.5	41.3	41.1	40.9	40.7
Non-Metallic Minerals			19.5	19.4	19.3	19.2	19.1	19.0	18.9	18.8	18.7
Food and Tobacco			3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4
Textile and Leather			4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5
Paper, Pulp and Print			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transport Equipment			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Machinery			10.2	10.1	10.1	10.0	10.0	9.9	9.9	9.8	9.8
Wood and Wood Products			10.4	10.4	10.3	10.3	10.2	10.2	10.1	10.1	10.0
Other manufacturing			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mining and Quarrying			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction			8.5	8.5	8.4	8.4	8.4	8.3	8.3	8.2	8.2
Diesel oil											
Agriculture	$[EI_{d,j}]$	[Wh/Euro]	324	323	321	319	318	316	315	313	312
Manufacturing											
Iron and Steel			7	7	7	7	7	7	7	7	7
Chemical and Petrochemical			17	17	17	16	16	16	16	16	16
Non-Metallic Minerals			114	113	113	112	111	111	110	110	109
Food and Tobacco			40	39	39	39	39	39	38	38	38
Textile and Leather			5	5	4	4	4	4	4	4	4
Paper, Pulp and Print			69	68	68	68	67	67	67	66	66
Transport Equipment			0	0	0	0	0	0	0	0	0
Machinery			5	5	5	5	5	5	5	5	5
Wood and Wood Products			92	91	91	90	90	89	89	88	88
Other manufacturing			6	6	6	6	6	6	6	6	6
Mining and Quarrying			81	81	80	80	79	79	79	78	78
Construction			158	157	156	155	154	154	153	152	151

ENERGY INTENSITY FOR INDUSTI	Code	Unit	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity -excluding electricity used for thermal energy use (FE)*											
Agriculture	[$EIe_{,j}$]	[Wh/Euro]	90	89	88	87	86	85	85	84	83
Manufacturing											
Iron and Steel			2962	2888	2815	2745	2676	2609	2544	2481	2419
Chemical and Petrochemical			2304	2246	2190	2135	2082	2030	1979	1930	1882
Non-Metallic Minerals			2135	2081	2029	1978	1929	1881	1834	1788	1743
Food and Tobacco			214	212	210	208	206	204	202	200	198
Textile and Leather			293	290	288	285	282	279	276	273	271
Paper, Pulp and Print			779	771	764	756	748	741	734	726	719
Transport Equipment			114	113	112	111	110	109	107	106	105
Machinery			906	896	887	879	870	861	853	844	836
Wood and Wood Products			565	560	554	548	543	538	532	527	522
Other manufacturing			91	90	89	88	87	86	85	85	84
Mining and Quarrying			115	114	113	112	111	110	109	107	106
Construction			59	58	58	57	56	56	55	55	54

ENERGY INTENSITY FOR INDUST	Code	Unit	2010	2015	2020	2025	2030	2035	2040	2045	2050
Thermal energy use (UE)											
Agriculture [A01-A03]	$[EI_{th,j}]$	[Wh/Euro]	66	65	63	62	60	58	57	56	54
Manufacturing	$[EI_{th,j,k}]$										
Iron and Steel [C24 Manufacture of b			8281	8074	7872	7675	7484	7296	7114	6936	6763
Furnace and direct heat (HT)			7688	7496	7309	7126	6948	6774	6605	6440	6279
Steam generation (MT)			376	366	357	348	339	331	323	315	307
Space and water heating (LT)			217	212	207	202	196	192	187	182	178
Chemical and Petrochemical [C20 M			8057	7855	7659	7467	7281	7099	6921	6748	6580
Furnace and direct heat (HT)			3798	3703	3611	3520	3432	3347	3263	3181	3102
Steam generation (MT)			1937	1889	1842	1796	1751	1707	1664	1623	1582
Space and water heating (LT)			2321	2263	2207	2151	2098	2045	1994	1944	1896
Non-Metallic Minerals [C23 Manufa			6580	6416	6255	6099	5946	5798	5653	5512	5374
Furnace and direct heat (HT)			5797	5652	5511	5373	5239	5108	4980	4855	4734
Steam generation (MT)			366	356	348	339	330	322	314	306	299
Space and water heating (LT)			418	407	397	387	378	368	359	350	341
Food and Tobacco [C10-C12 Manufa			392	388	384	381	377	373	369	366	362
Furnace and direct heat (HT)			0	0	0	0	0	0	0	0	0
Steam generation (MT)			154	153	151	150	148	147	145	144	142
Space and water heating (LT)			238	236	233	231	229	226	224	222	220
Textile and Leather[C13-C15 Manufa			273	271	268	265	262	260	257	255	252
Furnace and direct heat (HT)			47	47	46	46	45	45	44	44	43
Steam generation (MT)			132	131	129	128	127	125	124	123	122
Space and water heating (LT)			94	93	92	91	91	90	89	88	87
Paper, Pulp and Print [C17 Manufact			1034	1024	1014	1004	994	984	974	964	954
Furnace and direct heat (HT)			148	146	145	143	142	141	139	138	136
Steam generation (MT)			517	512	507	502	497	492	487	482	477
Space and water heating (LT)			369	366	362	358	355	351	348	344	341
Transport Equipment [C29 Manufact			59	58	58	57	56	56	55	55	54
Furnace and direct heat (HT)			7	6	6	6	6	6	6	6	6
Steam generation (MT)			13	13	13	13	13	12	12	12	12
Space and water heating (LT)			39	39	38	38	38	37	37	36	36
Machinery [C28 Manufacture of mac			242	240	237	235	233	230	228	226	224
Furnace and direct heat (HT)			23	23	23	22	22	22	22	22	21
Steam generation (MT)			46	46	45	45	44	44	43	43	43
Space and water heating (LT)			173	171	170	168	166	165	163	161	160
Wood and Wood Products [C16 Man			590	584	578	572	567	561	555	550	544
Furnace and direct heat (HT)			0	0	0	0	0	0	0	0	0
Steam generation (MT)			0	0	0	0	0	0	0	0	0
Space and water heating (LT)			590	584	578	572	567	561	555	550	544
Other manufacturing (non specified)			35	34	34	34	33	33	33	32	32
Furnace and direct heat (HT)			6	6	6	6	6	6	6	6	6
Steam generation (MT)			13	12	12	12	12	12	12	12	12
Space and water heating (LT)			16	16	15	15	15	15	15	15	15
Mining and Quarrying	$[EI_{th,j}]$		20	20	20	20	20	19	19	19	19
Construction			116	115	114	113	112	111	109	108	107

Annex F

Annex F.1: Conversion equivalent between units of energy

To: From:	TJ Multiply by:	Gcal	Mtoe	MBtu	GWh
Tera joule (TJ)	1	238.8	2.388×10^{-5}	947.8	0.2778
Giga calorie (Gcal)	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Million toe (Mtoe)	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11630
Million Btu (MBtu)	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
Gigawatt-hour (GWh)	3.6	860	8.6×10^{-5}	3412	1

Source: IEA (2005).

Annex F.2: Selected net calorific values of fuels

Fuel type	Net calorific value (as used) MJ/kg
Coal	
Anthracite	28.95 - 30.35
Coking coal	26.60 - 29.80
Other bituminous	22.60 - 25.50
Petroleum products	
LPG	46.15
Gasoline	44.75
Aviation turbine fuel	43.92
Kerosene	43.92
Diesel oil	43.38
Fuel oil, low sulfur	42.18
Natural gas	37.5-40.5 (in MJ/m^3)

Source: IEA (2005).

Annex G

The following basic common and specific assumptions are made under alternative low carbon scenario for residential, services and industry sectors:

Basic common assumptions

Romania		2015	2020	2025	2030	2035	2040	2045	2050
RESIDENTIAL SECTOR									
Demography and Dwelling data									
Permanent resident (July 1st)	[million]	22.23	21.90	21.47	21.04	20.73	20.42	20.11	19.81
Dwellings stock - total	[million]	8.88	9.08	9.27	9.45	9.62	9.79	9.94	10.09
Of which: New stock added	[million]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Dwellings occupancy rate	[%]	88.50	88.50	88.50	88.50	88.50	88.50	88.50	88.50
Dwelling demolition rate	[%]	0.07	0.07	0.10	0.10	0.13	0.13	0.16	0.16
Dwellings stock - occupied (effective)	[million]	7.86	8.04	8.20	8.36	8.51	8.66	8.80	8.93
Of which: New stock occupied (effective)	[million]	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Dwelling area (living floor space) per dwellin	[sqm]	41.23	40.32	39.52	38.75	38.07	37.41	36.84	36.29
Dwelling area (useful area) per dwelling (occ	[sqm]	65.41	63.97	62.69	61.47	60.39	59.35	58.45	57.57
Dwellings (occupied) population size	[person]	2.83	2.73	2.62	2.52	2.43	2.36	2.29	2.22
Ownership of durable goods									
TV sets		1.3	1.45	1.46	1.47	1.48	1.49	1.49	1.5
Refrigerators and freezers	t/dw (acutal u:	1.24	1.28	1.31	1.35	1.39	1.43	1.47	1.5
Electric washing machines		0.78	0.81	0.84	0.87	0.9	0.93	0.96	1
SERVICES SECTOR		2015	2020	2025	2030	2035	2040	2045	2050
Distribution of services floor area (total)	[million sqm]	68.23	76.37	85.69	96.40	108.77	123.11	139.82	159.35
Demolition rate	[%]	1.0	1.3	1.6	2.3	1.6	1.3	1.0	0.5
Occupancy rate	[%]	86	86	87	88	88	89	89	90
Distribution of services floor area (effective)	[million sqm]	57.74	64.88	73.07	82.14	94.12	107.66	123.56	142.62
Distribution of services floor area New Stock	[million sqm]	1.35	1.55	1.78	2.05	2.40	2.81	3.31	3.92

Residential

Refrigerator	1. Penetration of energy efficient refrigerators in existing stock in base year: 40%. 2. Cost of energy efficient refrigerator: US$ 684/unit. 3. Cost of non-energy efficient refrigerator: US$ 474/unit. 4. Electricity price: US$ 0.176/kWh (EUROSTAT, 2015). 5. CO2 emission factor for electricity generation: 0.67 kg/kWh (IEA, 2014) The following information (2012 data) is used to calculate CO2 emission factor: CO2 emissions from electricity and heat = 35.234074 Mt; Total Electricity Generation =52.54 TWh; CO2 emission factor for electricity and heat generation = 35.2/52.5 kg/kWh 6. Lifetime of refrigerator: 20 years 7. Electricity consumption: 500 kWh for efficient refrigerator and 800 kWh for non-efficient refrigerator.
TV	1. Penetration of energy efficient TV in existing stock in base year: 5%. 2. Cost of energy efficient refrigerator: US$ 421/unit. 3. Cost of non-energy efficient refrigerator: US$ 180/unit. 4. Electricity price: US$ 0.176/kWh (EUROSTAT, 2015).

	5. CO_2 emission factor for electricity generation: 0.67 kg/kWh (IEA, 2014) 6. Lifetime of TV: 20 years 7. Electricity consumption: 256 kWh for efficient TV and 365 kWh for non-efficient TV.
Washing machine	1. Penetration of energy efficient washing machine in existing stock in base year: 5%. 2. Cost of energy efficient washing machine: US$ 900/unit. 3. Cost of non-energy efficient washing machine: US$ 400/unit. 4. Electricity price: US$ 0.176/kWh (EUROSTAT, 2015). 5. CO_2 emission factor for electricity generation: 0.67 kg/kWh (IEA, 2014) 6. Lifetime of washing machine: 15 years 7. Electricity consumption: 548 kWh for efficient washing machine and 1095 kWh for non-efficient washing machine.
Lighting	1. Penetration of energy efficient lamp in existing stock in base year: 40%. 2. Cost of energy efficient lamp: US$ 4/unit. 3. Cost of non-energy efficient lamp: US$ 0.58/unit. 4. Electricity price: US$ 0.176/kWh (EUROSTAT, 2015). 5. CO_2 emission factor for electricity generation: 0.67 kg/kWh (IEA, 2014) 6. Lifetime: non efficient lamp is 2 years and efficient lamp is 8 years. 7. Capacity: non efficient lamp 60 watt/unit and efficient lamp 12 watt/unit. 8. Electricity consumption: non efficient lamp 131 kWh/lamp/year and efficient lamp 26 kWh/lamp/year.
AC	1. Penetration of energy efficient AC in existing stock in base year: 2%. 2. Cost of energy efficient AC: US$ 700/unit. 3. Cost of non-energy efficient AC: US$ 500/unit. 4. Electricity price: US$ 0.176/kWh (EUROSTAT, 2015). 5. CO_2 emission factor for electricity generation: 0.67 kg/kWh (IEA, 2014) 6. Lifetime of AC: 15 years 7. Electricity consumption: 206 kWh for efficient AC and 376 kWh for non-efficient AC.
Cookstove	1. Penetration of energy efficient LPG cookstove in existing stock in base year: 5%. 2. Cost of energy efficient cook stove: US$ 100/unit. 3. Cost of non-energy efficient AC: US$ 75/unit. 4. LPG price: US$ 0.13/kWh (EUROSTAT, 2015). Based on 0.7 Euro per liter. Exchange rate: 1 Euro = 1.3 US$. Conversion factor for LPG (IEA):1 ton = 1915 liter; 1 ton = 46.15 GJ; and 1 GJ = 277.78 kWh. 5. LPG CO_2 emission factor: 0.23 kg/kWh (IPCCC, 2006) 6. Lifetime of LPG cookstove: 5 years 7. Electricity consumption: 319 kWh for efficient cookstove and 364 kWh for non-efficient cookstove.
Insulation	1. Penetration of energy efficient insulation in existing stock in base year: 0%.

(window, roof and wall)	2. Cost of energy efficient insulation: US$ 3111/unit. 3. Cost of non-energy efficient insulation: US$ 0/unit. 4. Natural gas price: US$ 0.04/kWh (EUROSTAT, 2015). 5. Natural gas CO2 emission factor: 0.20 kg/kWh (IPCCC, 2006) 6. Lifetime of heating unit: 25 years 7. Electricity consumption: 5735 kWh/hh/year for efficient heating unit and 12403 kWh/hh/year for non-efficient heating unit.

Services sector

Insulation (windows, roof and wall)	1. Penetration of energy efficient insulation in existing stock in base year: 0%. 2. Cost of energy efficient insulation: US$ 3111/unit. 3. Cost of non-energy efficient insulation: US$ 0/unit. 4. Natural gas price: US$ 0.04/kWh (EUROSTAT, 2015). 5. Natural gas CO2 emission factor: 0.20 kg/kWh (IPCCC, 2006) 6. Lifetime of heating unit: 25 years 7. Electricity consumption: 6200 kWh/services building/year for efficient heating unit and 12403 kWh/services buildings/year for non-efficient heating unit. It is assumed that there are 1000 sqm of effective services floor area per services buildings.
AC	1. Penetration of energy efficient AC in existing stock in base year: 4%. 2. Cost of energy efficient AC: US$ 700/unit. 3. Cost of non-energy efficient AC: US$ 500/unit. 4. Electricity price: US$ 0.176/kWh (EUROSTAT, 2015). 5. CO2 emission factor for electricity generation: 0.67 kg/kWh (IEA, 2014) 6. Lifetime of AC: 20 years. 7. Electricity consumption: 513 kWh/1000 sqm/year for efficient AC and 939 kWh/1000 sqm/year for non-efficient AC.

Residential energy efficiency improvement

% Reduction wrt baseline scenario	2015	2020	2025	2030	2035	2040	2045	2050
Space heating (Wall, windows and roof insulation)	3.1	10.1	16.1	21.2	25.6	29.4	32.6	35.4
Air conditioning	8.1	20.2	27.6	33.0	35.9	38.9	41.9	45.0
Cooking	3.1	7.1	7.9	8.8	9.6	10.4	11.2	12.0
Lighting	42.3	47.6	51.5	55.2	58.0	59.9	60.1	57.8
Refrigerators	3.1	10.1	15.4	18.1	19.6	22.5	25.3	28.1
Washing machines	5.4	18.7	32.0	36.3	40.0	43.2	45.7	48.9
TVs	2.7	9.4	16.0	22.0	23.6	25.4	27.2	29.1

Services energy efficiency improvement

% Reduction wrt baseline scenario	2015	2020	2025	2030	2035	2040	2045	2050
Space heating	5.1	15.7	23.9	30.0	35.0	38.8	41.6	43.8
Air conditioning	3.2	11.7	21.1	34.9	36.9	39.3	41.9	44.7

Industrial energy efficiency improvement in every 5 years

% Reduction wrt baseline scenario	2015-30	2030-50
Electric motor		
Agriculture	2	1.5
Manufacturing		
C24, C20 and C23	5	4
Rest		
Mining and Quarrying	3	2
Construction	3	2
Thermal energy		
Agriculture	5	4
Manufacturing		
C24, C20 and C23	5	4
Rest	3	2
Mining and Quarrying	3	2

Construction	3	2

Annex H

Industry sector thermal energy use by sub-sector and by type of heat, 2010-2050 (ktoe)

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Agriculture	40	41	42	44	45	45	45	45	44
Manufacturing	2990	3164	3417	3679	3946	4208	4489	4718	4895
Iron and Steel	1128	1021	1003	1010	1013	1005	1000	974	938
Furnace and direct heat (HT)	1047	948	931	938	941	933	929	905	871
Steam generation (MT)	51	46	45	46	46	46	45	44	43
Space and water heating (LT)	30	27	26	27	27	26	26	26	25
Chemical and Petrochemical	991	1193	1348	1507	1688	1876	2078	2263	2424
Furnace and direct heat (HT)	467	563	635	710	796	885	980	1067	1143
Steam generation (MT)	238	287	324	362	406	451	500	544	583
Space and water heating (LT)	285	344	388	434	486	541	599	652	698
Non-Metallic Minerals	355	352	393	421	439	455	466	473	475
Furnace and direct heat (HT)	313	310	346	371	387	401	410	417	419
Steam generation (MT)	20	20	22	23	24	25	26	26	26
Space and water heating (LT)	23	22	25	27	28	29	30	30	30
Food and Tobacco	234	277	311	334	358	386	415	438	455
Furnace and direct heat (HT)	0	0	0	0	0	0	0	0	0
Steam generation (MT)	92	109	122	131	141	152	163	172	179
Space and water heating (LT)	142	168	189	203	217	234	252	266	276
Textile and Leather	62	73	82	89	95	102	110	116	121
Furnace and direct heat (HT)	11	13	14	15	16	18	19	20	21
Steam generation (MT)	30	35	40	43	46	49	53	56	58
Space and water heating (LT)	21	25	28	31	33	35	38	40	42
Paper, Pulp and Print	62	59	59	60	62	64	68	69	68
Furnace and direct heat (HT)	9	8	8	9	9	9	10	10	10
Steam generation (MT)	31	30	30	30	31	32	34	34	34
Space and water heating (LT)	22	21	21	21	22	23	24	25	24
Transport Equipment	20	24	30	37	43	47	53	59	65
Furnace and direct heat (HT)	2	3	3	4	5	5	6	7	7
Steam generation (MT)	4	5	7	8	9	11	12	13	14
Space and water heating (LT)	13	16	20	25	28	32	35	39	43
Machinery	49	61	75	94	110	123	139	155	171
Furnace and direct heat (HT)	5	6	7	9	10	12	13	15	16
Steam generation (MT)	9	12	14	18	21	23	26	29	33
Space and water heating (LT)	35	43	53	67	79	88	99	110	122
Wood and Wood Products	59	71	79	85	91	98	106	112	116
Furnace and direct heat (HT)	0	0	0	0	0	0	0	0	0
Steam generation (MT)	0	0	0	0	0	0	0	0	0
Space and water heating (LT)	59	71	79	85	91	98	106	112	116
Other manufacturing (non-specified)	30	33	37	42	47	50	54	59	62
Furnace and direct heat (HT)	5	6	7	8	8	9	10	11	11
Steam generation (MT)	11	12	13	15	17	18	20	21	23
Space and water heating (LT)	14	15	17	19	21	23	25	27	28
Mining and Quarrying	4	4	4	4	5	5	5	5	5
Construction	113	101	128	152	174	195	216	236	253

Notes: HT is high temperature, MT is medium temperature and LT is low temperature.

Annex I

Roamina's sectoral useful energy demand by end-uses under baseline and LCS scenarios during 2010−2050 period

	2010	Baseline scenario								LCS 2050							
		2015	2020	2025	2030	2035	2040	2045	2050	2015	2020	2025	2030	2035	2040	2045	2050
Residential																	
Space heating	31045	39776	41987	44321	46785	48071	49392	50750	52145	38536	37735	37193	36862	35773	34891	34211	33693
Air conditioning	296	437	575	717	864	1015	1170	1328	1490	402	459	519	579	651	715	771	820
Water heating	9062	8958	8824	8649	8477	8351	8226	8104	7983	8958	8824	8649	8477	8351	8226	8104	7983
Cooking	11763	11628	11454	11227	11004	10840	10679	10519	10363	11265	10638	10336	10041	9803	9570	9341	9117
Lighting	1807	2315	2444	2579	2723	2798	2875	2954	3035	1336	1281	1252	1221	1174	1154	1179	1279
Electric appliances	6881	7756	8065	8371	8699	9108	9457	9807	10168	7516	7218	6935	6891	7072	7136	7199	7237
Total (Residential)	60855	70870	73349	75865	78552	80182	81799	83462	85184	68012	66155	64884	64072	62823	61693	60805	60129
Services																	
Space heating	7734	8935	10566	12062	13392	15107	16678	18291	19787	8476	8906	9184	9370	9814	10212	10682	11129
Space cooling	1142	1319	1560	1781	1977	2231	2463	2701	2922	1277	1378	1405	1287	1408	1494	1569	1617
Water heating	830	959	1135	1295	1438	1622	1791	1964	2125	959	1135	1295	1438	1622	1791	1964	2125

Lighting	1785	2215	2617	2983	3304	3724	4105	4497	4860	2215	2617	2983	3304	3724	4105	4497	4860
Others	2914	3333	3863	4322	4703	5199	5624	6045	6408	3333	3863	4322	4703	5199	5624	6045	6408
Total (Services)	14406	16763	19741	22443	24814	27882	30660	33497	36101	16262	17899	19190	20102	21766	23226	24756	26139
Industry																	
Electric motor	17845	19199	21299	23614	25738	27702	29872	31795	33466	17748	19233	20845	22185	23546	25049	26311	27342
Thermal energy	36605	38492	41767	45113	48484	51779	55301	58187	60446	20996	22265	23764	24988	26235	27643	28745	29587
Others	5165	5167	5889	6551	7165	7727	8307	8808	9245	5167	5889	6551	7165	7727	8307	8808	9245
Total (Industry)	59615	62858	68955	75278	81386	87208	93480	98790	103158	43911	47387	51159	54337	57508	60999	63864	66174

Project co-financed by the European Regional Development Fund through OPTA 2007 – 2013

Romania Climate Change and Low Carbon Green Growth Program

Output C1.1
Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors

ENERGY SECTOR SUPPLY TECHNICAL REPORT: ACHIEVING MITIGATION OF EMISSIONS FROM ENERGY SUPPLY USING A TIMES-MARKAL MODEL FOR ROMANIA

November 2015

This report corresponds to "Output C1.1: Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors" in the Advisory Services Agreement on "Romania: Climate Change and Low Carbon Green Growth Program" signed between the Ministry of Environment and Climate Change[1] and the International Bank for Reconstruction and Development on July 23, 2013.

[1] Now, Ministry of Environment, Waters and Forests

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1. Introduction

1.1 Study Objectives

This Energy Sector Assessment is part of a multi-sectoral advisory program on climate change and low carbon green growth conducted by the World Bank for the Government of Romania. The main objective of the assessment is to identify climate change related investment priorities and necessary implementation support for the 2014-2020 Operational Programs, with a view to achieving the EU 20-20-20 targets and laying a foundation for continued de-carbonization of the energy sector.

The energy sector analysis focuses on assessing energy saving potentials in the different sectors in Romania (households, services, industry and transport) and on identifying cleaner/greener energy supply options to meet the energy demand in the country through 2050. Two models are employed to achieve this: End-use energy[2] demand forecasting model (ESDA model) and (ii) Energy supply optimization model (TIMES model).

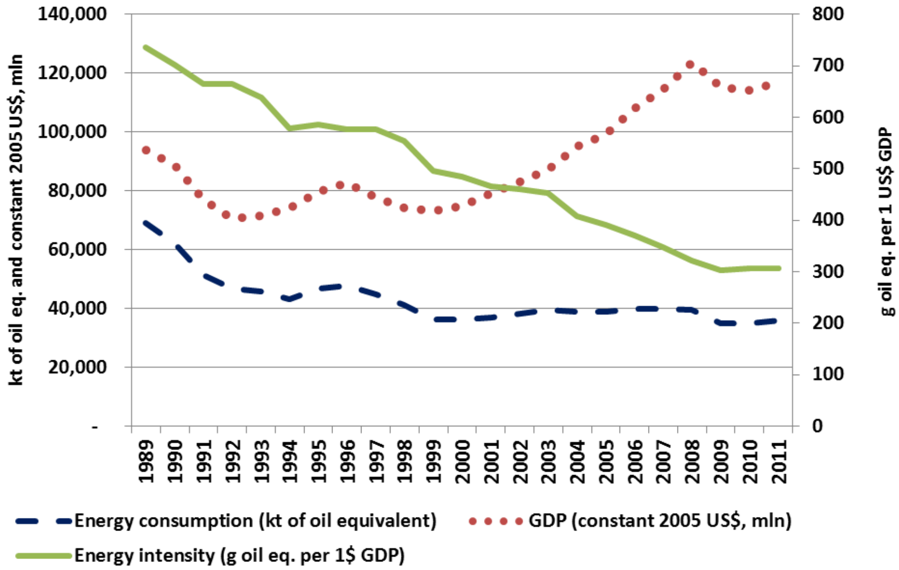
1.2 Overview

Romania's economic growth and energy consumption have been decoupling since the early 1990s, and the energy intensity of the economy[3] has been continuously decreasing. However, a significant increase in energy demand is expected to accompany future growth. After the large contractions of the economy and energy consumption in the 1990s, Romania's GDP recovered, expanding by 53 percent during 2000 to 2011, while energy demand remained flat. This slow growth of energy demand was in large part due to structural shifts of the economy toward higher-value-added manufacturing and services and away from energy-intensive industries, as well as significant improvements of energy efficiency within industries. As a result of these two factors, energy intensity of the economy has been continuously decreasing for more than two decades and is now 240 percent below its 1989 level (Figure 1). In the medium- to long-term, energy consumption patterns are expected to converge toward those of high-income EU countries and energy demand will increase, in particular, due to growth in demand for transportation and services. These changes are already occurring: from 2000 to 2011, energy demand in transport grew by 25 percent and in the services sector by 260 percent (although from a relatively small base), while residential and industrial demand declined by 6 and 21 percent, respectively.

[2] End-use energy refers to energy services such as light, heat, motive or traction power etc.

[3] Primary energy consumption (g of oil eq.) per $1 GDP (constant 2005 US$). Energy sector statistical definition in this chapter is based on the standard IEA/IPCC definition and includes electricity and heat production and energy sector own use.

Figure 1. Trends in growth, energy use, and energy intensity in Romania



Source: World Bank staff calculations based on WB data from 2015

At present, primary energy consumption is characterized by a relatively high and growing share of zero-carbon energy sources, leading to a shrinking carbon footprint of the energy sector. This trend has been supported by Romania's high renewable energy potential and production, as well as by nuclear power production. From 1990 to 2012, the share of primary energy supply from the zero-carbon sources (nuclear, hydro, wind, solar, and geothermal) increased from 1.6 to 12 percent, and the share of renewable sources grew from 2.5 to 15 percent of the total. At the same time, natural gas declined slightly, from 46 to 31 percent of the total. This trend continues to be supported by the country's rich renewable energy potential: hydropower technical potential of 36 TWh per year, wind generation potential of 23 TWh per year (the highest in Southern Europe),[4] high solar potential with an average solar radiation level of 1,400 kWh/m^2/year, and rich forestry resources promising to cover 19 percent of total demand.

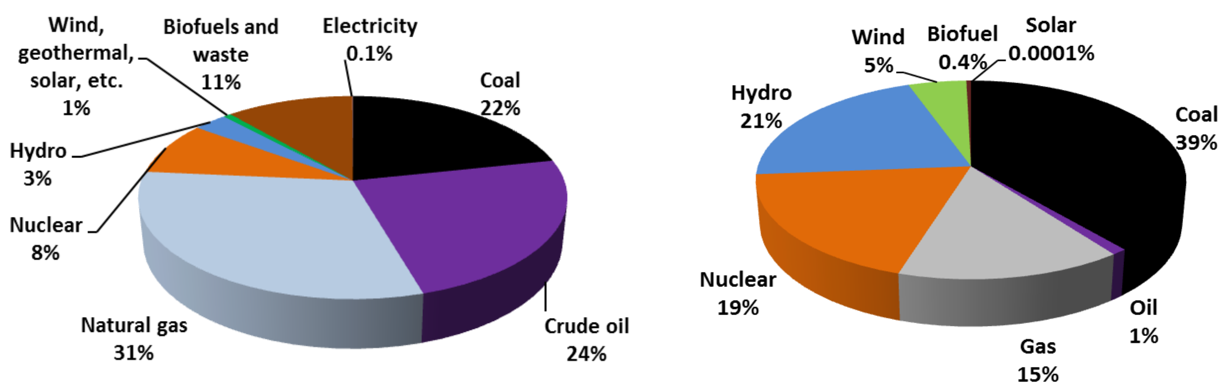
Electricity production also uses, to a large extent, zero-carbon sources and a growing share of renewables. Total installed capacity at the end of 2013 was 22,947 MW and total production was 59,045 GWh, consisting of 55 percent fossil fuel-based generation, 19 percent nuclear and 26 percent renewables.[5] Romania has one of the largest wind capacities in Eastern Europe. It ranks 14th among the EU's 29 countries according to the share of zero-carbon generation and 13th according to the share of renewable generation. However, fossil-based generation, still dominates electricity production. About one-third of the fossil fuel-fired capacity is co-generation. The fossil

[4] World Energy Council, 2013
[5] International Energy Agency (IEA)

fuel-fired plants consist of predominantly obsolete, high-emission coal, lignite and gas-fired generation units, most of which need to be decommissioned or modernized. Over the period 2005-2011, Romania decommissioned 3,000 MW of thermal generation capacity. Further decommissioning is expected because many plants do not meet the EU requirements. Overall, many generation assets are beyond their useful life: 30 percent are approximately 40 years old. [6]

Figure 2. Primary energy supply and electricity generation mix in 2012

a. Primary energy supply by fuel, 2012 b. Electricity generation by source, 2012



Source: IEA

Romania is a significant producer of oil and natural gas, and most of gas consumption is covered by domestic sources; it uses own coal and lignite entirely for heat and power generation. It has the fifth-largest proven natural gas reserves in Europe, 3.9 trillion cubic feet, and the fourth-largest proven crude oil reserves in Europe, 600 million barrels.[7] A significant proportion of gas demand is met from domestic supplies. However, production of these fuels has been declining.[8] Romania also holds 51 trillion cubic feet of technically-recoverable shale gas resources, and there are plans to develop the domestic shale gas industry.[9] However, these plans remain uncertain because of public concerns regarding related environmental issues and perceived potentially high costs of production. Currently, all imported natural gas comes from Russia and is delivered via Ukraine. Romania is exploring the possibility to diversify and import natural gas from other producers (mainly, Azeri gas)

[6] Jorge Morales Pedraza. Electrical Energy Generation in Europe. Springer. 2015.
[7] As of the end of 2012. BP Statistical Review of World Energy. June 2013. http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html
[8] From 1990 to 2012, crude oil production in Romania declined from 169.1 thousand to 83.1 thousand barrels per day and natural gas production decreased from 2.74 billion to 1.06 billion cubic feet per day. The reserve to production ratio is estimated at 6 years (BP 2014: http://www.worldenergy.org/data/resources/country/romania/gas/).
[9] Technically Recoverable Shale Oil and Shale Gas Resources. http://www.eia.gov/analysis/studies/worldshalegas/

and is discussing various transporting options. Importing LNG (liquefied natural gas) is also a possibility, depending on how global LNG prices evolve over time. Romania's total hard coal resources are estimated at near 2,500 million tons, of which about 11 million tons are commercially exploitable reserves. Lignite resources amount to 9,640 million tons, including reserves of 280 million tons.[10]

Romania has achieved significant progress in reforming energy sector pricing in recent years. One achievement is completing the regulatory reform in relation to non-residential electricity and gas prices, which happened in January 2014 and January 2015, respectively. Resulting gas price increases to industries have contributed to a significant reduction in gas consumption. While the regulatory reform in concerning the residential electricity prices is progressing, the same process with respect to residential gas prices stalled in mid-2014. Pricing of district heat is the second remaining pricing issue in the energy sector. Heat prices are defined by the regulator, and municipalities can either charge these prices to the consumers or reduce them using subsidies from local budgets. However, non-payment of subsidies by municipalities is common. A law allowing the Ministry of Public Finance to deduct non-payments from the municipalities' allocation of central transfers was enacted in 2011 but proved politically unfeasible to implement.

Romania has also undertaken important reforms that promote good governance, managerial and operational efficiency, and financial improvements in the power and gas sectors. Following restructuring and privatization measures taken during the previous decade, several measures were implemented recently: the Government Emergency Ordinance on State-Owned Enterprise Governance in 2011, a new Electricity and Gas Law, and new regulator (ANRE) Law in 2012, initial public offerings of shares of Nuclearelectrica, Romgaz and Electrica and secondary public offerings of the shares of Transelectrica and Transgaz during 2012-2014, as well as mandatory competitive electricity trade by the generators through OPCOM (the electricity and gas exchange).

Romania's support mechanism for renewable energy (a Green Certificate System, with centralized trading at OPCOM) was implemented, but later scaled back because it pushed up end-user tariffs. The support mechanism attracted substantial investment (estimated €7-8 billion), resulting in construction of approximately 5,200 MW of renewable energy capacity, mostly during the last four years and including 3,221 MW of wind, 1,293 MW of solar, 586 MW of mini-hydro, and 102 MW of biomass. Originally envisioned support levels were doubled when the support system was approved by the Parliament, making the system highly attractive to investors – and very expensive to electricity consumers, triggering protests. The energy regulator (ANRE) concluded that the system over compensated producers and scaled it back in 2013.

[10] EURACOAL, 2012.

These measures have put Romania's lignite and coal power-generating companies under operational and financial stress, depressing their share in total power generation and bringing Romania closer to its emissions and renewable energy targets. Electricity price liberalization, mandatory use of OPCOM for trading, and the renewables support scheme, against a backdrop of subdued demand for electricity following the 2008-2009 crisis, led to a drop in the market share of lignite and coal power generating companies. In some European electricity markets, most notably in Germany, the increase in renewable energy at a time of flat electricity demand has led to a decrease in gas-fired power generation and the shutdown of gas-fired generating units. In Romania, this impact was softened by the country's rising electricity exports, and lignite and coal power plants have largely absorbed it, losing competitiveness against existing hydro and nuclear power plants.[11] However, they are provided financial support by the government. As a result of the decreased coal and lignite power production, Romania now expects to exceed its EU-mandated renewable energy target of 24 percent renewable energy in gross final energy consumption.

1.3 Challenges

The energy supply sector is the largest contributor to the country's carbon footprint, being responsible for 58 percent of total greenhouse gas (GHG) emissions (excluding LULUCF)[12], and the emissions intensity of the economy significantly exceeds the EU average. Romania's total and per capita emissions[13] have dropped significantly from their peak in the late 1980s as a co-benefit of structural transformation, a pattern typical for transition economies, and the growth in the share of non-emitting energy sources. Total CO_2 emissions in Romania amounted to 78.7 million tons in 2010, accounting for a modest 2.1 percent of total European Union emissions and 0.23 percent of the world emissions. Per capita CO_2 emissions were also low, at approximately half of the EU average and just over one-third of the OECD average. However, the emissions intensity of the economy[14], while dropping 3.3 times from its 1989 level, was still much higher in 2010 than in many

[11] Use of gas in power is concentrated in municipal power and heating plants.

[12] Emissions from electricity and heat production, the sum of three IEA categories: (1) emissions from electricity generation, combined heat and power generation and heat plants (emissions from own use of fuel in power plants are included), supplying the public; (2) emissions from generation of electricity and/or heat by autoproducers (in whole or partly for their own use as an activity which supports their primary activity), these emissions would normally be distributed between industry, transport and "other" sectors; (3) Other: emissions from fuel combusted in petroleum refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries. (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp), International Energy Agency electronic files on CO_2 Emissions from Fuel Combustion; Catalog Sources World Development Indicators).

[13] Total emissions include emissions from the following sectors: energy (electricity and heat production and energy sector own use), transport (all transport activity regardless of the economic sector), residential (fuel combustion in households), and "Other" (commercial/institutional activities, fishing and emissions not specified elsewhere) (IEA/IPCC definition).

[14] Kg CO_2 per $1 GDP (constant 2005 US$).

other countries: 2.8 times above the EU level, 2.1 times above the OECD average, and seven percent higher than the world average.[15]

The expense of reducing energy sector emissions comes on top of already high investment needs to address obsolete fossil-based plants and is further augmented by the intermittency of the renewable plants that are replacing them. Eighty percent of existing fossil fuel-fired generation plants and 60 percent of the power distribution networks in the country are already old; and retrofitting of fossil fuel-fired power plants in the last 20 years has yielded scant returns. Replacing such massive existing capacity with new capacity is financially challenging. This capacity will be partially replaced by renewable energy, which creates another challenge. Expansion of wind and solar is expensive but also technically difficult. Since wind and solar are variable resources and do not provide capacity commitments against peak load, increase in their penetration will require complementary peak load capacity.

The continued deterioration and decline of district heating systems is particularly wasteful of existing assets and undermines the quality of life in Romanian cities. Many of the remaining operators are no longer economically viable because a substantial number of dissatisfied customers have disconnected from the systems and chosen alternative heating options. Inefficiency and high losses in the district heating systems also make them among the most costly to operate in the EU. A multi-year comprehensive program is needed to modernize those district heating systems that are economically viable: improve efficiency and service quality on the one hand and implement sector reforms to restore district heating company financial sustainability on the other, while ensuring that subsidies are well targeted to poor households.

Despite substantial progress, Romania still lags significantly behind most EU countries in the broadest measure of energy efficiency and in key end-user sectors. Its energy intensity was 40 percent higher than the EU average[16] in 2011. The efficiency gap is most pronounced for residential space heating where specific heat consumption (kgoe/m^2) is 32 percent higher than comparable best EU practice. For the two dominating industrial energy users, chemicals manufacturing has a value-added energy intensity over 4 times higher than the EU average (indicating structural issues), and steel making has an energy intensity per ton of steel that is 70 percent higher than the EU average. These three areas of end-use together account for roughly 40 percent of Romania's final energy consumption.

Thermal retrofit of residential buildings is financial and implementation challenge. Only about 1 percent of the 150 million m^2 of apartment buildings which were determined in need of thermal

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[15] Calculated on the basis of the International Energy Agency's data.

[16] Measured in GDP US$. When energy intensity of the economy is measured using GDP in PPP terms, the Romanian energy intensity exceeds that of the EU by 5.3 percent only.

retrofit had been retrofitted as of 2012. Despite very high capital subsidies (up to 80 percent) provided by the national and local governments, many low income households are still reluctant to participate. Subsidized energy prices create disincentives. In addition, a lack of incentives, information, necessary skills upgrades, and administrative improvements such as strategic planning, prioritization, systematic evaluations and coordination between different levels of government are to blame.

2. Methodology, Data and Assumptions

2.1 Overall Analytical Approach

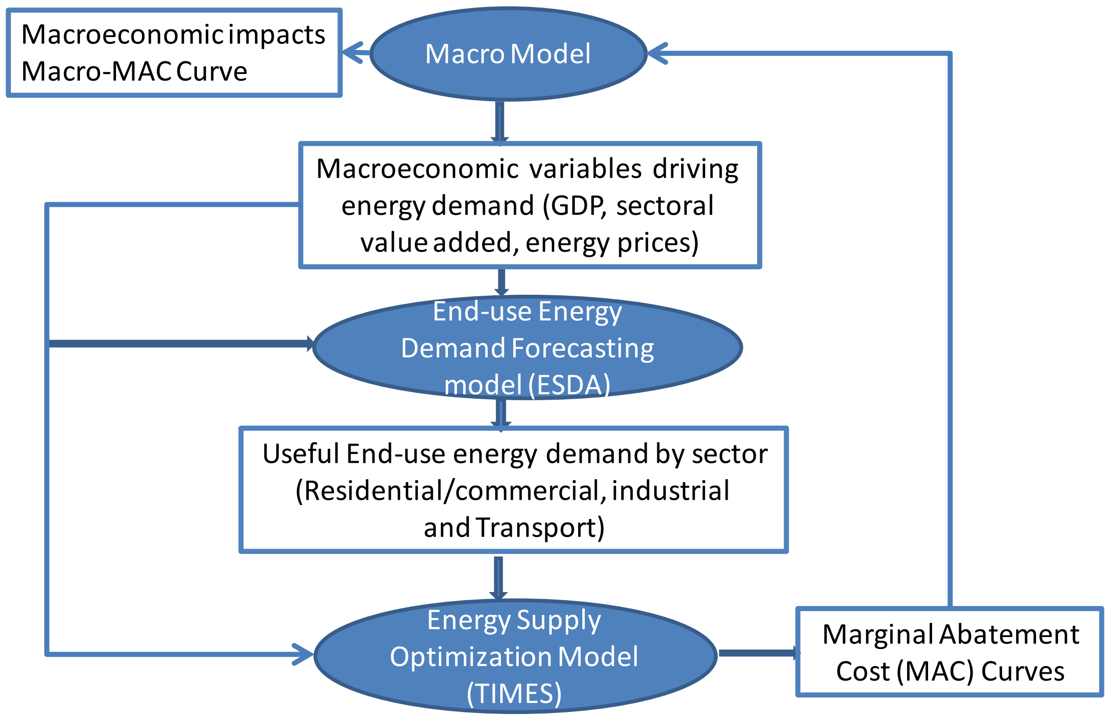
The energy sector study uses two sets of models for the analysis. Energy end-use demand model for projecting end-use energy demand in various sectors (e.g., residential/commercial, industrial, etc.) and TIMES model for producing an optimal energy supply mix to meet the projected demand.

The Demand model is an end-use accounting type model, where energy demand is projected based on the growth of driving variables. The driving variables for the transport sector, for example, include stock of vehicles, average utilization per annum, and fuel efficiency. The driving variables for residential energy demand include housing stock and income level for residential sector, stock of household appliances that consume energy, efficiency of those appliances and so on. Industry output and specific consumption of energy are the main driving variables for energy demand in the industrial sector. Similarly, floor space and unit energy consumption are the main driving variables for the commercial and service sector.

With the end-use energy demand forecasts, TIMES, the energy supply model, determines the optimum mix of devices and processes to meet the end-use demand and thereby determine the demand for energy commodities, such as electricity, processed natural gas, coal, petroleum products and so on. The projection of final energy demand will be made based on the determination of the demand for these energy commodities. To meet the projected final energy demand, TIMES optimizes the energy supply system accounting for all potential resources (such as coal, crude oil, natural gas, and hydropower), production/transformation facilities and transportation/transmission/distribution networks, satisfying various resource, technical, social-economic, environmental and other constraints.

The energy sector models are linked with a macroeconomic model to capture economy wide impacts of specific energy sector interventions. Figure 3 illustrates the linkages.

Figure 3. Overall framework adopted for energy sector work



First, the macroeconomic model projects economic variables such as, GDP, sectoral value added, and prices, which normally serve as the key driving variables for energy demand projections in an economy. Based on these macroeconomic variables, the baseline energy supply plan consistent with the projections is developed and then followed by the development of alternative clean/green scenarios, with considerations for relevant green/clean options/measures in both energy demand and supply sides.

The incremental costs under the green/clean energy supply plans on top of the baseline plans are calculated. At the same time, reductions of GHG emissions under the clean/green scenarios from the baseline scenario are derived. Finally, marginal abatement cost curves are developed using the incremental costs and the GHG reductions from the green/clean scenarios.

2.2 Overview of the Times Model

TIMES (an acronym for The Integrated MARKAL-EFOM System) is an economic model generator for local, national or multi-regional energy systems, which provides a technology-rich basis for estimating energy dynamics over a long-term, multi-period time horizon.[17] The model does multi-year optimization (computes the least cost path of an energy system for the specified time frame)

[17] TIMES getting started manual. http://www.iea-etsap.org/web/docs/ANSWER-TIMES%20Getting%20Started%20Manual-plus-Appendix-Jan2014-final.pdf

and can be used at the global, multi-regional, national, state/province or community level to test a series of policy options, such as CO_2 constraints, taxes or subsidies.

The structure of TIMES is defined by variables and equations determined from the data input provided by the user. This information collectively defines each TIMES regional model database, and therefore the resulting mathematical representation of a Reference Energy System for the region. The database comprise both qualitative and quantitative data.

The qualitative data includes, for example, lists of energy carriers, the technologies that the modeler feels are applicable (to each region) over a specified time horizon, as well as the environmental emissions that are to be tracked. This information may be further classified into subgroups, for example energy carriers may be split by type (e.g., fossil, nuclear, renewable, etc). Quantitative data contains the technological and economic parameter assumptions specific to each technology, region, and time period.

Reference case estimates of end-use energy service demands (e.g., car road travel; residential lighting; steam heat requirements in the paper industry; etc.) are provided by the user for each region. In addition, the user provides estimates of the existing stock of energy related equipment in all sectors, and the characteristics of available future technologies, as well as present and future sources of primary energy supply and their potentials.

Using these data inputs, the TIMES model aims to supply energy services at minimum global cost (more accurately at minimum loss of surplus) by simultaneously making equipment investment, operating primary energy supply, and making energy trade decisions by the region. It is important to note that the TIMES energy economy is made up of producers and consumers of commodities such as energy carriers, materials, energy services, and emissions, and because of this, like most equilibrium models, it assumes competitive markets for all commodities. Thereby, ensuring there is a supply-demand equilibrium that maximizes the net total surplus, i.e. their prices and quantities in each time period are such that the suppliers produce exactly the quantities demanded by the consumers (Figure 4).

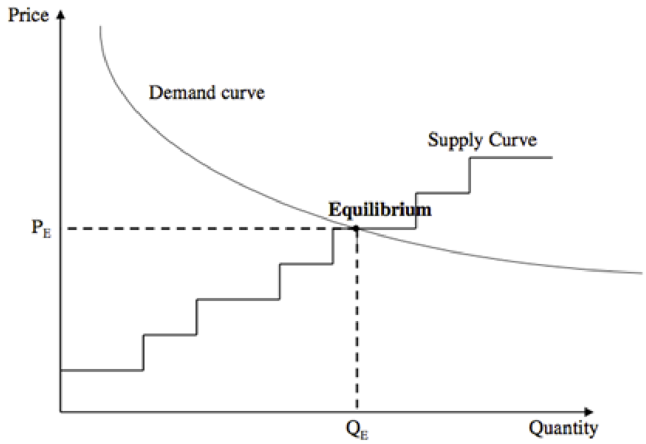


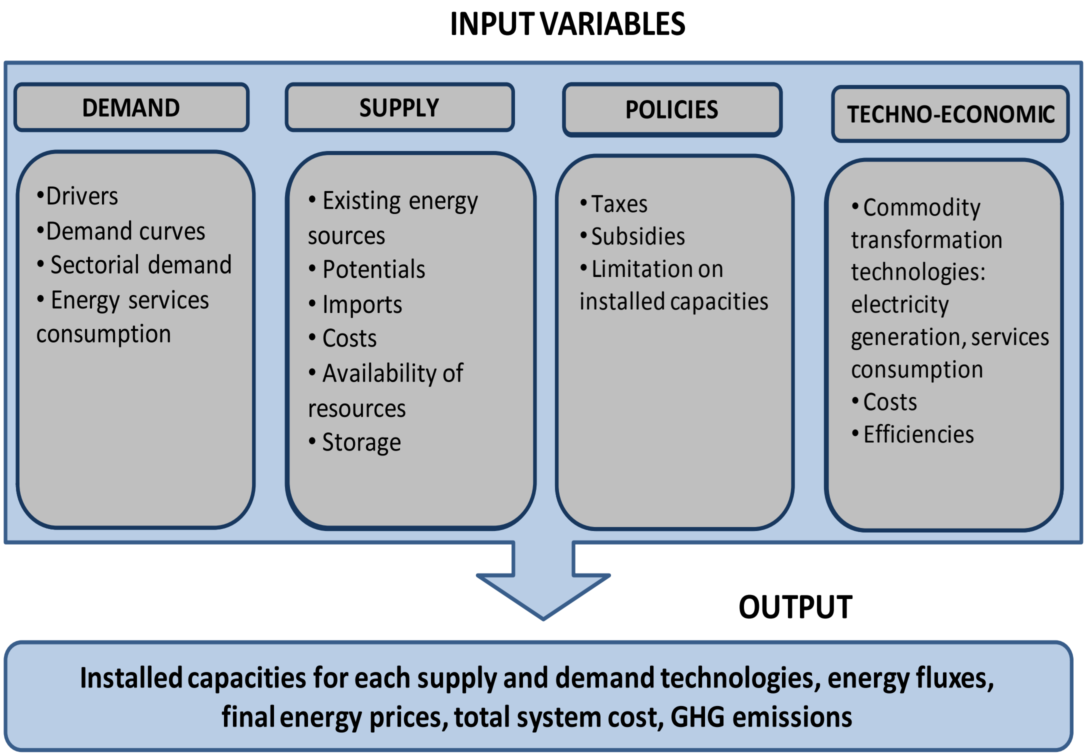
Figure 4: Achieving market equilibrium in TIMES. source: (Loulou et al., 2005)

The TIMES model uses a scenario approach that consists of a set of coherent assumptions about the future trajectories of these drivers, leading to a coherent organization of the system under study. A complete scenario typically consists of four types of inputs: energy service demands, primary resource potentials, a policy setting, and the descriptions of a set of technologies (Figure 5 and 6).

Input Variables

- The TIMES demand components consist primarily of a set of assumptions on the drivers (GDP, population, households) and on the elasticities of the demands to the drivers and to their own prices.
- The supply component consists of a set of supply curves for primary energy and material resources. Multi-stepped supply curves can be easily modeled in TIMES, each step representing a certain potential of the resource available at a particular cost. In some cases, the potential may be expressed as a cumulative potential over the model horizon (e.g. reserves of gas, crude oil, etc), and as a cumulative potential over the resource base (e.g. available areas for wind converters differentiated by velocities, available farmland for biocrops, roof areas for PV installations).
- Policies that impact on the energy system may also become an integral part of the scenario definition. For instance, a No-Policy scenario may perfectly ignore emissions of various pollutants, while alternate policy scenarios may enforce emission restrictions, or emission taxes, etc. The detailed technological nature of TIMES allows the simulation of a wide variety of both micro measures (e.g. technology portfolios, or targeted subsidies to groups of technologies), and broader policy targets (such as general carbon tax, or permit trading system on air contaminants).

Figure 5: Schematic Times Model Input -Output



Source: TIMES modeling

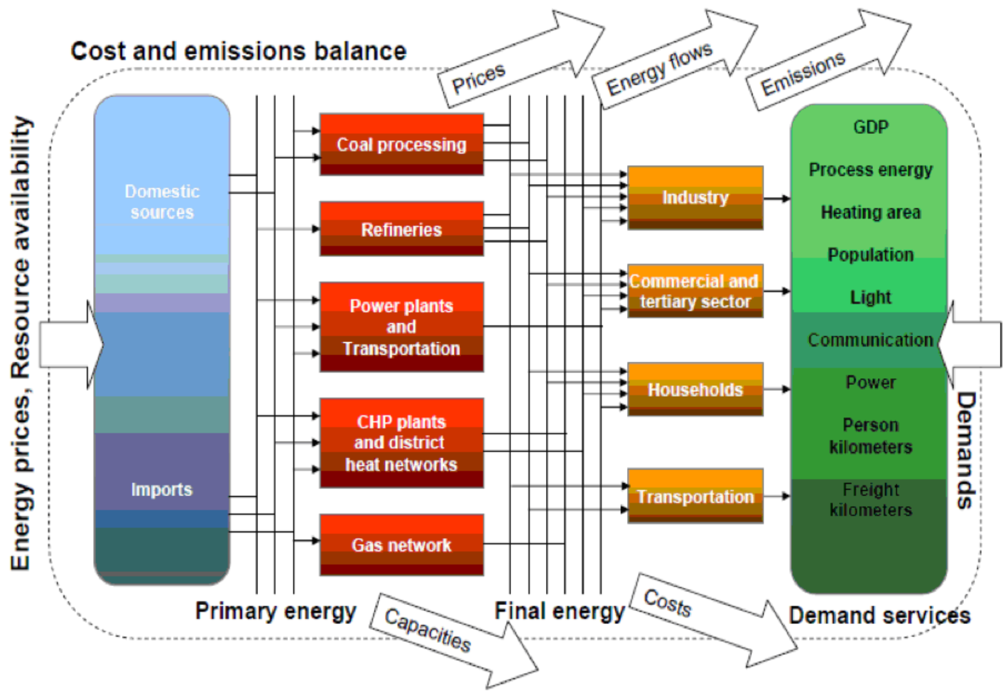
- Techno-economic parameters are described in the form of technologies (or processes) that transform some commodities into others (fuels, materials, energy services, emissions).

Output

The main output of the TIMES are energy system configurations, which meet the end-use energy service demands at least cost while also adhering to the various constraints.

Figure 6: Schematic of TIMES inputs and outputs [18]

[18] Remme et al., 2001



2.3 Model Input Assumptions

Data and Baseline Scenario Assumptions

The main sources of data that have been used in this modeling exercise are presented in Table 1 below.

Table 1: Key Data Sources

Data Requirement	Source
Energy Balance	• National Institute of Statistics, Romania of Romania
Resource Potential, including imports/exports	• Various sources published by ANRE, Ministry of Economic Affairs
Installed capacity and characterization of new technologies for electricity generation, heating and CHP plants	• ANRE, Electrica, Hidroelectrica, Nuclearelectrica • IEA Clean Coal Centre Database, Energy Information Administration of USDOE • World Bank: Private Participation in Renewable Energy Database
Load Profile	• European Network of Transmission System Operators for Electricity
Demand Drivers	• GDP growth –provided by macro-economic team of the Romania Low Carbon Team • Useful energy demand from the Energy demand model
Fuel prices projections	• IEA World Energy Outlook

a) Demand Drivers

The macro-economic drivers such as GDP, GNP, private income, population and number of households used in the study were supplied by the Romania Low Carbon macro team (Table 5). Where data was not made available from the macro team, other sources such as the Eurostat, UN and the World Bank data portal were used.

Table 2: Macro Economic Variables, 2010 - 2050

		2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
GDP	(€ Mill.)	90735	96566	113037	130977	144610	159661	176278	189902	204578
GDP growth rate	%	2	3	3	2	2	2	2	2	2
Population	million	21	21	21	21	20	20	20	19	19

Source: TIMES modeling

b) Power Plant Characterization: New and Existing Plants

Refer to Appendix 2.

3. Energy Supply Scenarios and Analysis

Three energy supply scenarios - baseline, green and super green scenarios have been developed taking into account specific characteristics of the national energy system, existing energy technology stock, domestic resource availability and existing policy interventions in Romania.

3.1 Description of Scenarios

I. Baseline scenario

This scenario is the most likely scenario unless the government plans to change energy supply system in line with EU's long-term plan to mitigate climate change. This scenario incorporates already announced/implemented policies and measures to mitigate climate change including EU's target to reduce 20% of GHG emissions from the 2005 level in the ETS sectors.

II. Green scenario

This scenario represents EU's 2030 target for GHG mitigation. EU 2030 energy strategy sets targets of a 40% cut in GHG emissions compared to 1990 levels, and at least a 27% share of renewable energy in total primary energy supply. For the power sector, EU 2030 target corresponds to the reduction of CO_2 emissions between 54% and 68% by 2030 compared to 1990 levels.

III. Super Green scenario

This scenario is driven by EU's 2050 low carbon development aspiration reducing GHG emissions by at least 80% below 1990 levels by 2050, especially by almost a total de-carbonization of the power sector

Each of these three scenarios were implemented under two cases: '**low demand**' case and '**normal demand**' case. The low demand case considers a large scale energy efficiency improvements in the demand side or energy end-use sectors (e.g., residential and commercial sectors). Major energy efficiency improvement measures include use of more efficient lighting and electric appliances, retrofitting buildings with wall, window and roof insulation, heating system improvement in the residential, commercial and public buildings, and use of efficient electric motor and thermal energy equipment in the industry sector. The implementation of these measures leads to 26% reduction of residential sector energy consumption by 2050 from that in the normal demand case. The energy efficiency measures in the non-residential buildings sector (e.g., more energy efficient space heating and space cooling) results in about 30% reduction in services energy demand. However, the size of service (or commercial) sector in the total energy consumption is small. In the case of industrial sector, the introduction of more energy-efficient technologies especially electric motors and boilers reduces leads to about 16% reduction of industrial sector energy consumption from that in the normal demand case by 2050. The design of the low demand scenario reflects Romania's commitment to EU’s energy and climate strategies.

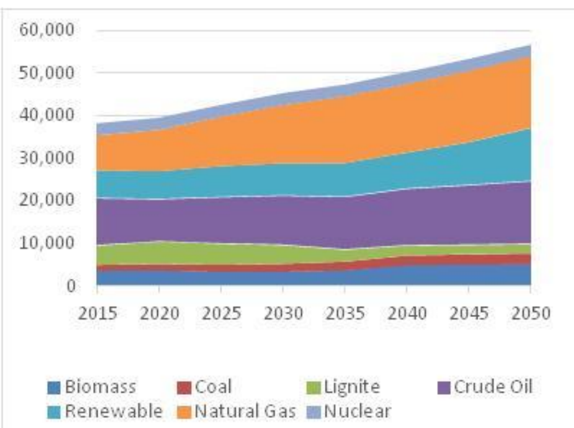
3.2 Primary Energy Supply

Primary energy supply projections in Romania under different scenarios are presented in Figure 9a to 9f. Under the baseline scenario, Romania's total primary energy supply in 2050 is projected to increase by approximately 49 percent from the 2015 levels, from about 38,184 ktoe to about 56,779 ktoe (Figure 7). Under the low demand baseline scenario, total primary energy supply in 2050 would be 14 percent smaller compared to that in the baseline scenario.

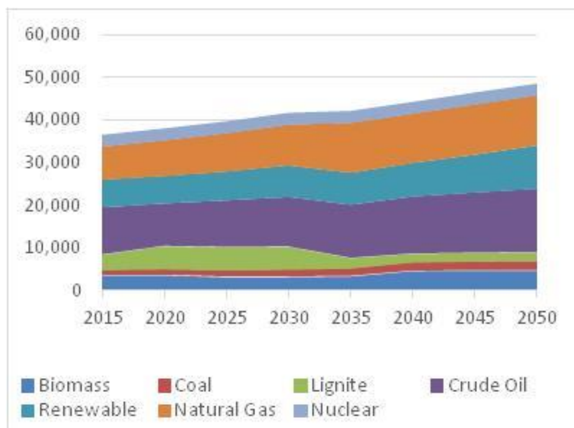
Oil and natural gas are the most important sources of primary energy. While the share of oil in the baseline drops slightly from 29% in 2015 to 26% in 2050, share of gas increases by 8 percentage point, from 22% in 2015 to 30% in 2050 because Romania needs cleaner fuels to meet the EU’s GHG mitigation targets. For the same reason, share of coal drops from 16% in 2015 to 8% in 2050 in the baseline.

Figure 7. Primary Energy by Fuel Group (percent share), 2010 -2050

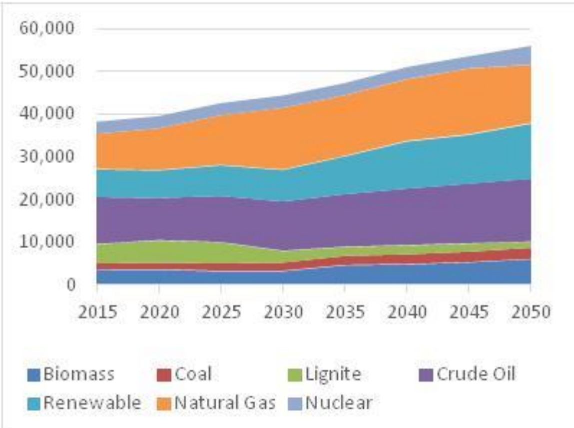
(a) Baseline



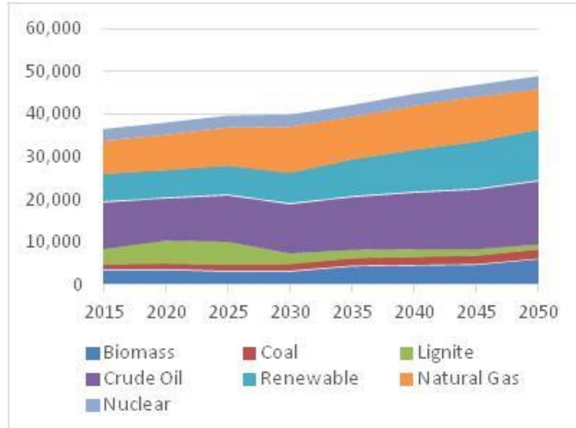
(b) Baseline with low demand



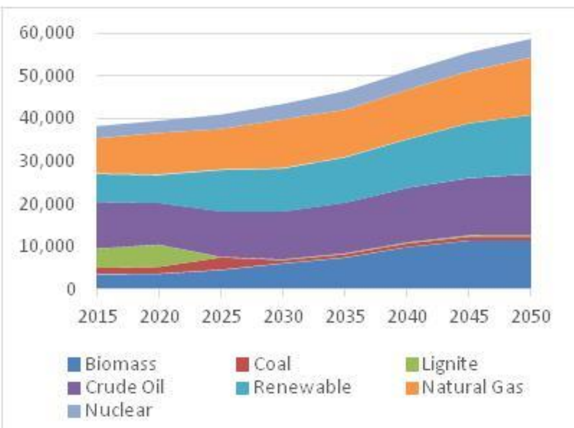
(c) Green



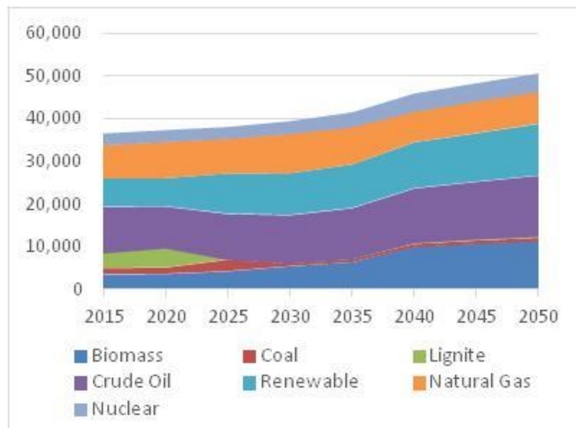
(d) Green with low demand



(e) Super green



(f) Super green with low demand



Source: TIMES modeling

As expected the primary energy supply mixes in the green and super-green scenarios are different from that in the baseline scenario because of substitution of fossil fuels with renewables and nuclear. For example, in the green scenario, the shares of renewables (hydro, wind and solar) in 2050 increases to 23% from 21% in the baseline. The reverse would happen in the case of natural gas, where its share decreases from 30% in 2015 to 24% in 2050. The share of biomass increases dramatically under the super-green scenario where Romania reduces energy sector emissions by more than 40% from the 2005 level. Please note that the super green scenario is an extreme scenario which assumes no GHG emissions from power generation and heat production activities. This is an implausible scenario included here to test how the energy supply system will look like in case Romania adopts such as extreme measure. Considering this scenario does not mean Romania should follow this type of extreme measure for climate change mitigation.

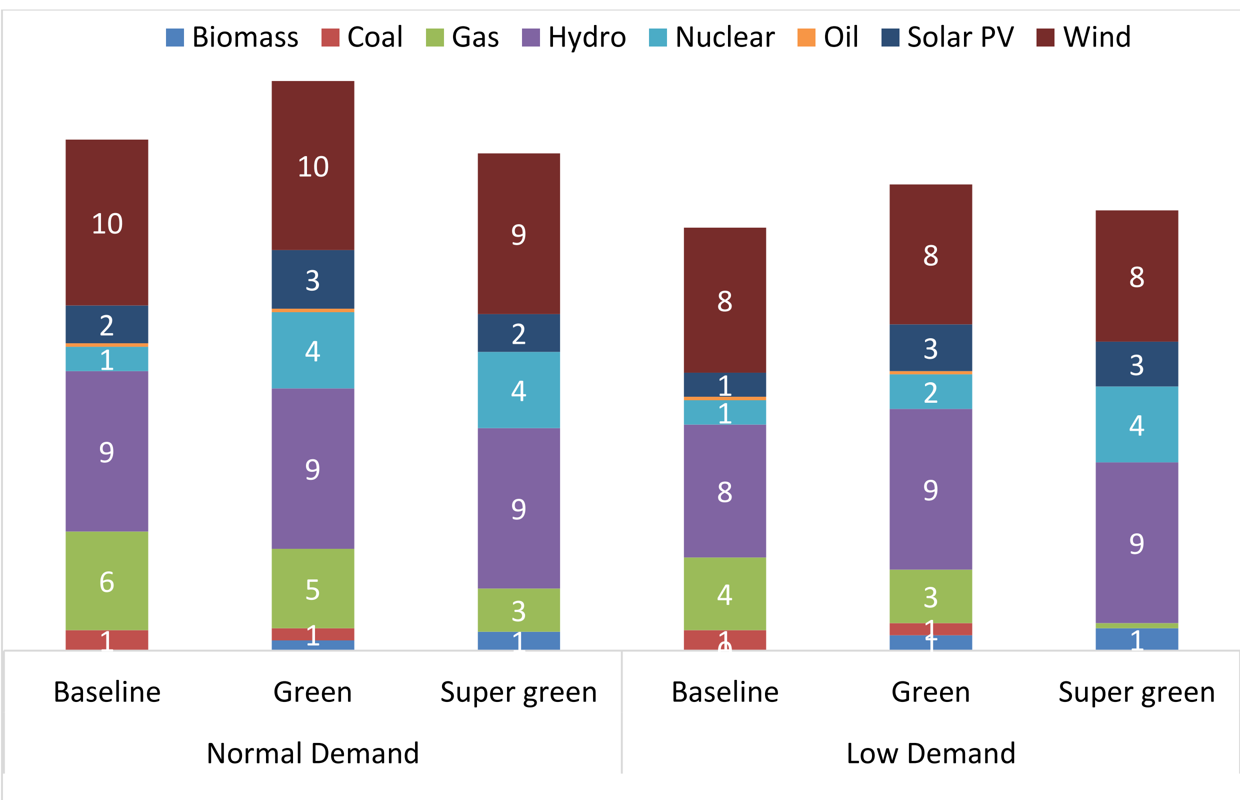
3.3 Electricity Supply

3.3.1 Total Installed Capacity

Figure 8 presents total installed capacity need in Romania by 2050. Romania's installed capacity for power generation is projected to grow from 23 GW in 2015 to 30 GW in 2050 under the baseline. Under the low demand case, the installed capacity would remain almost the flat during the planning horizon (2015-2050) as new capacity requirement would be offset by improvements in energy efficiency in the demand sectors. Total installed capacity under the green and super green scenarios would be higher than that in the baseline due to large share of renewables sources which have lower availability factors.

The electricity supply system would be relatively cleaner in Romania because this sector is covered under the existing EU emission trading regime and it expected to reduce its emissions by 20% from the 2005 level. This existing mandate would push the country to adopt cleaner sources for electricity generation even in the baseline. Therefore, the share of coal rapidly diminish and drops to 4% in 2050 from 30% in 2015.

Figure 8: Total Installed Capacity for Electricity Generation by 2050 (GW)



Source: TIMES modeling

Hydropower, the largest source of clean energy for the country, accounted for about 32 percent of the installed capacity in 2010, slightly low (28%) in 2015 but rebounds back above 30% by 2050.

Wind power, which accounted for 12 percent of the total installed capacity in 2013 is expected to grow significantly to 32 percent by 2050. Romania's only two nuclear power plants, Cernavado plant 1 and 2, currently account for about 6 percent of the country's total installed capacity. There will be no installation of new nuclear capacity under the baseline[19]. Under the low demand baseline case, solar PV installation drops to 1 GW from the 2 GW installed under the normal demand baseline scenario; similarly installed capacity of hydropower drops to 8 GW from 9 GW installed under the normal demand baseline scenario.

Table 3: Total Installed Capacity (% and GW)[20]

	Normal demand				**Low demand**			
	2020	**2030**	**2040**	**2050**	2020	2030	2040	2050
Baseline Scenario								
Biomass	0%	0%	0%	0%	0%	0%	0%	0%
Coal	30%	16%	6%	4%	30%	22%	6%	5%
Natural Gas	14%	17%	25%	19%	14%	9%	20%	17%
Hydro	28%	30%	28%	31%	28%	31%	31%	31%
Nuclear	6%	7%	6%	5%	6%	7%	7%	6%
Oil	7%	1%	1%	1%	7%	1%	1%	1%
PV	3%	2%	9%	7%	3%	2%	7%	6%
Wind	13%	28%	25%	32%	13%	28%	28%	34%
Total (GW)	23	21	23	30	23	20	21	25
Green Scenario								
Biomass	0%	0%	0%	2%	0%	0%	0%	3%
Coal	30%	9%	5%	2%	30%	9%	5%	3%
Natural Gas	14%	21%	18%	14%	14%	17%	14%	11%
Hydro	28%	31%	36%	28%	28%	35%	39%	34%
Nuclear	6%	7%	5%	13%	6%	8%	6%	7%
Oil	7%	1%	1%	1%	7%	1%	1%	1%
PV	3%	2%	13%	10%	3%	3%	12%	10%
Wind	13%	28%	22%	30%	13%	27%	23%	30%
Total (GW)	23	20	26	33	23	18	22	27
Super-green scenario								
Biomass	0%	5%	4%	4%	0%	4%	3%	5%
Coal	30%	0%	0%	0%	30%	0%	0%	0%
Natural Gas	14%	8%	5%	9%	14%	8%	1%	1%

[19] Our analysis like any other long-term electricity generation plans, is based on least cost expansion satisfying resources and environmental constraints. While the results from this analysis could provide important insight for the development of power sector strategy, it is not itself an electricity sector development strategy, which would consider several factors in addition to economic factors. While nuclear is not found economically attractive for the baseline in this analysis, the government could still consider nuclear from other consideration, such security of supply.

[20] The breakdown of existing vs. new capacity installed is provided in Table A1 in Appendix 1 of this report.

Hydro	28%	44%	38%	32%	28%	49%	41%	36%
Nuclear	6%	13%	18%	15%	6%	9%	20%	17%
Oil	7%	0%	0%	0%	7%	0%	0%	0%
PV	3%	14%	19%	8%	3%	8%	16%	10%
Wind	13%	16%	16%	32%	13%	22%	19%	30%
Total (GW)	23	21	25	29	23	19	23	26

Source: TIMES modeling

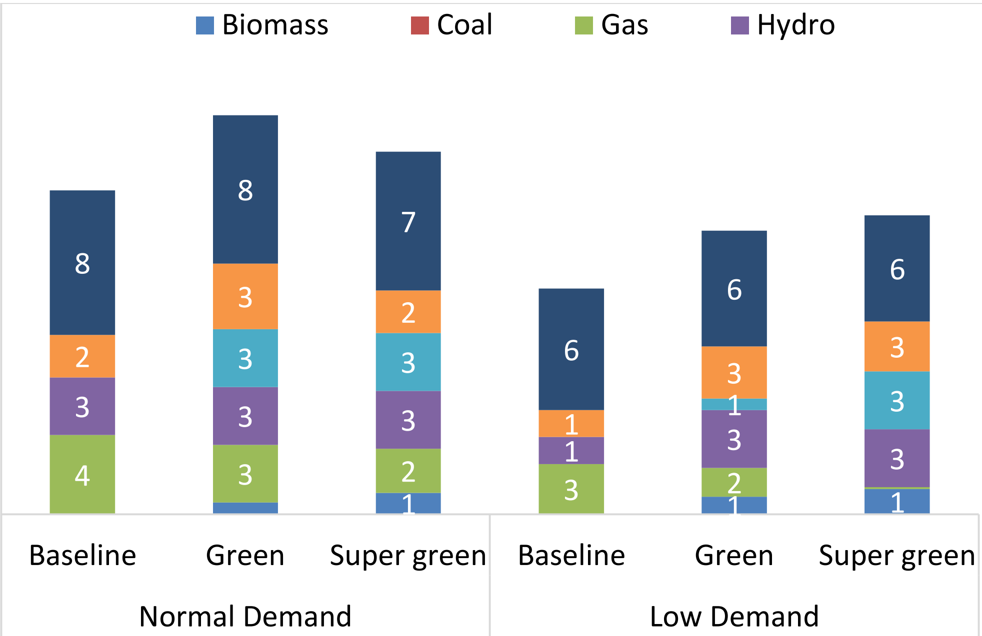
Under the green and super green scenario, the electricity generation capacity mix would be significantly different from that in the baseline. The share of wind and solar PV will increase tremendously by 2050; while wind will occupy 30 to 32% and solar PV will occupy 8 to 10% of the total electricity generation capacity by 2050. The share of natural gas in the total electricity generation capacity in 2050 would drop to 14% in the green scenario from 19% in the baseline scenario. It would drop further to 9% under the super-green scenario. The share of nuclear power in 2050 would increase to 13% and 15% under the green and super green scenario, respectively from the 6% in 2015 under the baseline scenario.

Please note that at present Romania has much higher installed capacity compared to its peak load (20 GW installed capacity vs. 10 GW peak load). Adding more renewable sources for energy generation, particularly the intermittent sources (wind and solar) would further increase the gap between total installed capacity because intermittent sources do not provide commitments to meet peak load. Thus, the higher installed capacity because of higher penetration of intermittent renewable sources to meet climate change mitigation targets could create a situation where fossil fuel based generation sources (e.g., coal, gas) are built to meet the peak load but they will not be utilized unless their exist export markets for electricity generated from fossil fuel sources, which is unlikely in EU due to climate change mitigation obligations.

3.3.2 New Capacity Addition

Figure 9 presents total new installed capacity added during the 2015-2050 period. Under the baseline, more than 8GW of new wind capacity would be added by 2050. Note that Romania has 12 GW economically exploitable wind capacity of which 3 GW has been already exploited. About 3 GW of new hydropower capacity would be added; this capacity is assumed to operate at very low capacity factors, around 34% thereby incorporating any adverse impacts on catchment areas and run-off due to potential climate change impacts. Another main source of electricity generation is solar PV, which currently accounts for less than 1GW. About 2 GW of new solar PV capacities would be installed by 2050. Nuclear capacity of 3 GW would be added only in the green and super-green scenarios replacing natural gas capacity installed under the baseline scenario.

Figure 9: New Installed Capacity during the 2015-2050 Period (GW)



Source: TIMES modeling

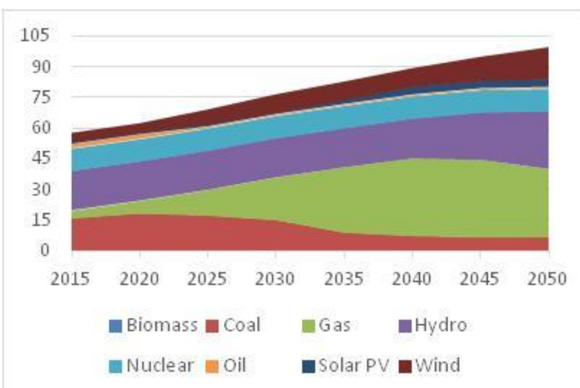
It is very important to note here that it is not only the realization of clean electricity scenarios is challenging, realization of baseline scenario, which is developed in line with EU 2020 climate target, itself is challenging. This is because the existing renewable electricity capacity (especially wind and solar) resulted from generous renewable energy support mechanism has already created price pressure on retail level which is deemed unaffordable. Adding further renewables would mean electricity supply costs would further increase if the cost of renewable energy supports are also included. Moreover, Romania has one of the best lignite resources in the region and it does not have an international market; throwing it out of the future electricity supply mix due to climate change policies would cause an economic loss to the country.

4.3.3 Electricity Generation

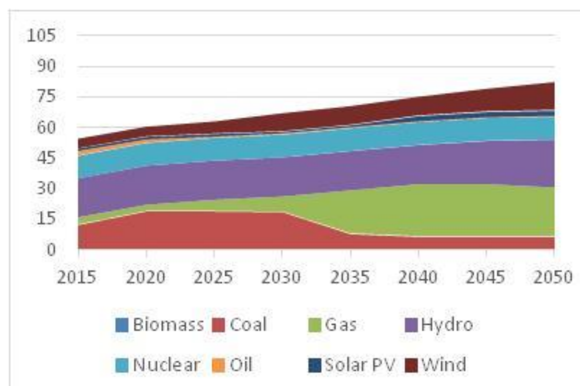
Figure 10 presents electricity generation mix from various sources under different scenarios. Under the baseline scenario, total electricity generation over the planning horizon almost doubles, from 58 TWh in 2015 to 100 TWh in 2050. Under low demand base case, total electricity generation in 2050 would be 18% less compared to the baseline scenario. As expected, electricity generation mix does not change much between the baseline and low demand baseline cases. However, there is significant changes of electricity mix in green and super green scenarios from that in the baseline scenario. Under the green and super green scenarios, the electricity generation from fossil fuel based sources decreases rapidly. For example, there would be no electricity generation from coal based sources by 2030 under the super green scenario. The generation from gas fired power plant still operating by 2050 would be equipped with CCS so that there would be no GHG emissions released from power generation by that year. Electricity generation from nuclear power generation facilities under the green and super green scenarios would be almost three times as high as that of under the baseline scenario. Please note that the main difference between the baseline and super-green scenario is the coal and nuclear based power generation. Due to EU mandate for 2030, Romania would replace coal based generation with renewable energy resources even in the baseline. Under the green and super-green scenarios, nuclear power would serve as the main base load plants. There is no change on hydro, solar and wind based generations between the base and green/super green scenarios. Nuclear, biomass, CCS gas and hydro would be main sources for non-intermittent resources for power generation and their combined capacity would exceed the projected peak load by 2050.

Figure 10. Electricity Generation by plant type (TWh)

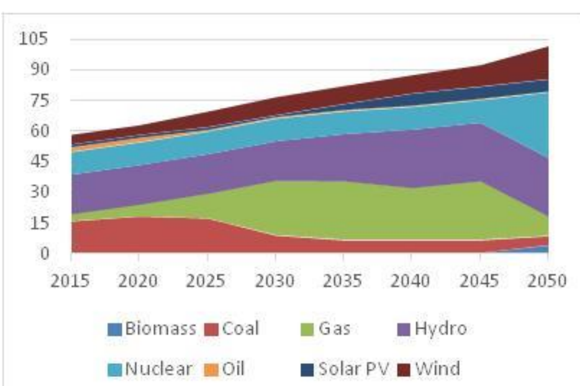
(b) Baseline



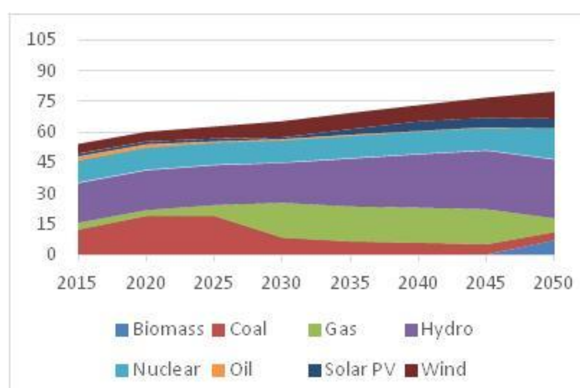
(b) Baseline with low demand



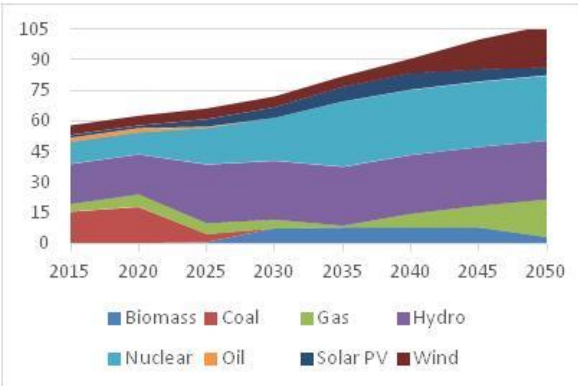
(c) Green



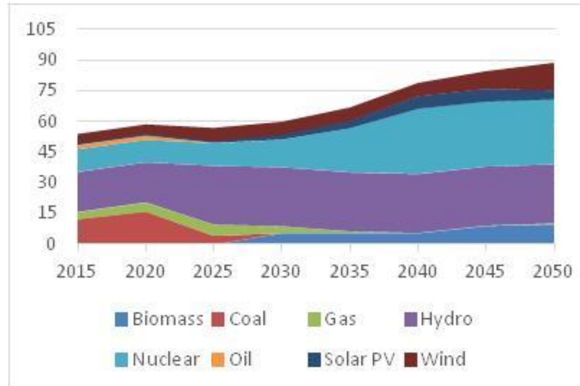
(d) Green with low demand



(e) Super green



(f) Super green with low demand



Source: TIMES modeling

3.3.4 Heat Supply

Like electricity heat is another main energy commodity in Romania. Demand for space heating is expected to grow faster along with increased heating areas resulted from increasing demand for larger living spaces. Unlike electricity which is mainly produced from power plants, heat is produced directly and through district heating facilities, normally, combined heat and power (CHP) plants. Direct heating refers to, for example, use of natural gas or biomass for home heating. Heat produced from CHP plants distributed to buildings through pipelines. Table 2 in the Appendix 1 of this report presents heat supply from various energy sources. Based on the numbers presented in the table, it can be observed that total demand for heat (final demand not useful demand) increases by 20-23% in 2050 compared to that in 2015 if energy efficiency measures are not implemented. If energy efficiency measures are implemented final heat demand drops by 10-14% in 2050 from the 2015 level. Natural gas remains as the main source for heat energy, in all years and in all scenarios. This is intuitive as there is no other alternative source to replace it for heating even under the strict climate change mitigation scenarios (e.g., super-green). Due to climate policies heat coming from CHP plants, which fall under the ETS category, is replaced with heat from direct sources.

3.4 Total Energy Supply Costs and Investment

Figure 11a presents the total system costs for the energy supply during 2015-2050 period. Energy supply costs for different time intervals are presented in Table 4 (a). Under the baseline (with normal demand case), Romania would need 28 billion investment (discounted at 5%) for energy supply system expansion on top of costs that incur to purchase energy commodities, such as natural gas and oil & oil products.[21] The total energy supply costs for the 2015-2050 period would be €336

[21] While the model conducts a detailed simulation for the power sector and combined heat and power and estimates investment need for generating electricity and district heat, it however treats other energy commodities as purchased from the market. Thus, it does not include investment needed for coal/lignite mining, natural gas pipelines. Since the

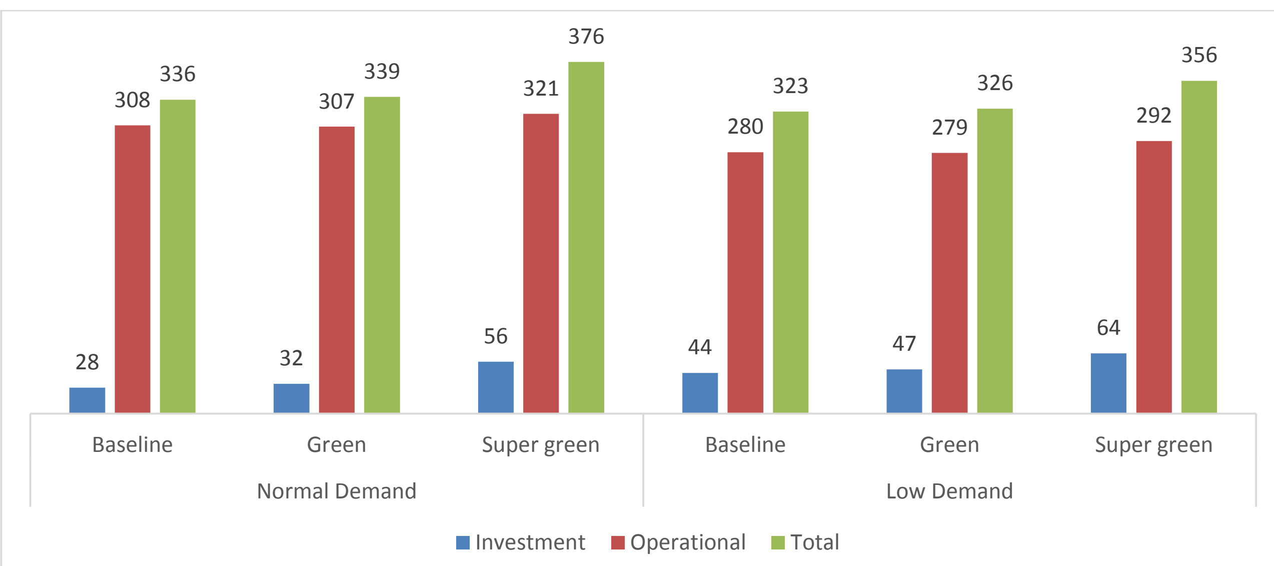
billion or approximately 10 billion euro per year, on average, over the next 35 years. The total energy supply costs in the normal demand case would increase by one percent under the green scenario and by 12% under the super green scenario, as compared with the Baseline. In the low demand case, the total energy supply costs would decrease by three percent under the green scenario and increase by six percent under the super green scenario, also as compared with the normal demand Baseline.

The change in total energy supply costs from the baseline to the green scenario(both under normal demand case) is explained by the following: the green scenario needs 3 GW new nuclear plants (there was no nuclear in the baseline) and substitution of 1 MW of gas capacity with solar. As the nuclear capacity is added only after 2045, its discounted value is low. Thus, the incremental investment (discounted) for energy supply system expansion under the green scenario's normal demand case is not substantially higher (and even lower in the low demand case) as compared to that under the baseline (normal demand case).

However, the total energy supply costs under the super green scenario are 15% higher compared to that under the green scenario in the normal demand case and by 9 percent in the low demand case. This is because of early requirement of nuclear power under the former case. If a plant is installed earlier from now, the discounted costs would be higher (i.e., lower impacts of discounting) as compared to a situation where a plant is commissioned in a later date. Moreover, super-green scenario requires 1 GW of biomass based power generation.

Figure 11. Discounted total energy supply costs for 2015-2050 Period (Billion €)

(a) For the energy system as a whole

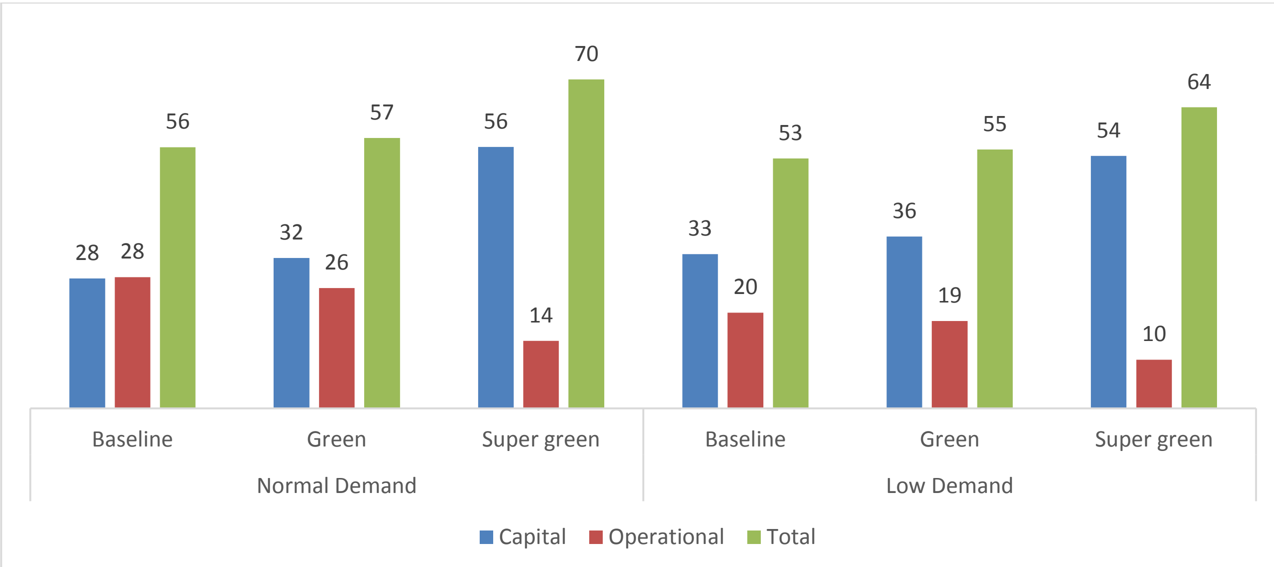


study is for low carbon development and most low carbon options fall under the power sector, it does not underestimate the investment need in low carbon scenarios.

Note: Supply costs for coal, oil and oil products, natural gas and biomass are treated as purchased costs and therefore are included in the operational costs in this figure.

Source: TIMES modeling

(b) Electricity supply system



Source: TIMES modeling

Energy efficiency improvement in the demand side (i.e., low demand case) would reduce the total cost of energy supply by 3%, from €336 billion to €326 (from the baseline scenario in the normal demand case to the green scenario in the low demand case). To realize this, about €19 billion of investment would be needed to increase energy efficiency in the demand side.

The power supply system would need €28 billion investment over the next 35 years to meet country's electricity need under the baseline (Figure 11 (b) and Table 4 (b)). The investments required for power system expansion in different intervals of time are presented in Table 4 (b). The total power supply system investment would increase to €37 billion under the green scenario when electricity related energy efficiency measures[22] are undertaken (low demand case). If power sector emissions to be completely eliminated by 2050 (the Super Green scenario), investment in the power sector would be twice as high as that in the baseline and equal €54 billion. This is because elimination of power sector emissions would require massive replacement of fossil fuel based generation with more capital intensive renewable and nuclear energy based generation. The lower demand due to energy efficiency improvements in the demand side would reduce the total costs of electricity supply, but it would require additional investment in the demand side. Note that the investment required for energy efficiency measures here would be €8.3 billion instead of €19 billion mentioned above because we accounted for energy efficiency improvements only on electricity

[22] Electricity energy efficiency is more efficient electrical appliances in residential and nonresidential buildings.

using end-use services, whereas the €19 billion accounts for all energy efficiency measures including in space heating, cooking.

Table 4: Detailed energy supply costs and investments for the electricity system expansion

(a) Total energy supply costs (Billion €, undiscounted unless specified otherwise)

	2015-2020	2020-2030	2030-2040	2040-2050	2015-2050 (Discounted)
	Without Energy efficiency in the demand side (or normal demand case)				
Baseline	91	178	231	281	336
Green	91	179	235	287	339
Super green	91	194	274	352	376
Energy Efficiency*	3	11	15	19	19
	With Energy efficiency in the demand side (low demand case)**				
Baseline	88	174	221	264	323
Green	88	175	224	270	326
Super green	88	187	257	322	356

* includes energy efficiency measures using all types of energy sources

** Includes the cost of energy efficiency measures and accounts for reduced power demand resulting from the implementation of the energy efficiency measures.

Source: TIMES modeling

(b) Total investment required for electricity system expansion (Billion €, undiscounted unless specified otherwise)

	2015-2020	2020-2030	2030-2040	2040-2050	2010-2050 (discounted)*
Electricity supply:					
Baseline	7.4	14.2	17.5	27.6	27.6
Green	7.4	12.5	19.5	31.6	28.2
Super Green	7.3	22.5	38.3	51.9	45.3
Energy efficiency:	3.1	11.1	15.2	19	**19.1**
Electricity**	1.6	5.3	5.9	6.8	8.3
Other***	1.4	5.8	9.3	12.2	10.8
Total electricity investment:***					
Baseline	7.4	14.2	17.5	27.6	27.6
Green	9	17.8	25.5	38.4	36.5
Super Green	9	27.8	44.2	58.7	53.6
Total energy investment:****					
Baseline	7.4	14.2	17.5	27.6	27.6
Green	10.4	23.6	34.8	50.6	47.3

Super Green	10.4	33.6	53.6	70.9	64.5

Notes: * using a five percent discount rate. All other columns are in constant prices but not discounted. **electricity energy efficiency is more efficient electrical appliances in residential and nonresidential buildings. **other energy efficiency is residential and nonresidential space heating and cooking measures. ***electricity supply investment and investments in electricity-saving efficiency measures. ***electricity supply investment and investments in all energy efficiency measures.

Source: TIMES modeling

3.5 CO_2 Emissions

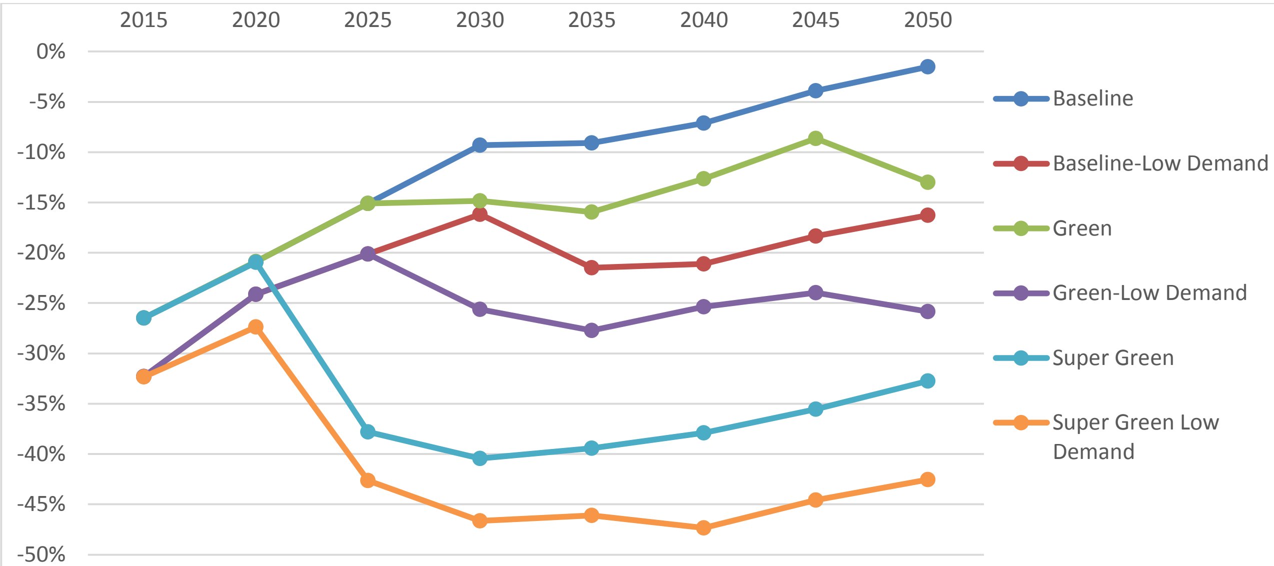
The reductions of CO_2 emissions from the energy sector as whole and power sector specifically are presented in Figure 12(a) and (b). In all scenarios, energy related CO_2 emission in Romania would be lower in years between 2015 and 2050 from the level in 2005. If energy efficiency measures are not implemented, total energy related GHG emissions in 2030 and 2050 under the baseline scenario would be, respectively, 9% and 2% lower from 2005 level. It is very important to note that historically energy related CO2 emissions in Romania are dropping from the level of 2005. For example, according to emissions data published by IEA (IEA, 2014b), Romania's 2012 emissions are 16% lower compared to 2005 level. If efficiency measures in the demand side are implemented, the baseline emissions in 2030 and 2050 would be 16% below from the 2005 level in both years. Under the green scenario, total energy activity related CO2 emissions would be 26% below 2005 level in both years. Under the stringent super green scenario total national CO2 emissions from energy activities in 2030 and 2050 would be respectively, 47% and 43% below 2005 level.

The power sector will experience a large reduction of CO_2 in all scenarios. Since it is an ETS sector and mandated to reduce emission even in the baseline, its emissions in the baseline scenario will drop by 20% in 2030 and 36% in 2050 from the 2005 level. If energy efficiency improvements in the demand side are also accounted for (i.e., low demand case), the drop (i.e., emission reduction compared to 2005 level) would be as high as 45% in 2050. Under the green scenario, power sector emissions in 2030 and 2050 would be 34% and 68% smaller as compared to the 2005 level. If energy efficiency improvements in the demand side are accounted for (i.e., low demand case), the corresponding drops would be 45% and 72%, respectively.

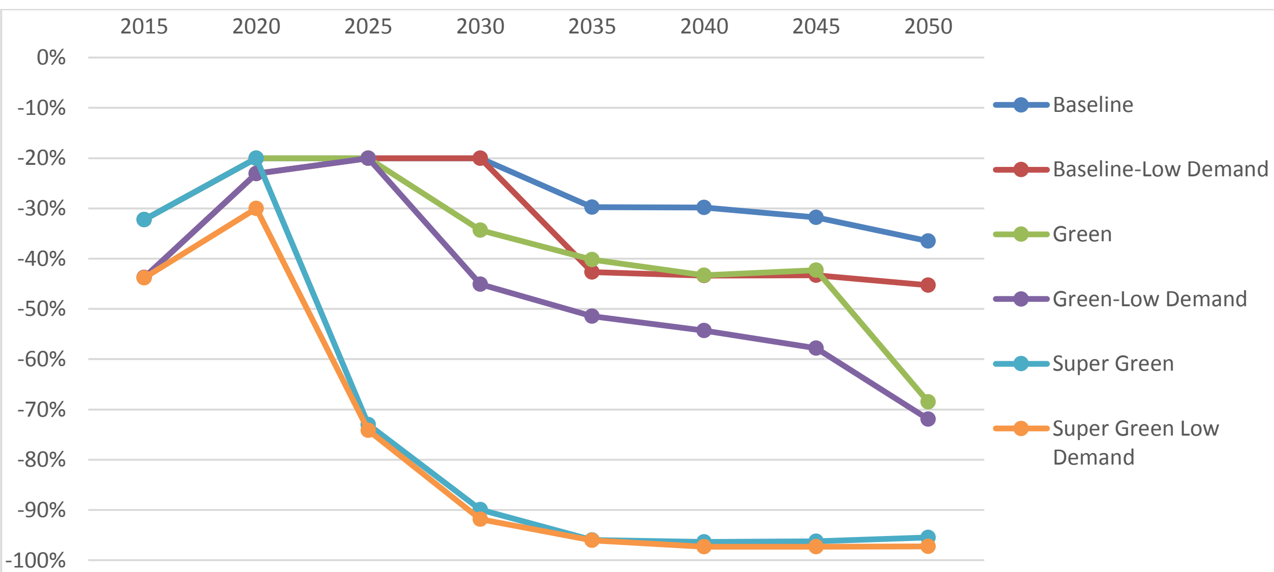
By design, the super green scenario almost eliminates CO_2 emissions from the power sector by 2050 (95% reduction under the super green and 97% reduction under the low demand super green scenarios from the 2005 level). In fact, more than 90% of emission reductions from the 2005 level would be achieved by 2030.

Figure 12. Energy related CO_2 emissions reduction from 2005 level (%)

(a) Energy sector as a whole



(b) Power sector



Source: TIMES modeling

Conclusions

Energy sector, including energy consumption and production activities, would play a crucial role in meeting EU mandates on climate change and marching towards low carbon economic growth in Romania. Three quarters of the energy sector GHG emissions are from power and heat generation and non-transport fuel consumption. Power sector falls under ETS (emission trading sector) and an existing EU climate agreement mandates that CO_2 emissions from the power sector should be 20% below the 2005 level by 2020. This implies that climate change mitigation targets beyond EU2020 cannot be achieved without significant action in the energy and specifically the power and heat supply sectors.

We developed six scenarios to explore climate change mitigation and low carbon growth opportunities in Romania. In the baseline scenario, which is consistent in line with EU 2020 climate mitigation targets, total national GHG emissions in year 2050 would be 2% below 2005 if energy efficiency measures are not included. If energy efficiency measures are included, emission in 2050 would be 16% below from the 2005 level. If energy efficiency measures are not included, the baseline energy supply costs in Romania would be €336 billion (discounted to 2015 at 5% rate) over the next 35 years (2015-2050 period), €10 billion per year, on average. It would be slightly lower (€323 billion) when energy efficiency improvements in the demand side are included. The demand side energy efficiency improvement would cost €19 billion in total but saves €29 billion through avoidance of capacity expansion in the electricity sector and also reducing fuel costs in all energy supply sectors. Thus, improving energy efficiency across the board in all economic sectors but especially in the residential sector and district heating offers the most effective and also viable means for containing the growth of energy demand.

The baseline scenario requires an addition of 6 GW of wind, 1 GW each of hydro and solar and 3 GW of natural gas based electricity generation capacity by 2050 even if energy efficiency measures are included. This would pose a challenge to a power system which already has 5 GW of wind and 1 GW of solar already operating as of present. This is because adding more renewable sources for energy generation, particularly the intermittent sources (wind and solar) would further increase the excess electricity generation capacity on top of its peak load since intermittent sources do not provide commitments to meet the peak load. Thus, the higher installed capacity because of higher penetration of intermittent renewable sources to meet climate change mitigation targets could create a situation where fossil fuel based generation sources (e.g., coal, gas) are built to meet the peak load but they will not be utilized unless their exist export markets for electricity generated from fossil fuel sources, which is unlikely in EU due to climate change mitigation obligations.

A green scenario along with energy efficiency improvements in the demand sectors would lead to 26% reduction of energy related CO_2 emissions from the 2005 level by 2030. The discounted total energy supply costs over the next 35 years would be €326 billion (or additional €3 billion on top of the €323 billion under the baseline scenario with energy efficiency measures implemented).[23] The green scenario with low energy demand (i.e., energy efficiency measures implemented), requires additional 2 GW of solar 2 GW of hydro, 1 GW biomass and 1 GW of nuclear power during the 2015-2050 period. The total investment to expand energy supply under the green scenario would be 9% higher from that under the baseline with energy efficiency measures considered under both scenarios. In order to achieve the green scenario, Romania will require to abandon plans for new coal-based power generation capacity and life-extension of existing plants; this would be challenging as coal based generation accounts for almost 40% of total electricity generation at present.

If Romania aims to eliminate GHG emissions from the power sector, a rather radical approach would be needed. It would require entire 16 GW capacity addition during the 2015-2050 period run with non-fossil sources (biomass, hydro, wind, solar and nuclear). Specifically, it would need 1 GW of new biomass based electricity generation capacity, 3 GW new hydro power capacity, 3 GW new nuclear capacity, 6 GW new wind capacity and 3 GW of new solar capacity. The total energy supply costs including the investment needed in the demand side to improve energy efficiency would be €356 billion over the next 35 years. For the power sector, this scenario needs 63% higher investment from the baseline when both scenarios includes energy efficiency investments. This is an expensive scenario to Romania's energy sector. Thus, this analysis recommends to stay low demand green scenario (i.e., green scenario with implementation of energy efficiency measures in the demand side). Yet, the low demand green scenario requires 9 GW of intermittent resources (6 GW wind and 3 GW solar) and realization of this scenario would still be challenging. Note further that if energy efficiency in the demand side are not realized, the requirement of new intermittent capacity would be 11 GW adding the challenge further. Realizing energy efficiency measures is itself tough considering the hidden and transaction costs involved with them. Often, energy efficiency measures look very attractive in an economic analysis but their deployment in the real world is slow due to several barriers.

[23] It should not be interpreted that the additional €3 billion causes additional 10% emission reduction from the base case in 2050. The investment is for 35 years (2015-2050) and it would cause certain reductions in emissions in all years during the 2015-2050 period. The comparison of cumulative investment with a single year's emission reduction would be misleading and therefore should be avoided.

Appendix 1

Table A1. Total Installed Capacity for Electricity Generation (GW)[24]

	2015	2020	2025	2030	2035	2040	2045	2050	2015	2020	2025	2030	2035	2040	2045	2050
	Baseline – Normal Demand								Baseline – Low Demand							
Biomass New	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coal existing	7	7	4	3	2	1	1	1	7	7	5	4	2	1	1	1
Coal New	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar CSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas existing	3	3	2	2	2	2	2	2	3	3	2	2	2	2	2	2
Gas New	0	0	1	2	3	4	4	4	0	0	0	0	2	3	3	3
Hydro existing	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Hydro New	0	0	0	0	0	0	1	3	0	0	0	0	0	0	1	1
Nuclear existing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nuclear New	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil Existing	2	2	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Solar PV	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1
Wind existing	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	2
Wind new	0	0	2	3	3	3	5	8	0	0	1	3	3	3	4	6
Total	23	23	20	21	22	23	26	30	23	23	18	20	19	20	22	24

[24] "New" means a newly built capacity in the modelled period 2015-2050.

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Table A1 (Continue). Total Installed Capacity for Electricity Generation (GW)

	2015	2020	2025	2030	2035	2040	2045	2050	2015	2020	2025	2030	2035	2040	2045	2050
	Green – Normal Demand								Green – Low Demand							
Biomass New	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
CCS Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coal existing	7	7	4	2	1	1	1	1	7	7	5	2	1	1	1	1
Coal New	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar CSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas existing	3	3	2	2	2	2	2	2	3	3	2	2	2	2	2	2
Gas New	0	0	1	3	3	3	3	3	0	0	0	2	2	2	2	2
Hydro existing	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Hydro New	0	0	0	0	1	3	3	3	0	0	0	0	1	2	3	3
Nuclear existing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nuclear New	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1
Oil Existing	2	2	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Solar PV	1	1	1	1	2	3	3	3	1	1	1	1	2	3	3	3
Wind existing	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	2
Wind new	0	0	2	3	3	3	4	8	0	0	1	2	2	2	3	6
Total	23	23	20	20	22	26	27	33	23	23	18	18	20	22	24	27

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Table A1 (Continue). Total Installed Capacity for Electricity Generation (GW)

	2015	2020	2025	2030	2035	2040	2045	2050	2015	2020	2025	2030	2035	2040	2045	2050
	Super Green – Normal Demand								Super Green – Low Demand							
Biomass New	0	0	0	1	1	1	1	1	0	0	0	1	1	1	1	1
CCS Coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Gas	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0
Coal existing	7	7	1	0	0	0	0	0	7	7	1	0	0	0	0	0
Coal New	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar CSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas existing	3	3	2	2	1	0	0	0	3	3	2	2	1	0	0	0
Gas New	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro existing	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Hydro New	0	0	3	3	3	3	3	3	0	0	3	3	3	3	3	3
Nuclear existing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nuclear New	0	0	1	1	3	3	3	3	0	0	0	0	2	3	3	3
Oil Existing	2	2	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Solar PV	1	1	2	3	4	5	3	2	1	1	1	2	2	4	4	3
Wind existing	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	2
Wind new	0	0	0	0	0	1	3	7	0	0	1	1	1	1	2	6
Total	23	23	20	21	23	25	26	29	23	23	18	19	20	23	24	26

Table A2. Heat Supply Sources (PJ)

Scenario	2015	2020	2030	2050	2015	2020	2030	2050
Baseline Scenario	**Normal Demand**				**Low Demand**			
Biomass	76.67	61.33	46.00	46.00	76.67	61.33	46.00	46.00
Diesel	1.25	1.49	1.91	2.32	1.19	1.25	1.34	1.45
Electricity	0.83				0.83	0.67		
CHP Heat	41.10	36.84	34.14	37.53	40.58	34.93	29.44	30.33
Natural Gas	116.94	148.91	190.88	211.36	110.02	124.24	135.14	129.31
Other Petroleum Products	8.33	6.67	5.00	5.00	8.33	6.67	5.00	5.00
Total	245.13	255.24	277.93	302.22	237.62	229.09	216.92	212.08
Green Scenario	**Normal Demand**				**Low Demand**			
Biomass	76.67	61.33	46.00	46.00	76.67	61.33	46.00	46.00
Diesel	1.25	1.49	1.91	2.32	1.19	1.25	1.34	1.42
Final Elec	0.83				0.83	0.67		
Final Heat	41.10	36.84	34.14	37.53	40.58	34.93	29.44	30.15
Natural Gas	116.94	148.91	190.88	211.36	110.02	124.24	135.14	128.64
Other Petroleum Products	8.33	6.67	5.00	5.00	8.33	6.67	5.00	5.00
Total	**245.13**	**255.24**	**277.93**	**302.22**	237.62	229.09	216.92	211.21
Super green Scenario	**Normal Demand**				**Low Demand**			
Biomass	76.67	61.33	46.00	46.00	76.67	61.33	46.00	46.00
Diesel	1.25	1.49	1.82	2.22	1.19	1.25	1.28	1.36
Electricity	0.83				0.83			
CHP Heat	41.10	36.84	14.93	18.16	40.58	34.93	10.45	11.12
Natural Gas	116.94	148.91	203.65	223.51	110.02	124.87	148.71	142.05
Other Petroleum Products	8.33	6.67	5.00	5.00	8.33	6.67	5.00	5.00
Total	**245.13**	**255.24**	**271.41**	**294.89**	**237.62**	**229.05**	**211.43**	**205.53**

Appendix 2

Plants Characteristics Used for Modeling: Existing Plants[25]

i. Thermal Electricity-only plants[26]

Unit Name	Capacity (MW)	Generic Process Transformation (Efficiency) (ratio)	Annual Availability/ Utilization factor (ratio)	Year of Commissioning	Annual fixed O&M (US$/MWh)	Annual Variable O&M (US$/MWh)	Fuel Type
Ploiesti	860	0.46	0.24	2010	18.00	1.44	natural gas
TPP Braila 1	330	0.46	0.13	1973	18.00	1.44	HFO
TPP Braila 2A	227	0.46	0.13	1973	18.00	1.44	HFO
TPP Braila 2B	210	0.46	0.30	1974	18.00	1.44	HFO
TPP Braila 2C	210	0.46	0.25	1979	18.00	1.44	HFO
TPP Craiova I.	150	0.40	0.30	1987	30.00	1.54	lignite
TPP Craiova II.	150	0.40	0.50	1988	30.00	1.54	lignite
TPP Iernut 4 (Mures)	100	0.46	0.09	1966	18.00		natural gas
TPP Iernut 5 (Mures)	200	0.46	0.09	1966	18.00	1.44	natural gas
TPP Iernut 6 (Mures)	200	0.46	0.09	1967	18.00	1.54	natural gas
TPP Isalnita 1	315	0.40	0.09	1967	30.00	1.54	Lignite
TPP Isalnita 2	315	0.40	0.70	1968	30.00	1.54	Lignite
TPP Mintia I.	210	0.40	0.70	1969	30.00	1.54	coal
TPP Mintia II.	210	0.40	0.36	1971	30.00	1.54	coal
TPP Mintia III.-IV.	420	0.40	0.36	1973	30.00	1.54	coal
TPP Mintia V.	210	0.40	0.36	1975	30.00	1.54	coal
TPP Mintia VI.	210	0.40	0.36	1977	30.00	1.54	coal
TPP Rovinari III.	330	0.40	0.36	1976	30.00	1.54	lignite

[25] Plant data confirmed by the Ministry of Energy as of xxx date. The source of data on plant capacity and year of commissioning are from Romania's electricity transmission company Transelectrica. Other data came from International sources – International Energy Agency and Energy Information Administration – and were confirmed by the Romanian Government.

[26] The table presents all larger thermal capacities.

TPP Rovinari IV.	330	0.40	0.28	1977	30.00	1.54	lignite
TPP Rovinari V.	330	0.40	0.28	1978	30.00	1.54	lignite
TPP Rovinari VI.	330	0.40	0.28	1979	30.00	1.54	lignite
TPP Turceni 3	330	0.40	0.28	1980	30.00	1.54	lignite
TPP Turceni 4	330	0.40	0.35	1981	30.00	1.54	lignite
TPP Turceni 5	330	0.40	0.35	1983	30.00	1.54	lignite
TPP Turceni 6	330	0.40	0.35	1985	30.00	1.54	lignite
TPP Turceni 7	330	0.40	0.35	1987	30.00	1.44	lignite

ii. Combined Heat and Power (CHP) plants

Plant Type/Fuel	Capacity (MW)	Ratio of heat produced to electricity produced	Generic Process Transformation (Efficiency) (ratio)	Annual Availability/ Utilization factor (ratio)	Year of Commissioning	Annual fixed O&M (US$/MWh)	Annual Variable O&M (US$/MWh)	Fuel Type
Bucaresti Progresul CHP 1	50	2.00	0.42	0.43	1987	18.00	1.44	LFO
Bucaresti Progresul CHP 2	50	2.00	0.42	0.43	1988	18.00	1.44	LFO
Bucaresti Progresul CHP 3	50	2.00	0.42	0.43	1989	18.00	1.44	LFO
Bucaresti Progresul CHP 4	50	2.00	0.42	0.43	1994	18.00	1.44	LFO
Bucaresti "Titan" CHP 1	4	2.00	0.42	0.51	1965	18.00	1.44	HFO
Bucaresti "Titan" CHP 2	4	2.00	0.42	0.51	1970	18.00	1.44	HFO

Plant Type/Fuel	Capacity (MW)	Ratio of heat produced to electricity produced	Generic Process Transformation (Efficiency) (ratio)	Annual Availability/ Utilization factor (ratio)	Year of Commissioning	Annual fixed O&M (US$/MWh)	Annual Variable O&M (US$/MWh)	Fuel Type
Bucaresti Sud CHP 1	50	2.00	0.42	0.51	1965	18.00	1.44	natural gas
Bucaresti Sud CHP 2	50	2.00	0.42	0.51	1966	18.00	1.44	natural gas
Bucaresti Sud CHP 3-4	200	2.00	0.42	0.39	1967	18.00	1.44	natural gas
Bucaresti Sud CHP 5-6	250	2.00	0.42	0.39	1975	30.00	1.54	natural gas
Bucaresti Vest CHP 1-2	250	2.00	0.36	0.80	1975	30.00	1.54	natural gas
Cet Vest 3	186	2.00	0.36	0.84	2009	30.00	1.54	natural gas
CHP Arad	50	2.00	0.36	0.84	1992	18.00	1.44	coal
CHP Brasov A	50	2.00	0.42	0.51	1991	18.00	1.44	coal
CHP Brasov B	50	2.00	0.42	0.51	1995	18.00	1.44	coal
CHP Galati 2	100	2.00	0.42	0.51	1975	18.00	1.44	natural gas
CHP Galati 3	60	2.00	0.42	0.51	1983	30.00	1.54	natural gas
CHP Galati 4	60	2.00	0.36	0.85	1984	30.00	1.54	natural gas
CHP Galati1	315	2.00	0.36	0.85	1969	30.00	1.54	natural gas
CHP Giurgiu	100	2.00	0.36	0.85	1984	18.00	1.44	coal
CHP Govora I.	50	2.00	0.42	0.85	1986	30.00	1.54	coal
CHP Govora II.	50	2.00	0.36	0.54	1987	30.00	1.54	coal

Plant Type/Fuel	Capacity (MW)	Ratio of heat produced to electricity produced	Generic Process Transformation (Efficiency) (ratio)	Annual Availability/ Utilization factor (ratio)	Year of Commissioning	Annual fixed O&M (US$/MWh)	Annual Variable O&M (US$/MWh)	Fuel Type
CHP Govora III.	100	2.00	0.36	0.54	1988	30.00	1.54	natural gas
CHP Iasi II. A	50	2.00	0.36	0.85	1986	30.00	1.54	coal
CHP Iasi II. B	50	2.00	0.36	0.85	1988	30.00	1.54	coal
CHP Orodea I. A-B	50	2.00	0.36	0.85	1966	30.00	1.54	coal
CHP Orodea I. C	55	2.00	0.36	0.85	1967	30.00	1.54	coal
CHP Orodea I. D-E	100	2.00	0.36	0.85	1971	30.00	1.54	coal
CHP Orodea II. A	50	2.00	0.36	0.85	1987	30.00	1.54	coal
CHP Orodea II. B	50	2.00	0.36	0.56	1988	30.00	1.54	coal
CHP Orodea II. C	50	2.00	0.36	0.56	1989	30.00	1.54	coal
CHP Paroseni I.	150	2.00	0.36	0.56	1964	30.00	1.54	coal
CHP Paroseni II. A	50	2.00	0.36	0.56	1956	30.00	1.54	coal
CHP Paroseni II. B	50	2.00	0.36	0.85	1957	30.00	1.54	coal
CHP Paroseni II. C	50	2.00	0.36	0.85	1959	18.00	1.44	coal
CHP Suceava A	50	2.00	0.42	0.43	1987	18.00	1.44	coal
CHP Suceava B	50	2.00	0.42	0.43	1989	18.00	1.44	coal

iii. Hydro power plants[27]

Unit Name	Capacity (MW)	Unit Name	Capacity (MW)	Unit Name	Capacity (MW)	Unit Name	Capacity (MW)	Unit Name	Capacity (MW)	Unit Name	Capacity (MW)
Agigea	7.15	Calimanesti-siret	0.5	Ehresti	0	Ivo II	0.3	Pascani	16.45	Sebes Nord Fagaras	8.58
Albesti	10.73	Calinesti	0.03	Fagaras	0.19	Izbiceni	37.9	Pausa	9.05	Sebes Sugag	0.58
Alunul	0.01	Calugarita	0.26	Falticeni	0.34	Izvoare I	0.29	Petresti	0.06	Sebis	150
Andrisesti	0.02	Capra II	0.88	Fcl Cimpulung	0.06	Izvoarele	11.44	Piatra Bulz	2.86	Sihastria I	0.19
Anies	0.07	Capra III	0.71	Fincel I	0.06	Izvorul Alb	0.13	Piatra Neamt	1.29	Sihla	0.39
Arcesti	27.17	Caralita	0.1	Fincel II	10.01	Lapusna-secuieni	0.02	Piriul Turcului	7.87	Simeria	0.28
Arnis	0.16	Casin-1a	0.11	Firiza	0.23	Lesu	2.65	Pitesti	0.18	Simileasca	0
Arpasu	2	Casin-1b	0.11	Florei	4.93	Lilieci	16.45	Plai Monah	5.51	Sinaia I	8.37
Astileu I	0.79	Casin-2	0.15	Floresti I	0.93	Limpedea	0.23	Plopi	1.72	Sinaia II	0.64
Astileu	10.15	Casin-3	0.14	Floresti II	37.9	Lopatari	0.61	Poiana Marului	5.72	Sinaia III	0.86
Avrig	0.12	Casin-4	0.18	Frunzaru	2.5	Lotrioara	0	Poiana Teiului	57.2	Sirbesti III	0.86
Azuga	26.46	Catanas	0	Fughiu	14.3	Lotru	432.28	Poiana Uzului	7.87	Somesul Cald	0.03

[27] The aggregate annual utilization factor is 35 percent (Source: Romanian government)

Babeni	38.97	Ceahlau	10.73	Galanesti I	0.32	Lucaciu	0.29	Polovraci	2.97	Somesul Rece	8.58
Bacau	0	Cerbureni	9.01	Galanesti II	0.35	Lugasu	12.87	Portile De Fier	0.02	Sovata II	0.2
Bacia	0.54	Cernavoda	0.15	Galanesti III	0.36	Malaia	13.09	Posaga De Sus	1,166.00	Stejaru	0.24
Baia De Fier	11.01	Cet Restitutie	0.03	Galbeni	20.84	Mariselu	221	Pucioasa-1	0.18	Stinca Costesti	150.16
Baiculesti	0.19	Cheile Segacii	0.5	Galu	0	Merisani	8.22	Pucioasa-2	1.43	Strei	10.73
Baile Herculane	0.46	Chemp Munten	0.49	Gilau	9.87	Mihailesti	6.01	Putna	0.89	Strejesti	11.3
Baraj Cet Oradea	0.24	Chiojd-1	0.54	Gilceag	107.26	Milisauti	0.31	Racaciuni	0.17	Strunga	35.75
Barnar	0.31	Chiojd-2	0.44	Girda Seaca	0.02	Minastire a Dej-1	0.27	Racova	31.89	Subcetate	0.26
Baru Mare	5.51	Chiojd-3	0.36	Girleni	16.45	Mineciu Ungurnei	0.27	Racovita	16.45	Surduc Mini	8.44
Bascov	1.07	Chiuzbaia	20.16	Gistesti	0.14	Mintia Restitutie	7.15	Radovanu	0	Surduc	0.86
Bega	31.11	Ciineni	0.57	Godeanu I	0.71	Minzalesti	1	Ramnicu Valcea	0	Suseni	0
Beresti	210	Cincis I	8.01	Gogosu	38.61	Mocrea	0.61	Rasinari I	32.89	Talmaciu	0.79
Bicaz-Stejaru	0.18	Cindesti	14.3	Golesti Dam	0	Moroieni	0.04	Rasnov-3	0.06	Targu Jiu	0.18
Bilciuresti	0.54	Ciresu	19.59	Golesti	5.72	Motru	10.73	Rasnov-4	0.42	Targu Mures	7.87
Bistra I	0.22	Cirnesti	45.76	Gresu I	0.64	Movileni	35.75	Rastolita	0.64	Tarlug-1	0.64
Bistra II	1.35	Clabucet	7.15	Gura Haitii I	0.9	Munteni	28.03	Raul Alb	0	Tarlug-4	0.52
Bistra Noua	0.56	Clocotis	10.01	Gura Haitii II	0.71	Neagra	42.04	Reghin	0	Tarnita Dam	0.86
Bixad	0.03	Clopotiva	0.64	Gura Lotrului	17.73	Neagra Sarului I	0.17	Remeti	0.04	Tarnita	2.65

Boga	1.43	Cluj I	0.09	Gura Raului Aliment	0	Neagra Sarului II	0.54	Riul Alb	100	Tarnita-lapustesti	32.18
Bogdanesti I	0.36	Codlea I	0.11	Hanesti	0.04	Nedelea I	1.31	Riureni	28.6	Tibeni	0
Boia I	0.79	Codlea II	15.02	Hateg	11.37	Nedelea II	0.53	Robesti	34.32	Tileagd	0.37
Boia III	0.39	Colibita	0.15	Hateg Retezat	239.55	Nehoiu	0.64	Rogojesti	20.38	Tirlung-2	12.87
Bolovani	0.36	Constantin Daicoviciu	21.81	Hemeius	0.06	Niamesti-4	30.03	Roznov	2.29	Tirlung-3	1.72
Borsa-complex	0.26	Cornetu	26.17	Herculane	4.86	Noaptes	0.84	Rucar	10.01	Tisa River	1.07
Borzesti Restituti	115	Cosmesti	10.01	Herculane -belareca	0	Novaci I	11.01	Ruieni	16.45	Tismana Aval	0
Bradisor	0.4	Costisa	3.58	Horezu-1	0.02	Novaci II	0.64	Runcu I	153	Tismana	2.15
Bran 0	0.45	Cumpanita	5.51	Horezu-2	0.71	Novaci III	1.57	Rusanesti	0.39	Tohani-zarnesti	106
Bran-1	1.07	Curtea De Arges	0	Hotarele	0	Novaci IV	1.5	Sacadat	37.9	Tomsani I	0.11
Bran-2	0.08	Curtisoara	25.74	Huza-1	0.15	Novaci V	1.43	Sacelu Bai	7.15	Tomsani II	1
Bran-9	1.31	Daesti	1	Huza-2	0.26	Ogrezeni	0.81	Sadau	0.02	Tomsani III	1
Branesti	0.3	Deva Rebuild	0.07	Iaz I	0.08	Oiesti	0.47	Sadova II	0.38	Totesti	1
Brasov	11.44	Dezna	0	Iaz II	0.04	Olanesti	10.73	Sadu Gorj	0.13	Turcinesti	22.74
Bretea	0.45	Dimitra	0.49	Iernut Restitutie	0.82	Oltet I	0.03	Sadu I	1.14	Turnu	0
Brodina I	0.09	Dirmoxa	0.58	Ilies I	0.15	Oltet II	1.22	Sadu II	1.35	Tusa I	50.05
Brodina II	0.84	Dobra I	11.44	Ilies II	0.13	Oradea-restitutie	1.25	Sadu-sat	1.1	Tusa II	0.02
Bucecea	0.57	Dobresti	0.01	Iod-1	0.2	Orasa II	0.15	Salasele-1	1.07	Vacaresti	0.02

Budac I	8.22	Dobroneag	0.29	Iod-2	0.2	Orlea	0.03	Salasele-2	0.02	Vadeni	3.43
Budaesa	0.52	Doftana	1.35	Iod-3	0.29	Ostrovul Mare	8.22	Salatrucel	0.02	Vaduri	7.87
Budureasa	0.08	Dornisoara	0.04	Ionesti	27.17	Ostrovul Mic	11.37	Saru Dornei I	0.02	Valea Cracului I	31.46
Buftea	7.87	Dracsani	40.4	Iosasel	0.09	Ovidiu	11.37	Saru Dornei II	1.3	Valea De Pesti	0.38
Buhusi	0	Draganesti	32.18	Ipotesti	37.9	Paclisa	0	Sasciori	0.9	Valea Iasului	0.35
Bumbesti	0.64	Dragasani	5.43	Isalnita Restituti	2.02	Paltinul	11.37	Savinesti	30.03	Valea Lui Iovah	0.4
Buteni	5.58	Dragoslavele	1.75	Islaz	0	Panaci	7.29	Scoreiu	0.13	Valea Sadului	0.14
Calan	27.17	Dridu	0.44	Isticeu	0.63	Pangarati	0.33	Scropoasa	10.15	Valenii De Munte	10.73
Calimanesti-olt	28.6										

iv. Wind power plants

Project name	Location	Installed Capacity (MW)	Year of Commissioning
CEZ Fantanele	Fantenele and Cogealac, southeastern Romania	348	2011
EDPR Cernavoda I - II	Constanta county; Dobrogea region;	138	2011
EDPR Pestera	Constanta county; Dobrogea	90	2011
Enel Corugea	Tulcea county; dobrogea	70	2012
Enel Moldova Noua	Santa Elena, Caras Severin province	45	2011
Enel Salbatica I - II	Tulcea county; dobrogea region; Valea Nucarilor municipality	30	2011
Iberdrola Mihai Viteazu	Tulcea county; dobrogea	80	2011
Martifer Babadag	County of Tulcea, Babadag City	42	2012
Sinus Vaslui	Vaskyu County	700	2012
GE-Prowind Banca	Banca; Vaslui county	300	2012
Enel Targusor-Zephyr	Constanta county; Dobrogea	272	2012
CEZ Cogealac	Constanta county; Dobrogea	252.5	2012
Iberdrola Beidaud	Gradina; Tulcea county	244	2013
CWP Independenta I	Galati County, Moldavia	226	2013
Iberdrola Cogealac A	Constanta county; Dobrogea	214	2012
Verbund Casimcea 1 - 2	Tulcea district; Casimcea	200	2013
Green Energy Agichiol	Agichiol; Tulcea county	200	2012
Sorgenia Falciu	Vaslui County, Moldavia	196	2013
Iberdrola Sacele	Constanta county; Dobrogea	164	2012
Monsson Pantelimon	Pantelimon in Constanta County	150	2012
Monsson Serbotesti	Vaslui County, Moldavia	150	2013
Iberdrola Baia	Tulcea county; dobrogea	132	2013
Iberdrola Casimcea	Casimcea; Consatnta county	112	2012
Iberdrola Gradina	Gradina; Constanta County	112	2012
Iberdrola Cogealac B	Constanta county; Dobrogea	108	2013
STEAG Constanta	Constanta; Dobrogea	108	2012
Iberdrola Saricioi	Sarichioi, Tulcea County	102	2012
Iberdrola Istria	Tulcea county; dobrogea	84	2014

LUKERG Land Power	Tulcea Region, Southeastern Romania	84	2013
Windkraft Sfanta Elena	Sfanta Elena; Caras Severin county	84	2013
EPGE Chirnogeni-Independenta	Chirnogeni and Indepdenta municipalities; Dobrogea region	80	2012
Iberdrola Corbu	Corbu; Constanta County	68	2012
Alerion Auseu-Borod	Bihor County; Transylvania Eoliana	65	2012
Energowind Negresti-Osesti	Negresti and Osesti; Vaslui county	64	2013
Iberdrola Piatra	Constanta county; Dobrogea	64	2012
EDPR Sarichioi - Vutcani	Sarichioi; tulcea county	57	2013
EPGE Amzacea (Phase 1)	Eastern region of Dobrogea	50	2013
EPGE Ciocarlia (Phase 1)	Eastern region of Dobrogea	50	2013
EPGE Cobadin (Phase 1)	Eastern region of Dobrogea	50	2013

c) New Power plants Characteristics

Technology	Overnight construction costs (US$/kW)	Life Span (years)	Availability Factor (ratio)	Efficiency (ratio)
Steam Coal – Ultra Super Critical	3,000	40	0.85	0.4
Steam Coal – Ultra Super Critical with CCS	5,010	40	0.85	0.38
Natural Gas Combine Cycle (CCGT)	1,146	30	0.9	0.56
CCGT with CCS	2,388	30	0.9	0.53
Gas turbine	700	25	0.9	0.37
Biomass	3,330	35	0.85	0.44
Steam Oil (HFO)	2,727	30	0.9	0.38
Hydro	2,175	50	0.3-0.6	0.35
Wind Onshore	2,000	25	0.2-0.3	varies
Solar PV	2,279	20	0.2	varies
Nuclear	3,931	50	0.9	0.35

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EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments 2007 - 2013

Project co-financed by the European Regional Development Fund through OPTA 2007 – 2013

Romania Climate Change and Low Carbon Green Growth Program

Output C1.1
Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors

FORESTRY SECTOR TECHNICAL REPORT: OPPORTUNITIES FOR MITIGATION AND ADAPTATION THROUGH FORESTS

November 2015

THE WORLD BANK
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This report corresponds to Output C1.1: "Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors" in the Advisory Services Agreement on "Romania: Climate Change and Low Carbon Green Growth Program" signed between the Ministry of Environment and Climate Change[1] and the International Bank for Reconstruction and Development on July 23, 2013.

[1] Now named Ministry of Environment, Waters and Forests

Abbreviations and Acronyms

APPR	Romanian Forest Owners Association
BAU	Business as usual
CO2	Carbon dioxide
EARDF	European Agriculture and Rural Development Fund
EFISCEN	European Forest Information Scenario Model
EFI	European Forest Institute
ESIF	European Structural and Investment Funds
ETS	Emission Trading System
EU	European Union
FMP	Forest Management Plan
GDP	Gross Domestic Product
GDPSPWFF	The General Directorate for Policy, Strategies and Projects for Waters, Forestry and Fisheries
GHG	Greenhouse Gases
NAM	National Administration for Meteorology
ICAS	Institutul de Cercetări şi Amenajări Silvice
JRC	Joint Research Centre of the European Commission
LULUCF	Land use, land use change and forests
MARD	Ministry of Agriculture and Rural Development
MECC	Ministry of Environment and Climate Change
NFA	National Forest Administration - Romsilva
NFI	National Forest Inventory
NRDP	National Rural Development Plan
NTFP	Non timber forest products
PFD	Private Forest Districts
SCF	Structural Cohesion Funds

SCI	Sites of Communitarian Interest
SEM	Sustainable Ecosystem Management
SMEs	Small and Medium Scale Enterprises
SOP	Structural Operational Program
SWOT	Strength, weakness, opportunities and threats
tCO_2e	Metric ton of CO_2 equivalent
TEEB	The Economics of Ecosystems and Biodiversity

Contents

INTRODUCTION

1. The forest sector chapter provides a sector analysis and baseline for informing a larger multi-sectoral effort to advise the Government of Romania on a low-carbon green economy. The sector analysis presents information on adaptation and mitigation options, and identifies the contribution of sectoral policies to climate change and a green economy. This assessment draws on information, data, and findings from existing studies and models, and makes recommendations for forest sector measures that can enhance how forests are used to address climate change (both mitigation and adaptation) while contributing to sustainable growth.[2]

BACKGROUND

2. **Romania has the largest remaining intact tract of contiguous natural and naturally regenerated forests in Europe.** Romania's forests cover 6.539 million ha or 27.4 percent of the country land surface (NEPA, 2014,), of which 225,000 ha are listed as primary forests (MECC, 2011) and the rest as secondary forests. Forest cover in Romania, however, is well below the EU average of 42 percent (World Bank, 2011) and slightly more than half of what is envisioned as the national target level (40 percent).

3. **Romania's forest sector has undergone significant changes in the last two decades** resulting from the transition from a centralized economy to a market one. In addition, the restitution of forest land restitution completely modified the structure of forest land ownership. The development of the private sector in wood harvesting and processing industry (which currently is almost entirely privately owned) is also a notable change.

4. **In spite of these changes, over the past years, the forest sector, including industry, has contributed between 2.2 percent and 4.5 percent to Gross Domestic Product (GDP)** (Abrudan et al, 2009; FAO, 2012, FAO, 2014), with signs of increases in the contribution to the economy. In 2006, the sawmilling sector contributed 3.5 percent of GDP and made up 6 percent of manufacturing sector output (EBRD and MARD, 2007). In 2009, the furniture manufacturing sector represented 1.6 percent of the Romanian GDP and in 2011 represented 1.9 percent of the Romanian GDP (FAO, 2014). (FRD Center, 2011).[3] In 2010, the forest sector and wood industry contributed 3.5 percent of GDP (source INS-CON105D). In 2011, the national exports from the forest sector constituted between 5.5 (FAO, 2014) and 7 percent (compared to 10 percent from agriculture sector and food industry).

5. **The forest sector is, in some contexts, the only source of employment with a low barrier to entry**. The forestry sector is an important employer, especially in rural areas. In 2008, there were an estimated 3,500 furniture plants and workshops employing about 80,000 people. The average total

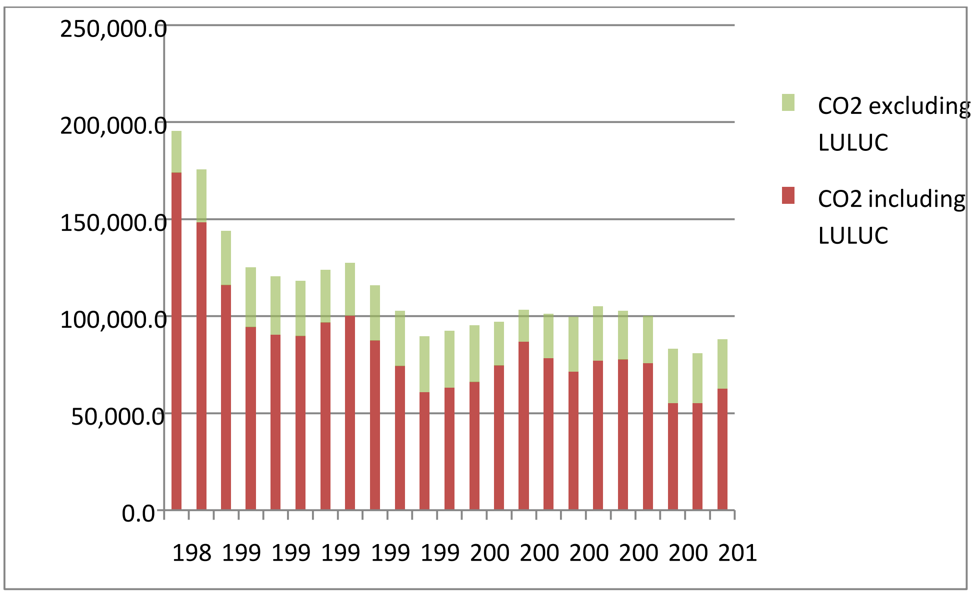
[2] See Reference list as well as references in text and figures for more specifics.

[3] According to the Romanian Center for Trade and Investment, the share of furniture export in the total Romanian exports was 3.86 percent in 2009 and 3.45 percent in 2010 (FRD Center, 2011).

number of staff under NFA management was 17,042 at the beginning of 2014. The numbers, however, have dropped from 235,000 in 2000 to an estimated 142,676 formally employed in 2011.

6. **Forests also play an important role in reducing Green House Gas (GHG) emissions.** The total GHG emissions in 2011, excluding removals by sinks, amounted to 123,345.54 Gg CO2 equivalents (MECC, 2013). CO2 emissions from LULUCF are largely from land conversion. Since 1999, there is a reduction in total CO2 emissions by approximately 30 percent on average every year when LULUCF is taken into account (see Figure 1). When examining the change in emissions compared to the base year, **LULUCF constitutes approximately 10 percent of the total reduction in emissions**. To use forests to mitigate climate change will require putting in place conditions that help reduce CO2 emissions and sequester carbon. This includes conditions for planting more trees (through afforestation or reforestation) and maintaining the health and resilience of forests (through sustainable forest management)

Figure 1. Difference between CO2 emissions including and excluding LULUCF (Gg Tons)



Source: Chandrasekharan Behr and Popa, 2014

7. Although better known for their contribution to mitigating climate change, **forests can also serve strengthening resilience to climate change**. The planting of forests in degraded lands and abandoned agricultural land offer the opportunity to reduce GHG emissions while generating adaptation co-benefits. **Existing degraded lands and lands with limited agricultural potential offer opportunities for afforestation in Romania**. Areas of agricultural land that are subject to several limiting factors because of adverse meteorological and climatic factors such as drought, flooding, erosion or landslides, low humus reserves or low supplies of key soil nutrients are considered lands with limited potential. Every year, such tracts of agricultural land become classified as being of “lowest suitability” in spite of measures taken to ameliorate the agricultural potential of the area (e.g., irrigation, land

reclamation and use of fertilizers)[4]. There are an estimated 2 million ha of such agricultural land every year. 700,000 ha of this area was arable land and 1.2-1.3 million ha are pastures and hayfields. (Bohateret, 2012).

FOREST SECTOR CHARACTERISTICS

8. **Key characteristic of Romania's forests that shape the link between climate change and forests are distribution of forests, species composition and age class distribution.** The percent of forests in each of these categories is show in Figures 2-4 below. The total forest growing stock is estimated as being 1.413 million cubic meters. Of this volume, 39 percent is coniferous, 37 percent is beech, and 13 percent are oaks. Average volume per ha is 218 m^3/ha while the European average is 147 m^3/ha. Annual increment is estimated at 5 m^3/ha.

Figure 2. Distribution of forests

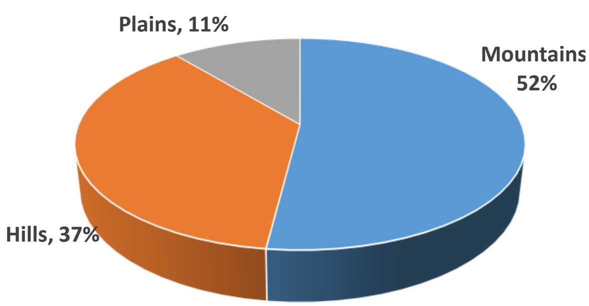


Figure 3. Species Composition

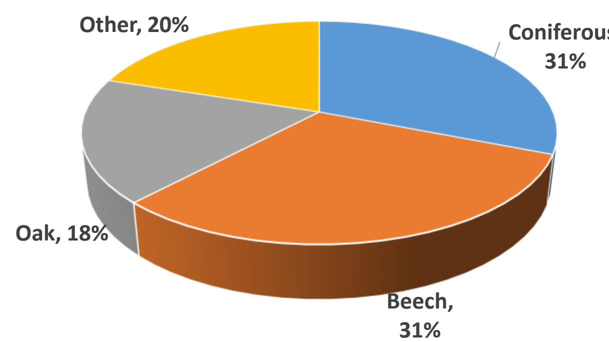
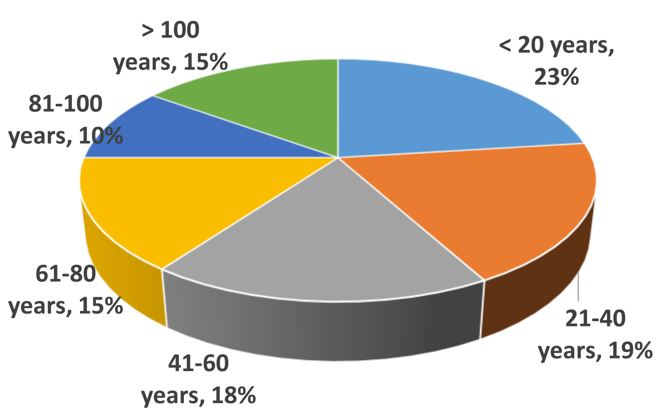


Figure 4. Age Class Distribution in Years



Source: MECC, 2014.

[4] Agricultural land scoring below 25 points in soil quality assessments is neither of economic interest for agriculture, nor attractive for businesses, because production costs far exceed any potential agricultural yields. Agriculture practiced under such adverse conditions would impoverish the population using agricultural produce for own consumption and also cause further fragmentation of agriculture (Bohateret, 2012)

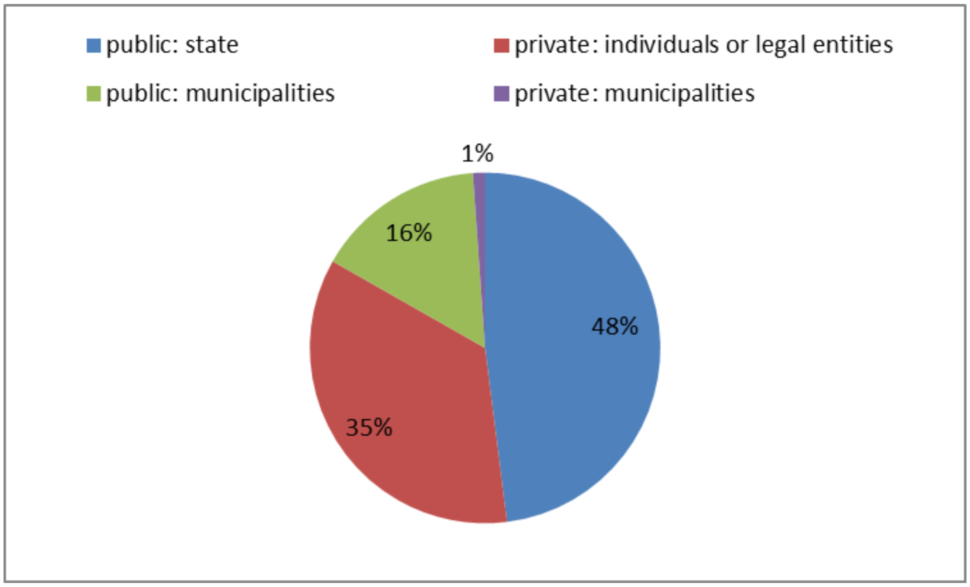
9. **The annual allowable cut has been around 22.3 million ha, but the cutting rate is now a "possible establishment by arrangement" under law.** In 2013, however, removals from the forests were 19.06 million ha, mainly due to reduced accessibility. In 2013 removals accounted for approximately 59 percent of the growing stock volume increment and 85 percent of the annual allowable cut. The species composition of the maximum volume of exploitable wood is 45 percent beech, 24 percent softwood, 13 percent various hardwood, 10 percent oak and 8 percent various softwood species (Bohateret, 2012). (According to Law no. 46/2008 - Forest Code, harvesting ceilings will be set by m^3 rather than ha.)

10. **Based on the provisions of Forest Management Plans (FMP), 53.3 percent of the Romanian forests are included in the protection forests functional category**, of which 43 percent serves soil protection, 31 percent water protection, 5 percent flood protection, 11 percent includes forest with recreation functions and 10 percent are forests with scientific interest. The remaining 46.7 percent of the surface is production forest (MECC, 2012). From the management point of view, Romanian forests are split in 6 functional types: Type I – 2 percent - no silvicultural interventions, Type II – 20 percent - conservation interventions, Type III – 8 percent and Type 4- 20 percent - silvicultural interventions are promoting natural regeneration and Types V – 5 percent and VI – 45 percent, all types of silvicultural interventions are permitted.

11. **The Romanian Network of Protected Areas (which includes areas of national importance, reserves, parks and Natura 2000 sites) covers approximately 23 percent of the forest area**. Excluding the Danube Delta Biosphere Reserve there are 13 national parks and 14 nature parks (Ioja et al., 2010). These 27 large protected areas include 134 nature reserves and natural monuments, and covering 1.17 million ha. More than 693 nature reserves and natural monuments are outside the large protected areas and cover 102,534 ha (Borlea et al., 2006; Abrudan et al., 2005). About 10.4 percent of the national forest area is included in the national and nature parks and 160,429 ha of forests are strictly protected.

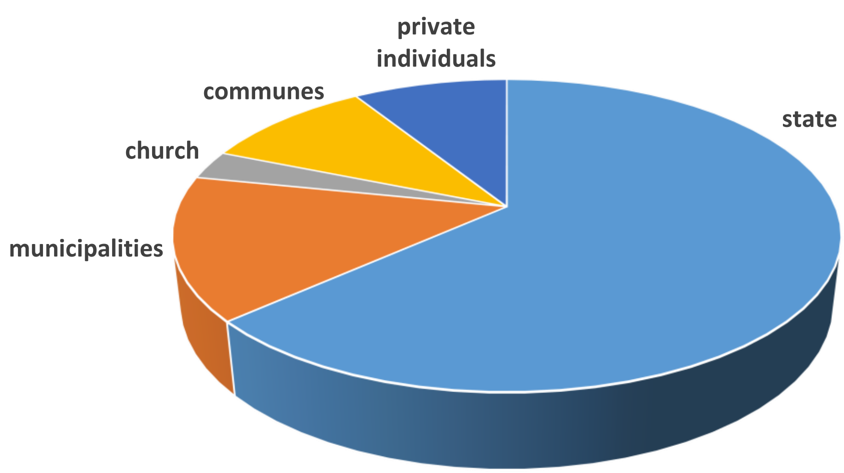
12. **By 2013, 63 percent of the wooded land areas were in the public domain while 37 percent were privately owned.** There are an estimated 850,000 forest owners in Romania. Private forest ownership in Romania spans both small and large, and individuals, indivisible communes, and churches. The predominant ownership structure is characterized by relatively small holdings and fragmentation of the forest system (World Bank, 2011) – see Figure 5 and Table 1. The distribution of forest ownership under the Natura 2000 protection network is the following: 64 percent of the forests in sites with communitarian importance (SCI) and are state owned and 36 percent is privately owned (756,600 ha) (Figure 6).

Figure 5. Forest ownership by land area, 2013



Source: MECC, 2014.

Figure 6. Forest ownership under the Natura 2000 protection network, 2012



Source: MECC, 2013; data from the national research agency for the forest sector (ICAS)

Table 1: Distribution of Forest Land (by Size) among private owners (without forests owned by local authorities)

Ownership category	Number of owners	Total Area (million ha)
Forest < 10 ha	828,000	0.85
Forest > 10 ha	2,200	1.35
Totals	830,200	2.20

Source: World Bank, 2011

13. While the export of logs has been decreasing since 1990 (ASFOR, 2014), new industrial plants in Romania are importing logs from Ukraine and Russia (about 400,000 m^3 in 2013). The sawmilling industry generated 3.762 mill $m^3$of sawn wood, and the export of sawn wood has increased. It is estimated at about 2.6 million m^3. The wood based panel industry is also rapidly increasing in Romania with 1.1 million m^3 of boards exported in 2013. The entire furniture industry in Romania generates about 1 billion EUR/year with about 65% are from exports. There is evidence that demand for wood will increase in the medium term and the processing capacity is also forecast to grow. The shifts will depend on how consumption in Eastern Europe recovers and the export of processed wood increases.

CLIMATE CHANGE AND FORESTS

14. **Climate change projections indicate that at the country level there will be a 2°C increase in average winter temperatures and over 3°C increase in average summer temperatures.** The areas outside the Carpathian arch, in particular, will experience higher temperatures in winter, while the South and Southeast will experience higher temperatures in summer. Climate models also predict an increased frequency of extreme meteorological events. Precipitations are expected to be more abundant across short periods of time, and across smaller areas, leading to more frequent flash floods, and also to more intense drought periods. While the regime of precipitations may not change significantly in the winter[5], there will be an overall decrease in precipitations in the summer[6]. The average daily rate of precipitations for Romania will decrease by about 20 percent. However, the predictability of precipitation will vary greatly across regions, especially in Eastern Romania. (MECC, 2012). Together with the floods, the long periods of drought cause important economic losses in agriculture, transports and supply of energy, water management, health and households.

15. **Forests are important for sequestering GHGs and reducing emissions, thus mitigating climate change. Romania's GHG Inventory (National Inventory Report) from 1989 to 2011 stated that "[i]n 2011, the GHG emissions without [land use, land use change, and forests (LULUCF)] have decreased [by] 54.9 percent comparing with the base year level.**" When factoring in LULUCF, "the net GHG emissions/removals (taking into account the carbon dioxide (CO2) removals) decreased [by] 61.1

[5] The exception will be a slight increases in the Northwest and slight decreases in the Southwest

[6] The decrease will be up to 40 percent, especially in the South and Southeast

percent." (MECC, 2013). The detailed reporting of GHG emissions and removals from LULUCF[78] reveals the significant contribution of forest land remaining forest land in sequestering GHGs (or "removals" of GHG), as show in Table 2.

Table 2: Net GHGs emissions for the LULUCF Sector in 1989, 2010 and 2011 (source MECC, 2013)

IPCC subcategories	Emissions (+) / Removals (-) in Gg CO2eq		
	(BY) 1989	2010	2011
5A1. Forestland[14] remaining Forestland	-18863	-22263	-20384
5A2. Land converted to Forestland	-122	-2498	-3061
5B1. Cropland[15] remaining Cropland	-5784	-2336	-3223
5B2. Land converted to Cropland	-17	18	20
5C1. Grassland remaining Grassland	NO	NO	NO
5C2. Land converted to Grassland	-654	130	118
5D1. Wetlands remaining Wetlands	NO	NO	NO
5D2. Land converted to Wetlands	-215	-126	-130
5E1. Settlements remaining Settlements	NO	NO	NO
5E2. Land converted to Settlements	4125	419	410
5F1. Other land remaining Other Land	NO	NO	NO
5F2. Land converted to Other Land	-30	789	835

Source: MECC (2013)

16. **Forests, like other natural systems, are affected by climate change.** [9] Projected changes in precipitation and temperature in Romania are anticipated to primarily weaken existing forest systems

[7] Estimating emissions and removals of GHG from LULUCF follows the Guidelines 1996 methodology presented in Good Practice Guidance for LULUCF, IPCC, 2003 (MECC, 2013) 14 This category includes: forest lands or those that serve the culture, production or administration of forest, lands for afforestation and unproductive lands comprising rocks, steep and stony slopes, ravines, gullies, torrents, if they are included in forestry planning (for better understanding of forest vegetation issue please check the section 5A1 Forestland and descriptions of other land categories, i.e. Grassland). (MECC, 2013)

[8] This category includes: arable land, vineyards, orchards, vineyards and orchards, nurseries, hops and mulberry trees, pastures, hayfields, greenhouses, solariums, greenhouses, the land covered with forest vegetation if it is not part of forest fund, wooded pastures, land occupied with agro-zoo-technical constructions and land improvements, fishery facilities, roads and technological storage

[9] The effects of climate change on forests can reduce the contribution of forests to mitigating climate change, as many of the impacts of climate change decrease the growth rate of forests and cause degradation of forest areas.

and decrease growth. In Romania, approximately 1 million m^3 of timber are lost annually to wind and snow. **Drying of stands and species is another phenomenon related to climate change**. ICAS (2003) found poplar and willow drying in the meadows (even where there are investments to provide adequate water). There have been drying phenomena reported in oaks during several time periods[10]. The latest wave of oak drying in Romania also impacted species that are considered to be resistant to the phenomena: *Quercus frainetto*. A study on beech found that average defoliation increased from 29 percent to 42 percent once the damaging effect of the drying phenomena occurred between 2001 to 2004 (Chira et al., 2005). These losses affect the health of the forest ecosystem. During the period of 1990-2006, forest health monitoring in Romania indicates that the forest health was poor in 1991, 2005, and 2006. The country had moderately disturbed forests in 1990, 1992, 1995-1999, 2000-2004. Compounding the situation are the losses resulting from the damages caused by insect attacks.

17. **Changing stand productivity (decrease in growth) is a likely outcome of climate change.** Different growth scenarios (JABOWA III), based on climate change scenarios developed by the National Institute for Meteorology (INM), show up to 30 percent reduction of trees population and a decrease in growth, especially for forests in the plain areas (ICAS, 2005). Badea and Neagu (2010) found that there were different average annual growth in volume among different tree species in Romania that could be explained by the conditions of vegetation, climate and site. They also found that for healthy trees there were higher values of annual growth in volumes than the more damaged trees. The difference ranged from 0.09m^3/year/ha for Oak and 6.44m^3/year/ha for beech. The value of volume of growth loss (percent) due to damage was between 1-12 percent for the 10 year period. If it was assumed that between 90-100 percent of trees are damaged by the biotic and abiotic factors, mean growth loss would increase to 40- 45 percent (Badea and Neagu, 2010).

18. **There are several other consequences to climate change that can reduce the contribution of forests to sequestering carbon and result in net GHG emissions.** Examples include an increase in pest infestation. There has been an increase in outbreaks of the bark beetle in Europe at higher altitudes and latitudes, where there are favorable temperature conditions (Hlásny & Turčáni, 2009). **Climate change is also expected to shift in suitable eco-zones for species. This has implications for any future efforts that involve the planting of trees.** When tree species are planted outside of their natural areas they are more susceptible to negative biotic factors – pests, water stress, and so on. In the mountains, forests are invading pastures. The process is driven by pioneer species but also species such as Norway spruce. In the southern part of the country, nonnative species are invading natural forests -- for example *Rosa canina* and black locust (*Robinia pseudacacia*). Nonnative species are also invading natural forests in the plains region. Trombik et al., (2013) found that the projected changes in temperature and precipitation in the Carpathians would cause species such as Beech to lose their competitive vigor in the Outer Eastern Carpathians that fall within Romania's boundaries. Beech

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Climate change causes and, in some cases, compounds biological risks to forests. Climate change also can accelerate degradation of forests and increasing incidence of fires, both of which result in emissions of CO2.

[10] The periods included: 1910-1914, 1937-1943, 1947-1949, 1955-1961, 1980-1990

mortality was likely to occur in in the Transylvanian Plateau, where beech occurs marginally. The degradation of forests in turn results in GHG emissions.

19. Forest fires incidence in Romania, under current climatic conditions, is rather low. However, in the occurrence of forest fire in the south and south west part of the country is certain (Adam, 2010). This area is similar to the area with the biggest incidence of forest fires in Europe (the Mediterranean region) where 85% of the forest fires are presently recorded (Barbosa et al., 2008). Forest fires are intricately linked with forest pests and diseases –infested forest, with dying trees, are more susceptible to forest fire and fire damaged stands are more prone to pest infestation. At present, Romania has a monitoring and intervention forest fires intervention system that involves mainly NFA, and local authorities in charge with emergency events (County Inspectorates for Emergency Situations). This system is able to cope with the present level of fire incidence and its effectiveness is affected by many issues, one of them being forest accessibility.

20. In the face of climate change, forest managers need to choose the appropriate management approaches for maintaining and increasing ecosystem services from forests. Reduction of the vulnerability of forest ecosystems requires reducing exposure of forests to climate change and decreasing their sensitivity to changes in climate. Adaptation measures should be based on scientific research and technological advances which support the sustainable development of forests, taking into account the environmental and socio-economic context. These measures must also be accompanied by adequate monitoring of the health of forests, as well as of their development. Currently there is limited information on the adaptation requirements for Romania's forests and the monitoring capacities can be significantly improved.

OPPORTUNITIES FOR FORESTS TO CONTRIBUTE TO CLIMATE CHANGE MITIGATION AND ADAPTATION AND GROWTH

MANAGING FORESTS TO MITIGATE CLIMATE CHANGE

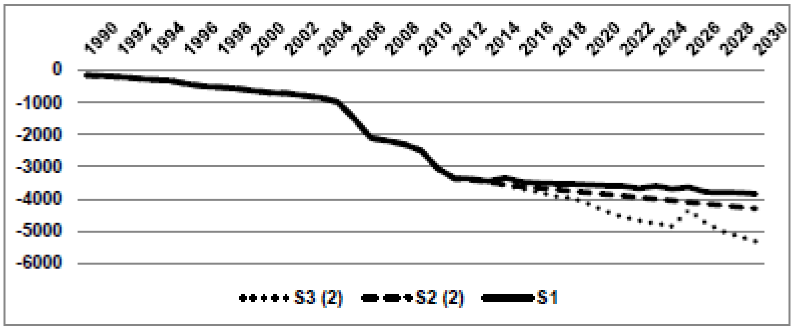
National Modeling and International Models

21. Under the business as usual scenario and the assumptions used in the Joint Research Center of the European Commission (JRC) and ICAS modeling exercise done in 2012, it is expected that under the current forest management norms and accessibility conditions there will be a **shift of trees to older age classes,** therefore, there will be a decrease in the carbon sink for the period 2013-2020. The study states that an abrupt decrease in carbon sink (during the period 2013-2020) could happen if the following occurred: i) Revision of the regulations that dictate forest management planning and harvesting wood (these are hereafter referred to as technical norms), ii) Large-scale investment in forest infrastructure, iii) Large scale natural disturbances which may imply larger concentrated cuttings in some years.

22. The second study, let by ICAS, examines GHG projections for 2015-2030 under three scenarios:

- Scenario 1 (S1): assumes the current practices of resource management for all types of lands. This scenario also includes afforestation of 2000 ha annually;
- Scenario 2 (S2): measures to improve land use (by increasing annual harvest of wood to the pre-1989 levels (when there was excessive logging and allowable annual extraction levels were constantly exceeded by 15-30% (Bohateret, 2012), afforesting degraded lands at 5000ha/year (this will include re-vegetation and forest belts (from 2012-2030) and implementing 'no-till' practices for 30% of the arable land in rotation per year, and
- Scenario 3 (S3): measures to improve land use and additional financial incentives for specific public good services (This will include measures to increase annual harvest of wood to pre-1989 levels through intensification of forest management, afforestation of degraded lands at a rate of 10,000ha annually (including re-vegetation and forest belts), creation of woody biomass from fast growing crops (at a rate of 5000ha/year), implementation of "no-till" practices for 40% of the area of arable land (in rotation) per year from 2015 to 2030, and increasing the protected area of nature conservation and biodiversity protection). This study concludes that for the timeframe considered (2015-2030) the quantity of CO2 removals is highest under S1 (i.e., has a greater negative value). In contrast, under S2 and S3 less CO2 is removed each year, so the value is a lower negative value.

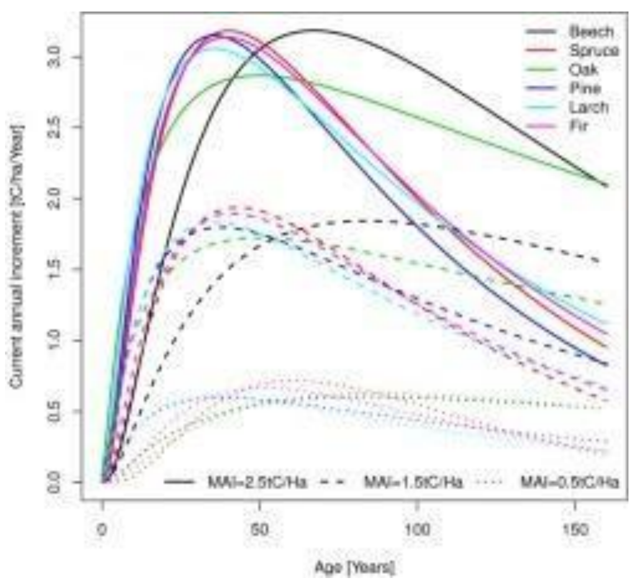
Figure 10: Graphical representation of the removals of CO2 by lands converted to forestland in the three scenarios (y-Axis is in Gg Co2e)



Source: World Bank staff calculations.

23. **Analysis in Nabuurs et al. (2007) and growth curves in Kinderman et al. (2013) indicate that intensive management of forests and increasing sustainable harvesting of timber can increase the level of CO2 sequestered compared to maintaining forest stands** (see Figure 11 and Figure 12). The general evidence is that if forests are not thinned and remain un-managed, then the more mature trees, as their growth slows, over-shade and suppress the younger more vigorous stems.

Figure 11: Growth curves for central region of Europe with Picus model

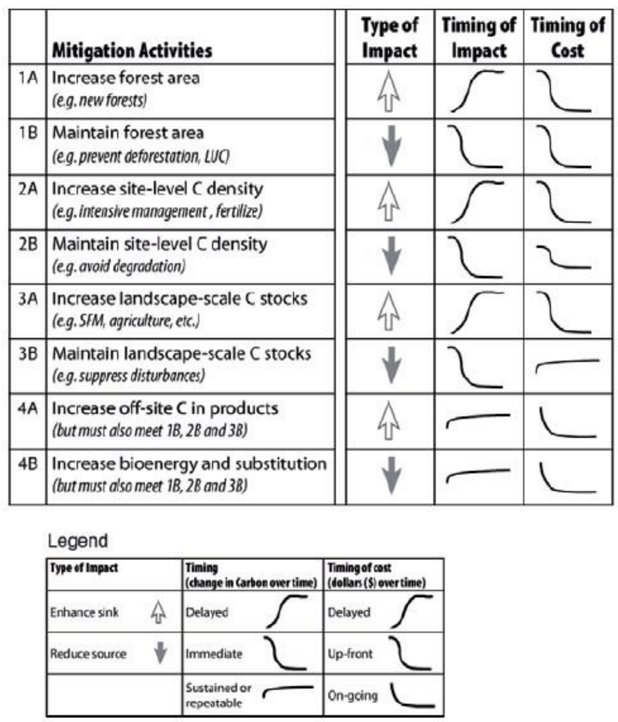


Source: Kinderman et al., 2013.

24. **Consistent with Nabuurs et al. (2007) and Kinderman et al. (2013) findings, increasing harvesting in Romania to the annual allowable cut should be positive, especially when considering the mean increment of carbon sequestered when trees are growing**. The modeling undertaken by JCA and ICAS show the reverse to be true based on the premise that young' stock replacing the cut stands initially have a low CO2 absorption.

25. **The total CO2 removed per ha may be low at an early stage. The rate, however, at which the forest is growing and hence absorbing CO2 should be highest when the stand is young, with the exception of perhaps the first two or three years.** Based on this rationale, increasing management intensity should result in a greater proportion of older trees being removed and a higher thinning intensity. While greater thinning of younger stands may not increase the overall growth of the stand, the growth is then concentrated on the remaining trees, and carbon has been removed in the thinning and is being used this for some other carbon beneficial process (e.g. fuelwood, which replaces use of fossil fuels, or it is stored in chipboard or paper). A possible explanation for this discrepancy could be that there is a **slightly skewed age class distribution.** This can be addressed by both overcutting in some years and undercutting in others. And the potential implication of such an approach on CO2 removals should be explored when ICAS revisits the model.

Figure 12: Generalized summary of forest sector options and type and timing of effects on carbon stocks and the timing of costs



Source: Nabuurs et al., 2007.

Translating Models on Forests' Mitigation of Climate Change into Practice: Enabling SFM

26. **To implement any of the scenarios described in the JRC and ICAS model above and ensure the long-term maintenance of forest health, sustainable management has to occur on both state and private forest lands**. The private landholders will need to be provided with the necessary support to comply with the requirements including technical services, markets, and infrastructure. Many of these will require public investments or financial support to buffer the upfront cost. As noted in the functional review of the forest sector (World Bank, 2011), "active management measures are required to ensure not only the maintenance of the forest as an ecosystem type but more specifically the conservation

of a certain type of forest". In Romania, climate sensitive sustainable management of production and protection will require reversing existing constraints in terms of technology, infrastructure, knowledge, research, and other enabling conditions (the same constraints that were described earlier). Additional investments in afforestation would enable the Romanian Government to increase harvesting in production forest to the AAC while minimizing any associated reduction in CO2 sequestration.

27. **The restitution process has fragmented the forest estate and raised challenges for ensuring sustainable forest management (SFM)**. Providing incentives for sustainable forest management or enabling consolidation initiatives requires knowing who owns each parcel of forests and each parcel's boundaries. Currently this information is not available as there is no cadaster of forest lands.

28. **Romania has a comprehensive forest regulatory framework including technical norms that regulate compositions, schemes and forest regeneration technologies**. The national forestry management norms and practices are in essence legacies from the past. **They are a challenge to implement under the new reality of diverse forest ownership types and a dynamic economy** (Stancioiu et al, 2010, as cited in World Bank, 2011). The costs associated with complying with the technical norms and forest management planning requirements have created a situation whereby small forest owners struggle to comply with all the legal and regulatory requirements. As a result, there are logging activities that, although potentially sustainable, are occurring without a formally approved management plan. These activities are considered illegal because they are in violation of the law. In addition, there are also unsustainable logging activities. In both cases, the forest owner has limited options regarding what to do with the wood, because it is considered illegal.

29. **There are approximately 1 million ha of forests (approximately 15 percent of total forest area) without management plans.** It is assumed that the majority of these are smallholders' forests because of the expense of complying with policy requirements for forest management planning. While in aggregate the area does not represent a significant portion of forest lands, these parcels are scattered throughout the forest ecosystem, creating fragmentation. **Another constraint, where management plans are available especially for state forest lands, is the lack of resources to approve and subsequently implement them**. There are 272 management plans for protected areas, of which only twelve have been approved.

30. **The technical norms need to be revised** and the revised norms should better reflect advances in forest management, forest operations and associated technologies (for example, nursery technology, seed quality, plant handling and site cultivation) (World Bank, 2011), and knowledge of climate change and its impacts on forests. **A simplified regulatory regime for small privately owned forest areas is required.** The simpler regulation should enable owners of forests under 10 ha to adhere to good forest practice and SFM guidance with simplified requirements for planning, marking, harvesting and sale of timber and non-timber forest products. (World Bank, 2011). **Modifying the technical norms will allow owners to seize opportunities reflected by long terms increased CO2 removal.**

31. **Limited forest roads for accessing forests are a significant constraint to SFM in Romania.** The average road density for Romania is 6.4 m/ha (World Bank, 2011). This is significantly below other European countries with broadly similar topography (Austria 36 m/ha, Switzerland 40 m/ha and France 26m/ha). A low density of forest roads implies the lack of access to timber resources in inaccessible sites and/or the need to skid logs longer distances from the point where they are felled to roads where they can be loaded onto trucks. **As a result, harvesting levels are below the recommendations of forest management plans in inaccessible areas, accessible forest stands are over harvested, fire and pest control are inefficient due to lack of access, etc.** In addition, exploitation costs are higher since they increase with the length of skidding. From an environmental perspective, the longer skidding distance results in erosion and soil compaction on arterial skidding trails. Thus, a forest road network of adequate density and quality is essential for an efficient and sustainable forest management (World Bank, 2008); reducing the likelihood of forest degradation and resulting GHG emissions. **To prevent increased accessibility of forests resulting in excessive extraction of activities that degrade the forest, the Government of Romania will need to ensure that road development and maintenance is done where it is most justified in terms or profitability and that the estimation of profits incorporates the emissions and sequestration of CO_2.**

32. Enabling management of protected areas is also important for reducing GHG emissions from forest degradation. At the end of 2011 approximately 50% of the total protected natural areas in Romania were under management, administration or custody of Romsilva. By 2012, out of the 272 management plans that had been drafted (or drafted through SOP ENV), 5 management plans had been approved (3 for national and natural parks and 2 for Natura 2000 sites). There is the opportunity to approve more of the management plans that are already prepared and to prepare plans for the remaining areas by:

    - Rectifying the limited administrative capacity in the environment authority
    - Undertaking a campaign to promote a wider understanding of the importance of biodiversity conservation, especially among private owners
    - Fostering management practices that reconnect natural areas that have been artificially divided, and form a functioning network
    - Restoring degraded natural areas to create a new space for animals, plants and leisure activities and prevent disasters.

33. The objective of protected areas is often to safeguard biodiversity and ecosystem services. Management plans for protected areas, therefore, must take into account climate change adaptation needs for the species and ecosystem services they were designed to protect. Lack of explicit consideration of climate change in the management plans, reduces the utility of protected areas in building the resilience of forest systems to climate change.

34. Thirty six percent of Natura 2000 sites are under private ownership. **To lift the current challenges to achieving Natura 2000 objectives, there is the need to develop a simpler way of ensuring that private lands within designated Natura 2000 areas are managed according to the requirements**. This

may involve providing needed incentives to property holders and also making more transparent how compensation is determined.

Enhancing the Resilience of Forests to Climate Change

35. **Adaptation of current forest management practices** (including forest regeneration that takes into account species composition, genetic resources, species distribution, and transfer of genetic material) can increase forest resilience and increase forests' ability to adapt to the expected shifts in eco-zones and associated species distribution, as well as the predicted increase in invasive species' competitive power. Management practices need to be adapted to recognize and reduce the potential consequence of climate change on forests. To define the necessary changes in management practices, including silvicultural interventions, recommended species composition for establishment for new forests, and others, sound scientific research, done locally that can underpin the necessary changes, needs to be expanded and to be robust. Alternatively, the results of studies at European level can be adapted to Romania and can be a great opportunity to enhance the resilience of forests to climate change.

36. An effective system to detect, monitor and manage forest-damaging phenomena (such as increasing incidence of forest pests, fires, and drying) can also be an important opportunity to prevent out-of-control GHG emissions.

SEQUESTERING CARBON AND GENERATING CO-BENEFITS THROUGH AFFORESTATION

37. **Afforestation represents over 26 percent of the total changed area in the period 1990-2006**. In the mountainous and Sub-Carpathian regions, the expansion of the forest area is largely due to natural regeneration. Regeneration occurred on deforested areas and abandoned farm land and pastures, especially with the decline of keeping livestock.

38. **National Program for Afforestation.** The National Program for Afforestation predicts a 422,000 ha increase in area under forest cover by 2035. 20.3 percent of the area for afforestation is currently degraded forest land that is part of public or privately owned forest land, 8.5 percent will be windbreak forests and 7.2 percent degraded agricultural land that is unsuitable for agriculture (Bohateret, 2012). The afforested area will total 340,200 ha, increasing the total forest cover to 29.3 percent at an average annual growth rate of 0.04 percent for 25 years. (Bohateret, 2012).

39. **Incentives will be important for successful afforestation initiatives**. Of the 115,129 hectares of degraded area found suitable for restoration through afforestation in 16 counties (roughly 14% of the land area), more than 80% is under private ownership or community management of public lands. **A barrier to the creation of forest belts and afforestation of agricultural land is the lack of financial resources to support such activities, especially for smallholders. The main reason for poor performance of the afforestation programs (including the initiatives of creating forest belts) was the fact that the owners were not properly compensated.**

40. **Equally important will be raising awareness regarding the benefits of afforestation as an as ecosystem-based adaptation strategy for other sectors, such as agriculture (see Figure 8).** The impacts of climate change (in the medium and long term) also point to the need to adapt forests to climate change. Studies by the Economics of Ecosystems and Biodiversity (TEEB) illustrate the economic benefits from ecosystem based adaptation including using forests for adaptation. Operationalization of this concept is increasing, although additional research is needed to better understand adaptation benefits. Examples from countries such as Germany, UK, and Belgium point to clear ecosystem benefits but offer less discussion on adaptation.

Figure 8. Forests for Adaptation, Adaptation for Forests

Source: Locatelli, 2011.

41. **Forests provide ecosystem benefits for agricultural landscapes**. Ivan (2012) identified forest belts as providing climate resilience benefits in agricultural systems. These benefits include:

- Improved microclimatic conditions of growth for protection development of agricultural crops up to a distance 25 times the height of belt in the sheltered and 5 times in the exposed area, due to the reduction of wind speed by 31-55 percent in the sheltered area and 10-15 percent in the exposed one;
- Reduced spread of diurnal air temperature in cropping area with 1-40C and the annual one with 120C;
- Increased humidity and level of ionization of air at soil level which enhances soil fertility and Ph;
- Reduced the depth and duration of freezing, and decreased evapo-transpiration;
- Sequestered GHGs: it is estimated to sequester 40 tCO_2e/ha/year of carbon dioxide.

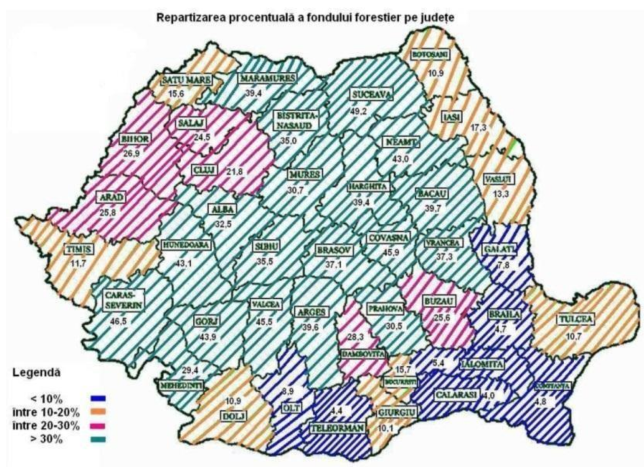
42. Popovici et al (2013) found that **as forested area decreased, the quality of land deteriorated** as a result of the impact of heavy precipitation events, erosion, landslides and the intensification of extreme climatic phenomena: floods, snowstorms and droughts. In the lowland regions, frequent and lengthy dry periods have been associated with climate change, the systematic destruction of irrigation

systems and the cutting of trees and forests used as wind breaks. This is having a negative effects on crop production, the environment and living conditions (Popovici et al., 2013).

43. Traditionally, **investments in management of upper forested watersheds** (watershed management) was done, within forested areas, by the forest administrators. The investments are important for decreasing the incidence of the flooding, water turbidity and regulation of debris. Due to the changes in ownership as well as lack of budgetary allocation for NFA – Romsilva to continue those investments, the incidence of flooding and fast moving water is increasing (Giurgiu, 2010).

44. Romania has a national strategy for combating drought, land degradation and desertification which includes short, medium and long term actions and measures to mitigate effects of drought, and to combat desertification and land degradation. Activities included planting of trees to reduce soil erosion and restore degraded lands (Figure 9). The planting of trees presents opportunities to sequester carbon while enhancing adaptation of land to climate change.

Figure 9: Forest on counties (percent)



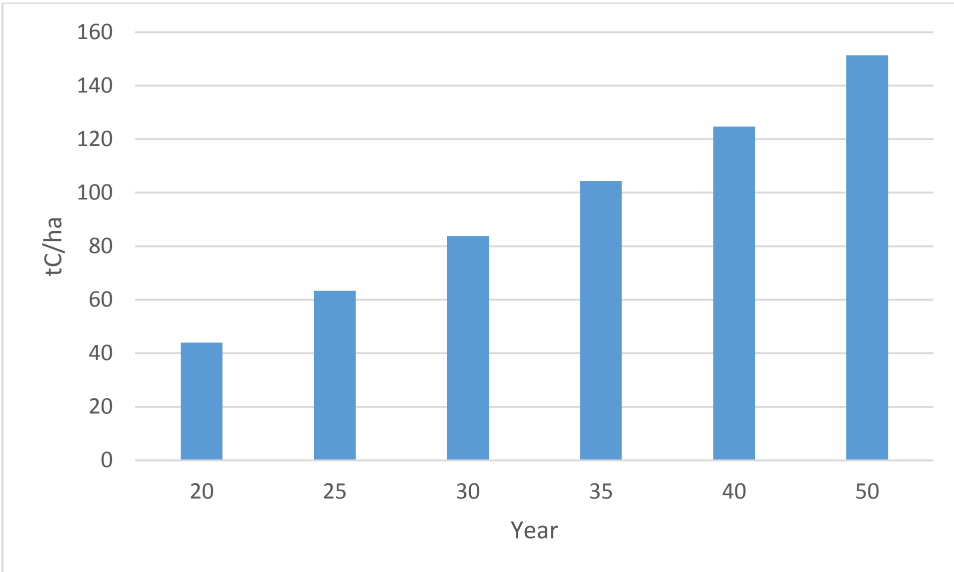
Source: National Program for Afforestation, 2012.

MARGINAL ABATEMENT POTENTIAL FROM FORESTRY MEASURES

45. **Marginal abatement cost curves (MACC) for measures in the forest sector are estimated** in addition to the models described above. The estimations rely on data on sustainable forest management and afforestation. The measures examined are presented with according to two characteristics: potential mitigation impact (kilo tons of emissions abated) and the unit cost of abatement (cost per ton of CO_2e abated). **The two main measures examined for the forest sector include afforestation, and sustainable management of production forests. The results of these analyses are presented below.**

46. **To estimate the total cost of afforestation per hectare and the expected sequestration, four afforestation projects were analyzed**. The resulting growth of the carbon stock, assuming average site conditions, is reflected in Figure 13. The average cost, without transaction expenses, is € 6,000 per hectare, which corresponds to a unit abatement cost of € 120/tCO_2/ha.

Figure 13. Carbon stock trend for a native hardwood plantation (60% Oaks 40% various other species)



Source: World Bank staff calculations.

47. **To estimate the MACC for sustainable management of production forests, first some of the constraints to sustainable forest management, described in earlier sections of this report, are examined – specifically limited accessibility and poor road conditions, degradation from poor management and pest infestation.** Possible "green" solutions (such as speeding up the procedures for harvesting wood that has been infested by bark beetle, and adopting more flexible technical standards) to some of these constraints that are considered when estimating the MACC.

48. Based on evidence regarding the impact of specific measures (e.g., that flexible technical standards including shorter rotations mean less disturbances and more valuable and healthy trees harvested), **the cost effectiveness of the proposed measure of shortening the average rotations for the most important forest species was estimated**. For example, shortening the rotation by ten years could result in a yield increase of 10 percent. Considering a 10 percent higher carbon sink, we estimated the cost-effectiveness of the shortened rotations:

$$C_e = \frac{NPV_{R-10} - NPV_R}{Change\ in\ carbon\ stock}$$

49. **The costs were calculated for Norway spruce, beech, and mixed forests with oaks, considering average productivity, harvestable volumes from the yield tables, and operational costs (tending works, thinning and final harvesting operations) under three scenarios: difficult harvesting conditions (long skidding distances, steeper slopes), medium conditions and easy conditions (corresponding to low harvesting costs).** The social discount rate used for NPV assessments was three percent. The main yield increment was assumed to be 10 percent, a conservative value (see Table 4).

Table 4. Average Change of Main Yield and Carbon sink due to shorter rotations

Main species	Change of the main yield due to shorter rotation (m^3/ha)	Change of the Carbon sink (tCO_2/ha)
Norway spruce	65	32.5
Beech	47	23.5
Oaks	60	30

Source: World Bank staff calculations.

50. **Because the Norway spruce is artificially regenerated (planted seedlings produced nurseries), the higher operational costs resulted in a negative net present value. Operational costs do not affect the NPVs of beech and oaks forests due to the use of natural regeneration ("shelterwood" systems, with three fellings).** The rate of regeneration was not altered in order to preserve ecosystem services, like water regulation (especially for beech forest) or biodiversity conservation and amenities (for oak forests). The results are summarized in Table 5.

Table 5. Expected average cost-effectiveness per ton of CO_2

Main forest species	NPV (€/ha) for actual rotation			
	Low costs	Medium costs	High costs	share at national level
Norway spruce	655.44	167.57	- 101.25	30%
Beech	1,573.14	1,394.80	1,298.21	32%
Oaks	1,591.43	1,304.15	1,033.81	18%
	NPV (€/ha) for shorter rotation			
Norway spruce	1,273.89	1,050.64	49.15	
Beech	1,813.14	1,630.53	1,317.67	
Oaks	1,998.60	1,701.57	1,063.19	
Weighted average cost-effectiveness of 10 years shorter rotation (€/ha)				
For the whole forest fund	14.28	17.18	2.29	

Source: World Bank staff calculations.

51. The findings align with **evidence from available MACC studies done in UK and in Russia which show that afforestation can be a cost effective option** for abatement of GHG emissions in the respective country context.

POTENTIAL CONTRIBUTION OF FORESTS TO GROWTH AGENDA

52. **The use of forests to mitigate and adapt to climate change can be done while forest products and services contribute to Romania's growth agenda. Romania is known globally for its wood products.** Wood products in Romania include sawn wood, lumber, pulp and paper, panel and veneer and furniture. There is a longstanding tradition of producing solid wood furniture, some of which are specialized furniture for foreign markets. Local manufacturers are actively involved in the sector.

There also are several domestic and foreign investors in Romania. The latter include investors from Spain, Italy, Germany, Austria and Sweden. (FRD Center, 2011). In 2013, there were 15,853 companies (compared to 20,882 in the agriculture sector and food industry) (INS, 2013). The primary wood processing industry, excluding furniture production, has 7,254 operational companies. The Romanian furniture market is made up of about 4,425 companies of which only 100 are big companies. The majority of the companies are small and medium-sized enterprises (SMEs) (FRD Center, 2013). This sector is especially attractive for small entrepreneurs, and approximately 96 percent of all wood processing companies are SMEs. Estimates indicate that the domestic furniture market, with a value of almost €1 billion business per year, registered a 15-20 percent decline in 2010 but a quarter of this decrease already covered during 2011. This was mainly due to the increase of the value added tax (VAT). At same time, the exports of furniture registered the highest figures in history in 2011 (FAO, 2014).

53. **Most analyses highlight a significant potential for the wood sector in Romania whether it is in manufacturing or biomass energy.** The sector, however, is also importing wood despite the available supply in the country. Romania suffers from overcapacity in the primary wood processing sector. This, however, has lessened in recent years (World Bank, 2011). A few reasons why there is a decline in the wood processing industry are listed below.

- Poor accessibility: The average road density is 6.4 m/ha (and decreasing due to lack of funds for rehabilitation).[11] This results in a more than 2 million ha of forests being practically out of reach for technical and economic reasons (World Bank, 2011). Poor accessibility also has implications for management of the forest stands independent of the management objective;
- Outdated technology: technologies continue to be outdated and production processes are inefficient for many firms in the Romanian forest sector. This is especially true for timber harvesting companies. Inefficient technologies also reduce the amount firms can pay for a cubic meter of standing timber;
- Weak forest associations: Given the number of smallholders involved in the sector, economies of scale are hard to achieve unless there are well functioning associations. Due to historical reasons, small holders have been apprehensive to engage in associations. This, however, is changing. There increasingly are examples of successful associations in the country;
- There has been limited exploration of biomass production plantations in the context of a increasing emphasis on other renewable sources of energy, especially in Europe more broadly;
- Limited training in the arena of climate change and coordinated research

54. **The biomass potential or Romania is estimated at 88,000 GWh per year.** In 2004, about 43 percent of the biomass potential in the country was exploited. The entirety of that biomass potential went to the production of heat. Heat generated from wood biomass was approximately 54 percent, and heat generated by agricultural biomass was about 46 percent (BERD, 2011). Large amounts of small-sized

[11] This is significantly below other European countries with similar topography (Austria 36m/ha, Switzerland 40m/ha, France 26m/ha, Germany 45 m/ha). (World Bank, 2011)

wood is obtained in wood industry, but utilization of this wood for energy purposes is insufficient due to difficulties related to gathering, processing and transportation. Firewood and agricultural waste account for about 80 percent of the total waste. About 66 percent of the firewood and wood waste is located in the Carpathians and Sub-Carpathians, and about 58 percent of agricultural waste is located in the South Plain, West Plain, and Moldavia (BERD, 2011). However, recent studies show that these wood wastes are economically viable resources. (BERD, 2011)

55. **Romania has long tradition in using wood based products for a range of purposes including building constructions**. Recently, the use of steel, concrete and bricks has increased replacing the use of wood. Nevertheless, there is notable potential to reengage traditional knowledge and promote the use of wood in construction and other long lasting products. Such a measure would contribute to reducing GHG emission as noted in a recent study (Borjensson and Gustavsson, 2000). The latter found that, when considering a life cycle analysis, using wood products in place of steel, concrete and bricks (the production of which emit considerable amounts of CO_2 and consume vast amounts of fossil fuels) can be an important opportunity for both climate change mitigation and sustainable growth by encouraging local traditions and economy.

ALIGNMENT WITH NATIONAL AGENDA ON FORESTS

56. **In November 2012, the Delegate Ministry of Forests started the process of elaborating the new Forest Development Strategy for a 10 years period.** A draft strategy was produced in June 2013 but the process was interrupted and expected to continue with consultations in 2015. The draft strategy envisages a role for forests in climate change mitigation and highlights necessary measures for adapting forests. These measures include:

- Increasing forest coverage by afforestation of degraded land;
- Developing new scientifically sound methodology for compensating private forest owners;
- Developing new technical guidance for forest management that reflects climate change adaptation;
- Creating National Forestry Body to supervise and monitor forestry;
- Increasing the accessibility of forests;
- Increasing investments in watershed management.

57. **New Forest Code**: A new Forest Code was adopted by the Romanian Parliament in March 2015. The key changes include: i) judicious administration of national forest on the principle of territoriality, with solutions for managing small forest properties which are currently not covered by forest management and services; ii) establishment of national targets for afforestation; iii) differentiation in the requirements for management planning based on the size of the property; iv) restrictions on the total quantity of wood that can be processed by companies to avoid monopolistic situations.

58. **Tracking Forest Products: A new Government Decision** (GD) (470/2014) includes clarifications regarding the use of special documents to prevent the introduction on the market of illegally harvested wood. The GD attempts to improve the”due diligence” established by EU Regulations 995/2010. The GD seeks to improve the institutional capacity of the Department of Waters, Forests and Fisheries and specialized territorial structures of the central public authority by establishing a system for control and supervision of wood material traceability. The system will require that from the start of the transport of wood from harvesting or storage, a delivery note issuer must send, via the computer system, online and / or offline, as appropriate, standardized information.

59. Presently, there are intense negotiations between the central authority in charge of forestry and the Administration of the Environment Fund for finding financing solutions for the implementation of the National Afforestation Program.

60. Using forests for mitigation and adaptation to climate change would align with the national agenda for forests.

RECOMMENDATIONS

61. **Support SFM: The forest sector of Romania is a key sector for mitigating climate change, as it is responsible for nearly 10 percent of reduction in GHG emissions**. Forests are a major sink of GHGs and can help maintain, and potentially even increase, the level of GHG emissions reduced by the country. Forest based mitigation measures can include conserving existing CO2 sinks, enhancing carbon sinks and reducing the trade-off between the sinks and tangible and intangible benefits from other land uses. An advantage of investing in the forest sector for mitigation is the co-benefits from SFM and forest conservation. Improved forest management and management practices that internalize the potential impact of climate change can build the resilience of forests to climate variability, enhance resilience of other sectors (e.g., agriculture) to disasters lowering their risk exposure, restore degraded lands, and provide a source of renewable energy for rural areas that has a low carbon footprint. Sustainable management of forests is instrumental for achieving Romania’s international obligations and EU directives.

62. **Several measures need to be in place to effectively support SFM and use forests for both growth and mitigation and resilience to climate change.** These measures are described below and organized according to policy and capacity building/institutional measures and investments necessary for the strategic objectives of mitigating climate change and adapting to climate change. It is noted when there is an overlap in the measures needed for the strategic objectives. These measures are also presented, in another report that includes sector level action plans for achieving the strategic mitigation and adaptation objectives using forests. The action plan includes details regarding the specific action, the estimated costs, potential financing sources, responsible parties and estimated time frames. Accordingly, this information is not included in this report.

STRATEGIC MEASURES FOR MITIGATION OF CLIMATE CHANGE WHILE CONTRIBUTING TO GROWTH

Policy Measures

63. **Update technical norms and simplify regulations for smallholder forestry to make SFM financial and technically viable, reducing the degradation and illegal management of forests:**

    a. Update technical norms for management, to enable production forest management to be more efficient and effective, and reduce unsustainable practices that could result in GHG emissions;
    b. Update technical norms for forest planning to reflect advances in growth and yield modeling and stand dynamics, making forest harvesting more efficient and effective in terms of carbon sequestration; and
    c. Simplify regulations for compliance with legal requirements for SFM for small privately owned forest areas. This is important given the area under private ownership and the need for incentives for small and large private forest landholders to comply with the national objectives for forest resource management.

64. **Promote afforestation outside of forests and update the National Program for Afforestation.** Measures on afforestation of agricultural and degraded lands can also help mitigate and adapt to climate change by enabling CO2 sequestration and contributing to resilience to climate change. The funding needs for implementing this recommendation should be sourced both from budgetary sources (e.g. Environmental Fund) and the EU based on a multiannual plan in line with the provisions of the National Afforestation Program and the New Forest Code. These documents contains ambitious targets, and their achievement will require establishing and effectively using existing supporting services (from private or public sector), for example to assure availability of good quality seedlings and extension support. The National Program for Afforestation needs to reflect present land availability, capacities, land ownership and funding sources and to highlight the climate change mitigation role of the afforestation activities. This measure is a cross-cutting measure for both strategic objectives.

65. To **facilitate management of forests classified as Natura 2000 sites**, it is fundamental to align requirements for forest management and management of Natura 2000 sites and put in place policy measures that make the compensation process of Natural 2000 more transparent. Putting in place regulations that help implement Natura 2000 or use available funds to purchase private land in areas designated for Natura 2000 will augment the area under sustainable management. Prior to finalizing the measure on Natura 2000, it is necessary to assess the suitability of using compensation to improve compliance with Natura 2000 requirements.

Improving Capacity Building/Institutional Capacity

66. **Improve capacity for monitoring the contribution of forest management to mitigation of climate change.** Creating and implementing a transparent and updated monitoring system for CO2 removal

together with a review of the modeling and analysis for CO2 removal from different scenarios would help provide more accurate assessments of the contribution of forests to the climate change mitigation efforts. Putting in place such a system will require improving information on land ownership and ownership transfers to facilitate implementation of any recommended measures. This measure is a cross-cutting measure for both the strategic objectives - mitigation of and adaptation to climate change

67. **Gradually improve the system for forest fires detection, monitoring and management.** The potential increase in forest fires incidence should motivate improving the system for detecting, monitoring and managing all forest damaging phenomena, including fires, pests, drought and invasive species. Risk maps based on scientific evidence should inform the gradually establishment of an effective and efficient system, and should include the involvement of other relevant sectors. This should be complemented with institutional capacity strengthening for using this information and coordinating efforts. This measure is a cross-cutting measure and relevant also for the strategic objective of adapting to climate change.

68. **Improve and adapt the management practices for naturally regenerated areas at the border between forests and alpine pastures**. These areas are currently mainly afforested with bushy resinous species (*Juniperus* sp. *Pinus mugo*, etc.) and require special attention and management. It is recommended that the management of these naturally regenerated 'frontier' areas be increasingly oriented towards climate change mitigation and adaptation objective than towards traditional silvicultural objectives of increased yield. This measure is a cross-cutting measure of relevance for the objective of adapting to climate change.

Necessary Investments

69. **Improve forest accessibility to effectively deliver positive climate outcomes implementing this recommendation it will be important to:**

    a. To ensure that the roads that are rehabilitated and the new roads constructed improve the contribution of forests to carbon sequestration, by ensuring the eligibility criteria are inclusive of all the entities managing forests and require a clear indication of the potential reduction in GHGs as a result of the project;
    b. Financing provided for forest roads should be based on the economic rationale and direct and indirect contribution to climate change mitigation (including based on rough estimates of carbon sequestration or accumulation in the medium term) - the investments made through this measure should result in benefits that would not have arisen without the measure;
    c. Consider the current distribution of markets and capacity for timber harvesting and processing; Raise awareness about the opportunity for financial support for road rehabilitation, maintenance and construction, including using the networks available to the forest associations.

70. **Invest in new technology, marketing and processing:** that helps forest companies upgrade their technology, improve SFM and have positive impact on soil and efficiency of management. It will also increase efficiency and improve value-addition and revenue from these products. To ensure this measure delivers positive benefits, the agency should:

    a. Give priority to co-financing technologies that promote sustainable management and use of forest resources;
    b. Ensure that if forest management technologies are being "imported", support is provided to adapt them to the conditions under which SMEs are operating in Romania;
    c. Encourage the development of new technologies within Romania;
    d. Provide information regarding importance of technologies that can result in sustainable management, and permanently sequester carbon in wood products (including the production of new wood based products; and
    e. Encourage the production and use of long lasting wood products based on local traditions in all sectors but mainly in building constructions.

71. **Support small forest owners:** Associations, several of which are already in existence and operating effectively, help increase the economies of scale of smallholder operations. Supporting such associations is extremely important given the majority of private forest landowners have parcels that are smaller than 10 ha. **The support should also help small forest owners to produce,** where economically viable, traditional wood products in building construction, woody biomass for energy production and new wood based products.

STRATEGIC MEASURES FOR ADAPTATION TO CLIMATE CHANGE WHILE CONTRIBUTING TO GROWTH

Policy Measures

72. **Similar to the policy measure for mitigation, it is important to update technical norms for management, to ensure forests management is more efficient and effective in terms of adaptation to climate change.** The technical norms for forest regeneration should include the latest scientific findings on species distribution and suitability in the context of climate change and include practical approaches to addressing threats to forests.

73. **Several of the key policy measures of relevance for mitigation of climate change are also important for adaptation to climate change.**

Improving Institutional Capacity

74. **Enable the gradual introduction of silvicultural operations and forest regeneration activities that enhance adaptation to climate change.** The Government of Romania should encourage the continuation and mainstreaming of the scientific research (including adjusting and downscaling research in progress or completed for Europe to local conditions) that aims to identify species or management practices that can better adapt to forecasted changes in climate. They should also

mainstream silvicultural practices that enhance the resilience of forest stands to changing conditions. While implementing these recommendations will require time and scientific effort, it is necessary to:

a. Identify and improving the biophysical connectivity of forest networks by restoring degraded areas and implementation of proper silvicultural operations;
b. Identify areas where new species composition must be considered; and
c. Assess the genetic resources of native forest species and adapt practices for transferring generative material (e.g., seeds, seedlings and cuttings) for regenerating forests.

Needed Investments

75. **Similar to the strategic investments proposed for mitigation of climate change, it will be important to:**

a. Invest in afforestation of degraded lands;
b. Create forest belts; and
c. Enhance management of forests in watersheds to reduce flooding

76. **Many of the proposed measures above are in the forest sector development strategy. There is a need to promote the necessary planning to implement and enforce this national Forest Strategy** and the associated measures. **The impact of forestry measures, however, requires time.** Steps should be taken in the short term to put the necessary supporting systems in place to avoid any further delays (e.g., afforestation measures will initially require increased capacity for seedling production). This reality underscores the importance of implementing the recommended actions early in the programming cycle to achieve the desired outcomes and envisaged impact on GHG emissions.

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Romania Climate Change and Low Carbon Green Growth Program

Output C1.1
Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors

TRANSPORT SECTOR TECHNICAL REPORT

November 2015

THE WORLD BANK
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This report corresponds to Output C1.1: "Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors" in the Advisory Services Agreement on "Romania: Climate Change and Low Carbon Green Growth Program" signed between the Ministry of Environment and Climate Change[1] and the International Bank for Reconstruction and Development on July 23, 2013.

[1] Now, Ministry of Environment, Waters and Forests

ABBREVIATIONS AND ACRONYMS

AVER	*Asociatia Pentru Promovarea Vehiculelor Electrice in Romania*, Romanian Electric Vehicle Association
BAU	Business as usual
CAPEX	Capital Costs
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
$KgCO_2e/MJ$	Kilograms of Carbon Dioxide Equivalent per Mega Joule
COPERT	Calculation of Emissions from Road Transport
CR	Commuter Rail
DC	Direct Current
EBAA	European Business Aviation Association
EC	European Commission
EEA	European Environment Agency
EES	Economically and Environmentally Efficient Scenario
EMEP	European Monitoring and Evaluation Program
EPER	European Pollutant Emission Register
E-PRTR	European Pollutant Release and Transfer Register
ES	Economically Efficient Scenario
ETS	Emission Trading System
EU	European Union
EV	Electric Vehicle
FCEV	Fuel Cell Vehicle
GBP	Great Britain Pound
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
GPS	Global Positioning System
GTMP	General Transport Master Plan
HDV	Heavy Duty Vehicle
HEV	Hybrid Electric Vehicle
HGV	Heavy Goods Vehicle
HSR	High Speed Rail
IATA	International Air Transport Association
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ITDP	Institute of Transportation Development and Policy
ITP	Integrated Transport Planning
ITS	Intelligent Transport Systems
KM	Kilometer

kW	Kilo Watt
KT	Kilo Ton
LDV	Light Duty Vehicle
LEZ	Low Emission Zone
LPG	Liquefied Petroleum Gas
MAC	Marginal Abatement Curve
MJ	Mega Joule
Mpkm	Million Metric Passenger Kilometer
Mt	Million Metric Ton
$MtCO_2e$	Million Metric Tons of Carbon Dioxide Equivalent
Mtkm	Million Metric Ton Kilometer
NTM	National Transport Model
OLEV	Office for Low Emission Vehicles
OPEX	Operating Costs
ORT	Open Road Tolling
PHEV	Plug in Hybrid Electric Vehicle
RATB	*Regia Autonomă de Transport Bucureşti*
RUC	Road User Charging
TRACE	Tool for Rapid Assessment of City Energy
TRANSEPT	Transport Strategic Emission Prediction Tool
TREMOVE	Economic transport and emissions model
UIC	*Union Internationale des Chemins de fer*, International Union of Railways
UK	United Kingdom
VAT	Value Added Tax
ULEV	Ultra Low Emission Vehicle
VKT	Vehicle Kilometer Travelled

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The World Bank's Romania Climate Change program is managed by Jian Xie and Erika Jorgensen, under the general guidance of Mamta Murthi, Kulsum Ahmed, Ivailo Izvorski, and Elisabetta Capannelli from the World Bank.

EXECUTIVE SUMMARY

Introduction

The Europe 2020 Strategy and the legislative package from the European Commission provide EU member states a framework and means for moving towards a greener and more competitive low carbon economy that makes efficient use of resources and is resilient to climate risk. As a member state of the EU, the Government of Romania is committed to fighting climate change and pursuing a low carbon development. The integration of both mitigation and adaptation actions into Romania's national policies, programs, and strategies will be a critical step in shifting its development path towards a climate resilient, low carbon and green economy.

This Report has been prepared by the World Bank for the Government of Romania, as part of an Advisory Services program on climate change and low carbon green growth. This component assists the Government of Romania in identifying climate change action mitigation actions through extensive greenhouse gas (GHG) modelling work. The objective under Component C is to model mitigation scenarios up to 2050 for the transport sector—Business as Usual, Green, and Super Green Scenario—through the development of a strategic model and to develop a marginal abatement cost (MAC) analysis of mitigation measures proposed, measured in terms of marginal abatement cost or net present value of costs and benefits per ton of GHG abated. The outputs are an Excel based Strategic Mitigation Model and this Report.

This Report's scope was to consider appropriate Government policy interventions and scenarios up to 2050 that would help minimize GHG emissions from the transport sector in a cost-effective way. To do that, the following tasks were undertaken:

- Development of an agile, flexible spreadsheet-based Strategic Mitigation Model that draws on the best available data sources and emission relationships appropriate to Romania;
- Definition of a Business-as-Usual (BAU) scenario for Romania, incorporating data from the GTMP, national data sources and other international trends;
- Identification of a range of policy interventions that show potential for emission reduction and complement and enhance some of the planned GTMP major infrastructure interventions;
- Use of the Strategic Mitigation Model to test the potential transport demand impacts and the consequent GHG emission impacts of all interventions versus the Business-as-Usual scenario;
- Preparation of broad cost estimates for the various interventions, drawing on international experience, but taking account of Romanian costs relative to international levels;
- Preparation of a marginal abatement cost curve, taking into account government costs associated with the modelled interventions; and

- Emission reduction potential, likely costs and broader implementation issues to define a preferred future Green Scenario that groups together the most promising interventions, as well as the development of a more ambitious Super Green Scenario.

Consideration of institutional arrangements for implementation of individual interventions and alternative financing arrangements for proposed investments were outside of the scope of this study.

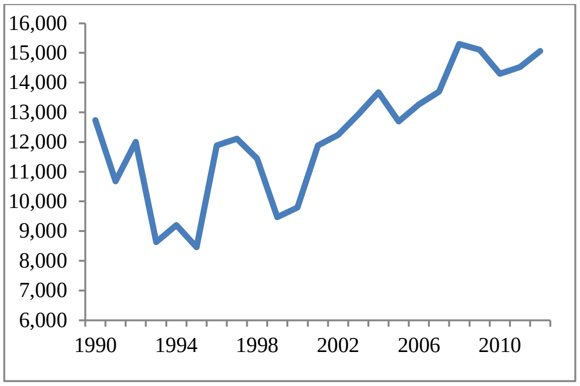
GHG emissions generated from transport are among the fastest growing in Europe, posing a challenge in creating a low-carbon future, as economic development has been paralleled with a modal share increasingly dominated by roads. This modal shift has been driven by a number of factors, including growing affluence, suburbanization, and falling land use densities in urban areas, which have translated into more widespread vehicle ownership, increasing trip numbers and lengths, while reducing the financial viability of public transport and non-motorized transport. On the freight transport front, while a number of East European countries had relatively high rates of rail modal share, these have generally been declining and have been approaching EU levels. Thus, Eastern European countries are moving toward EU motorization rates for passenger transport—with much higher GHG growth than in the EU-28, although overall levels remain lower—while trucks are making significant inroads vis-à-vis rail. Without any changes to transport policy, these trends in Eastern Europe, and in Romania, are likely to continue unabated in the next decades.

Greenhouse Gas Emissions from Transport in Romania

Figure 1 shows the annual GHG emissions from the domestic transport sector in Romania and how it has grown since 1990. The steady upward trend since the turn of the century is particularly noteworthy. Figure 2 shows how GHG emissions from transport have grown in Romania since 1990 in comparison with the EU-28, growing significantly faster than the EU average. As a percentage of total GHG emissions across all sectors, Romanian transport accounts for 12.7 percent (2012). While this is less than the EU's average of 19.7 percent, it is rising more quickly, driven in part by the declining modal share of rail and increased motorization. Road transport is the source of the majority of GHG emissions in the transport sector (93 percent of domestic transport emissions), similar to the EU-28 average.

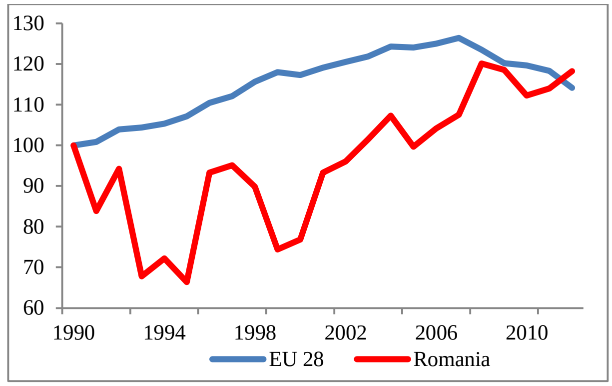
Although car mode share in Romania is at a similar level to the EU average, the motorization (or car ownership) rate in Romania is the lowest in the EU at 224 cars per 1000 inhabitants in 2012, but has grown significantly in recent years, up from 152 cars per 1000 inhabitants in 2006 (Figure 3). Experience across the world suggests that as the Romanian economy grows, it will continue to grow in future. Without intervention to provide better transport alternatives and encourage their use, as car ownership grows, car use is also likely to grow. The reasons for the decline in rail passengers are linked to the decaying state of the Romanian railway system.

Figure 1: GHG Emissions from Domestic Transport in Romania (1,000 tons CO2)



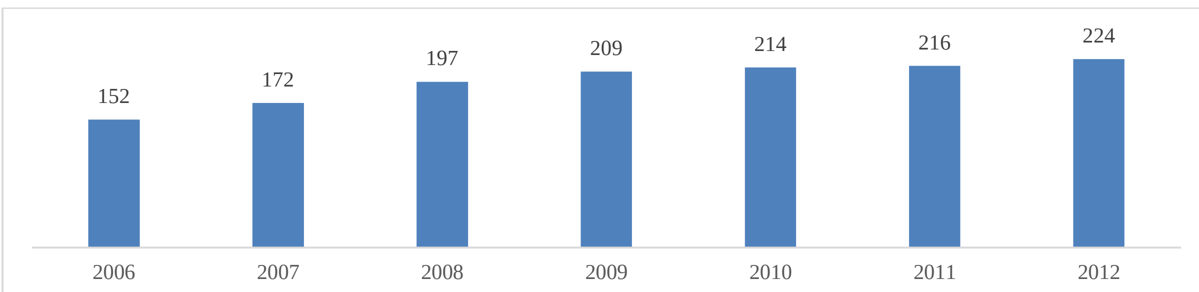
Source: EEA.

Figure 2: Trends in Romania's Transport Emissions Compared to EU-28 (1990=100)



Source: EEA.

Figure 3: Motorization Rates in Romania, 2006-2012 (passenger cars/1,000 inhabitants, 2012)



Source: Eurostat.

Mitigation Challenges

In a do nothing scenario, Romania's GHG emissions from transport are set to continue growing rapidly compared to the EU, particularly if its motorization rates converges to the EU average. The challenges for mitigating GHG in the transport sector are significant. This is illustrated by the recent European Environment Agency (EEA) report on the State of the European Environment which highlights the fact that 'transport, including emissions from international transport, is the only EU sector to have increased its GHG emissions since 1990'.[2]

A major overall challenge is decoupling economic growth from transport emissions. Figure 4 presents real GDP growth and GHG emissions from the transport sector in Romania over 2000-2012, suggesting that they move in tandem, with an inflexion in 2009 when real GDP started growing more rapidly than transported related GHG emissions. Over the 2000-2012 period, GHG emissions rose by 54 percent, while

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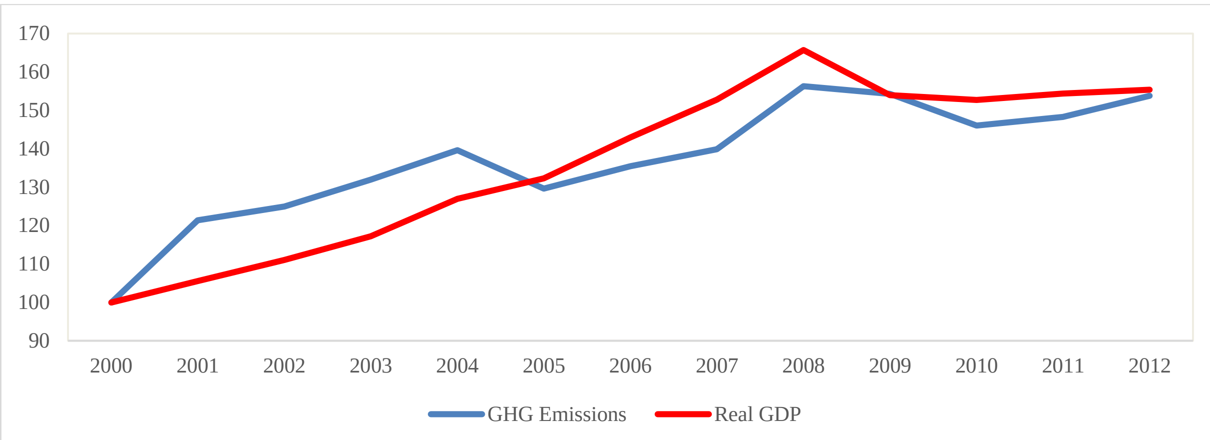
[2] EEA (2015), SOER 2015 - The European Environment - State and Outlook 2015. A comprehensive assessment of the European environment's state, trends and prospects, in a global context. Available at: http://www.eea.europa.eu/soer

real GDP rose by 55 percent. As noted in the EEA report, European demand for transport has increased in line with GDP in recent years, reflecting the close interdependence of transport and economic development. To mitigate GHG emissions, growth in demand needs to be either limited or managed in some way or targeted on low emission travel modes, coupled with reducing GHG rates (g/km emitted) from vehicles. The EEA report recognizes that while new engine technologies will help mitigate GHG, a more holistic approach is required. This includes measures to encourage change in people's travel behavior and choices (as well as technological measures), which is in line with the broad range of policy interventions examined in this Report.

Figure 4: Real GDP Growth and GHG Emissions from Transport Sector (2000=100)



Sources: IMF, World Economic Outlook, April 2015; EEA.

Increasing motorization (car ownership) is a particular issue for the transport sector in Romania. Although car mode share in Romania is at a similar level to the EU average, the motorization (or car ownership) rate in Romania is the lowest in the EU at 224 cars per 1000 inhabitants in 2012, having grown significantly in recent years from 152 cars per 1000 inhabitants in 2006. Experience across the world suggests that as the Romanian economy grows, the motorization rate will continue to grow in future. Without intervention to provide better transport alternatives and encourage their use, as car ownership grows, car use is also likely to grow. The General Transport Master Plan projects rapid growth in car ownership, with the motorization rate exceeding 350 cars per 1,000 inhabitants by 2030, which would represent an increase in excess of 50 percent increase over 2012-2030.

Mitigation Modelling Approach

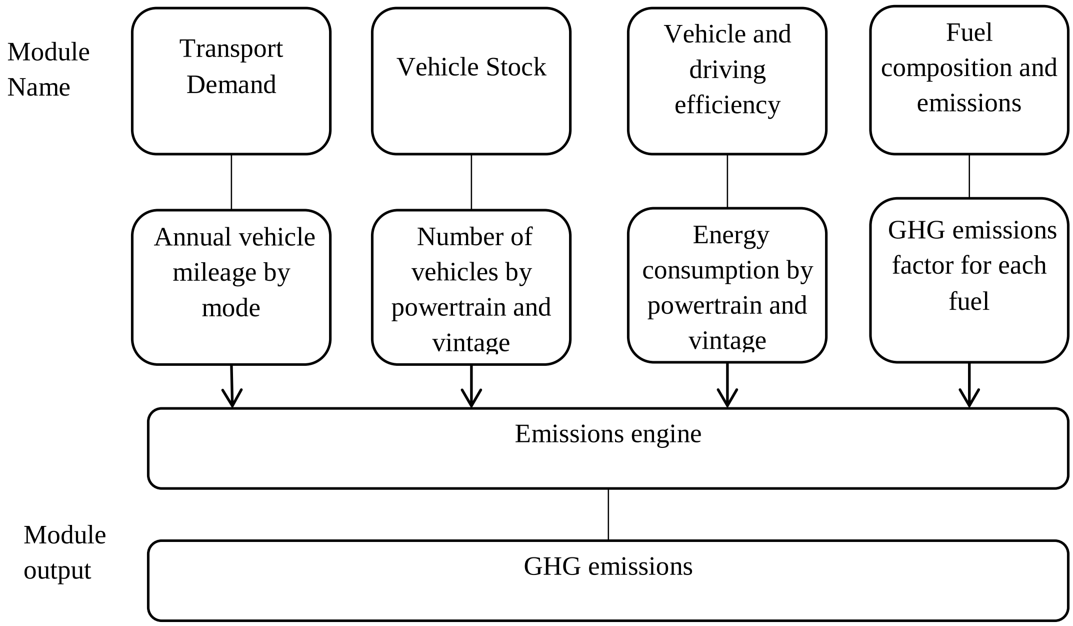
The overall objective of the transport mitigation modelling work was to develop a Green Scenario and an associated Action Plan that would guide the Romanian Government in their decisions on how best to invest in transport-related interventions that would contribute to climate change mitigation. The recommended scenario would take account of GHG benefit, as modelled in the study, and cost to the Government of Romania of alternative interventions, as well as qualitative consideration of co-benefits and implementation issues. A second, more ambitious Super Green Scenario is also developed, in order to assess additional possible efforts, although measures.

The strategic mitigation model that has been developed for Romania, the Transport Strategic Emission Prediction Tool (TRANSEPT) includes four modules which produce the input matrices for the emissions engine which calculates the GHG emissions. The four modules are: (a) transport demand; (b) vehicle stock; (c) vehicle and driving efficiency; and (d) fuel consumption. Only the direct impact on transport fleet, vehicle activity and energy intensity have been modelled. Each module takes a number of baseline datasets as input and applies the effect of relevant policy interventions to them. The adjusted datasets are then input to the emissions engine which calculates the resulting GHG emissions. The process is outlined in Figure 5. The TRANSEPT tool has the following main dimensions:

- It takes account of both direct (tailpipe) and indirect emissions.
- It covers road, rail, waterborne and air travel modes.
- Modes are split into passenger and freight transport.
- Transport activity and consequent emissions are split by urban / non-urban / highway locations.
- Different powertrain and fuel options are modelled as appropriate to each mode.
- Time horizons modelled are 2011 (base year), 2015, 2020, 2025, 2030, 2035, 2040, 2045, 2050.

The technical detail of the model including the source input data and basis for projections is included in Annex 1. The assessment of potential interventions to reduce GHG emissions from the transport sector were divided into five broad categories: (a) pricing instruments; (b) technology; (c) regulatory; and (d) operational efficiency; and (e) urban planning, behavioral change, and low carbon infrastructure investment. Modelling the impact of the various interventions makes use of the most relevant and appropriate case study evidence and research literature from across the EU, applied to Romanian specific baseline data in relation to vehicle fleet and transport activity. Where Romania specific evidence was available, for example, from the sensitivity testing using the National Transport Model, this was compared against the values selected from the literature review.

Figure 5: Overview of TRANSEPT Model Process



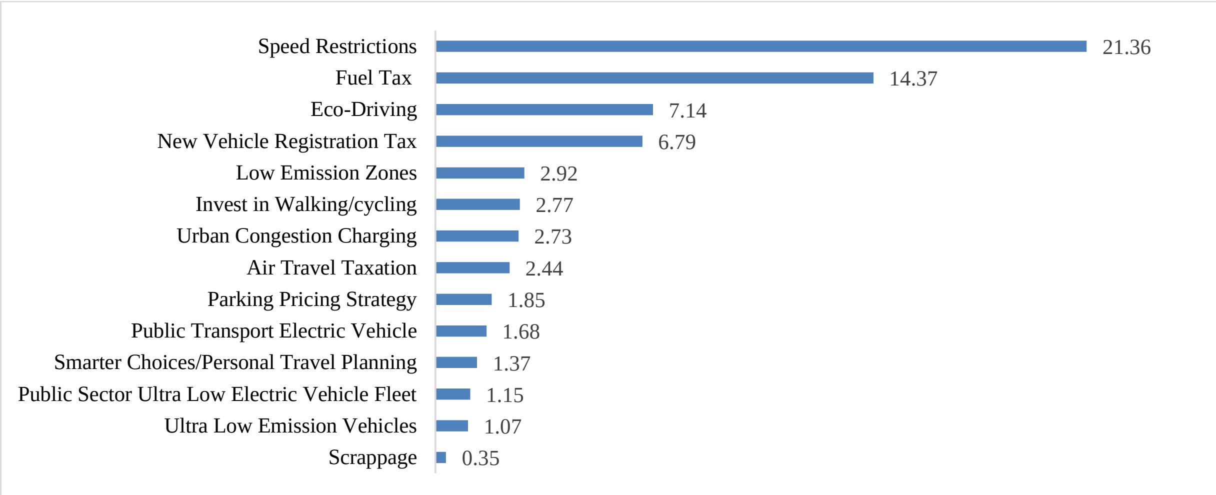
Source: World Bank.

Abatement Potential of Alternative Mitigation Interventions

The range of potential interventions have been defined and costed and assessed in terms of carbon abatement potential. The measures have been modelled individually to assess their relative mitigation potential and value for money in terms of investment against estimated abatement potential. These metrics sit alongside wider qualitative co-benefits to inform the ranking of those most appropriate for inclusion within the Green Scenario. The interventions performing best in the multi criteria appraisal were included in the Green Scenario, with explanation of why each should be pursued. An explanation of why the other options were not selected for adoption. However, all interventions have been included in the Super Green Scenario in order to assess an upper bound for slow GHG emission growth from the transport sector. No specific pre-defined GHG saving targets were used to constrain the choice of interventions, as a bottom-up approach was adopted. The identified measures have been drawn from a range of policy categories including: (a) pricing instruments; (b) technology; (c) regulatory; (d) operational efficiency; and (e) behavioral change and urban investments (Table 1 and Table 2).

Figure 6 provide a summary of the cumulative abatement results for each intervention over 2015-2050, while the table below provides a breakdown of the abatement potential per intervention in three different time periods. The measures which have the potential to deliver the greatest absolute carbon savings over the course of the modelled period are as follows: (a) the lowering of speed limits (speed restrictions); (b) increasing the fuel tax (as a substitute to more sophisticated road user charging); (c) the implementation of a more progressive first registration tax (Environmental Stamp) promoting the adoption of low emission vehicles; and (d) eco-driving programs which encourage more efficient driving patterns, with advertising campaigns targeted at private car users and training programs focused on the freight and public transport sector.

Figure 6: Cumulative Abatement Potential per Intervention, 2015-2050 (MtCO2e)



Source: TRANSEPT.

Table 1: Carbon Abatement from Interventions (MtCO2e)

Intervention	Action Plan (2015-2022)	Strategy (2015-2030)	2015-2050	% of Total Emissions
Fuel Price	1.032	4.139	14.365	2.08
Scrappage Scheme	0.241	0.331	0.354	0.05
Vehicle Registration Tax	0.071	0.566	6.789	0.98
Parking Pricing	0.191	0.639	1.852	0.27
Urban Cong Pricing	0.050	0.597	2.729	0.39
Air Travel Taxation	0.267	0.757	2.436	0.35
Ultra-low Emission Vehicles	0.019	0.118	1.075	0.16
Public Sector Electric Vehicles	0.020	0.130	1.149	0.17
Bus Electric Vehicles	0.036	0.231	1.678	0.24
Speed Restrictions	2.168	6.288	21.357	3.09
Eco Driving	1.059	2.693	7.140	1.03
Low Emissions Zones	0.229	0.724	2.920	0.42
Investment in Walking Cycling	0.464	1.203	2.774	0.40
Smarter Choices/Soft Measures	0.220	0.582	1.370	0.20

Source: TRANSEPT

Table 2: Summary of Intervention Measures Modelled

Policy	Policy Description	Implementation Timeframe	Investment Cost (Euro millions)	Modelling approach
Fuel Price Taxation	An increase in the rate of fuel price taxation which results in a 10% increase in the prevailing market price of fuel for both petrol and diesel. Price increases affect all vehicles with petrol or diesel drivetrains.	2015-2022	0.9	Modelled though application of a fuel price elasticity, using a long term elasticity of -0.3.
Scrappage Scheme	Rejuvenated scrappage scheme with higher incentives and tighter restrictions on emissions levels of new vehicles purchased. A higher incentive value of 7500 lei (€1700), with emissions requirements tightened to achieve a 120g/km average emissions rate for new vehicle purchase.	2016-2020	164	A take-up rate of 100,000 vehicles scrapped over the course of the 5 year period is modelled, with ageing vehicles removed from the existing fleet and replaced at a rate of two old vehicles to one new vehicle (as per evidence of existing scheme under the transferable voucher scheme). New vehicles modelled with average emissions of 120g/km with typical survival rates and replacement rates.
Vehicle Registration Tax	Adjusting of Vehicle Registration Tax (currently known as Environment Stamp) on first registration of vehicles to promote a move to more efficient and low polluting vehicles. The changes would maintain fiscal neutrality but increase the cost of registering high polluting vehicles, while decreasing the cost of registering low polluting vehicles.	2015-2022	0.9	The fiscal incentive regime has been modelled as a change in the vehicle purchasing profile, taking trajectories from the EU Commission transport emissions modelling work set out in the 'EU Transport GHG: Routes to 2050' work.
Parking Pricing	Widening of paid for parking to cover the major urban areas.	2015-2022	19	Application of case study evidence observed from other European cities which results in a 5% reduction in urban trips by 2030, ramping up from 2.5% in 2020 through 3.75% in 2025.
Urban Congestion Pricing	Application of congestion pricing in major urban areas. Charge proposed to be applied to private vehicle trips (car only).	2022-2030	1,600	Review of case study literature from London and Stockholm identifying the scale of reduction in traffic within the zone. Modelled impact of 5% reduction in urban traffic resulting from the scheme implementation.

Air Travel Taxation	Application of an air passenger duty on domestic (EU) and International flights levied at a level similar to that observed in Austria and Germany.	2015-2022	6*	Modelled as a 5% increase in ticket price, with demand impact modelled through the application of price elasticities of -1.2 for short haul and -0.9 for long haul.
Ultra-Low Emission Vehicles	Investment program in developing a national charging network for Electric Vehicles, with subsidy for home charging units and increased incentive rates for the purchase of Electric Vehicles.	2015-2030	195	Modelled impact based on an increased uptake in electric and plug in hybrid electric vehicles based on take-up rates observed in Estonia following implementation of the charging network and future trajectory taken from the Routes to 2050 ultra-low emission vehicle modelled scenario.
Public Sector EV	Kick-starting the uptake of ultra-low emissions vehicles by promoted use of new technology within public sector vehicle fleet. Public sector procurement targets of 5% of public sector fleet in 2020 increasing o 10% of public sector fleet in 2025.	2015-2030	35	Public sector vehicle fleet estimated to be c. 75,000 vehicles based on similar ratio to that observed in other EU countries. Targets modelled as a replacement of petrol based vehicles with electric vehicles at a rate which meets specified targets by 2020 and 2025.
Bus EV	Application of similar targets to the public transport sector, with the introduction of electric bus vehicles to the public transport fleet. Targets set at 5% of fleet in 2020 and 10% of fleet in 2025.	2015-2030	277	The policy is modelled to affect purchasing decisions of bus vehicles, with a switch from diesel buses to electric buses at a rate necessary to meet the specified targets.
Speed Restrictions	Reduction in speed limits to 100kph on all roads with higher current speed limits, applicable to all vehicle types.	2015-2022	39	Modelled as a reduction in the composite baseline speed (motorways and expressways) with an adherence rate of 70% to the new policy. This translates to a 10.5% reduction in average speed on motorways and expressways and a 1.8% reduction on national roads.
Eco-Driving	Promotion of the cost saving and efficiency benefits eco-driving through public awareness campaigns and driver training programs.	2015-2022	60	Case study evidence highlighting efficiency improvements of 8% in private car and 4% in HGV movements used as a basis for reduced vehicle energy intensity. Coverage of programs estimated to reach 25% of drivers by 2020.
Low Emissions Zones	Implementation of Low Emission Zones (LEZs) within the major urban areas restricting entry to vehicles meeting up-to-date emissions standards (Euro standards)	2015-2022	114	Vehicle purchasing decisions are affected for users who wish to continue to enter the zone. This is assumed to affect 5% of urban trips. In order to model the ongoing evolution of the zone as vehicle technologies improve, vehicle purchasing decisions by affected users are modelled through an advancement of purchasing

				profile of affected users by 10 years to the typical purchasing profile.
Investment in Walking Cycling	Investment in infrastructure to support walking and cycling, including cycle paths and parking facilities, footpaths and "pedestrian-ization".	2015-2030	70	The investment has been modelled as a modal shift from urban car trips to walking and cycling, with a shift of 4% applied based on evidence from Bogota, based on a similar level of per capita investment spend that has been allowed for within this intervention.
Smarter Choices/Soft Measures	Investment in behavioral change programs and the supporting of improvements to public transport services and facilities.	2015-2022	23	Modal shift from urban car trips has been modelled based on case study evidence, amounting to a shift of 3.2% from car and 1.1% from motorcycle trips towards bus trips, rail and slow modes.

Note: Further information on each of the individual measures can be found in Chapter 3.

Source: World Bank.

Table 3: Intervention Performance Table

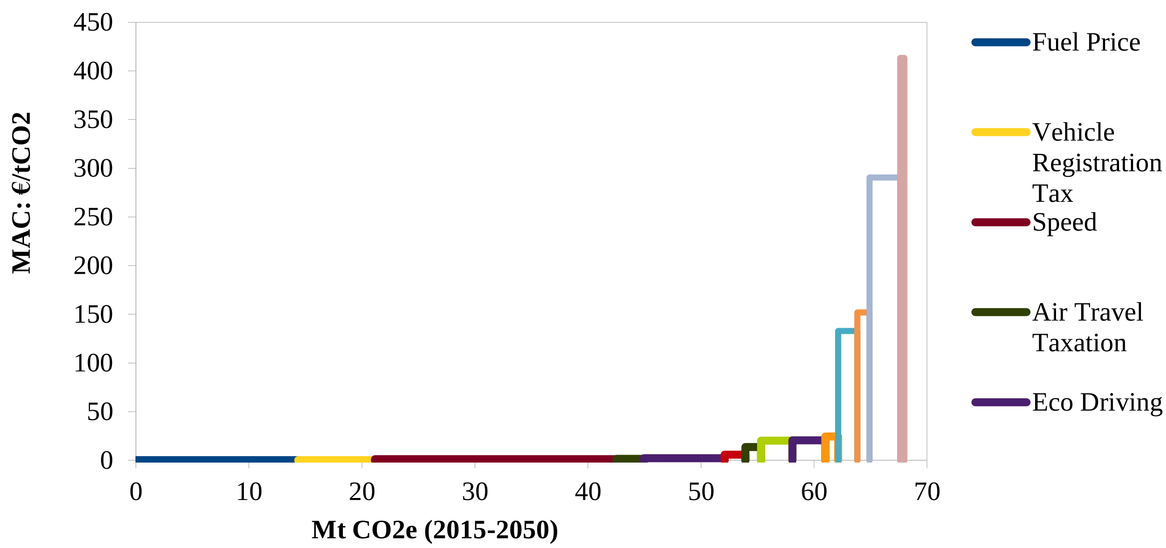
Intervention	Implementation	Investment Cost (Euro million)	Cost-Effectiveness (Euro/ton)	Co-benefits/Deliverability commentary
Fuel Tax	2015-2022	0.9*	0.06	Wider economic implications of higher fuel prices. Political resistance to increased taxation.
Scrappage Scheme	2016-2020	164	413	Economic boost to the domestic car industry and dealerships. Improved air quality from lower emissions vehicles.
Vehicle Registration Tax	2015-2022	0.9*	0.13	Economic and equity issues due to increasing the purchase cost of older (imported) vehicles. Potential boost for vehicle manufacturers. Political issues associated with previous tax.
Parking Pricing	2015-2022	19*	5.8	Enhancements to cityscape, urban safety and local air pollution. Barriers to implementation include political resistance and economic impacts on motorists and city commerce.
Urban Congestion Pricing	2022-2030	1,600	291	Air quality benefits. Equity issues. Technical barriers to implementation. Parking pricing a more efficient means of achieving similar results.
Air Travel Taxation	2015-2022	6*	1.4 #	Economic impacts of taxation. Positive equity impacts.
Ultra-low Emission Vehicles	2015-2030	195	152	Significant air quality benefits. Economic benefits to vehicle dealerships and manufacturers. Equity impacts.
Public Sector EV	2015-2030	35	24.5	
Bus EV	2015-2030	277	133	
Speed Restrictions	2015-2022	39	1.1 #	Safety and wider environmental benefits. Significant interest group pressure against reduction in speed limits expected.
Eco-Driving	2015-2022	60	2.3	Economic benefits of reduced fuel consumption. Increased safety.
Low Emissions Zones	2015-2022	114	20.7	Significant air quality benefits. Economic and equity impacts.
Investment in Walking Cycling	2015-2030	70	20.3	Health benefits and wider environmental and cityscape benefits expected.
Smarter Choices/	2015-2022	23	13.7	Health benefits.

* Public revenues also generated by scheme; # Particularly low values due to the consideration only of public investment.

Source: World Bank, ITP, TRANSEPT.

Having identified the abatement potential for each of the interventions modelled, consideration needs to be given to the most effective areas of investment to achieve emission reduction. Marginal abatement cost (MAC) analysis provides a framework within which to guide investment decisions, identifying the levels of abatement possible and at what level of investment cost. A key component of the MAC analysis is the cost of each intervention, in terms both of capital cost and ongoing operational and maintenance costs. The implementation and ongoing costs of delivering the identified schemes have been estimated using case study evidence and a variety of sources of estimated costs applied to the Romanian context. The scope of the estimated costs are limited to those borne directly by the Government of Romania in terms of capital investment costs and ongoing operational and maintenance costs. The potential costs or operating cost savings borne by the private sector are not estimated or included within the MAC analysis. The basis for the cost estimation has been set out for each intervention in the preceding chapter.[3] Table 3 summarizes the mitigation potential of each intervention against scheme value for money based on the cost per ton of carbon abated. A summary of the qualitative assessment of the wider societal impacts and deliverability issues (barriers to implementation) is also presented where relevant. The MAC can be found in Figure 7.

Figure 7: Marginal Abatement Cost Curve, 2015-2050



Source: TRANSEPT.

Development of the Green Scenario

The decision on which interventions to include in the Green Scenario were derived from a multi-criteria analysis that took into account the following: (a) scheme investment cost to the government; (b)

[3] Costs—capital and operational and maintenance costs—are discounted at a discount rate of 4 percent to provide the net present value (NPV). The abatement cost is hence cost (NPV) divided by total undiscounted cumulative carbon reduction over 2015-2050. The choice was made not to discount carbon savings as the resulting value is an abstract figure which cannot be directly compared back to any graph and would not be easily cross-compared to other literature evidence of abatement costs.

cumulative emission savings; (c) carbon reduction cost effectiveness; (d) deliverability and economic important; and (e) wider benefits. The wider benefits considered within the multi-criteria appraisal included local air quality, decongestion, noise, safety, equity and health benefits. These were considered at a qualitative level, and were not assigned a quantitative or monetary value. In order to achieve significant levels of carbon abatement, two schemes stand out above others. The implementation of speed restrictions is demonstrated to have significant potential to reduce vehicle emissions levels. Fuel taxation also can make a significant contribution to reducing emissions, through a combination of market forces acting to reduce the demand for travel and also in influencing purchasing decisions towards more efficient vehicles. Both of these policies have significant wider implications for the economy, with costs in terms of increased journey times in the case of speed restrictions and economic burden of higher taxation. In order to make meaningful reductions in carbon emissions in the transport sector, it is likely that at least one of these measures be adopted in some form. The wider costs and benefits will play an important role in determining the most appropriate, but ultimately it is likely that the political acceptability of one or other measure ultimately determines which may be more politically palatable.

Table 4: Abatement Intervention Performance

Intervention	**Discounted Investment Cost**	**Absolute Emissions Savings (MtCO2e)**	**Carbon reduction cost-effectiveness (€/ton)**	**Deliverability/ economic impact**	**Wider Benefits**
Fuel Price Taxation	€0.9m	14.37	€0.06/ton	Challenging	Very high
Vehicle Registration Tax	€0.9m	6.79	€0.13/ton	Moderate	Moderate
Speed Restrictions	€22.6m	21.36	€1.1/ton	Challenging	Very high
Air Travel Taxation	€3.5m	2.44	€1.4/ton	Moderate	Moderate
Eco-Driving	€34.4m	7.14	€4.8/ton	Good	Very High
Parking Pricing	€10.7m	1.85	€5.8/ton	Moderate	Moderate
Smarter Choices/ Soft Measures	€18.8m	1.37	€13.7/ton	Good	Very High
Investment in Walking Cycling	€56.3m	2.77	€20.3/ton	Good	Very High
Low Emissions Zones	€60.4m	2.92	€20.7/ton	Moderate	Moderate
Public Sector EV	€28.2m	1.15	€24.6/ton	Good	Moderate
Bus EV	€222.2m	1.68	€133/ton	Moderate	Moderate
Ultra-low Emission Vehicles	€163.2m	1.07	€152/ton	Moderate	Moderate
Urban Congestion Pricing	€792.8	2.73	€291/ton	Politically Challenging	Moderate
Scrappage Scheme	€146.3m	0.35	€413/ton	Good	Very High

Note: Costs are discounted, using a 4 percent discount rate, while emissions are undiscounted.
Sources: World Bank, TRANSEPT.

Table 5: Criteria for Defining the Performance of Each Intervention

Intervention	Good	Moderate	Poor/low
Scheme investment cost	Under Euro 10 million	Euro10-50 million	>Euro 50 million
Absolute Emissions Savings	>10 Mt	2-10 Mt	<2 Mt
Carbon reduction cost-effectiveness	<Euro10/ton	Euro 10-100/ton	>Euro 100/ton
Deliverability/economic impact	Positive impact/easily deliverable	Moderate, some challenges/some negative impacts	Politically challenging/significant economic impact
Wider Benefits	Strong wider benefits	Moderate benefits	Low wider benefits

Source: World Bank.

In the near term, whilst politically challenging and economically burdensome in particularly on the lower income households, applying increases in fuel taxation is more practicable. The requirements to change speed restrictions, with the associated awareness campaigns and need for reminder signage and enforcement would involve greater upheaval. It is therefore recommended that fuel taxation be considered as a key tool in achieving significant carbon abatement over the period of the Climate Change Action Plan and Climate Change and Low Carbon Green Growth Strategy. Of the 'second tier' intervention measures which may contribute valuable abatement to carbon emissions in absolute terms, the new vehicle registration tax is identified as a tool which can bring significant carbon savings through the influencing of purchasing decisions. Again, this measure has the potential to create adverse political pressure, even whilst remaining fiscally neutral, and may have negative equity implications in the increased taxation of older and less efficient vehicles. However, as seen in countries across Europe, influencing the make-up of the vehicle fleet at point of purchase is an effective means of encouraging evolution towards a lower emitting vehicle stock. The benefits of this continue to be realized over time, and represent a particularly important opportunity in the face of a high projected growth rate in motorization levels and car ownership.

Eco-driving programs also offer significant potential for the reduction in vehicle emissions, and unlike the previous interventions, there are no significant barriers to implementation or adverse impacts. In fact, eco-driving offers significant potential wider benefits in the form of cost savings for motorists and enhanced environmental and safety benefits. Investment costs will vary according to the nature of the program implemented, but studies have highlighted the measures as performing strongly in terms of both overall impacts and value for money.

The following interventions perform strongly in value for money terms and should also be considered for adoption within the action plan, and as a feature of the Green Scenario.

- **Smarter choices programs** combined with investment in walking and cycling infrastructure have been demonstrated to lead to modal shift, achieving not only a reduction in emissions levels but also significant wider benefits including health and wellbeing, and decongestion. In cost-benefit analysis, these schemes typically perform strongly, with cost-benefit ratios in excess of 20 by comparison with highway and public transport schemes in the low single figures. This analysis demonstrates that with concerted and sustained investment over the strategy period, emissions savings realized at a reasonable level of cost effectiveness.

- **Parking pricing** is a further market based measure which offers the potential for emissions savings with a high level of cost effectiveness. Indeed, the measure would be expected to offer a stream of revenue which could facilitate some of the investment measures highlighted above. Parking pricing, in conjunction with tightened parking regulation and enforcement, may be considered to be a more cost effective more readily implementable solution to in town congestion instead of urban congestion charging and most European cities are following this strategy in preference to congestion charging; and

- **Air travel taxation** presents a mechanism for exerting some control over the growing demand for air travel at the margins, and also offers a revenue stream which may be put to useful purpose. The implications for the economy need to be considered, but there is are potentially positive equity impacts in what may be expected to be a strongly progressive form of taxation.

Based on the analysis of the abatement potential of the identified measures and on the results of wider assessment, the following measures are proposed for consideration within the Climate Change Action Plan period under the Green Scenario:

- Fuel Price Taxation Increase
- New Vehicle Registration Tax
- Eco-Driving Program
- Smarter Choices/Personal Travel Planning Programs
- Investment in Walking and Cycling Infrastructure
- Parking Pricing
- Air Travel Taxation

Of the above measures, the market based policies where the taxation mechanisms already in place require no significant capital investment. The combined undiscounted capital investment of the above infrastructure dependent measures totals Euro 126 million over the timeframe of the Climate Change and Low Carbon Green Growth Strategy under the Green Scenario, but rise sharply for the Super Green Scenario (Table 4). For the Green Scenario, Euro 93 million of investment is profiled to fall within the period of the Action Plan, with ongoing investment in walking and cycling measures extending beyond 2022, based on a ten year investment profile. The mitigation impact of the combined bundle of interventions included within the Green Scenario is presented in Figure 8, together with the mitigation potential of the Super Green Scenario. Note that the impact of the bundle of measures is not identical to the sum of the individual measures due to the inter-relationship between certain policies.

The remaining interventions modelled as part of the study have not been considered suitable for inclusion within the Green Scenario, reflecting either the lower value for money based on the MAC analysis, or deliverability challenges. Non-inclusion within the Green Scenario does not however mean that the schemes have no value or that these should not be considered for implementation in Romania based on wider appraisal criteria such as economic impact or local air quality. The high costs of the Super Scenario are driven by the high cost of urban congestion charging scheme, both in terms of initial investment and operating and maintenance costs.

Table 6: Investment Costs of Green and Super Green Scenarios (Euro millions)

Scenario	Undiscounted Investment Cost			Discounted Investment Cost		
	CC Action Plan (2016-2020)	CC and Low Carbon Green Growth Strategy (2016-2030)	Model Period (2015-2020)	CC Action Plan (2016-2020)	CC and Low Carbon Green Growth Strategy (2016-2030)	Model Period (2015-2050)
Green Scenario	93	136	179	79	108	125
Super Green Scenario	885	1,477	2,603	748	1,136	1,562

Note: A 4 percent discount rate was used, in line with other sector reports. The period for modelling was 2015-2050, but the action plan will cover 2016-2020.
Source: TRANSEPT.

The promotion of Ultra Low Emission Vehicles (ULEVs) has a place within government policy, and indeed incentives are currently offered for the purchase of low emitting vehicles both in terms of direct subsidy and as an additional stackable incentive under the existing scrappage scheme. Take-up of electric or plug-in electric vehicles to date has been low, which is likely to be a reflection of the limited existing infrastructure for such vehicles. Large scale investment in charging infrastructure would have the potential to increase take-up. However, this infrastructure has been seen to come at high cost, based on existing technology and the current commercial suppliers operating within this market. The technology is evolving rapidly, and already exposing misallocation of investment based on the approaches adopted by the countries early to provide supporting infrastructure. Equally, the marketplace is changing, and new business models relating to the provision of charging infrastructure are being developed, whether by vehicle manufacturers or by private suppliers identifying commercial potential. As such, it is considered that the high level of investment required to hasten the implementation of supporting infrastructure does not represent best value for money or lead to sufficient emissions reduction savings or wider benefits to merit immediate consideration.

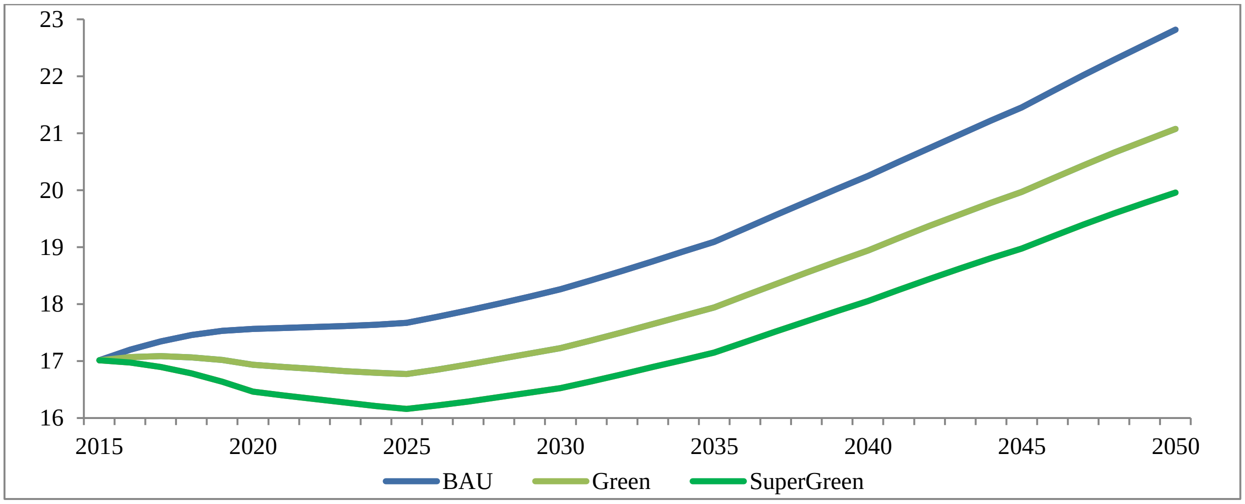
Equally, whilst target setting relating to the acquisition of ULEVs within the public sector fleet and the public transport fleet may be considered laudable as a means of promoting and raising awareness about the technology, the cost of the new technology remains high by comparison with the emissions savings achieved, and the technological barriers to effective integration within the fleets are also notable in the near term. Speed restrictions have been rejected in preference to higher fuel duties due to the implementation difficulties, the economic impact and the lack of revenue generated by such a measure. Low Emission Zones are demonstrated to have carbon saving potential, although the driving force behind implementation of such policies is typically local air quality. With its very poor air quality standards, Bucharest would potentially benefit most significantly from such a measure, and the policy should be considered within this context. However, with high implementation and operating costs, technological and enforcement barriers and potential political resistance, the pursuing of such a policy in the short/medium term is not considered cost effective as a means of carbon emissions saving.

Impact of Measures on GHG Emissions from the Transport Sector

To demonstrate the scale of mitigation achievable under a high intervention or Super Green scenario, the Green Scenario policies as well as policies which were not selected for inclusion within the Green Scenario, but which nevertheless provide GHG emission saving potential amongst wider benefits have been included. The Super Green Scenario therefore represents an all policy modelled scenario. The scale of abatement potential achievable in the Super Green Scenario by comparison with the Green Scenario and the BAU scenario is presented in Figure 8.

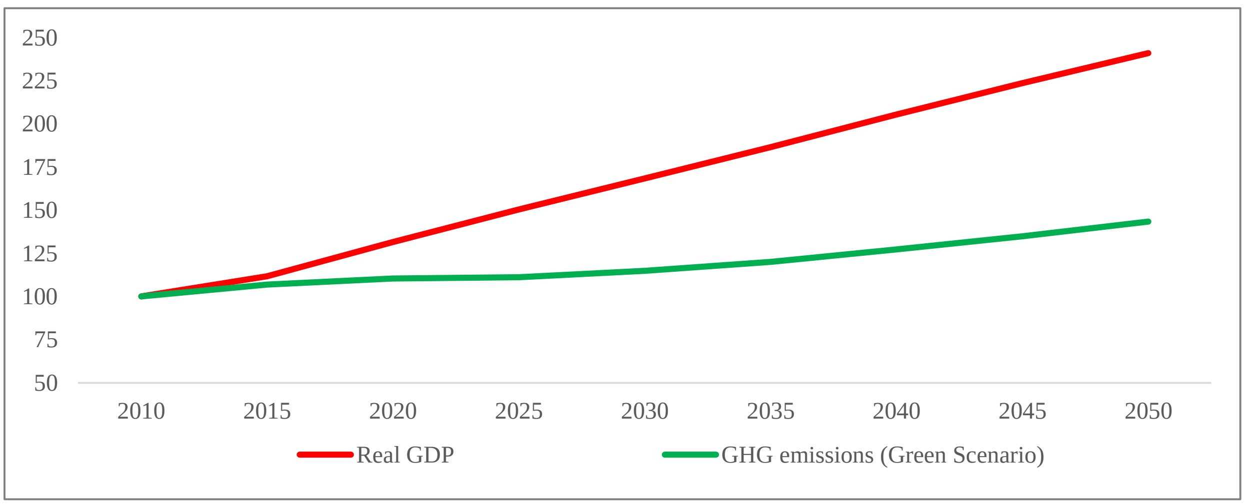
Under the BAU scenario emissions grow by 34 percent over 2015-2050, while under the Green Scenario emissions growth slows to 24 percent and under the Super Green Scenario growth slows to 17 percent. In all cases GHG emissions from the transport sector rise. These results are in line with many studies which suggest that reducing GHG emissions—as opposed to reducing GHG emission growth rate—is difficult in the transport sector. In order to reach a low emission scenario in 2050 Romania's transport sector has to have close to zero emissions, which will need large changes in behavior and technology. However, this growth in GHG emissions has to be seen in the context of a growing real economy. Figure 9 reveals that under a Green Scenario GHG emissions from transport are projected to grow more slowly than the real economy.

Figure 8: Transport Emissions under Alternative Carbon Abatement Scenarios (MtCO2e)



Source: TRANSEPT.

Figure 9: Transport GHG Emissions and Real GDP Trends, 2010-2050 (2010 = 100)



Source: TRANSEPT.

1 INTRODUCTION

1.1 Introduction

1. The Europe 2020 Strategy and the legislative package from the European Commission provide European Union (EU) member states a framework and means for moving towards a greener and more competitive low carbon economy that makes efficient use of resources and is resilient to climate risk. The European Council further determined in February 2013 that the Multiannual Financial Framework will mainstream climate objectives. As a member state of the EU, the Government of Romania is committed to fighting climate change and pursuing a low carbon development. The integration of both mitigation and adaptation actions into Romania's national policies, programs, and strategies will be a critical step in shifting its development path towards a climate resilient, low carbon and green economy.

2. In this context, the Government of Romania has requested the World Bank to provide Advisory Services on climate change, including operationalizing its national climate change strategy and action plan, identifying and integrating climate-related actions in new Operational Programs, building a solid analytical base for impact assessment and climate-related decision making, and enhancing climate-friendly practices and monitoring system. The Program aims to assist the Government of Romania to: (i) develop a comprehensive national climate change and low carbon development strategy and action plan; (ii) integrate associated climate-related actions into the 2014-2020 EU-funded Operational Programs; (iii) develop the institutional tools necessary to inform climate change policies and monitor their economic and environmental impacts; and (iv) identify future carbon trading opportunities.

3. This Report is a deliverable under Component C of the Advisory Services Agreement, *Support to the Recipient to build strong and sustainable analytical capacity and a suitable knowledge base*. This component assists the Government of Romania in identifying climate change action mitigation actions through extensive greenhouse gas (GHG) modelling work. The objective under Task C is to model mitigation scenarios up to 2050 for the transport sector—Business as Usual, Green, and Super Green Scenario—through the development of a strategic model and to develop a marginal abatement cost analysis of mitigation measures proposed, measured in terms of marginal abatement cost or net present value of costs and benefits per ton of GHG abated. The outputs are an Excel based Strategic Mitigation Model and this Report.

4. The work presented in this Report builds on the Transport Rapid Assessment Report, which was a deliverable under the Advisory Services Agreement. That report identified promising climate change mitigation and adaptation actions for consideration for the country's 2014-2020 Operational Programs that are supported by European Union funding. These were based on a qualitative assessment drawing on international evidence of potential effectiveness and consideration of applicability in the local

Romanian context. This Report, and associated model, is also intended to complement the National Transport Model (NTM) developed for General Transport Master Plan (GTMP) for Romania.[4]

5. The timeframe under consideration in this study extends beyond that of the Transport Rapid Assessment Report (2014-2022) and that of the NTM (2012-2030). This Report's scope was to consider appropriate Government policy interventions and scenarios up to 2050 that would help minimize GHG emissions from the transport sector in a cost-effective way. To do that, the following tasks were undertaken:

- Development of an agile, flexible spreadsheet-based Strategic Mitigation Model that draws on the best available data sources and emission relationships appropriate to Romania;
- Definition of a Business-as-Usual (BAU) scenario for Romania, incorporating data from the GTMP, national data sources and other international trends;
- Identification of a range of policy interventions that show potential for emission reduction and complement and enhance some of the planned GTMP major infrastructure interventions;
- Use of the Strategic Mitigation Model to test the potential transport demand impacts and the consequent GHG emission impacts of all interventions versus the Business-as-Usual scenario;
- Preparation of broad cost estimates for the various interventions, drawing on international experience, but taking account of Romanian costs relative to international levels;
- Preparation of a marginal abatement cost curve, taking into account government costs associated with the modelled interventions; and
- Emission reduction potential, likely costs and broader implementation issues to define a preferred future Green Scenario that groups together the most promising interventions, as well as the development of a more ambitious Super Green Scenario.

Consideration of institutional arrangements for implementation of individual interventions and alternative financing arrangements for proposed investments were outside of the scope of this study. It needs to be highlighted that the abatement cost analysis only takes account of government investment costs, with no quantitative assessment of wider socio-economic impacts or benefits. The policy interventions `assessed are ones which have precedent of adoption within other countries on the basis of

[4] The Ministry of Transport commissioned AECOM Ingeneria SRL in April 2012 to develop a Transport Master Plan for Romania (GTMP). An integral part of that commission was the development of a NTM for Romania (NTM). The NTM is a 'classic 4-stage transport model' based on a well-known software package, EMME3, similar to those widely used for transport appraisal purposes around the world. The NTM covers all modes and include inland waterway transport. Constanta Port also has its own freight demand sub-model within the NTM, because of its national importance as a freight gateway. The GTMP involved extensive appraisal and modelling of national scale infrastructure investments and complementary policies, including consideration of greenhouse gas (GHG) emission impacts. The GTMP covers a timeframe up to 2030, with delivery of some projects and interventions continuing for up to five years beyond that date.

their carbon reduction impacts or wider benefits. The strategic modelling exercise forecasts the potential abatement impact of individual interventions and bundles of interventions through the development of two scenarios. Whilst abatement cost effectiveness is one element in the ranking and selection of interventions, it is not the only criteria, and an analysis of qualitative wider impacts have played a role in preferring certain policies above others, for example fuel taxation over speed limit reductions. Prior to deciding on the adoption of any proposed intervention or bundle of interventions to reduce GHG emissions from the transport sector, detailed cost-benefit analysis of likely impacts may be required.

1.2 EU Transport Strategy and Policies

6. There are several formal documents adopted by the EU that are relevant for Romania's transport sector. Key among them is the European Commission White Paper "*Roadmap to a Single European Transport Area: Towards a competitive and resource efficient transport system"* (White Paper) adopted in March 2011.[5] This document sets targets and directions for transport sector development—EU transport policy is focused on assuring sustainable mobility for people and goods with a strong emphasis on contributing to a very ambitious GHG emission targets set for the EU as a whole. More specifically, the policy and related activities are expected to significantly reduce Europe's dependence on imported fuels (mostly oil) and cut carbon emissions in transport by 60 percent by 2050 compared to 2005. By 2050, key transport strategic goals include:

(a) no new conventionally-fueled cars in cities;
(b) at least 40 percent use of sustainable low carbon fuels in aviation;
(c) at least 40 percent reduction of emissions from maritime transport;
(d) at least 50 percent shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport.

7. Several important interim goals are also included in the White Paper and have to be taken into account when designing and implementing country specific transport strategies and programs. They are grouped into three categories: (a) developing and deploying new and sustainable fuels and propulsion systems; (b) optimizing the performance of multimodal logistic chains, including by making greater use of more energy-efficient modes; and (c) increasing the efficiency of transport and of infrastructure use with information systems and market-based incentives. The White Paper also includes 40 concrete initiatives for the next decade, which are expected to result in a competitive transport system that will increase mobility, remove major barriers in key areas, and stimulate growth and employment.

8. In order to ensure complementarity, the country specific strategic and policy directions should be coherent with the EU-level transport strategy, as well as country-wide specific programs and policy measures. In practice this means that national-level strategy, programs or Master Plan(s) should complement and "transpose" the guidelines from the European Commission White Paper and other

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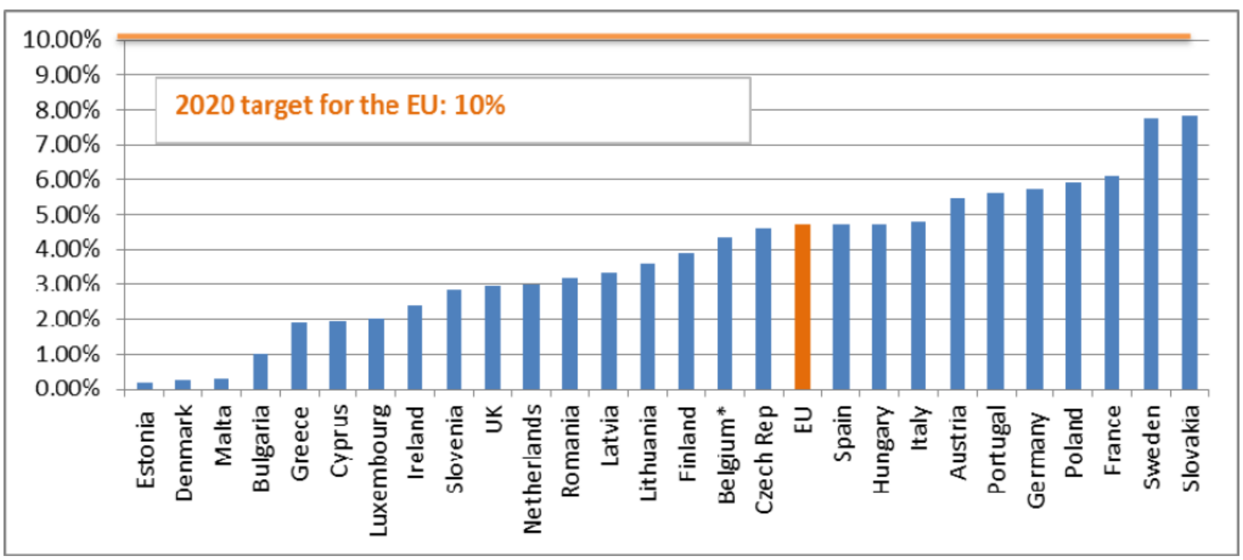
[5] European Commission (2011), *White Paper: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*. Brussels, March 28, 2011, COM (2011) 144 final.

important components of EU transport sector policy framework into Romania's transport sector. In addition, any regional, local or municipal transport strategies or programs should complement and be fully coherent with national level policies and EU policies. Therefore, Romania's transport strategy and policies across all modes of transport and all levels of transport sector public governance (from the national level down to the local level) should be internally coherent and should complement the EU transport strategy and policies by "translating" EU level documents into Romania reality. While all EU member states have to follow the general directions of the EU transport policy, they also have significant flexibility in designing their own transport strategies, programs and implementation arrangements reflecting country-specific needs in infrastructure development programs and policy measures. At the same time, country-level strategies should be aligned with and contribute to EU-wide transport policy goals.

9. The European Commission undertook a recent assessment of progress towards achieving the Europe 2020 targets, that is to say, to create 20 percent of energy consumption from renewables and increasing energy efficiency by 20 percent by 2020. For the transport sector, Romania needs to make significant efforts to increase the share of renewable energy used, which has an EU wide target of 10 percent (Figure 10). There is a need for further efforts aimed at reducing the energy intensity of the transport sector, as well as raising the use of renewable energy powering the transportation system. The low degree of efficiency of Romania's transport system was flagged in a recent European Commission assessment of Romania's progress with the national reform program.[6]

Figure 10: Share of Renewable Energy in the Transport Sector in 2010[7]



Source: European Commission.

[6] European Commission (2013), Recommendation for a Council Recommendation on Romania's 2013 National Reform Program and Delivering a Council Opinion on Romania's Convergence Program for 2012-2016. COM (2013) 373 final. Brussels, 29.5.2013. Available at:
http://ec.europa.eu/europe2020/pdf/nd/csr2013_romania_en.pdf
[7] http://ec.europa.eu/clima/policies/g-gas/progress/docs/13_energy_and_ghg_en.pdf

1.3 Transport and Greenhouse Gas Emissions

10. Transport is responsible for around a quarter of EU GHG greenhouse gas (GHG) emissions making it the second biggest greenhouse gas emitting sector after energy. Road transport alone contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas. While emissions from other sectors are generally falling, those from transport have increased 36 percent since 1990. The EU has policies in place to reduce emissions from a range of modes of transport, including aviation in the EU Emissions Trading System (EU ETS) and CO_2 emissions targets for cars. The majority of domestic transport-related greenhouse gas emissions are from road transport. However, there are also significant emissions from the aviation and maritime sectors and these sectors are experiencing the fastest growth in emissions, meaning that policies to reduce GHG emissions are required for a range of transport modes.

11. GHG emissions generated from transport are among the fastest growing in Europe, posing a challenge in creating a low-carbon future, as economic development has been paralleled with a modal share increasingly dominated by roads.[8] This modal shift has been driven by a number of factors, including growing affluence, suburbanization, and falling land use densities in urban areas, which have translated into more widespread vehicle ownership, increasing trip numbers and lengths, while reducing the financial viability of public transport and non-motorized transport. On the freight transport front, while a number of East European countries had relatively high rates of rail modal share, these have generally been declining and have been approaching EU levels. Thus, Eastern European countries are moving toward EU motorization rates for passenger transport—with much higher GHG growth than in the EU-28, although overall levels remain lower—while trucks are making significant inroads vis-à-vis rail. Without any changes to transport policy, these trends in Eastern Europe, and in Romania, are likely to continue unabated in the next decades.

12. Transport is a key facilitator of economic well-being worldwide and is likely to continue to grow to meet continued demand and growing transport needs in Romania. Affordable transport services are crucial for development. They connect rural areas to sales opportunities and inputs, and nations to export markets and foreign technologies. Affordability refers not just to consumer prices but also to all costs to society: the time losses due to congestion, the sometimes dramatic consequences of accidents, the health costs of local pollution, and the damage that severe climate events inflict on the population. Transport decisions, particularly those for infrastructure investments, will determine these costs for decades to come, offering opportunities to countries whose transport systems are not yet mature.

13. Recognition of climate implications in transport, unlike other sectors, has had a slow start. One reason is that the transition to a low-carbon context appears to be more costly than in other sectors. But broadening the policy agenda to shift behavior changes the cost picture completely, especially measures

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[8] In the case of the EU-27 in 2007 CO_2 emissions from the transport sector accounted for 25.1 percent of the total, up from 18.1 percent in 1990. Projections from the European Environment Agency estimate that the sector's emissions will increase by 25 percent over 1990-2020, whereas they are expected to decline from industrial and energy sectors.

to reduce congestion, local air pollution, safety risks, and road safety.[9] For example, a recent survey of 25 European cities found that Bucharest was the most polluted, and that air pollution reduced life expectancy by 2 years, due to high concentration of fine particles, largely due to emissions from diesel engines and heating.[10] Policies to guide demand to low-emission modes and technologies must be part of investment programs and projects. Such policies can reduce transport demand in the longer run by changing the economic geography of cities and countries. But that will take close coordination of transport, urban, environmental, and health policies.

14. Decoupling GHG emissions from the transport sector and economic growth or at least lowering the GHG intensity of future transport growth represents the key challenge and will require departure from the business as usual policies in the transport sector.[11] As noted in the EU's 2011 White Paper on transport, the main issue facing the transport sector is how to reduce the system's dependence on oil without sacrificing efficiency and compromising mobility—curbing mobility is not an option. The World Bank's own climate change strategy for the transport sector adopts a similar approach, arguing that climate change mitigation in the transport sector has to be seen in a broader context: sustainable transport should limit GHG emissions from transport and minimize other externalities, without compromising economic growth.[12]

15. Concerns about climate change are not likely to be the key driver of transport policies or investment decisions. Instead local co-benefits—such as reduced traffic congestion and noise, improved air quality and road safety, or enhanced energy security—are much more likely to drive the development of transport policies.[13] This is the same argument recently put forward in the World Bank's transport climate change strategy: attempting to sell measures to reduce GHG by marketing them as policies aimed at other social costs of transport can be much more attractive to policy-makers, who may not be concerned about climate change or who cannot gain political traction for policies if they are sold to the public exclusively on a climate change angle.[14] Looking at congestion levels in a city like Bucharest and trends toward increased motorization, the issue is as much a classic problem of transport and urban planning as it is a

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[9] The number of road fatalities in Romania is 58 percent higher than the EU-27 when adjusted for population. In 2012, 32 percent of road accidents involved a vehicle and a pedestrian, suggesting that much can be done in urban areas to make cities safer.

[10] See http://www.aphekom.org/c/document_library/get_file?uuid=5532fafa-921f-4ab1-9ed9-c0148f7da36a&groupId=10347

[11] OECD/International Transport Forum (2008), *Greenhouse Gas Reduction Strategies in the Transport Sector*. Preliminary Report. Paris: OECD /International Transport Forum.

[12] World Bank (2011), Turning the Right Corner: *Ensuring Development through a Low-Carbon Transport Sector, Andreas Kopp, Rachel I. Block, and Atsushi Iimi.* Available at: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/05/31/000445729_20130531125005/Rendered/PDF/780860PUB0EPI0050240130right0corner.pdf

[13] James Leather and the Clean Air Initiative for Asian Cities Center Team (2009), *Rethinking Transport and Climate Change*, Asian Development Bank Development Working Paper Series No.10, December 2009.

[14] One of the barriers to the use of a co-benefit approach to climate change is the cost and time it takes to measure co-benefits in a transport project, vis-à-vis the direct benefits.

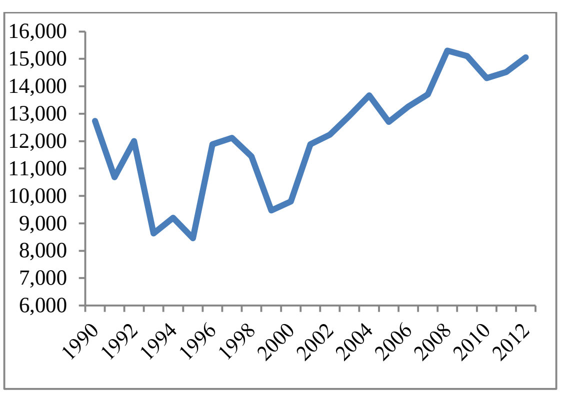
GHG emission problem. Co-benefits can motivate discussions on improved transport policies which are also GHG friendly policies.

16. The financing of the transport sector needs to be supported by adequate pricing policies, which can help change existing behavior and thus transport demand, allocate resources more efficiently, and raise funds to invest in more sustainable forms of transport. This means interlocking discussions about financing of transport infrastructure with pricing, as adequate financing needs to be supported by sound pricing policies. However, at present pricing does not reflect the full costs of transport, including costs of negative externalities, while investments tend to be heavily focused on roads, based on a motorization future which assumes ever growing vehicle ownership and usage.

1.4 Greenhouse Gas Emissions from Transport in Romania

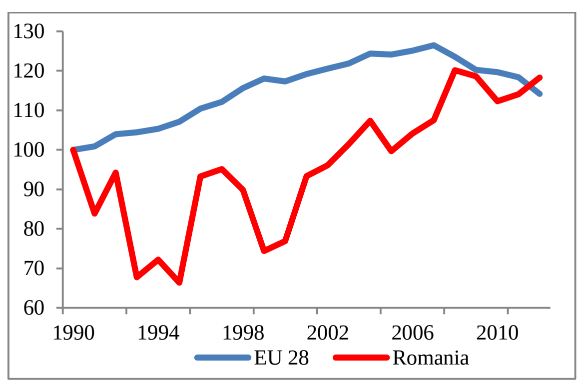
17. Figure 11 shows the annual GHG emissions from the domestic transport sector in Romania and how it has grown since 1990.[15] The steady upward trend since the turn of the century is particularly noteworthy. Figure 12 shows how GHG emissions from transport have grown in Romania since 1990 in comparison with the EU-28, growing significantly faster than the EU average. As a percentage of total GHG emissions across all sectors, Romanian transport accounts for 12.7 percent (2012). While this is less than the EU's average of 19.7 percent, it is rising more quickly, driven in part by the declining modal share of rail (Figure 14) and increased motorization. Road transport is the source of the majority of GHG emissions in the transport sector (93 percent of domestic transport emissions), similar to the EU-28 average.[16]

Figure 11: GHG Emissions from Domestic Transport in Romania (1,000 tons CO2)



Source: EEA.

Figure 12: Trends in Romania's Transport Emissions Compared to EU-28 (1990=100)

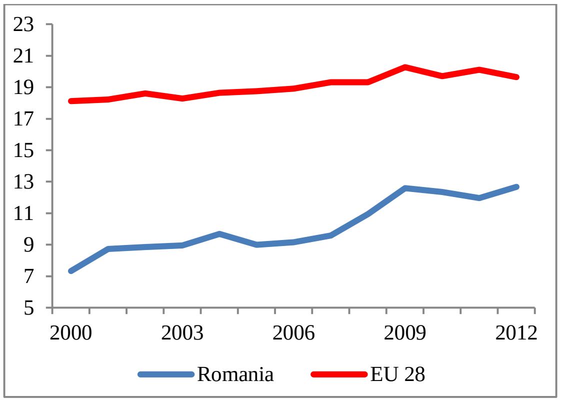


Source: EEA.

[15] This includes emissions from transport (road, rail, inland navigation and domestic aviation) of the GHG regulated by the Kyoto Protocol. Only three gases are relevant in the context of transport (carbon dioxide, methane, and nitrous oxide) and these have been aggregated according to their relative global warming potentials. Some of the downward fluctuations of emissions reflects slowdowns in economic activity.

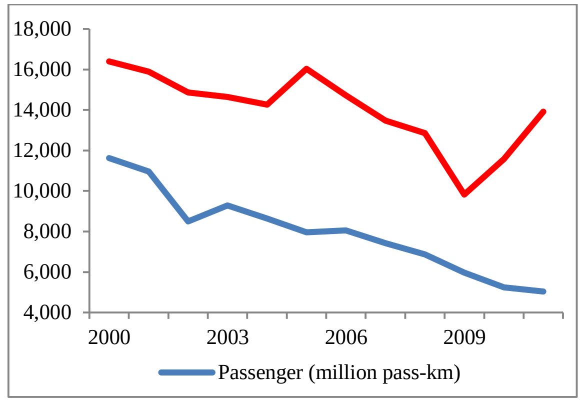
[16] European Environment Agency data, as of June 2013.

Figure 13: Transport GHG Emissions as a Percentage of Total GHG Emissions



Source: EEA.

Figure 14: Rail Traffic in Romania (2000-2012)



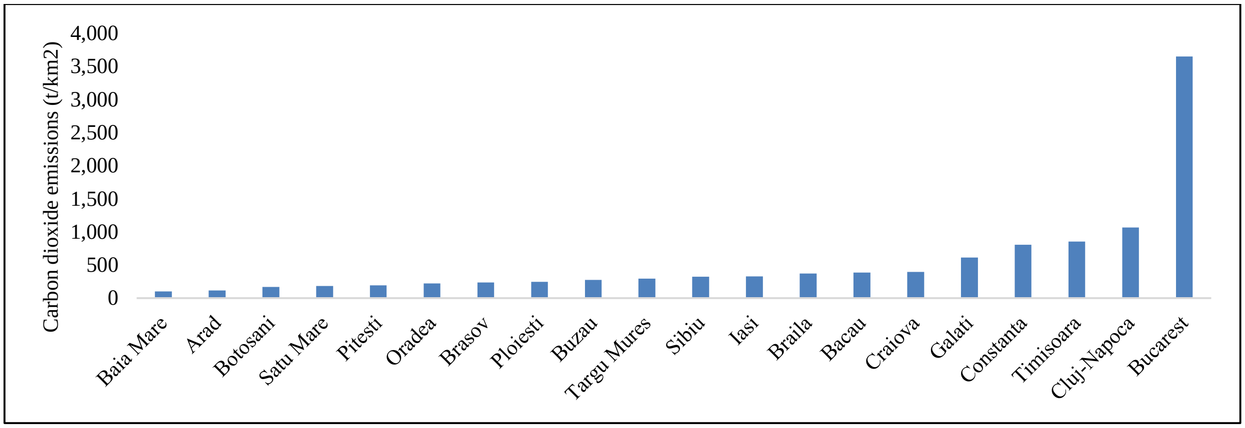
Source: UIC.

18. The E-PRTR dataset is a register that provides accessible environmental data from industrial facilities in European Union Member States and in Iceland, Liechtenstein, Norway, Serbia and Switzerland.[17] This data has been analyzed to better understand the distribution of emissions between urban and non-urban areas. The largest 20 cities (with populations over 100,000) were identified and their respective emissions levels analyzed. Bucharest's road transport emissions, at 833 kt/year is higher than that of the 19 next largest cities combined (596 kt/year). This is reflective both of the geographic size of the city, with six communes amalgamated to form the emissions estimate for the city and also the intensity of activity within the city. Figure 15 displays the emission density within each city by taking account of physical land area. Bucharest can be seen as having the greatest carbon dioxide emissions density, approximately 3.5 times that of the second largest city Cluj-Napoca. This would indicate that road transport activity is most concentrated within Bucharest when compared with other cities and is also reflective of a city which suffers from greater congestion pressures. As expected, urban areas in general display a substantially greater emissions density than the national average. The annual road transport CO_2

[17] To date, there are only four countries in the EU that have spatially disaggregated emissions inventories at a national level, namely, the UK, the Netherlands, Denmark and Sweden. Meanwhile, the European Environment Agency in 2011 released a spatial emission database as part of the European Pollutant Release and Transfer Register (E-PRTR) at a 5km resolution, making it possible to estimate emissions for cities based on geographic boundaries.[17] The EU Framework Seven project Carbon Aware Travel Choices (CATCH) sets a goal of filling this information gap on city-level CO2 using these data, but there are issues relating to the use of E-PRTR data. The main one is that the methodology is a top-down approach, based on the spatial disaggregation of national emissions totals. Secondly, the resolution of the data is at a 5 km level, and CO2 emissions data are distributed into 5 km by 5 km grids using geospatial-referenced datasets, such as road networks for the road transport emissions. As a result, the CO2 emissions captured through this database at a sub-national level are not as accurate as if a bottom-up approach was adopted. See European Environment Agency (EEA), 2009. *E-PRTR: The European Pollutant Release and Transfer Register: Welcome to E-PRTR*. EEA; Copenhagen. Available at: http://prtr.ec.europa.eu

emissions from the 20 largest cities in Romania represent 10 percent of the national total for the road sector.[18]

Figure 15: Road Transport CO_2 Emission Density for the Top 20 Romanian Cities



Source: World Bank, E-PRTR.

1.5 Passenger Transport

19. *Passenger land transport.* Figure 16 shows the modal split for passenger transport (in terms of percentage of total person-km travelled) between the three main land-based modes of domestic travel – private car, rail and bus/coach since 2000. This shows a marked rise in mode share of the private cars and a significant decline in rail mode share (with 2012 rail mode share being approximately one third of the 2000 figure). Bus and coach travel mode share has grown slightly between 2000 and 2011. Figure 17 shows how the modal split figures for Romania compare with the EU average. Private car mode share is now approaching the EU average, having been considerably lower at the turn of the millennium. Passenger rail mode share is lower than the EU average, having been above average in 2000.

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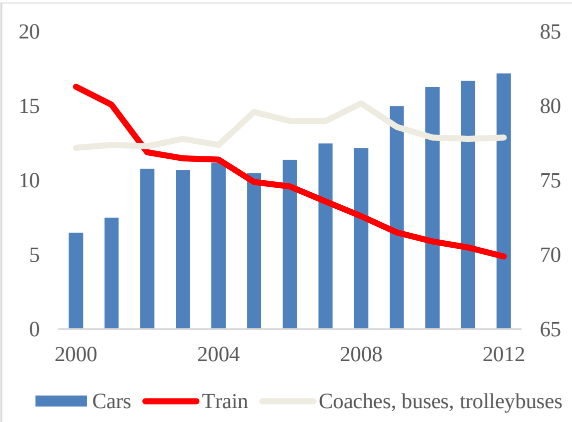
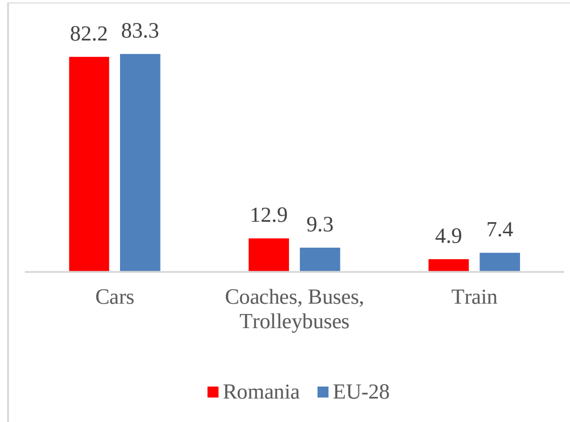
[18] This reflects the fact that for the exception of Bucharest urban areas are actually relatively low density, covering a large number of relatively small conurbations, the size of the haulage on Romania's highway network—Corridor IV is an important transit corridor--reflecting the importance of the ports and Romania's competitive advantage in haulage.

Figure 16: Passenger Transport Mode Share (land-based modes)



Source: Eurostat.

Figure 17: Comparison of Passenger Modal Split with EU-28 average (2012)

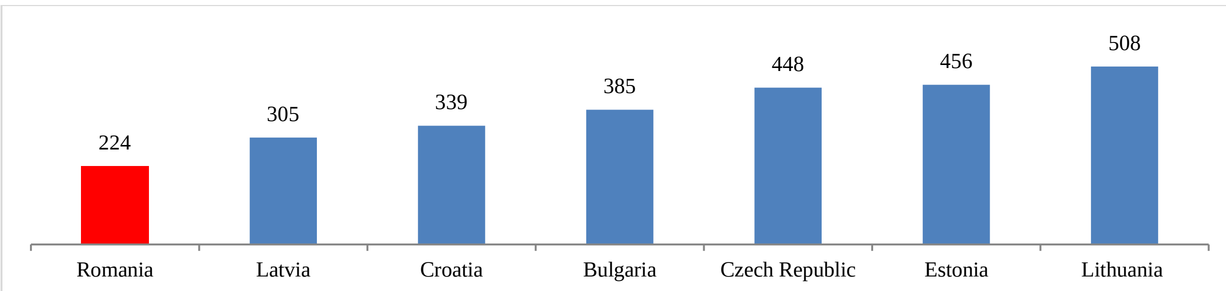


Source: Eurostat.

20. Although car mode share in Romania is at a similar level to the EU average, the motorization (or car ownership) rate in Romania is the lowest in the EU at 224 cars per 1000 inhabitants in 2012 (Figure 18), but has grown significantly in recent years, up from 152 cars per 1000 inhabitants in 2006 (

21. Figure 19). Experience across the world suggests that as the Romanian economy grows, it will continue to grow in future. Without intervention to provide better transport alternatives and encourage their use, as car ownership grows, car use is also likely to grow. The reasons for the decline in rail passengers are linked to the decaying state of the Romanian railway system. In its Position Paper on Romania in preparation for the 2014-2020 funding round, the European Commission notes that the railway system is suffering from underinvestment and poor maintenance, leading to slow and unreliable train services.[19]

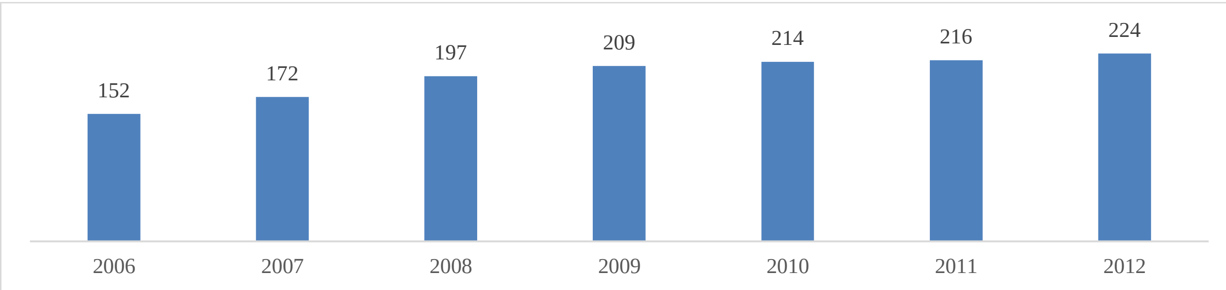
Figure 18: Motorization Rates in Selected EU Countries (passenger cars/1,000 inhabitants, 2012)



Source: Eurostat.

[19] European Commission (2012), Position of the Commission Services on the development of Partnership Agreement and programs in Romania for the period 2014-2020. European Commission, Ref. Ares (2012)1240252 - 19/10/2012.

Figure 19: Motorization Rates in Romania, 2006-2012 (passenger cars/1,000 inhabitants, 2012)

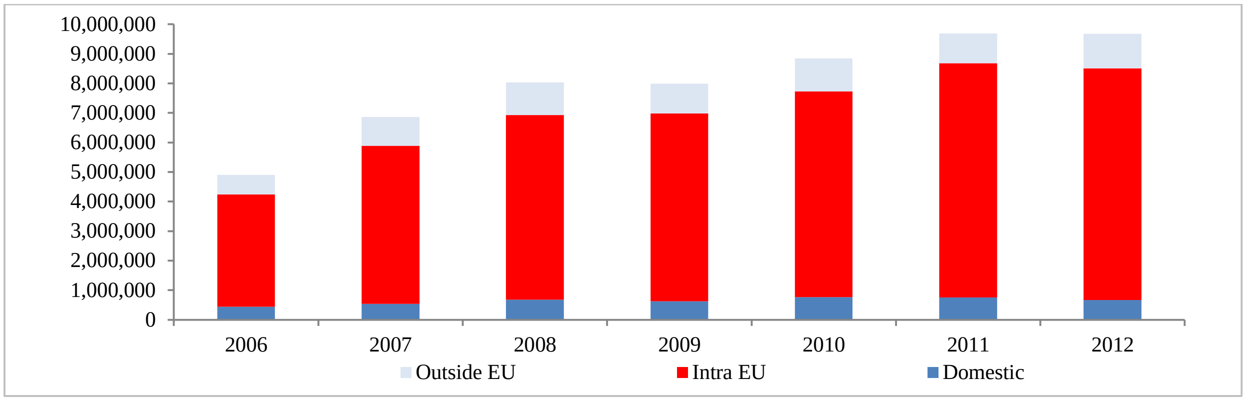


Source: Eurostat.

22. *Domestic air transport.* Air transport is well known as being an intensive emitter of greenhouse gases[20] – although there are a number of industry initiatives to reduce emissions. Domestic air passenger transport activity (internal within Romania) forms a small part (7 percent) of total passenger movements through Romanian airports. This is a relatively low level compared to other EU countries (the EU-27 average is 18 percent), although it has increased in recent years, as shown in **Error! Not a valid bookmark self-reference.**, despite the international economic downturn in 2007. Passengers flying to and from other EU countries form the great majority of passengers using Romanian airports (81 percent), with the remainder (12 percent) flying to and from destinations outside the EU.

[20] Factsheets: UK transport greenhouse gas emissions. UK Department for Transport. Available at www.gov.uk.

Figure 20: Air Passengers using Romanian Airports (excluding transit passengers)



Source: Statistical Office.

1.6 Freight Transport

23. The modal split for freight movements in Romania, in terms of ton-km, and how it has changed in recent years is shown in Figure 21 and Figure 22.[21] This shows a marked fall in rail freight mode share in recent years, together with a marked rise in road freight mode share. Also notable is the much larger waterborne freight mode share since 2009.[22] The reasons for the decline in rail freight and transfer to road and inland waterways are likely to be similar to those set out above for passenger transport. Rail freight mode share is higher than the EU average, in spite of its decline. Inland waterborne freight also has a much higher mode share than the EU average, while road freight is still below the EU average, despite its recent growth. It is important to stress that the growth of a clean transport mode, IWT, is an important development, and that the decline in rail's modal share has not translated into a one on one rise of road modal share. Also worth stressing is that the green transport modes (IWT and rail), had in 2010 a modal share of 51 percent in Romania, compared to only 24 percent for the EU-27.

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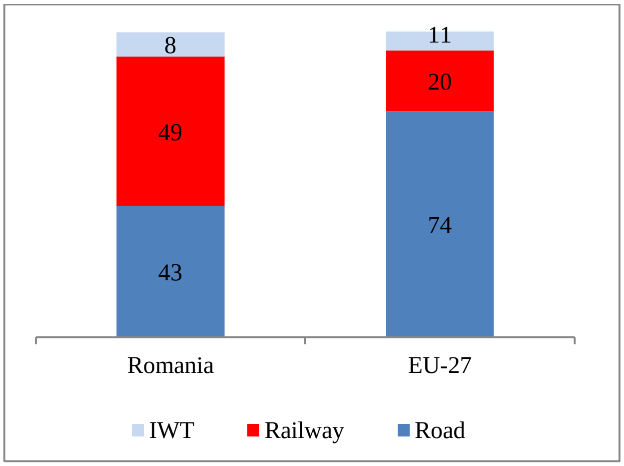
[21] Eurostat data at http://epp.eurostat.ec.europa.eu. The amount of freight moved by air (which is excluded from the modal split figures shown above) is very small - 28,523 tons in 2011, up from 19,229 tons in Romania's first year of EU membership in 2007. For comparison, some 65 million tons of freight were transported on Romania's railways in 2007.

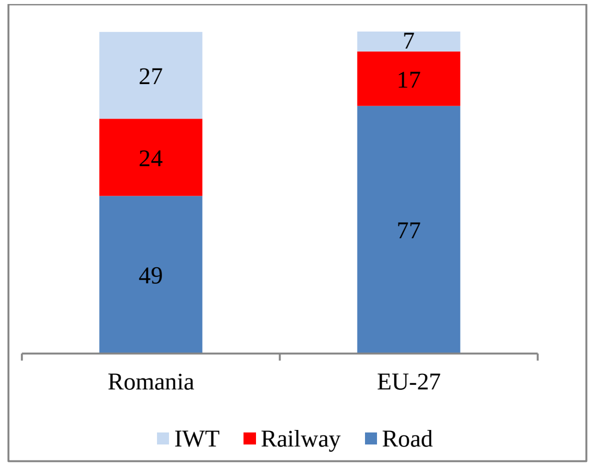
[22] According to a recent report, the three most important port locations in terms of transshipment volumes on the Danube are Izmail (Ukraine), Linz (Austria) and Galați (Romania). The seaport of Constanța in Romania is important as it is connected to the Danube via the Danube-Black Sea Canal and plays an important role as a transshipment gateway to the Black Sea, facilitating trade with Asia, the Middle East and the Black Sea region. See via Donau (2013), Manual on Danube Navigation. Available at:
http://www.via-donau.org/fileadmin/site_upload/viadonau/HBDS_en.pdf

Figure 21: Freight Land Modal Share (2000)



Source: Eurostat.

Figure 22: Freight Land Modal Share (2010)



Source: Eurostat.

1.7 Urban Transport

24. Urban transport forms a major part of overall transport movements in Romania. Some 54 percent of the country's population lives in towns and cities, according to the 2011 national census.[23]. Transport within urban areas forms a vital part of the functioning of those areas as economic and social entities. There are nine cities in Romania with populations in excess of 200,000. As well as Bucharest (by far the largest city at 1.9 million), seven others (Constanta, Craiova, Ploiesti, Iasi, Brasov, Cluj-Napoca and Timisoara) have been designated as regional "growth poles". Galati is the other city of over 200,000 people. There are also 11 Romanian cities with populations between 100,000 and 200, 000 and a further 21 towns/cities with populations between 50,000 and 100,000.

25. However, readily available quantitative information on the urban transport situation across Romania is limited, and consultation and information gathering with all the individual municipal authorities is beyond the scope of the Transport Mitigation Report. Recent TRACE[24] studies assessing the potential for energy efficiency improvements undertaken by the World Bank in individual cities (Brasov, Cluj, Ploiesti) have yielded information, and some further information is also available through the Sustainable Energy Action Plans prepared by various Romanian towns and cities through the European Covenant of Mayors program.[25] In addition, the World Bank held an initial discussion meeting with the Executive Director for Transport in the Municipality of Bucharest on challenges and ambitions in Bucharest. This section presents information from these sources which, while not comprehensive, "paints a picture" of the urban transport scene in Romania. As described later in this Report, eight of the main cities (the seven "growth poles" plus Bucharest/Ilfov County) will soon be in the process of developing

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[23] http://www.recensamantromania.ro/rezultate-2/

[24] http://esmap.org/TRACE

[25] http://www.covenantofmayors.eu/actions/sustainable-energy-action-plans

sustainable urban mobility plans, which will each investigate the urban transport challenges in depth and develop an overarching strategy for addressing them.

26. As noted in the TRACE study reports, there is limited reliable information on modal split in many Romanian cities. The Brasov study sums the situation up as follows "Like in other growth poles, the city lacks information on the transport mode split. The local government does not have information on how many people use public transport, how many walk, and how many of them commute using their own cars. City authorities should document information on trips, to understand exactly how many people complete trips and commute in the city and by what means. Without documenting such information, it is almost impossible to do proper transport planning."

27. *Traffic congestion*. Traffic congestion is reported to be an increasing problem in a number of cities, as vehicle ownership grows. For example, the rapid review of the situation in the TRACE studies in Brasov,[26] Cluj-Napoca[27] and Ploiesti[28] all identified traffic congestion as a problem issue. In Bucharest, congestion is also a significant problem,[29] as confirmed in our discussion with the Municipality of Bucharest. Congestion, with the resulting start-stop nature of the driving cycle it imposes on vehicles, significantly increases greenhouse and other gaseous emissions from road traffic. Bucharest has a traffic signal and control system, which is currently in the process of being upgraded. Other cities are also known to have traffic signal systems – but there is no readily available information on their type or operating status.

28. *Parking.* With the rapid growth in ownership and use of private vehicles since Romania started the transition to a market economy, the supply of designated parking spaces in Romania's cities has come under pressure and the number is often inadequate to meet demand. This often leads to "informal" parking arrangements, with vehicles parking on footways, cycle tracks and public spaces as well as on every available meter of legitimate roadside parking space. As well as causing difficulties for pedestrians, cyclists and other road users, this also adds to the congestion problems noted above. Management of parking in some Romanian cities is rudimentary or non-existent, with little or no enforcement of parking regulations, nor any attempt to use parking restraint (through charging or enforcement of restrictions) as a demand management tool. In other cities such as Brasov and Cluj-Napoca, new parking management systems including use of parking meters, mobile phone payment, among others, are however taking hold.

29. *Public transport*. Public transport in Bucharest includes a metro system (operated by Metrorex), a tram network, trolley buses, and an extensive bus network (all operated by RATB). RATB is an operating company overseen by the Municipality of Bucharest, while Metrorex is an operating company under the

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[26] Improving energy efficiency in Brasov, Romania: TRACE city energy efficiency diagnostic study. World Bank (under the Romania Regional Development Program), undated.
[27] Improving energy efficiency in Cluj-Napoca, Romania: TRACE city energy efficiency diagnostic study. World Bank (under the Romania Regional Development Program), undated.
[28] Improving energy efficiency in Ploiesti, Romania: TRACE city energy efficiency diagnostic study. World Bank (under the Romania Regional Development Program), undated.
[29] Bucharest - sustainable mobility case study. Mihaila Raducu, Goteborg University, 2010.

auspices of the Ministry of Transport. Rail lines also exist which could potentially provide suburban transport services for commuting.[30] In other Romanian cities and towns, public transport consists of buses, minibuses, trolley buses and trams. The city of Brasov took the decision in 2005 to abandon its tram line due to the prohibitive cost of upgrading and maintaining it. It now focuses on buses and trolley buses. Cluj-Napoca has upgraded its tram system, while other cities have similar plans but lack funding to implement them.

30. Although data is hard to obtain, it is understood that public transport patronage in many Romanian towns and cities is in decline, with a corresponding increase in private traffic levels. For example, in Ploiesti, public transport patronage fell from 7 million trips per month in 2011 to 6.7 million in 2012. Ridership is going slightly down[31]. Some cities are making concerted efforts to reverse this trend through modernization of infrastructure and services, although lack of funding remains a serious constraint. For example, the Brasov Municipality and by operating company renewed its bus fleet with 109 new vehicles in 2006, using an EBRD loan, and purchased a further 15 Euro V diesel buses in 2011[32]. The whole fleet purchased in 2006 is reaching the end of its life, however, and will need replacement by2015.

31. *Taxis, pedestrian and cycling infrastructure.* There is a plentiful supply of taxis in most Romanian cities. However, many of the vehicles are old and not fuel-efficient, mirroring the make-up of the national vehicle park. Some cities have an age limit for taxi vehicles, but this varies significantly (Brasov has an age limit of five years, while in Cluj-Napoca the age limit is 12 years). Pedestrian and cycling infrastructure varies greatly in quality and quantity between different towns and cities, and within different city areas. A number of Romanian towns and cities have recognized the value of these modes in improving energy efficiency, reducing congestion and creating pleasant urban environments. For example, efforts to improve walking and cycling facilities are reported in all three TRACE studies cited above, and mention is made of encouraging these modes in some Sustainable Energy Action Plans.[33] As with other modes, however, data is hard to come by on the numbers of urban trips being made on foot or bicycle.

32. In Brasov in 2008, the Municipality developed a pedestrian area in the historical center with 10 streets closed to car traffic and streets repaved with cobblestones, using funding from the 2007-2013 Regional Operational Program. In Ploiesti, an EU-supported CIVITAS project promoted walking and a pedestrian zone was created in the city center, backed by a campaign to encourage behavioral change. As a consequence, there has reportedly been a 20 percent improvement in public transport speed, in addition to a 15 percent reduction in pollution in the central zone of the city.

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[30] European funds warm up modernization works in Romania. Railway Pro, 26th February 2013 issue, available at http://www.railwaypro.com/wp/?p=11645
[31] Improving energy efficiency in Ploiesti, Romania: TRACE city energy efficiency diagnostic study. World Bank (under the Romania Regional Development Program), undated.
[32] Improving energy efficiency in Brasov, Romania: TRACE city energy efficiency diagnostic study. World Bank (under the Romania Regional Development Program), undated.
[33] Sustainable Energy Action Plan of Vaslui 2011-2020. Municipality of Vaslui, 2009.

33. In terms of cycling, good cycling infrastructure exists in some cities but it is generally patchy and does not form a coherent network, and is often poorly maintained. As noted above, parking on cycle lanes is also a problem, reducing their usability further. However, there are examples where the cycling environment is being improved. In Cluj-Napoca, the municipality is extending its cycle lane network by 18km (to 58km in total) in the city and out to the suburbs; 50 self-service bicycle docking stations in the metropolitan area are also being built. The Municipality of Ploiesti also took part in SPICYCLES[34], a project developed under the EU Intelligent Energy Europe program, along with Barcelona, Bucharest, Berlin, Goteborg, and Rome. Ploiești ran a bike-sharing pilot scheme which was promoted among commercial companies, local government institutions and educational institutions.

1.8 Mitigation Challenges

34. The previous section has reviewed GHG from the transport sector in Romania and presented a brief overview of modal share, as well as some of the challenges facing urban transport. In a do nothing scenario, Romania's GHG emissions from transport are set to continue growing rapidly compared to the EU, particularly if its motorization rates converges to the EU average. The challenges for mitigating GHG in the transport sector are significant. This is illustrated by the recent European Environment Agency (EEA) report on the State of the European Environment which highlights the fact that 'transport, including emissions from international transport, is the only EU sector to have increased its GHG emissions since 1990'. [35]

35. A major overall challenge is decoupling economic growth from transport emissions.[36] Figure 23 presents real GDP growth and GHG emissions from the transport sector in Romania over 2000-2012, suggesting that they move in tandem, with an inflexion in 2009 when real GDP started growing more rapidly than transported related GHG emissions.[37] Over the 2000-2012 period, GHG emissions rose by 54 percent, while real GDP rose by 55 percent. As noted in the EEA report, European demand for transport has increased in line with GDP in recent years, reflecting the close interdependence of transport and economic development. To mitigate GHG emissions, growth in demand needs to be either limited or managed in some way or targeted on low emission travel modes, coupled with reducing GHG rates (g/km emitted) from vehicles. The EEA report recognizes that while new engine technologies will help mitigate GHG, a more holistic approach is required. This includes measures to encourage change in people's travel

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[34] Newsletter Spicycles Available at:
http://www2.trafikkontoret.goteborg.se/resourcelibrary/SPICYCLES percent20Newsletter percent201.pdf

[35] EEA (2015), SOER 2015 - The European Environment - State and Outlook 2015. A comprehensive assessment of the European environment's state, trends and prospects, in a global context. Available at: http://www.eea.europa.eu/soer

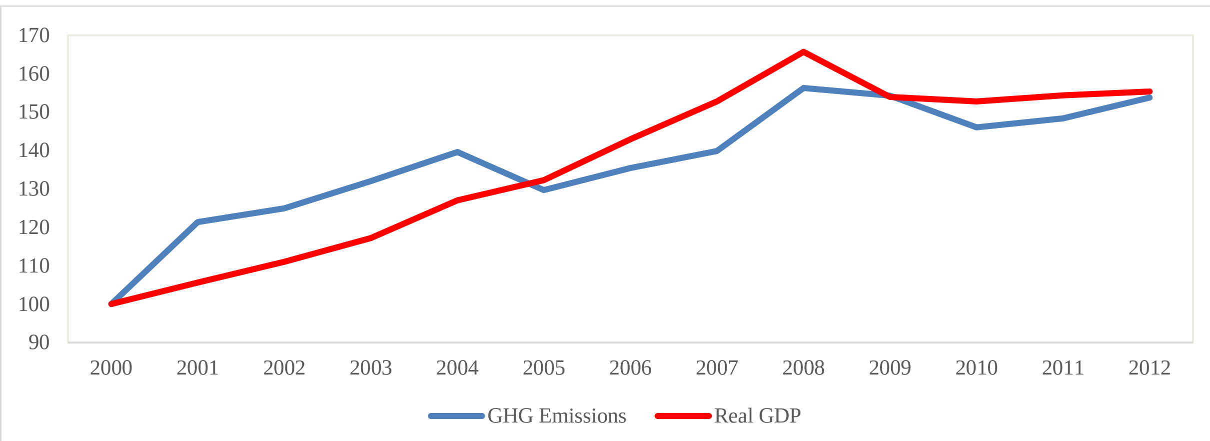
[36] Decoupling can be understood in different manners. One interpretation would be that transport emissions go down while real economic activity is positive. This is a very ambitious target, but a more realistic one is ensuring that the growth of GHG emissions from the transport sector is slower than the growth of real GDP.

[37] The observed decoupling of transport GHG emissions to GDP may be in part attributable to the evolution I fuel prices which rose rapidly in 2004 and 2006, before falling back by 2008. By 2010 fuel prices had bounced back, reaching new highs and continued to rise rapidly, constraining travel demand and leading to a fall in emissions. See: https://energypedia.info/wiki/Fuel_Price_Data_Romania

behavior and choices (as well as technological measures) – which is in line with the broad range of policy interventions examined in this Report.

36. Increasing motorization (car ownership) is a particular issue for the transport sector in Romania. Although car mode share in Romania is at a similar level to the EU average, the motorization (or car ownership) rate in Romania is the lowest in the EU at 224 cars per 1000 inhabitants in 2012, having grown significantly in recent years from 152 cars per 1000 inhabitants in 2006. Experience across the world suggests that as the Romanian economy grows, the motorization rate will continue to grow in future. Without intervention to provide better transport alternatives and encourage their use, as car ownership grows, car use is also likely to grow. The General Transport Master Plan projects rapid growth in car ownership, with the motorization rate exceeding 350 cars per 1,000 inhabitants by 2030, which would represent an increase in excess of 50 percent increase over 2012-2030.[38]

Figure 23: Real GDP Growth and GHG Emissions from Transport Sector (2000=100)



Sources: IMF, World Economic Outlook, April 2015; EEA.

37. The current state of the railway system in Romania is also a key issue when considering mitigating GHG emissions in the transport sector. Both passenger and freight movements by rail have declined dramatically in recent years. This is linked to the decaying state of the Romanian railway system. In its Position Paper on Romania in preparation for the 2014-2020 funding round, the European Commission noted that the railway system is suffering from underinvestment and poor maintenance, leading to slow and unreliable train services.[39] The GTMP report argues that Romanian railways 'are in a crisis situation', and recommends:

- serious structural reforms;
- substantially increased spending on maintenance and renewals;
- increased investment in rehabilitation to current design speeds; and

[38] The draft version of the GTMP of October 2014 was used for the purposes of the modelling.

[39] European Commission (2012), Position of the Commission Services on the development of Partnership Agreement and programs in Romania for the period 2014-2020. European Commission, Ref. Ares (2012)1240252 - 19/10/2012.

- introduction of regular interval timetables, convenient for passenger needs.

38. These measures are built into the GTMP, and thus are included in the Business-as-Usual scenario for this study. Inevitably, however, there will be a process of transition to go through, during which it would be difficult to implement effective additional interventions aimed at encouraging greater rail use (which would reduce emissions compared with road or air travel). At the same time, significant GTMP investments in improved road infrastructure would increase demand for road travel.

39. Lack of infrastructure for alternative fuels is an issue that needs to be addressed if take-up of low carbon vehicle technologies (with associated GHG emission savings) is to be accelerated beyond the trajectory achievable by market forces alone. This has already been recognized in other countries where governments have invested to provide such infrastructure. It is also recognized by the European Commission—a directive for the deployment of the alternative fuels infrastructure was adopted in October 2014, requiring EU member states to provide a minimum infrastructure for alternative fuels such as electricity, hydrogen and natural gas, as well as common EU-wide standards for equipment needed and user information.[40] Member States must set and make public their targets and present their national policy frameworks by the end of 2016. At present, Romania has a low level of such infrastructure—there are only 20 electric vehicle charging stations according to the Romanian Electric Vehicle Association (AVER)[41]. This clearly constrains the use of alternative fuel vehicles, even if the number of such vehicles available on the commercial market is growing rapidly.

40. Finally, integrated land use and transport planning in urban areas is a key issue that needs to be addressed if transport emissions are to be minimized in future. Although this aspect is covered under the Bucharest modelling work undertaken by the World Bank urban sector team, it is worth noting that failure to consider land use and transport in an integrated manner in Romania's towns and cities in the future will inevitably lead to unnecessary motorized travel and consequent GHG.

1.9 Structure of the Report

41. Following this introductory chapter, Chapter 2 presents a brief overview of the methodological approach to modelling emissions in the transport sector, a more detailed discussion can be found in Annex 1. Chapter 3 assesses potential interventions aimed at limiting GHG emissions, focusing on pricing instruments, technology, regulatory, and operational efficiency interventions, before turning to urban planning, behavioral change, and zero carbon urban investments. Chapter provides a presentation of the marginal abatement cost curve, the underlying framework for developing the Green and Super Green Scenarios, before providing the final results of the modelling work, comparing business as usual emissions with those from the two modelled scenarios.

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[40] Directive 2014 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the Deployment of Alternative Fuels Infrastructure. See: http://ec.europa.eu/transport/themes/urban/cpt/index_en.htm

[41] www.aver.ro

2 METHODOLOGICAL APPROACH TO MODELLING TRANSPORT EMISSIONS

2.1 Introduction

42. The overall objective of the transport mitigation modelling work was to develop a Green Scenario and an associated Action Plan that would guide the Romanian Government in their decisions on how best to invest in transport-related interventions that would contribute to climate change mitigation. The recommended scenario would take account of GHG benefit, as modelled in the study, and cost to the Government of Romania of alternative interventions, as well as qualitative consideration of co-benefits and implementation issues. A second, more ambitious Super Green Scenario is also developed, in order to assess additional possible efforts, although measures. This chapter will provide a succinct overview of the general approach to GHG emission modelling adopted in the study—further details can be found in Annex 1—before turning to the intervention cost estimation and the marginal abatement cost curve analysis. This sets the stage for the next chapter which provides an assessment of alternative interventions to reduce GHG emissions in the transport sector.

2.2 General Approach to Transport GHG Emission Modelling

43. A fundamental task involved developing a flexible, agile and user-friendly modelling tool that could be used for appraisal of the emission impacts of alternative interventions. Only the direct impact on transport fleet, vehicle activity and energy intensity have been modelled. Second order impacts on the wider economy would require further modelling. TRANSEPT (Transport Strategic Emission Prediction Tool) is an Excel spreadsheet based tool, which draws on data and relationships from a variety of sources, including:

- **National Transport Model (NTM)**: The NTM was developed to appraise a wide range of potential interventions (both infrastructure and policy interventions) within the GTMP study. It has been designed to provide a robust tool for assessment of: (a) national and regional impacts of changes in population and its distribution; (b) national and regional changes in economic activity; (c) strategic inter urban highway schemes; (d) rail infrastructure and service proposals including major investment such as high speed rail; national and regional bus strategy development; and (e) national policy measures such differential pricing for rail and air; internalization of external transport costs; climate change policies (e.g. subsidy of low emission modes); implementation of a road tax; and car ownership and its linkage to level of taxation.

  The NTM includes modelling of both passenger and freight movements, by road, rail, air and inland waterways. It is based on the EMME3 transport planning software platform and has spatially detailed representation of travel demand patterns and transport networks. It has been calibrated using existing data and validated using internationally accepted standards. A number of transport policy interventions have been appraised using the NTM—including GHG impacts assessed using the NTM in conjunction with the TREMOVE emissions module. The NTM can be used directly to model alternative mitigation policy options and provide outputs to TREMOVE that can calculate GHG impacts. Data inputs and outputs from the model runs undertaken within the GTMP study and various modelling reports were used to develop the transport mitigation modelling work.

- **TREMOVE**: The publicly available EU wide policy assessment model, designed to study the effects of different transport and environment policies on the transport sector. The model estimates for technical and non-technical measures and policies such as road pricing, public transport pricing, emission standards, subsidies for cleaner cars etc., the transport demand, modal shifts, vehicle stock renewal and scrappage decisions as well as the emissions of GHG, air pollutants and the welfare level. TREMOVE models both passenger and freight transport. The model covers all inland urban and interurban transport modes - road, rail, water and air transportation, from 1995-2030. Input databases are calibrated to feed the model for 30 countries (EU-28 plus Norway, Switzerland and Turkey).[42]
- **COPERT**. COPERT 4 is a software tool used world-wide to calculate air pollutant and greenhouse gas emissions from road transport.[43] COPERT has been developed for official road transport emission inventory preparation in EEA member countries. The COPERT 4 methodology is part of the EMEP/EEA air pollutant emission inventory guidebook for the calculation of air pollutant emissions and is consistent with the 2006 IPCC Guidelines for the calculation of GHG emissions. The use of a software tool to calculate road transport emissions allows for transparent and standardized, consistent and comparable, data collecting and emissions reporting procedure, in accordance with the requirements of international conventions and protocols and EU legislation.
- **SULTAN**. The SULTAN (**SU**stainab**L**e **T**r**AN**sport) Illustrative Scenarios Tool has been developed as a high-level calculator to help provide indicative estimates of the possible impacts of policy on transport in the EU (primarily energy use and GHG emissions, also costs, energy security, NOx and PM emissions). The purpose of the tool is to allow the quick scoping of a wide range of transport policy options to help get a feel for what scale of action might be required and will also be used as part of the analysis for the final written technical outputs of the project. Many of the core inputs to the TRANSEPT model were taken from SULTAN as the SULTAN emissions forecasting module as part of the model, including the fleet evolution profile (technologies, survival rates), emissions factors, and fuel mix.[44]

[42] For more information visit the website http://www.tremove.org/

[43] The development of COPERT is coordinated by the European Environment Agency (EEA), in the framework of the activities of the European Topic Centre for Air Pollution and Climate Change Mitigation. The European Commission's Joint Research Centre manages the scientific development of the model.

[44] SULTAN was developed as part of the *EU Transport GHG: Routes to 2050 II* project, a 15-month project funded by the European Commission's Directorate General Climate Action that started in January 2011 and was completed in July 2012. The context of the project was the Commission's long-term objective for tackling climate change. Further information can be found at: http://ec.europa.eu/eurostat/about/overview

- **Eurostat data**. Eurostat is the statistical office of the European Union situated in Luxembourg. Its task is to provide the European Union with statistics at European level that enable comparisons between countries and regions.
- **General Transport Master Plan (GTMP)**. The GTMP produced by AECOM for the Romanian Government in October 2014, has formed a key input to the emissions modelling process. The GTMP sets out the investment objectives over the period to 2030. The proposed investment program covers a range of measures including highway infrastructure, rail network extension and enhancement and the upgrading of ports.
- **E-PRTR**. The CO_2 emissions from road transport in the 20 cities in Romania with a population in excess of 100,000 have been estimated using ArcGIS software with the E-PRTR dataset in 2011 at the 5km by 5km grid level. This allowed factoring urban measure impacts to that which would be likely to be achieved with the 20 largest cities appropriate for which urban interventions were considered.

44. The impact of the planned investment as foreseen in the GTMP on travel demand, vehicle activity and implicitly on transport emissions are tested within the NTM which underpins the development of the GTMP. The outputs of the NTM have been utilized within the emissions modelling as the most thorough and robust source of projections for future transport activity, taking account of planned investment. It should be noted however that the NTM outputs are subject to the following constraints:

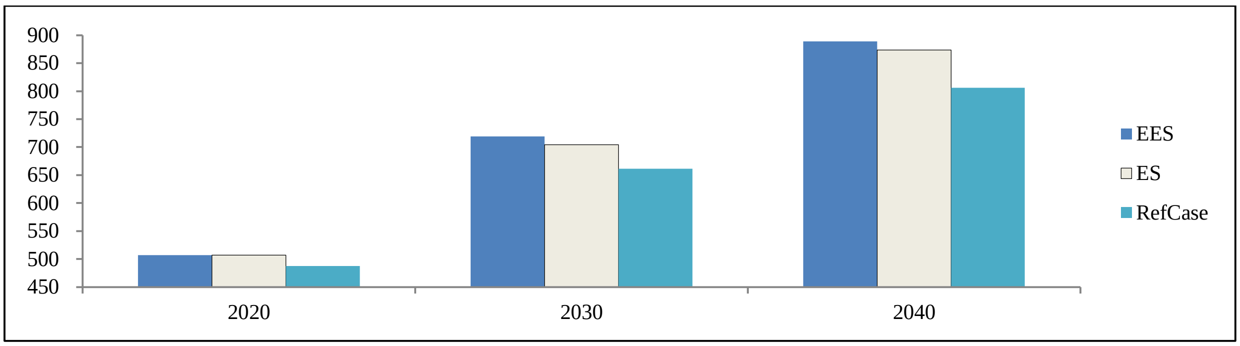
- Only the strategic route network is included within the model. This includes all of the motorways, expressways, major national routes and also the strategic urban routes. However, local urban roads and smaller rural roads are not included within the modelled network. Urban and non-strategic highway network emissions have been calculated based on COPERT vehicle activity data.
- The future year projections cover the period of the GTMP—up to 2030—with a further modelled year of 2040. Beyond 2040 trends must be extrapolated.
- The NTM includes representation of private vehicles, goods vehicles, passenger and freight rail, maritime and air transport. However, travel activity is represented in terms of vehicle-km with no detailed modelling of the characteristics of the vehicle fleet. Hence, the evolution in vehicle fleet technology needs to be derived from other sources (with the exception of rail, for which details of planned investment in new units is provided within the GTMP).

The GTMP sets out two future scenarios, an economically efficient scenario (ES) and an economically and environmentally efficient scenario' (EES), both of which are modelled within the NTM, and a reference case, with slightly different phasing of investments.

45. Figure 24 highlights the increase in forecast vehicle activity under the projected scenarios, driven primarily by investment in improved highway infrastructure which offers increased opportunity to travel, with a marginal difference in trajectory of vehicle activity between the alternative scenarios.

46. For each input required by the model, the available data sources were reviewed, and the most robust data selected to populate the model. The Romania specific COPERT dataset formed the preferred primary data source for existing vehicle stock and vehicle activity, having consistency with the TREMOVE Routes to 2050 modelling work. The NTM represents the most detailed set of projections for future vehicle activity on the Romanian highway, rail and waterways network. SULTAN EU wide data formed a secondary source of data, where Romania specific data was not available. The NTM focuses on the strategic highway network and as such, much of the urban activity taking place on local roads, and activity on small rural roads are not represented in the NTM outputs. To capture this missing activity, COPERT vehicle activity data was used as the reference point for the split of urban, non-urban and expressway activity. This COPERT data estimates the proportion of activity taking place in in urban areas, disaggregated by vehicle type. This split formed the basis for baseline emissions estimates.

Figure 24: Passenger Car Activity (‘000s km)



Sources: TRANSEPT derived from AECOM NTM.

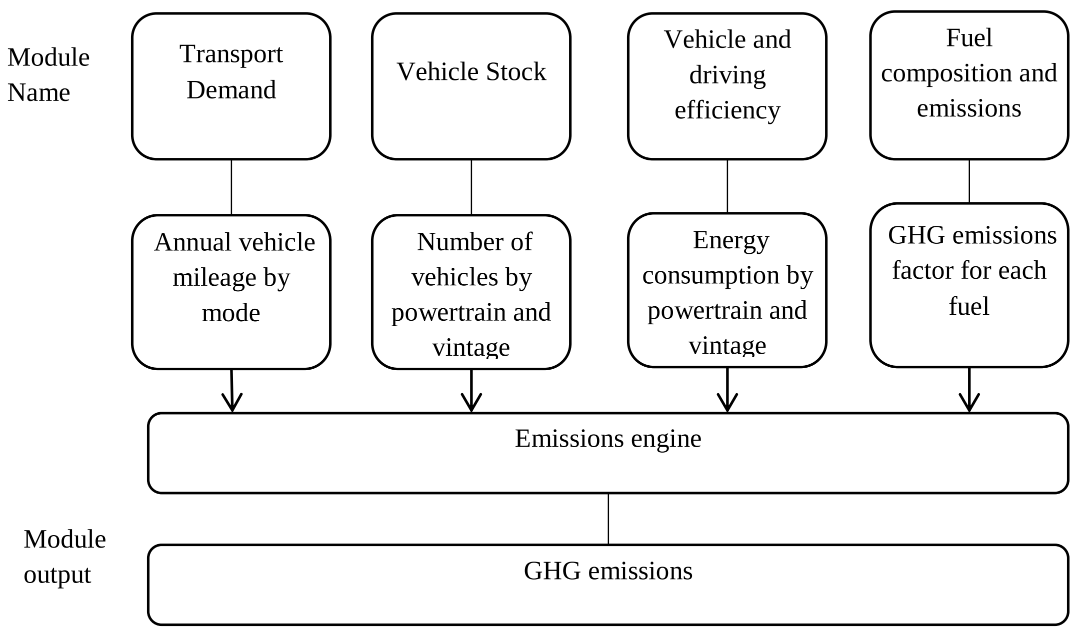
47. In determining the appropriate baseline scenario for the transport emissions model, the merits of the three NTM modelled scenarios were considered. The reference case includes none of the proposed investment and hence represents an unrealistic projection of future travel growth. Given Romania’s objectives of delivering both an economically efficient and environmentally sustainable transport network, the EES scenario and its modelled investment profile has been adopted within the baseline for the emissions modelling. It should be noted that the proposed investments underpinning the EES scenario may only materialize with significant delays and consideration was given to lagging transport demand growth accordingly. However, the development of a hybrid profile to reflect this would require divergence from the wide range of output statistics from the NTM, including vehicle and passenger activity and vehicle speeds across different modes. In practical terms, this was considered to potentially undermine the integrity of the data inputs, and therefore the inclusion of the EES scenario as modelled was adopted as the preferred approach. It should be noted that if implementation of investments falls short of the investment profile proposed within the GTMP, this would likely to lead to *lower* transport emissions across all scenarios. As such, the modelled business as usual (BAU) represents a conservative projection of transport emissions to the upper side.

48. TRANSEPT includes four modules which produce the input matrices for the emissions engine which calculates the GHG emissions. The four modules are: (a) transport demand; (b) vehicle stock; (c) vehicle and driving efficiency; and (d) fuel consumption. Each module takes a number of baseline datasets as

input and applies the effect of relevant policy interventions to them. The adjusted datasets are then input to the emissions engine which calculates the resulting GHG emissions. The process is outlined in Figure 25. The TRANSEPT tool has the following main dimensions:

- It takes account of both direct (tailpipe) and indirect emissions.
- It covers road, rail, waterborne and air travel modes.
- Modes are split into passenger and freight transport.
- Transport activity and consequent emissions are split by urban / non-urban / highway locations.
- Different powertrain and fuel options are modelled as appropriate to each mode.
- Time horizons modelled are 2011 (base year), 2015, 2020, 2025, 2030, 2035, 2040, 2045, 2050.

Figure 26: Overview of TRANSEPT Model Process



Source: World Bank.

The technical detail of the model including the source input data and basis for projections is included in Annex 1. The assessment of potential interventions to reduce GHG emissions from the transport sector were divided into five broad categories: (a) pricing instruments; (b) technology; (c) regulatory; and (d) operational efficiency; and (e) urban planning, behavioral change, and low carbon infrastructure investment. The model is able to forecast the impact on GHG emissions of individual interventions and bundles of interventions, with the synergies between interventions reflected in the abatement results under the scenarios. In other words, the sum of carbon savings from each individual intervention will not match the combined impact under the Green or Super Green Scenario.

49. For all urban measures that are modelled, the intervention is applied to Romania's largest 20 cities, with the exception of urban congestion charging which has been costed for one major scheme in Bucharest, as the only city appropriate for this intervention. For each intervention, the Report summarizes the key issues associated with that intervention in a succinct format, as set out in subsequent sections of this Report. This included the potential GHG emission reduction impacts, the costs involved, and implementation issues. Taken together, this allowed us to reach conclusions on which interventions should be included in the recommended Green Scenario. The TRANSEPT model was then re-run with all the constituent scenario interventions included. To demonstrate the potential impact of adopting the full package of identified measures, a Super Green Scenario was developed, which included all modelled interventions.

50. A large proportion of the population in Romania live in urban areas, with significant transport activity concentrated in these areas accordingly. The COPERT Romania dataset suggests that 44 percent of private road vehicle activity takes place within the urban areas.[45] Whilst the scope of the project does not extend to detailed modelling of individual urban areas, Bucharest is being covered by the Urban Rapid Assessment under Component C, the scale of carbon emissions generated within the urban areas are sizable and therefore form an essential component of national emissions estimates. Urban emissions are therefore included within the baseline at a strategic level, through their inclusion as a single 'urban' area type—that is to say, not broken down to the individual city level. The impact of urban intervention measures are also estimated, based on assessment at the strategic level. Where the applicability of certain policies relate to only the largest cities or only Bucharest (urban congestion charging for example), the relative scale of vehicle activity within these locations is considered in assessing likely scheme impact. This strategic analysis draws on the scale of vehicle activity within the major cities, data related to spatial coverage, population, population density and also from the EU road transport emissions database (E-PRTR data).

2.3 Intervention Cost Estimation

51. In parallel with the emission modelling, broad cost estimates have been calculated for the interventions under consideration. These were prepared at a level of accuracy that is appropriate to the strategic nature of this study, and included both capital costs and operating costs relative to the business-as-usual scenario. Costs considered were costs to Government in implementing the interventions under consideration. Existing knowledge of the potential costs of the interventions was supplemented through further research and investigation as required, including:

[45] COPERT vehicle activity data is broken down by Urban, non-urban and highway.

- Published research and information on the costs of interventions (for example, from EU research projects);
- Consideration of the general level of Romanian cost in comparison to other European countries;
- Cost databases (where appropriate); and
- Cost estimates used in the World Bank's recent Macedonia Mitigation Study.

52. Where schemes generate ongoing revenues, these revenues have not been included within the scheme cost projections. The revenues are typically transfer payments from the private sector, and without inclusion of the corresponding private sector costs—which have been excluded from the analysis—would paint an imbalanced picture of scheme merit.

2.4 Marginal Abatement Cost Analysis

53. A marginal abatement cost (MAC) analysis was made drawing on the emission impact forecasts and the discounted cost estimates over the appraisal period to 2050. This was originally restricted to the policy interventions associated with new transport technology options. This is because, within the transport sector, planning a low carbon development pathway should generally involve more than choosing the options with the largest GHG abatement potential per euro, as this forms a very narrow, one-dimensional view. Outside the area of technological interventions, other transport interventions have impacts in many other key areas such as economic, safety, social and other environmental impacts which may well be larger in magnitude than GHG abatement potential. In order to inform the appraisal of alternative policies for inclusion in the Green Scenario, a high level marginal abatement cost analysis was undertaken to provide a means of comparison. The results of this analysis are also included within the MAC curve reporting, although caveats are made in relation to the unquantified nature of the wider benefits of these schemes.

3 ASSESSMENT OF POTENTIAL INTERVENTIONS

3.1 Introduction

54. A good way of thinking of mechanisms to reduce emissions in the transport sector is the avoid-shift-improve (A-S-I) paradigm, associated with Holger Dalkmann:[46]

(a) **Avoid** growth of CO_2 emissions through urban and interurban development that reduces the need for long-distance travel in passenger vehicles. Singapore is a good example of a coherent and comprehensive set of land use and development policies aimed at reducing the dependence on passenger vehicles, in contrast to the US suburbanization model. This is clearly linked to urban development issues and transport policies developed in response to these.

(b) **Shift** transport to modes with lower emissions, by shifting passenger traffic to buses, rail or metro and freight to rail, and away from passenger vehicles and trucks. Given that cities produce a large share of emissions, this would require developing policies to encourage modal shift from passenger vehicles to mass transit, either to increase the modal share of public transport or to slow down a declining modal share. Increasing the role of rail, particularly for freight, is critical; a successful example that comes to mind is Switzerland.

(c) **Improve** vehicles, fuels and operations in order to mitigation emissions with existing and future vehicles technologies, fuel economy standards, and through traffic management policies.

55. The set of policies aimed at dealing with A-S-I can be broadly considered to be pricing instruments, regulatory, operational efficiency, and investments. Pricing policies, such as the introduction of a congestion charge aimed at encouraging modal shift from passenger vehicles to public transport and non-motorized transport, but could be combined with restrictive parking regulations and investing funds from the congestion charge for improving and extending mass transit. All three sets of policies, pricing, regulatory, and investment decisions are clearly needed, and in practice, it is a whole set of policies, rather than one policy introduced in isolation, which has helped reduce the usage of passenger vehicles in a number of European cities. In what follows a menu of individual policy options is presented, with a greater focus on roads, as this is the sector which generates the most emissions in the transport sector. It goes without saying that greater investments in public transport is needed in order to reduce vehicle use, and this has not been elaborated in this section, as this is embedded into the BAU.

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[46] This chapter draws on Monsalve, Carolina (2013), Controlling Greenhouse Gas Emissions Generated by the Transport Sector in ECA: Policy Options, World Bank Transport Paper TP-40, February 2013. Available at: http://siteresources.worldbank.org/INTTRANSPORT/Resources/336291-1227561426235/5611053-1229359963828/TP40-Final.pdf

56. The range of interventions selected and tested within this study focus on measures which could conceivably be implemented within the period of the climate change Action Plan (2016-2020) or the preparatory studies undertaken to allow implementation by 2030, consistent with the GTMP investment horizon. The impact of the policies extends beyond 2030, with the majority of the modelled interventions continuing to have an impact on vehicle activity and purchasing decisions through to 2050. A focus on policy measures which would not be implementable or appropriate before 2030 was not pursued, as these would not have great relevance to actions which could be taken by the Government of Romania within the action plan period, and the evolving landscape would be likely to undermine the relevance of such long term proposals within the extended timeframe.

57. This chapter begins by reviewing pricing instruments, then turns to regulatory and operational efficiency, and ends with a review of urban planning, behavioral change, and low carbon infrastructure investment. Each potential intervention is described, together with examples from around the world, potential implementation timeframe, information on costs, how the intervention was modelled (where applicable), and likely GHG benefits. With all interventions, implementation was assumed to take place as early as is likely to be feasible in order to maximize benefits.[47]

3.2 Pricing Instruments

58. **Road User Charging (RUC).** When deciding to make a journey a driver will normally consider the costs to him/herself, that is to say the cost of fuel, personal cost if delayed due to heavy traffic, and parking costs, when in fact there are many other associated costs. Road pricing theory argues that the socially optimal amount of transport in total and by mode requires that users be confronted with a price at the point of use that reflects the full social cost of his/her trip at the margin or marginal social cost pricing. Social costs are defined to include private marginal costs (fuel, vehicle maintenance, driver and passenger time for a specific vehicle trip), together with any damage done to the infrastructure, the capital costs of the infrastructure, the impact of exhaust emissions locally, regionally or globally in the form of CO_2 or GHG emissions, and the contribution to congestion, noise, and accidents. Internalizing these costs—adopting the user pays principle—requires making each driver pay for their part of the general costs generated.

[47] No direct intervention was modelled with regard to railways. Enhancements to the rail network are modelled within the GTMP, in terms of extended network coverage and new units to provide greater service levels. If service levels are not achieved then the mode share of the rail system may be expected to continue to decline and ultimately cease to function. Improvements to the rail network are implicit to the business as usual forecasts. Additional measures, not modelled, would focus on ensuring greater commercial orientation in the running of the state-owned rail companies, through for example, the hiring of commercially orientated executives through a best practice international recruitment effort. Individual railway infrastructure projects need to be implemented as part of a holistic package to improve the attractiveness of rail travel (including rolling stock, maintenance, operational efficiency and customer service) on the relevant rail lines. Without such an approach, neither the economic nor the GHG mitigation benefits will be realized.

59. Road pricing can be used as a flexible way of charging people and can help end the idea that one can drive a vehicle without thinking about the external consequences to society. Pricing is critical to reducing GHG emissions and represents one of the key transport policies to reduce demand by raising the relative price of vehicle use to alternative mass transit in cities or other modes outside of urban areas. This section presents a brief overview of some of the pricing policy options available to policy makers wishing to contain the growth of the modal share of vehicles, drawing on international experience. Road user charging can be seen as an alternative to fuel taxation, which is also based on the 'user pays' principle. However, the adoption of road user charging allows greater flexibility and adaptability, for example with differential pricing on particularly congested roads or within cities for example.

60. A policy of making road users pay for their use of the highway network can be an efficient means of internalizing the externality of carbon emissions in addition to contributing to the upkeep of the highways as a public utility. Road user charging can be seen as an alternative to fuel taxation, which is also based on the 'user pays' principle. However, the adoption of road user charging allows greater flexibility and adaptability, for example with differential pricing on particularly congested roads or within cities for example.

61. Extension and enhancement to the motorway network in Romania is forecast to generate increased desire and opportunity to travel, leading to an increase in vehicle km. User charging on the motorway network would allow the gathering of funds to contribute to the maintenance of the network and place some constraint on the growth in travel. Currently, a vignette is payable to permit travel on national roads and expressways in Romania. The cost varies by vehicle weight, and can be bought for periods ranging from one week (daily for HGVs) to one year. The annual cost of the vignette is Euro 28 increasing to Euro 320 for 7.5 ton trucks and Euro 560 for heavier vehicles.

62. Some examples of road user charging are seen in Europe, for example in France in the form of motorway tolls. Tolls have been generally used for specific roads, bridges and tunnels, although increasingly they are being introduced for networks. There are two main types—a closed toll system, where any vehicle entering the facility collects a ticket and pays a graduated fee at the exit point—as occurs in motorways in the EU.[48] The introduction of such a system requires that the road be fully 'closed' so no user can gain access to the road without collecting the ticket and paying the toll. The level of facilities required increases, and the provision of a free alternative route is usually mandated by law. Open road tolling (ORT), also known as free-flow tolling, is the collection of tolls without the use of toll booths. The major advantage is that users are able to drive through the toll plaza at highway speeds without having to slow down to pay the toll. ORT may also reduce congestion at the plazas, and hence GHG emissions, by allowing more vehicles per hour per lane. A disadvantage is the increased risk of violators who do not pay. Collection of tolls on open toll roads is usually conducted through the use of transponders or automatic plate recognition. Both methods aim to eliminate the delay on toll roads by collecting tolls electronically

[48] The introduction of a closed system normally requires the availability of a free alternative route for road users who chose not to use the tolled route.

by debiting the accounts of registered vehicle owners without requiring them to stop. Given the technological requirements, ORT is more expensive and may be appropriate for only some countries in EU-12.

63. Elsewhere, there has been much research into the potential for road user charging, but to date no move has been made to implement such a system beyond the use of certain toll roads. Advancement in technology including the more widespread use of black boxes and in-car advances with GPS technology bring the potential for the implementation of accurate However, at present, the majority of EU countries rely on a combination of road user licensing—for example the vignette—and fuel taxation which provides a progressive means of linking taxation with the level of transport activity. The main area in which fuel taxation is lacking is in the lack of differentiation between the location of the travel activity, and the inability to fully capture the high 'externality' cost of travel activity in certain areas in terms of congestion and local air pollution.

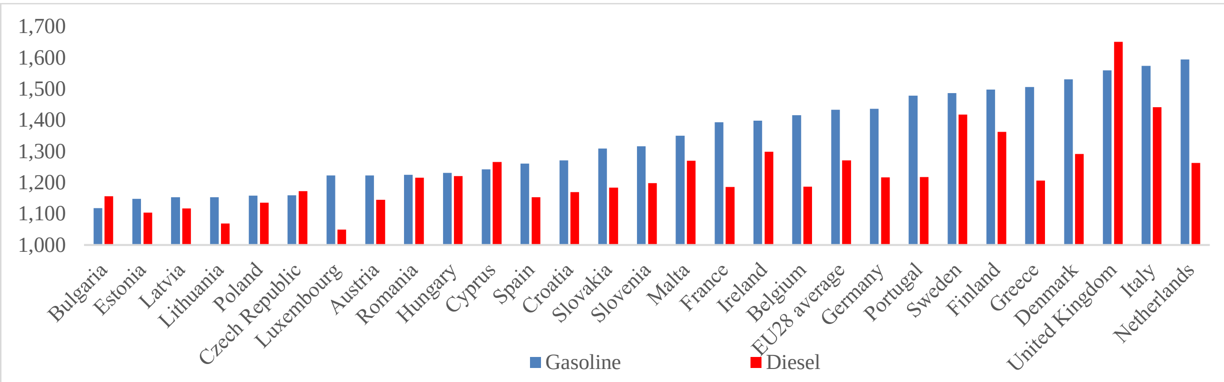
64. The cost of implementation of road user charging would be strongly dependent on the nature of the scheme, with tolling on the expressways requiring different infrastructure to a national road user charging scheme with costs varying according to the location in which travel is made. As technology advances however, the feasibility of intelligent road user charging increases, and the cost of implementation is likely to fall. Nevertheless, infrastructure costs of such a scheme are likely to remain significant, in terms of the technological equipment necessary to accurately collect travel movements and the back office infrastructure to support invoicing and payments. Given the existing mechanism of fuel taxation already in place, the use of this lever to bring about similar impacts to road user pricing at much lower cost would suggest that in the short to medium term, any move towards greater taxation of travel activity should be focus on this. Consequently, modelling efforts have been focused on the fuel taxation level in preference to national road user charging.

65. **Fuel Taxation**. Fuel pricing is a particularly effective policy instrument in that it can discourage vehicle usage—although this is a function of the short, medium, and long-term price elasticity of demand—and encourage the purchase of more fuel-efficient vehicles, thereby reducing vehicle-fuel intensity. Fuel taxes are relatively inexpensive to collect, easy to administer and reasonably equitable, since the charge is broadly proportional to road use. They do not however discriminate between road type, location of the road, or time of usage. On the latter point, this means that fuel taxes cannot tackle the issue of high externalities associated with congestion in peak traffic times. Another weakness is that they do not fully reflect the additional damage done and road space demanded by heavy vehicles. For this reason, fuel taxes are frequently supplemented by additional charges on heavy vehicles. Taxes on fuel are also used by governments for other purposes such as restraining fuel consumption or more commonly raising revenues for the budget, reflecting weaknesses in revenue collection in developing and emerging economies.

66. All EU member states levy excise duty on fuel. The fuel price payable is hence a combination of the cost price of fuel in each nation state, and the level of taxation on that fuel. The level of the duty is set nationally, but is subject to minimum levels as set by the EU. Most EU countries levy fuel duty rates well

in excess of the EU minimum. Until 2014, Romania's fuel duty rate was one of the lowest in EU at 32 euro cents /liter for diesel and 35 euro cents/liter for gasoline, but in April 2014, an increase in the fuel duty amounting to 7 euro cents/liter was applied. Increasing fuel taxes remains an option for Romania, although issues of affordability need to be taken into account when considering fuel tax rises. Nevertheless, gasoline and diesel prices remain significantly below the EU-28 average, using April 2015 data (Figure 27).

Figure 27: Gasoline and Oil Prices as of April 13, 2015 (Euros per 1,000 liters)



Source: European Commission[49]

67. *Modelling approach used and GHG benefits.* Adopting the proposal of increased fuel taxation would be rapidly implementable, given the existing structures in place. The intervention has been modelled an increase in fuel taxation, leading to a 10 percent overall increase in fuel prices. At current prices, this amounts to an increase of around 12.5 cents/liter (including VAT) on petrol and diesel. Evidence of fuel price elasticities, suggest values of -0.15 in the short term and -0.3 in the long term, an increase on this scale will be expected to lead to a reduction in km travelled in the order of 3 percent over the longer term.[50] One would also expect second order effects in terms of a move towards more efficient vehicles in response to the higher fuel prices. A 5 percent increase in fuel price has been modelled for 2020 which increases to 10 percent in 2025 where it remains till 2050. Application of the 30 percent elasticity results in a 3 percent reduction in trips in the long term for vehicles which use either gasoline or diesel. The profile of annual GHG emission savings to 2050 is presented below when the policy is applied as part of the Green

[49] https://ec.europa.eu/energy/sites/ener/files/documents/2015_04_13_with_taxes_1747.pdf

[50] *Unit elasticity* refers to a 1.0 absolute value (1.0 or -1.0) elasticity, meaning that price changes cause proportional consumption changes. Elasticities of less than 1.0 absolute value are called *inelastic*, meaning that prices cause less than proportional consumption changes. Elasticity values greater than 1.0 absolute value are called *elastic*, meaning that price changes cause more than proportional consumption changes. As normally measured, vehicle travel is considered *inelastic*, meaning that changes in fuel, parking and road toll prices generally cause proportionately smaller changes in mileage and fuel consumption, but this reflects the way these impacts are measured. People often focus on short-run (within a year) impacts, which are typically only a third of long-run effects. See Todd Litman (2012), Changing Vehicle Travel Price Sensitivities, *The Rebounding Rebound Effect,* Victoria Transport Policy Institute, 10 September 2012. Available at: http://www.vtpi.org/VMT_Elasticities.pdf. Analysis conducted as part of the NTM work in Romania found an elasticity of fuel price increase of -0.29, which is within the range found elsewhere.

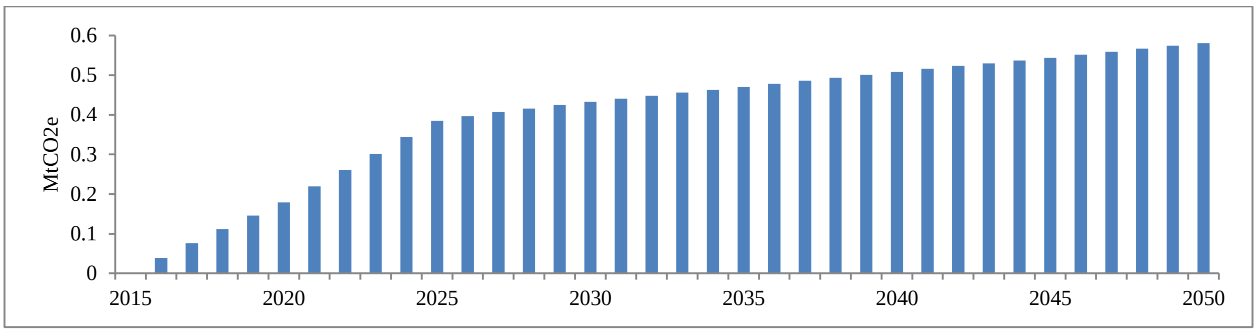
Scenario package of measures. The policy reduces annual GHG emissions by 0.4 $MtCO_2e$ by 2025 and 0.6 $MtCO_2e$ by 2050. The main barrier to implementation would be political. In 2014, a fuel tax increase of 7 euro cents was enacted despite strong opposition.

Table 7: Summary of Modelling Approach – Fuel Price Taxation

	Modelling Approach
Policy	10% increase in gross fuel prices (petrol and diesel)
Implementation timeframe	10% increase by 2025, with ramp up from 0% in 2015 through 5% in 2020
Vehicles Affected	All petrol and diesel vehicles
Geographical Areas/Road Types affected	All areas and road types
Impact	Reduction in trips
Mechanism	Elasticity response to fuel price changes -0.3%

Source: World Bank.

Figure 28: GHG Emissions Savings – Fuel Prices



Source: TRANSEPT.

68. **Vehicle scrappage scheme**. Romania has had a vehicle scrappage scheme in place since 2005, known as the '*Rabla*' (clunkers) scheme. This has seen the scrapping of approaching 500,000 ageing and high-polluting vehicles, and the subsidized purchase of around 250,000 more efficient vehicles. Uptake of the scrappage scheme peaked in 2010, with almost 190,000 cars scrapped, and has since fallen to much lower levels (c. 20,000). Whilst the impact of the scrappage scheme to date on vehicle fleet age and characteristics are reflected in the baseline emissions forecasts, the business as usual scenario projects an evolution in vehicle fleet which does not reflect a return to the high levels of new vehicle purchase achieved by the scrappage scheme in its top performing years.

69. The objective of the scrappage scheme is to encourage the removal of the oldest and highest polluting vehicles from the fleet, and the purchase of new lesser polluting models. The intervention considered focuses on a renewed and re-invigorated scrappage scheme which adopts more stringent standards and greater generosity in the level of subsidy for the purchase of the most efficient vehicles. The rate of the incentive for vehicle scrappage is proposed to be increased to 7,500 lei (Euro 1,700), which represents an increase of 1000 lei from the 6,500 lei in recent years (originally 3500 lei). The scrappage vouchers remain transferable and 'stackable' as under the existing scheme, with the criteria for eligible

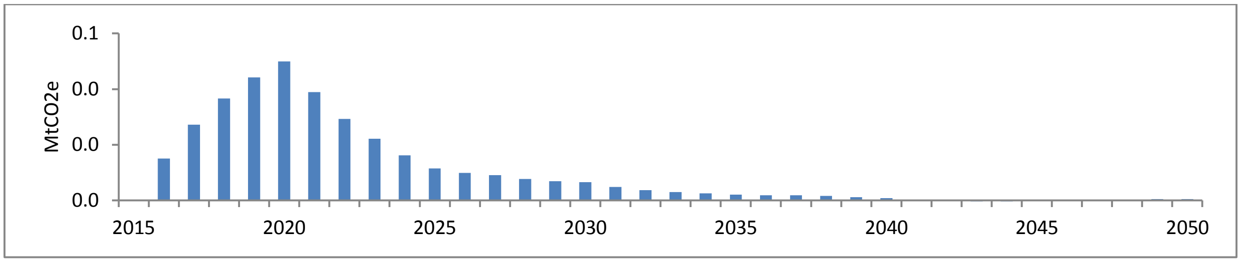
vehicles also remaining the same (over 8 years old as of 2014). However, the level of the emissions requirements are tightened to achieve a new vehicle purchase average emissions level of 120g/km.

70. Romania is already familiar with the benefits and impacts which a scrappage program can bring, with evidence collected from the historical scheme. There are many other examples of successful scrappage schemes, with other European countries including Germany, Austria, France and the UK. The level of the incentive is an important aspect of the scrappage program. Only vehicles with a lesser value than the incentive may be expected to be scrapped. The conditions attached to the vehicles eligible for scrapping and also those which may be purchased with the vouchers are also important determinants of the overall impact as regards emissions reduction. The value of scrappage scheme incentives typically ranged from Euro 1,000 to Euro 2,500 for European schemes. As such, the proposed 7500 lei (Euro 1,700) is in line with other schemes, with the increase over previous years' values reflective of the tightening conditions regarding the emissions standards of the new vehicle purchased.

71. *Costs.* The cost of the scheme has been estimated based on historical scheme costs, increased to reflect the higher level of the incentive. A take-up rate of 100,000 vehicles scrapped over the course of 5 years (20,000 in each year) has been adopted as the scheme target, based on the average annual scrappage rate achieved under the historical scheme. The total cost of the scheme is estimated to be Euro 177.5 million. Note that this is the full cost of the program rather than the net cost of the increased incentive value. Accordingly, the full impact of the scheme carbon savings are quantified against the counterfactual of the scrappage scheme drawing to an end.

72. *Modelling approach used and GHG benefits.* Ageing vehicles fitting within the scrappage criteria are removed from the vehicle fleet. It is assumed that the target number of vehicles to be scrapped are achieved over the five years of the modelled scheme period of the current program, 2016 to 2020. These vehicles are replaced by new vehicles meeting the emissions standards required, at a rate of one new vehicle to two scrapped vehicles, based on the historical ratio of new to old vehicles (more than one scrappage voucher can be used towards the purchase of a new vehicle). Older vehicles which are scrapped may be expected to have a lower utilization rate, in terms of annual km travelled, than new vehicles. This is reflected in the modelling, taking typical usage rates according to age as featuring in the fleet model. In practice, scrappage schemes typically lead to the advancement of anticipated purchasing decisions and therefore the impact relates to the quickening of fleet turnover compared to the natural rate of evolution under the counter-factual. New vehicles purchased under the scrappage scheme are subject to the same survival rates as other vehicles of the same vintage, and therefore fleet evolution continues to be affected beyond the period of the scrappage scheme. The annual GHG emission savings are presented below. Overall the scheme has a minimal impact, attaining a maximum annual saving of 0.1 $MtCO_2e$ in 2020. However due to the nature of the scrappage scheme the impacts reduce over time. The mechanisms for implementing the scrappage scheme are well set up and have undergone a number of revisions during the life of the current scheme. Therefore, a reinvigorated scheme supported by increased funding is not seen to present any significant technical barriers.

Figure 29: GHG Emissions Savings – Vehicle Scrappage Scheme



Source: World Bank.

73. **New Vehicle Registration Tax (Environmental Stamp)**. Romania currently has an 'Environment Stamp' tax on new vehicle registrations, introduced in 2013 as an evolution from the pollution tax which was deemed illegal under EU law. The Environment Stamp is levied under according to a vehicle's Euro standard, CO_2 emissions, engine displacement, with a discount rate applied depending on the age of the vehicle being registered. The amendment to the system from the pollution tax means that older vehicles receive a significant discount to newer vehicles and that non-Euro standard vehicles and Euro 1 and 2 vehicles would pay less than under the previous system. In its present form, the cost of registration falls for registering older vehicles, even if these are higher polluting vehicles. It is proposed that the rates payable under the Environmental Stamp be reviewed and the potential for greater encouragement to purchase more efficient lower polluting models be explored. Most European countries charge a vehicle registration tax based on CO_2 emissions, Euro standard or engine displacement. A gradual pre-announced increase in the levy payable for registration of the most polluting cars has been a means of influencing purchasing decisions. In the UK for example, the following rates (please see Table 8) are payable on first registration of a vehicle, demonstrating the significant fiscal penalty applied for the purchase of higher polluting models.[51]

Table 8: First Year Vehicle Registration Tax Rates UK

CO2 emission (g/km)	First Year Registration Tax	
	£	EUR
Up to 100	£0.00	€ 0.00
101-110	£0.00	€ 0.00
111-120	£0.00	€ 0.00
121-130	£0.00	€ 0.00
131-140	£130.00	€ 175.50
141-150	£145.00	€ 195.75
151-165	£180.00	€ 243.00
166-175	£290.00	€ 391.50
176-185	£345.00	€ 465.75
186-200	£485.00	€ 654.75
201-225	£635.00	€ 857.25
226-255	£860.00	€ 1,161.00
Over 255	£1,090.00	€ 1,471.50

Source: UK Government.[52]

[51] Note that after the first year, an annual road tax is levied. This is also a progressive tax related to the CO2 emissions of the vehicle, but the scale of the annual payment for the highest polluting vehicles reaches a maximum of £500 (Euro 675)

[52] See https://www.gov.uk/vehicle-tax-rate-tables

74. Given the existence in Romania of a first year registration tax, the regulatory framework is already broadly in place. As such, the cost of making changes to the rates payable under the scheme would be negligible. In terms of wider costs to society, it is assumed that the change to tax rates is fiscally neutral so that higher taxes for high polluting vehicles are offset by lower taxes for more efficient vehicles. As the Environment Stamp rates are subject to regular review, changes to the rates payable could be quickly implemented and able to influence the purchasing decisions of motorists within the Action Plan period.

75. *Modelling approach used and GHG benefits*. The modelled intervention relates to evolution in the Environment Stamp at a rate greater than the natural evolution in fleet technology within the BAU scenario to further incentivize the adoption of clean vehicle technologies. The adjustments to the scheme have been modelled to lead to increased trajectory in greener vehicle technology uptake, with new trajectories taken from the "EU Transport GHG: Routes to 2050 work". The policy is applied to the purchase of new cars from the years 2016 onwards as a shift in the powertrain of new vehicles purchased from gasoline and diesel to plug-in hybrid electric vehicle (PHEV) gasoline, PHEV diesel and electric vehicles (EV). The size of the shift is presented in the table below. This is shared between PHEV gasoline, PHEV diesel and EV by the following respective shares, 29 percent, 29 percent and 43 percent. The annual GHG emission savings are presented in the graph below when the policy is applied as part of the Green package of measures. By 2050 the policy saves 0.6 $MtCO_2e$. Although the policy is applied in 2020, interpolation from 2015 to 2020 presents the policy as if it were ramped up from 2015 to 2020.

Table 9: Assumptions Concerning Shift Away from Gas and Diesel Vehicles

	2020	2025	2030	2035	2040	2045	2050
Gasoline	-2.3%	-4.0%	-5.8%	-6.9%	-8.0%	-11.5%	-15.0%
Diesel	-1.0%	-1.8%	-2.4%	-2.7%	-3.0%	-4.5%	-6.0%

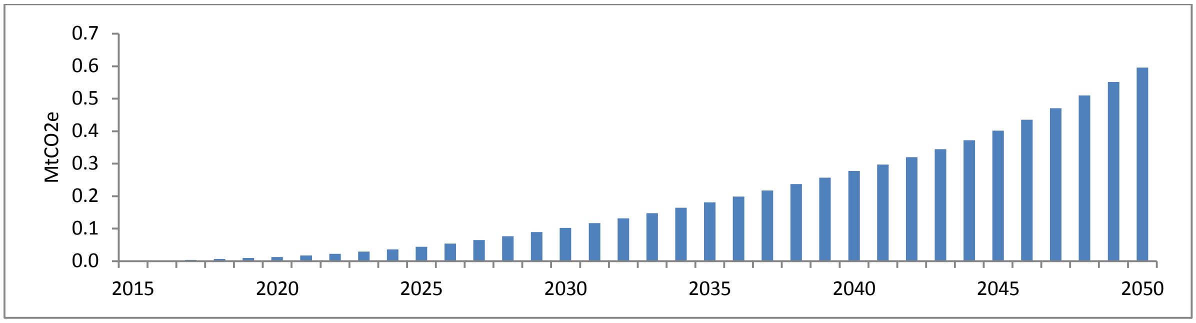
Source: Europe Transport GHG: routes to 2050 Work, TRANSEPT.

Table 10: Summary of Modelling Approach – New Vehicle Registration Tax

	Modelling Approach
Policy	Review of the new vehicle registration tax (Environmental Stamp) rates to promote a shift to low emitting vehicles
Implementation timeframe	2016
Vehicles Affected	Cars
Geographical Areas/Road Types affected	All areas and road types
Impact/Mechanism	Shift in the powertrain of new vehicles purchased from gasoline and diesel to PHEV gasoline, PHEV diesel and EV through the adjustment of new vehicle purchasing profiles.

Source: World Bank.

Figure 30: GHG Emissions Savings – New Vehicle Registration Tax



Source: World Bank.

76. The main barrier to significant change in the first registration tax regime is likely to be political. The previous pollution tax was disliked due to the additional burden it placed on the purchase of older vehicles, and was ultimately overturned leading to the new Environment Tax scheme.

77. **Parking pricing**. One pricing mechanism to discourage using vehicles is adopting a policy of high parking pricing, particularly if parking is expensive in relation to mass transit public transport. An annual survey on daily parking rates shows that Bucharest's parking fees are quite low compared to other EU-12 cities, although this information is dated and the picture may be slightly different now (

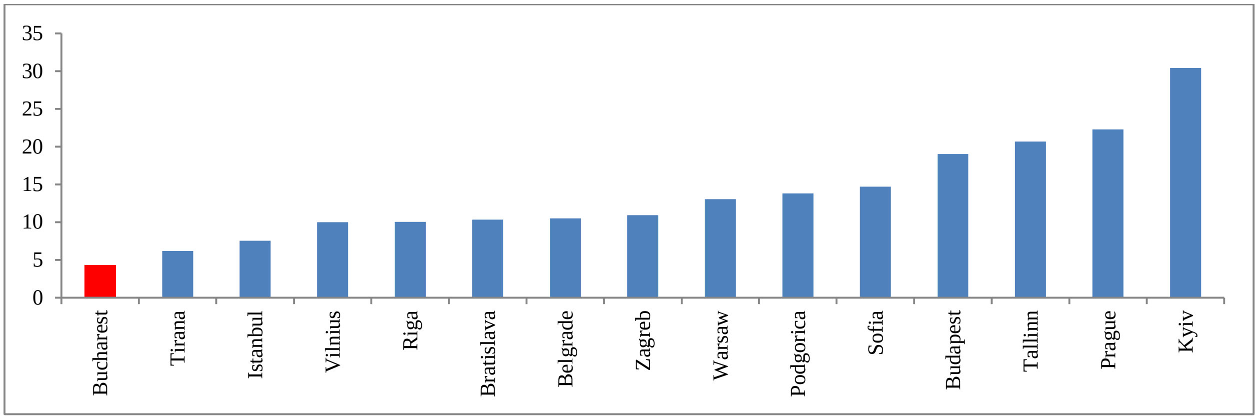
78. Figure 31).[53] In the EU, changing parking policies are part of larger goals, such as complying with air quality standards or reducing GHG emissions. While London and Stockholm and a few other cities have introduced congestion charging, this has not spread widely, whereas charging for parking is widespread, and thus raising rates would be relatively straightforward.[54] Parking pricing also represents a source of potential revenue for the authority through the control of public parking provision.

79. The use of parking charges as a means of demand management is well established and can be an effective means of promoting modal shift to more sustainable travel such as by public transport or walking and cycling. Parking charging is fundamentally an urban measure, and can be flexibly applied in ways to influence different categories of user whilst minimizing the economic impact for commerce. The intervention considered here does not relate to significant increases in parking charges but a widening of the control of parking within the urban areas, and a reduction in the proportion of free on-street parking. The policy is focused on the 20 largest conurbations, with the increase in the proportion of paid parking intended to discourage private vehicle usage and promote modal shift.

[53] A critical aspect in Bucharest is enforcement of parking regulations—cars occupy sidewalks, forcing pedestrians on to streets. Enforcement of parking regulations and recovery of penalties are essential steps, in addition to higher parking pricing.

[54] Parking pricing policies are usually complemented with policies aimed at controlling the growth of parking spaces.

Figure 31: Daily Parking Rate (US dollars)[55]



Source: Colliers International (2011), Global/Central Business District Parking Rate Survey.

80. Parking charges are widely used as a means of demand management in cities across Europe. Best practice examples typically combine the disincentive of high parking charges with an effective and efficient public transport system, good walking and cycling facilities and other travel options such as Park and Ride. Those which achieve the highest rates of modal shift are the cities perceived to be non-car friendly, and for which the thought of talking the car into the city is considered to be more challenging than the alternative options. Examples of such cities include most of the capital European cities. ITDP has reviewed case studies of parking best practice in Europe and sets out the key principals and conclusions in its report 'Europe's Parking U-Turn.[56] It highlights the experience in Paris, where on-street parking supply has been reduced by over 9 percent since 2003, and of the remaining stock, 95 percent is paid parking. The result, along with other transport infrastructure improvements, has been a 13 percent decrease in driving.

81. In Bucharest, there are both public and private parking facilities in addition to free on street parking. The extension of paid-for parking across the city will require the implementation of new parking regulations to the on-street parking within the main conurbations, and the need for stronger enforcement. Other major cities will have varying levels of parking provision. The necessary signage and road markings constitute the main capital costs. An allowance of Euro 2.5 million is estimated in order to cover the associated capital costs in the major conurbations.[57] Increase in enforcement personnel and parking fee collection requirements would be funded by increased revenue generated by the wider measures.

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[55] Available at:
http://downtownhouston.org/site_media/uploads/attachments/2011-07-19/Colliers_International_Global_Parking_Rate_Survey_2011.pdf

[56] Europe's Parking U-Turn: From Accommodation to Regulation, ITDP, 2011. Available at:
https://www.itdp.org/wp-content/uploads/2014/12/Euro-Parking-Fact-Sheet.pdf

[57] The largest cities already have in place payment machines within the city centres. Therefore the investment is incremental through widening the coverage, but also tightening up enforcement of existing provision/facilities

82. *Modelling approach used and GHG benefits*. The modelling of the parking charges has been applied to urban trips in the major urban areas (top 20 cities). The experience of Paris identified a 9 percent reduction in car trips, whilst Munich saw a 14 percent reduction in car trips within the inner city resulting from a combination of traffic demand measures which in addition to the parking management measures included improving cycling infrastructure and enhancing public transport. The parking management measures have been assumed to result in a reduction in urban car trips of 5 percent—the urban areas have not been modelled separately in this study. However, the impact of the policy is felt incrementally, firstly achieving a reduction in car trips of 2.5 percent in 2020, 3.75 percent in 2025 and finally 5 percent by 2030. The annual GHG emission savings are presented in the graph below when the policy is part of the Green package of measures, achieving a maximum reduction in annual GHG emission savings of 0.07MtCO_2e in 2030. The savings decline thereafter to the year 2050 as other policies act to reduce the car mode share in urban areas.

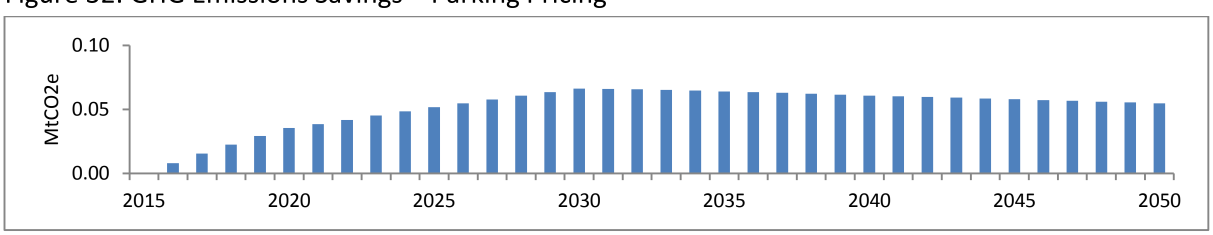
83. Parking charges remain a contentious issue with city residents and commerce alike. The benefits of an effective and strong parking policy are often not universally recognized, particularly by those who are subject to penalty under the necessary enforcement measures. The revenue generation potential for authorities under the extended parking charge scheme offers an opportunity to mitigate against the impacts, for example by ring-fencing funding for the provision of improved walking and cycling infrastructure, enhanced public transport provision and an improved cityscape environment.

Table 11: Summary of Modelling Approach – New Vehicle Registration Tax

	Modelling Approach
Policy	Implementation of parking charges in Bucharest and other major cities
Implementation timeframe	Full implementation in 2030 with ramp up from 2015
Vehicles Affected	Cars
Geographical Areas/Road Types affected	Urban
Impact/Mechanism	Reduction urban trips made by car of 2.5% in 2020, 3.75% in 2025 and 5% in 2030 and beyond.

Source: World Bank.

Figure 32: GHG Emissions Savings – Parking Pricing



Source: TRANSEPT.

84. **Urban Congestion Pricing**. This a system of charging users of a transport network to reduce traffic congestion. The application on urban roads is limited to a small number of cities, including London, Stockholm, Singapore, and Milan. The London Congestion Charge is a fee paid by drivers travelling within the Congestion Charge Zone and as its name suggests was introduced with the aim of reducing congestion,

as well as raise investment funds for London's transport system.[58] The charge, standing currently at GBP 11.50 (Euro 16) generates significant revenues. During the first decade of the scheme, criticism was made of the high proportion of the revenues taken up by operating costs. However, increases in the level of the charge, and reductions in operating costs have occurred, due to the reduction in marketing and awareness campaigns required with the maturing of the scheme mean that the operating costs have gone down as a proportion of generated revenues. Implementing a congestion charging scheme can involve significant capital costs and also ongoing operational costs. The scale of these costs are dependent on the nature of the scheme and the technology adopted in the collection and monitoring of the charge. There are however revenues generated by the scheme which should outweigh the cost of operation.

85. The infrastructure costs involved in implementing the London Congestion Charge were estimated to be GBP 197million in 2007 market prices (Euro 340 million in 2015 prices). An indicative infrastructure cost estimate of Euro 150m is provisioned, based on the London experience, but accounting for falling cost of the technology to implement the scheme. Ongoing operating costs of the scheme are estimated to be Euro 50 million per annum. Whilst these would be covered by the expected scheme revenue, only infrastructure and operating and maintenance costs are included within the MAC analysis as the scheme revenues represent a transfer payment from motorists.

86. *Modelling approach used and GHG benefits*. The model has assumed that this policy reduces urban car trips in urban areas by 5 percent when fully implemented. The policy is scheduled to come into full effect in 2025, however a ramp-up during 2020 to 2025 has been modelled. The annual GHG emission savings are presented in the figure below when the policy is implemented as part of the Super-Green package of measures. The policy reduces GHG emissions by 0.14MtCO_2e by 2050.

Table 12: Summary of Modelling Approach – Urban Congestion Pricing

	Modelling Approach
Policy	Urban Congestion Charging implemented in Bucharest and other major cities
Implementation timeframe	Full implementation in 2025 with ramp up from 2020
Vehicles Affected	Cars

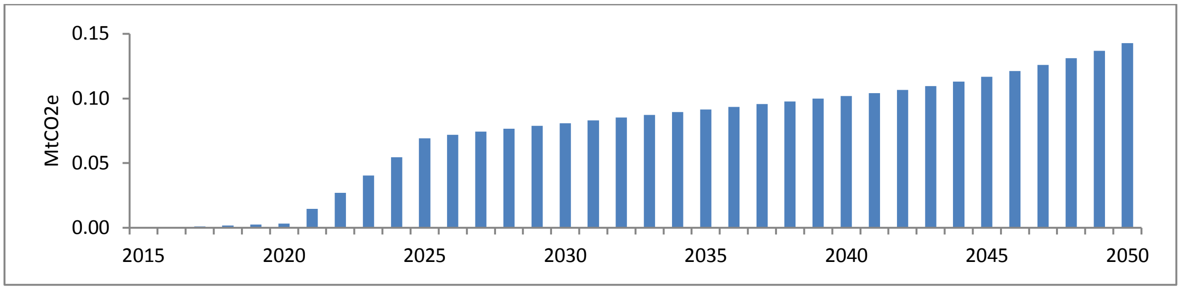
[58] The zone was introduced in central London in February 2003, and extended into parts of west London in February 2007, although this was discontinued in 2008. The 2007 report prepared by Transport for London found that traffic entering the charging zone was 21 percent lower than in 2002, creating opportunities over this period for re-use of a proportion of the road space made available. Reduced levels of traffic mean that when compared to conditions without the scheme congestion charging continued to deliver congestion relief that was broadly in line with the 30 percent reduction achieved in the first year of operation. Congestion charging was also estimated to have led directly to reductions of about 16 percent in CO_2 emissions from traffic within the charging zone over 2002-2003, these more directly reflecting the overall traffic reductions and efficiency gains. Over the post-charging period 2003-2006, vehicle fleet improvements are estimated to have reduced emissions from road traffic, both within the central London charging zone and more widely, by 17 percent for NO_x, 24 percent for PM_{10} and 3 percent for CO_2, assuming a stable traffic mix. In terms of revenues and costs, over 2006-2007, the London Congestion Charge generated GBP 213 million in total revenues, compared to total operating and administrative costs of GBP 90 million, with revenues used for upgrades to bus infrastructure and operations.

Geographical Areas/Road Types affected	Urban
Impact/Mechanism	Reduction urban trips made by car of 5%

Source: World Bank.

87. The main barriers to implementation of a congestion charging scheme are political and technical. Many cities have concluded that the positive benefits which congestion charging may bring about can more cost effectively be delivered through the use of parking restrictions and increasing parking charges. As parking charging is already in place in the majority of cities, this intervention can be delivered at much lower cost whilst leading to similar impacts.

Figure 33: GHG Emissions Savings – Urban Congestion Charging



Source: TRANSEPT.

88. **Aviation Travel Tax**. A number of countries in the EU apply aviation taxes to travelers on short and long haul flights departing from the country. These are variously identified as a civil aviation tax, airport tax, luxury tax or air passenger duty. In certain cases the tax is related to a particular impact such as the tax on air transport noise pollution in France. Romania currently has no airport departure tax. The emissions from aviation make up a small proportion of overall emissions in the transport sector but are projected to increase in absolute terms over time at a slightly faster rate than overall travel activity. Applying a departure tax to those travelling domestically or internationally would provide a stream of revenue and may be expected to lead to suppression in the growth of air travel, which as one of the most polluting forms of travel on a per-km basis, would contribute to the low carbon scenario. The table below shows the rate of duty applicable in selected EU countries. The introduction of a departure tax at the rates observed in Austria and Germany would generate significant revenues from 10 million or more passengers each year travelling from airports in Romania.

Table 13: Air Passenger Duty in Selected EU Countries (Euro, 2014)

	Short Haul	**Medium Haul**	**Long Haul**
Austria	7	15	35
Bosnia	12		
Germany	7.50	23.43	42.18

Source: EBAA[59]

[59] http://www.ebaa.org/documents/document/20140116101401-aviation_taxes_in_europe_-_a_snapshot_jan_2014.pdf

89. The cost of collection of the air passenger duty would depend on the mechanism and could either be collected at the airport or as a supplement on the airline ticket. A capital cost of Euro 1 million is allowed as the setup costs across the major airports in Romania as well as office back up costs for processing the tax. Ongoing collection costs of Euro 150,000 per annum are allowed for. The ongoing cost of collection would be far outweighed by the revenue generated by the departure tax which would be expected to be in the order of Euro 125 million per annum, increasing in line with ticket price inflation. This revenue is not included within the marginal abatement cost analysis as it is a transfer payment. The tax could be rapidly implemented, following the necessary impact assessment, and could be in effect within the Action Plan period. No barriers to implementation are expected, except pressure from airlines and regular travelers.

90. *Modelling approach used and GHG benefits*. An elasticity based approach has been used to model the impact of the tax. The departure tax has been modelled as a 5 percent increase to the fare paid for a return journey, noting that the tax only applies to outbound flights. Price elasticity information was derived from IATA's Air Travel Demand Briefing.[60] The policy was modelled to be implemented in 2020. The resulting impact is a reduction in EU aviation trips of 6 percent and 4.5 percent reduction in International aviation trips. The policy has been applied from 2020, however interpolation between the years 2015 and 2020 present the policy as ramping up between these years. The annual GHG emission savings are presented in the figure below when the policy is implemented as part of the Green package of measures. Annual savings of 0.1 MtCO2e are forecast by 2050.

Table 14: Summary of Modelling Approach – Air Travel Taxation

	Modelling Approach
Policy	Introduction of an Air Travel Duty on international travel
Implementation timeframe	Full implementation in 2020 with ramp up from 2015
Vehicles Affected	EU and International Aviation
Geographical Areas/Road Types affected	All
Impact/Mechanism	Reduction EU aviation trips of 6% and international aviation of 4.5%

Source: World Bank.

3.3 Technology

91. This section covers a number of interventions that have the potential to reduce carbon emissions from the adoption of new more efficient technologies, including vehicle engine technologies and alternative fuels. The encouragement of the more rapid adoption of new vehicle technologies is an objective of many of the market based interventions and also on the regulation side. The potential for the government to promote and encourage the uptake of more efficient technologies beyond fiscal or regulatory measures is considered. The following interventions are considered:

[60] https://www.iata.org/whatwedo/Documents/economics/air_travel_demand.pdf

- Roll-out of an electric charging network to support the uptake of electric and plug in hybrid electric vehicles;
- Adoption of ultra-low emissions vehicles within the public sector vehicle fleet; and
- Introduction of electric vehicles into the public transport vehicle fleet

92. **Electric Vehicle Charging Network**. The vehicle fleet in Romania is older and less efficient than elsewhere in Europe. The scrappage scheme has encouraged the purchase of newer vehicles, and further incentives have been put in place to entice the purchase of the least polluting models. However, the adoption of ultra-low emissions vehicles (ULEVs) such as electric vehicles (EVs), hybrid vehicles and plug in hybrid electric vehicles (PHEV) is lagging behind that observed in other countries, and particularly those which have in place programs to strongly promote and invest in supporting infrastructure for these alternative technologies.

93. In 2014 just 7 electric or hybrid electric vehicles were registered in Romania. By comparison, a total of over 75,000 electric vehicles (all electric, range extender electric and plug in hybrid electric vehicles) were registered across the EU. A factor likely to hamper the uptake of EV/PHEV vehicle technology is the lack of public charging infrastructure. Investment in a rapid charging network which focuses on the major urban areas and charging points interspersed across the strategic highway network would facilitate much greater potential for the usage of electric vehicles. This intervention considers the investment required to roll out a national charging network to complement the fiscal and regulatory measures which encourage the take-up of electric vehicles.

94. As well as early adopter countries such as Norway and Holland, there has been recent examples of successful investment programs in other countries designed to boost uptake of alternative fueled vehicles. Estonia has become the first country to install a nationwide fast charging network for electric vehicles. A network of 165 rapid charging posts have been located in urban areas with more than 5,000 inhabitants and on major roads throughout the country. These 50kW DC rapid charging posts have the ability to charge vehicles in around 30 minutes as compared to 8-10 hours for conventional 3.3kW charging points. The deal was financed through the sale of 10 million surplus CO_2 emission permits to Japan's Mitsubishi Corporation. This deal also included the provision of a fleet of 500 electric vehicles for use by the public authorities to help kick-start EV usage, and also the funding for EV subsidies for private purchasers.

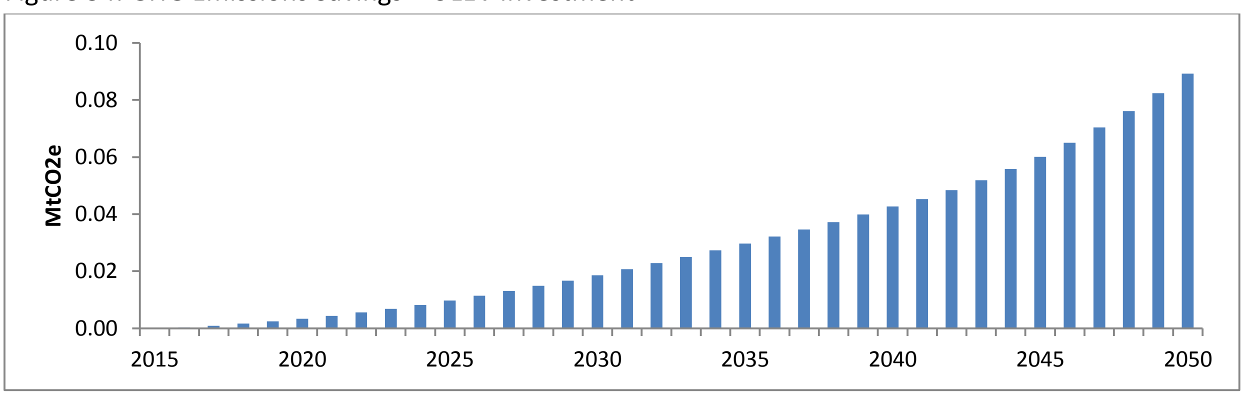
95. The modelled intervention takes costs from infrastructure roll-outs in Estonia and OLEV in UK to estimate the cost of provision of strategic charging network. The costs are based on the installation of a network of 500 rapid charging points in major conurbations and on the strategic highway network throughout Romania, at a cost of Euro 50,000 each. In addition, a subsidy for up to 50,000 home charging points has been costed, at a unit rate of Euro 3,500, reflecting the potential rate of electric vehicle take-up given a concerted investment program. The ongoing costs in terms of electricity are assumed to be funded by user charging tariffs/subscriptions. However, the maintenance of the charging points has been allowed for in ongoing operations and maintenance costs as experience has demonstrated that inclusion

of these costs in user charging rates makes them uneconomic for electric vehicle users. The upfront cost of electric vehicles is assumed to be offset by fuel efficiency savings, reflecting rational decision making on the part of private purchasers.

96. *Potential implementation timeframe*. Estonia was able to deliver a national charging network within 2 years of tendering the contract. However, in a larger and more densely populated country with greater numbers of charging points required, implementation in Romania may be expected to take a little longer, and the preparatory studies required prior to contracting mean that delivery of the national network within the 2015-2022 action period timeframe is likely to be challenging. However, implementation could be phased, with a focus on the most strategic locations, including densely populated cities and selected points along the most well used expressways. Barriers to implementation may include planning approval issues relating to the identification of sites for the units, technical barriers regarding the supply of electricity to the units and commercial barriers in identifying a suitable business model for the installation and ongoing maintenance of the units.

97. *Modelling approach used and GHG benefits*. The delivery of the charging network does not in itself provide carbon emissions savings, but acts as an important enabler to the take-up of low emissions vehicles. The impact of the provision of the charging infrastructure has therefore not been modelled in isolation but in combination with the ultra-low vehicle emissions incentives. Purchasing profiles have adjusted to reflect projected take-up rates bringing Romania's vehicle electric vehicle adoption rates into line with those observed in Estonia. Forward looking projections build on these relative rates, taking reference from Sultan Green Scenario profiles regarding electric vehicle take-up. The annual GHG emission savings are presented in the figure below when the policy is implemented as part of the Super-Green package of measures. Annual savings of 0.09 $MtCO_2e$ are forecast by 2050.

Figure 34: GHG Emissions Savings – ULEV Investment



Source: TRANSEPT.

98. **Adoption of Ultra Low Emissions Vehicles in the Public Sector**. The uptake of ultra-low emissions vehicles (ULEVs) and in particular the adoption of electric vehicles can be given a kick-start through the promoted use of this technology within the state's own vehicle fleet. Setting targets for the proportion of the public sector fleet which are electric or plug-in hybrid is a means of accelerating the trajectory of new technology uptake. For this scenario, we have taken a similar target to that adopted in the modelling of

Macedonia interventions, with electric vehicles making up 5% of the public sector fleet in 2020, increasing to 10 percent in 2025. Again looking to the flagship case of Estonia with its national charging network roll-out and strong promotion of electric vehicles through fiscal subsidies, the scheme was kick-started with a large-scale demonstration project involving 500 electric vehicles adopted by government agencies. These vehicles provided a conspicuous demonstration of the technology, a test-bed for collection of research data and to test the infrastructure.

99. The purchase of electric vehicles comes at a higher cost to standard vehicles. However, there are ongoing operations and maintenance savings to be made resulting from the lower vehicle operating costs. The scheme costings draw on achieving the target rates of 5 percent and 10 percent of the public sector vehicle fleet of 75,000 vehicles by 2020 and 2025 respectively, with a cost premium on the purchase of the electric vehicles of Euro 4,450 per vehicle. The cost of phased vehicle purchase from 2016-2025 equates to Euro 3.5 million per annum (undiscounted 2015 prices), with total investment costs of Euro 35 million.

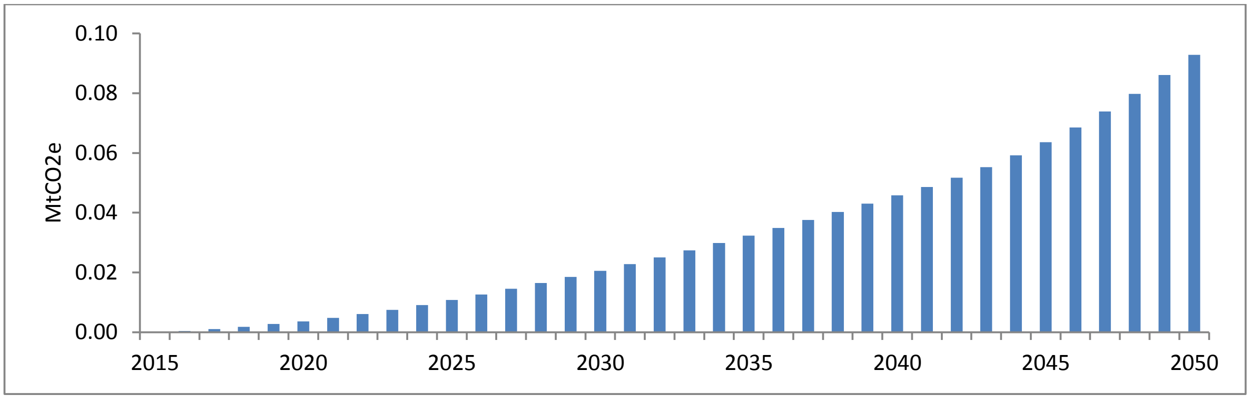
100. *Modelling approach used and GHG benefits*. Utilization of ULEVs within the governmental fleet can be increased incrementally, supported by the necessary infrastructure, which will include workplace charging points initially, whilst the wider infrastructure roll-out is underway. A target of 5 percent of the vehicle fleet by 2020 is proposed, increasing to 10 percent by 2025. The modelling focuses on the targeting of the introduction of electric vehicles to the public transport vehicle fleet at 5 percent in 2020 increasing to 10 percent in 2025. This may be achieved through the setting of vehicle regulation for certain routes within the regulated network. The additional investment cost relating to the purchase of electric vehicles, be it by state owned operator or private bus company, is included within the costing of this intervention. A resultant shift in new vehicle powertrain is modelled for cars from gasoline to EV from the year 2020 onwards. The annual GHG emission savings are presented in the graph below when the policy is implemented as part of the Super-Green package of measures. Annual savings of 0.09 $MtCO_2e$ are forecast by 2050.

Table 15: Summary of Modelling Approach – Ultra Low Emissions Vehicles in the Public Sector

	Modelling Approach
Policy	Targeting of EV adoption within public sector vehicle fleet
Implementation timeframe	Full implementation in 2020 with ramp up from 2015
Vehicles Affected	Cars
Geographical Areas/Road Types affected	All
Impact/Mechanism	Shift in the powertrain of new cars purchased from gasoline to EV

Source: World Bank.

Figure 35: GHG Emissions Savings – Public Sector Fleet ULEV Targets



Source: TRANSEPT.

101. *Implementation barriers*. Budgetary pressure constitute the main barrier to implementation, with the higher cost of vehicles incurring greater upfront capital costs. However, manufacturers have been keen to promote the new technology and the cost premium over conventional vehicles has fallen recently. The potential scope for preferential terms in the purchase of a fleet of electric or plug-in hybrid electric vehicles is strong given the quantity of vehicles in question. Technical barriers to adoption of the new vehicle technologies might feature initially in the roll-out, with issues such as finding suitable charging locations and ensuring that the vehicles are placed in usage best suited to their range limitations. These issues may be expected to be overcome early in the roll-out and new generations of electric and hybrid electric vehicles with increased range combined with the implementation of the supporting infrastructure will make the vehicles more practical across the wider range of usage patterns exhibited by agency vehicles.

102. **Electric Public Transport Fleet**. The adoption of electric or hybrid electric vehicles is also feasible within another key area of urban transport activity, which is the public transport sector. Diesel powertrain buses contribute significantly to urban transport emissions, and in particular local air pollution. As with the public sector vehicle fleet scheme presented above, this intervention focuses on the targeting of the introduction of electric vehicles to the public transport vehicle fleet at 5% in 2020 increasing to 10% in 2025. This may be achieved through offering subsidy for particular routes or by including the requirement for electric or hybrid electric vehicle usage within the franchising on certain routes within the regulated network. Many European cities have introduced hybrid powertrain vehicles into their public transport fleets recently. Hybrid electric vehicles will be operating in Stockholm, Hamburg and Luxemburg. In Milton Keynes, UK, a fleet of fully electric vehicles operates a busy route between the city center and the suburbs which is able to charge wirelessly on the stand at the beginning and end of each trip. This allows the bus to remain in operation for the whole day with a full charge before leaving the depot and top-up charges whilst in service.

103. The additional investment cost relating to the purchase of electric vehicles, be it by state owned operator or private bus company, is included within the costing of this intervention. The supplemental cost of the purchase of hybrid-electric vehicles over conventional powertrains is Euro 100,000 per vehicle.

To meet the proposed targets, the purchase of an average of 285 hybrid electric vehicles per year is require. This equates to an investment of Euro 28.5 million per annum, totaling Euro 300 million over the 10 year time frame. The timeframe for implementation is phased roll-out to 2025, with an initial pilot of 100 vehicles commencing in 2016.

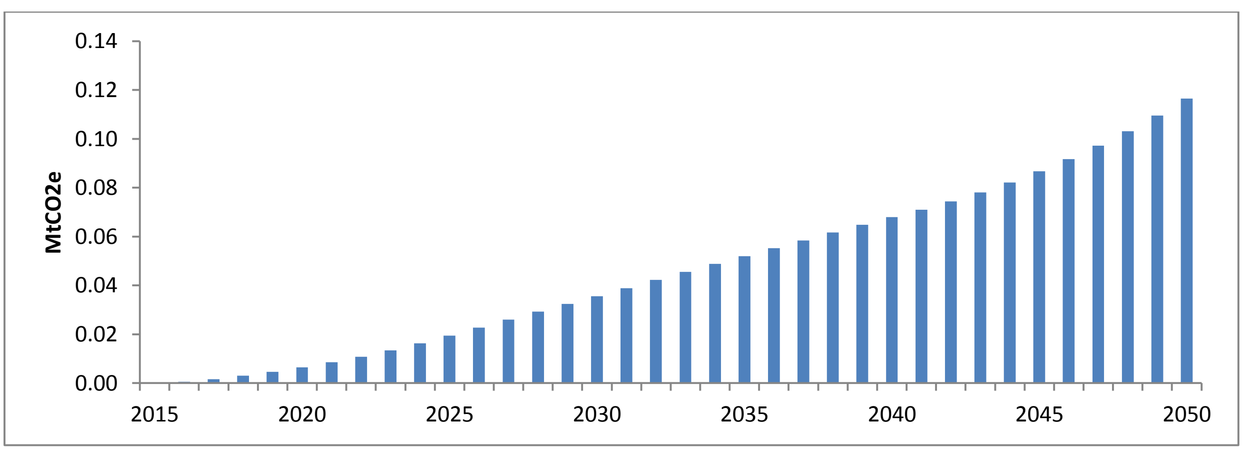
104. *Modelling approach used and GHG benefits*. The policy is modelled by shifting the powertrain of a proportion of new vehicles purchased from diesel to EV. The policy comes into full effect in 2025 when the powertrain of 10 percent of new buses shifts from diesel to EV, with an intermediate step of 5 percent shifting in 2020. The annual GHG emission savings are presented in the graph below when the policy is implemented as part of the Super-Green package of measures. Annual savings of 0.12 $MtCO_2e$ are forecast by 2050.

105. The purchase of hybrid vehicles is costly, and operators are typically unwilling to invest in such vehicles without strong incentives, typically in the form of capital cost subsidy. In addition, the vehicles require specialist maintenance regimes, and whilst the uptake is still in its infancy this is seen as challenging in the bus operating environment. Operating cost savings are to a large extent offset by the specialist maintenance required. However, as the technology becomes more widespread, and industry knowledge in operations and maintenance increases, these concerns will diminish.

Table 16: Summary of Modelling Approach – Electric Public Transport Fleet (*Source*: World Bank)

	Modelling Approach
Policy	Targeting of electric bus vehicle adoption within public transport fleet.
Implementation timeframe	Full implementation in 2025 with ramp up from 2015
Vehicles Affected	Buses
Geographical Areas/Road Types affected	All
Impact/Mechanism	Shift in the powertrain of new buses purchased from diesel to EV. A full shift of 10% experienced in 2025, with 5% shift in 2020.

Figure 36: GHG Emissions Savings – Electric Public Transport Fleet



Source: TRANSEPT.

3.4 Regulatory

106. **Traffic Management Measures**. This intervention is outlined here as an identified measure for consideration. As an urban measure, and one which is of most relevant to Bucharest in the first instance, it is pertinent that a significant investment in this area has already been made recently. The modelling of potential impacts are therefore not appropriate given the current context, as these form part of the baseline. The historical policies of 'predict and provide' in terms of highway infrastructure provision to serve an ever increasing demand for motorized transport have been replaced by those promoting achieving maximum efficiency from the existing infrastructure. This is particularly pertinent in urban areas where space constraints set against increasing traffic levels set a path for increasing congestion without measures to facilitate efficient movement. Traffic cities across Europe to enhance the smooth flow of traffic on the urban routes and to enable rapid response to incidents or issues which can lead to downstream congestion.

107. Bucharest has an Urban Traffic Control Centre recently implemented as a joint-venture of SWARCO AG and UTI International, with funding from Bucharest Municipality and the European Bank of Reconstruction and Development. The project delivered a new traffic control center including an adaptive urban traffic control and public transport management system which it is estimated has reduced travel times within the controlled area by about 20 percent and achieved a 10 percent reduction in CO_2 within the area.[61] The extension and wider roll-out of such a system within the capital and in the largest cities, and areas where urban congestion is most felt could bring about wider benefits.

108. The cost of implementation of urban traffic control systems with the control centers themselves and the infrastructure which provide the intelligent traffic management functions are highly bespoke to the situation and requirements. High capital costs combined with ongoing support mean that significant investment must be made in the implementation of such systems. However, the benefits in terms of decongestion, both time savings for highway users and operating cost savings, and the benefits to the city environment and air quality are identified as key benefits. Further extension of traffic management systems may be appropriate as other cities begin to experience significant congestion. As noted above, the impacts of this measure were not modelled in this study.

109. **Parking Regulation**. Effective parking regulation is important to a well-functioning urban network. In addition to parking charging policies which have been set out earlier in the pricing instrument analysis, effective regulation on existing parking places and the provision of parking under new developments is critical. As previously referenced, ITDP has reviewed case studies of parking best practice in Europe and sets out the key principals and conclusions in its report 'Europe's Parking U-Turn'.[62] The mechanisms and procedures for applying parking regulations are in place and can be used to extend parking regulation

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[61] http://www.swarco.com/mizar-en/Projects/ITS-References/URBAN-TRAFFIC-MANAGEMENT,-Romania,-Bucharest-City-of-Bucharest

[62] Europe's Parking U-Turn: From Accommodation to Regulation, ITDP, 2011. Available at: https://www.itdp.org/wp-content/uploads/2014/12/Euro-Parking-Fact-Sheet.pdf

wider across the urban areas, to tackle problem areas and to control new development parking provision. Effective enforcement is however also important, which requires ongoing resources. Parking regulations can be applied rapidly, subject to the necessary drafting of parking orders and adherence to notice periods etc. The impact of parking regulation measures are considered to be complementary to a logical parking charge regime and have not been modelled separately.

110. **Low Emission Zone**. A Low Emission Zone (LEZ) is an area in which vehicles entering are restricted or deterred based on their emissions levels. This may take the form of a blanket ban on vehicles with emissions higher than a certain level or by higher emitting vehicles incurring a charge for entering the zone. These zones may be applied to heavy goods vehicles and or buses only, or to all vehicles. The driving factor behind the introduction of these zones has typically been due to local air pollutant concerns and meeting EU air quality standards rather than GHG emissions. More than a dozen EU countries now have LEZs of some form in place in one or more of their major cities or in some cases to particular routes or tunnels (e.g. the Mont Blanc Tunnel which is only accessible to Euro 3 and onwards lorries).[63] City based LEZ examples include Bergen, Durham, London and Oslo for which all vehicles, whether locally registered or foreign are subject to the access regulations. The regulations vary by scheme and can be quite complicated. For example, in Milan, from 15th October to 15th April each year, Monday to Friday 0930-1930, petrol vehicles not conforming to Euro1 and diesel vehicles to Euro3 are not allowed within the zone. Two stroke motorcycles and mopeds not conforming to Euro1 are banned throughout the year.

111. In the context of Romania, Bucharest would represent the most likely target for implementation of an LEZ, given the city's reputation not only as the worst for air quality in Romania but in its ranking as one of the worst in Europe.[64] Bucharest already has access restrictions which apply to vehicles over 5 tons, which are banned from the central area of Bucharest at certain times, and only allowed to circulate outside of these times with a permit. Extending these restrictions to smaller vehicles, and those with greater emissions levels, in the form of a Low Emissions Zone, could be strongly beneficial to local air quality. The impact in terms of carbon emissions savings would be expected to be less marked, with little variation in fuel consumption between the different Euro standards, although the purchase of newer more efficient vehicles would lead to some gains. There may however be offsetting impacts, with trips by larger vehicles replaced by a greater number of smaller vehicle journeys to maintain the city delivery requirements whist conforming to the restrictions. The costs of implementing a Low Emission Zone would involve the preparatory studies and impact assessments, the necessary awareness campaigns and signage, and importantly the ongoing monitoring and enforcement of the regulations. The scale of these costs may vary significantly be nature and complexity of the scheme and by means of enforcement (for example automatic number plate recognition).

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[63] http://urbanaccessregulations.eu/general-overview/low-emission-zones-overview

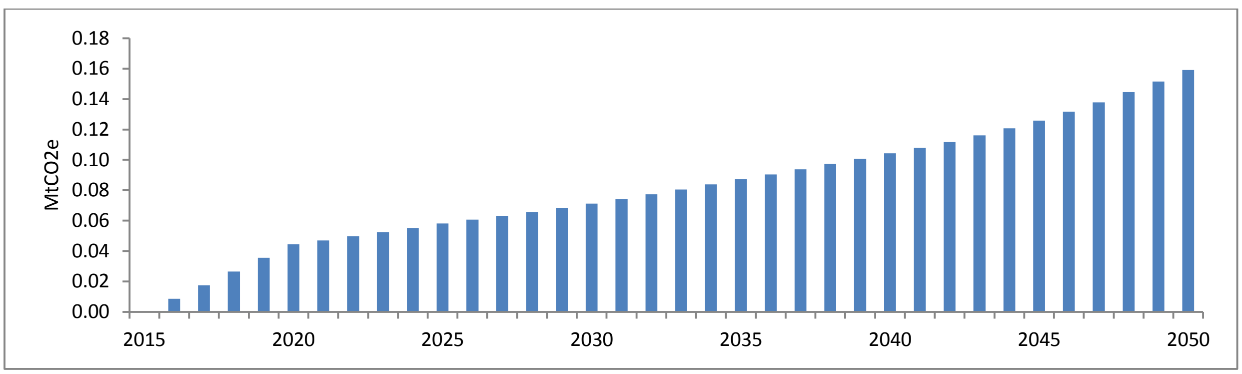
[64] Aphekom project. Available at: http://www.aphekom.org/c/document_library/get_file?uuid=5532fafa-921f-4ab1-9ed9-c0148f7da36a&groupId=10347

112. *Modelling approach used and GHG benefits*. It has been assumed that the LEZ influences affected users to purchase more energy efficient vehicles. Affected users will be those who currently undertake travel activity in the major urban areas. It has been assumed that 5 percent of car users will be affected. The influence on purchasing decisions has been modelling by bringing forward the average emissions factors of affected vehicles by 10 years, reflecting the purchase of more efficient vehicles within the affected user fleet. The annual GHG emission savings are presented in the graph below when the policy is implemented as part of the Super-Green package of measures. Annual savings of 0.16 $MtCO_2e$ are forecast by 2050.

Table 17: Summary of Modelling Approach – Low Emission Zones (*Source*: World Bank)

	Modelling Approach
Policy	Implementation of Low Emission Zones in all major urban areas
Implementation timeframe	Full implementation in 2020 with ramp up from 2015
Vehicles Affected	Car, motorcycle, bus, van, medium and heavy truck
Geographical Areas/Road Types affected	Affects 10% of urban trips
Impact	Promotes the uptake in more energy efficient vehicles
Mechanism	Brings forward the average energy efficiency of affected vehicles by 10 years.

Figure 37: GHG Emissions Savings – Low Emissions Zones



Source: TRANSEPT.

113. **Speed Restrictions**. Vehicle fuel consumption increases rapidly when speed progresses beyond the optimally efficient speed of around 90 km/hour, with fuel consumption rising by up to 20 percent when cruising at 120 km/hour. Limiting the speed of vehicles to more fuel efficient levels represents a powerful means of reducing emissions. Romania's speed limits are currently set at 130 km/hour on motorways, 110 km/hour on expressways, 90 km/hour on other non-urban roads for cars and motorcycles; trucks and buses are limited to 110 km/hour, 90 km/hour and 80 km/hour respectively. A lowering of the speed limit for all vehicle types to a speed of 100kph on all road types could be implemented to increase fuel efficiency levels and reduce emissions.

114. Many European countries have similar speed limits to those in force in Romania. However, certain countries have applied more stringent speed limits, such as Switzerland which introduced lower speed limits in 1984 for the environmental benefits the new measures would bring. The Swiss have a speed limit

of 120 km/hour on motorways whilst the speed limit on national roads is just 80 km/hour. Other countries which have a lower speed limits on motorways include Sweden (110-120 km/hour) and the United Kingdom (70 miles/hour or 113 km/hour) and Latvia (100 km/hour). The most significant implementation barrier to reduced vehicle speeds is the political dimension of enforcing the lower speeds and hence extended journey times on road users. Strong political protest from interest groups including the freight sector (both domestic and pan-European) may be expected.

115. The cost of implementing a change of speed limits would include the necessary revisions to regulation and the sensitization and awareness raising of the public through advertising campaigns.[65] The capital cost of implementing speed reminder signs in the period also need to be taken into account. It is estimated that these costs could amount to Euro 10 million, which would be incurred within the period of implementation. Enforcement of speed limits is also a key factor to the effectiveness of the policy. Allowance has been made within the modelling for a lack of compliance. However, expenditure on enforcement on high traffic roads enhance policy effectiveness. An allowance of Euro 1 million per annum for speed limit enforcement has been made. It should also be noted that speed restrictions have wider economic impacts, including costs associated with longer journey times, which need to be taken into account when assessing this intervention.

116. *Modelling approach used and GHG benefits*. In the model motorways and expressways are combined together into a single classification referred to only as motorway as the length of motorway in Romania is very short, so we have used the expressway speed limit to estimate current average vehicle speeds. The modelled change in average vehicle speeds which result from reducing the speed limit is presented below. We have assumed there is 70 percent adherence to the new speed limits. Reducing the speed limit acts to increase driving efficiency, but also reduce the demand for travel. The increase in driving efficiency is measured in terms of the reduction in energy consumed. The reduction in trip demand uses an elasticity between travel time and demand of 0.5 for cars and motorcycles and 0.25 for vans. The annual GHG emission savings are presented in the figure below when the policy is implemented as part of the Super-Green package of measures. Annual savings of 1.0 $MtCO_2e$ are forecast by 2050.

Table 18: Summary of Modelling Approach – Speed restrictions

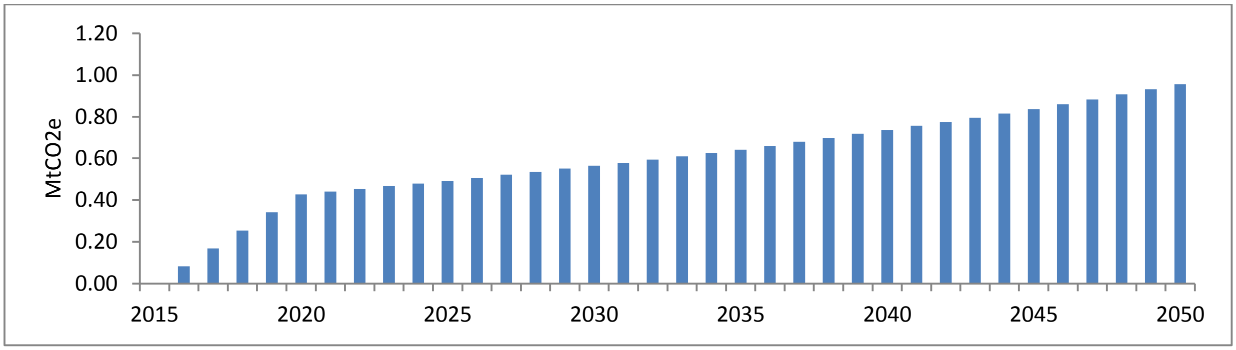
	Modelling Approach
Policy	Reduction in speed limits on Motorways and Expressways to 100kph
Implementation timeframe	Full implementation in 2020 with ramp up from 2015
Vehicles Affected	Car, motorcycle, van
Geographical Areas/Road Types affected	Motorway and non-urban trips
Impact	Increases driving efficiency and reduce demand for travel

[65] An alternative and related intervention which was not modelled was enhanced speed limit enforcement. To model this in detail would require having data on present levels of adherence and an assumption relating to enforcement effectiveness.

Mechanism	Reduce the energy consumed per km and reduce the overall demand for trips on motorways and non-urban roads.

Source: World Bank.

Figure 38: GHG Emissions Savings – Speed Restrictions



Source: TRANSEPT.

3.5 Operational Efficiency

117. **Eco-Driving**. Eco-driving reduces emissions by reducing the amount of fuel consumed through efficient driving techniques to reduce the intensity of engine activity to cover the same distance. Eco-driving programs are well established within the freight sector, given the importance of minimizing fuel consumption to commercial performance. However, eco-driving techniques can equally be applied to all road usage, to the benefit of drivers operating costs and to environmental objectives. A recent EU funded study looked at the potential benefits of eco-driving amongst others. The stated aim of the eCoMove project was to achieve fuel savings of 20 percent through a combination of intelligent transport systems (ITS) and eco-driving measures.[66] The cost of the eCoMove program was Euro 20 million, covering a range of research streams. A similar budget is proposed for the implementation of a package of measures to encourage eco-driving in Romania, including marketing campaigns and driver training programs targeted initially at drivers of high polluting vehicles including those in the freight sector and public transport vehicles.

118. *Modelling approach used and GHG benefits*. This package of measures could be included within the Action Plan timeframe, with a targeted campaign to promote eco-driving commencing by 2020. The impact of eco-driving measures have been modelled based on evidence of fuel efficiency savings observed in similar programs, which found that 8 percent efficiency improvements in private car and 4 percent efficiency improvements in HGV movements (recognizing that eco-measures such as fleet monitoring are already present in much of the freight sector). It has been assumed that the package of measures will achieve a 25 percent coverage rate in terms of changing driving behavior, applicable across all journeys,

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[66] The eCoMove concept is that of the "perfect eco-driver" travelling through the perfectly "eco-managed" road network, i.e. a combination of cooperative applications for eco-driving and eco-traffic management can – for any given trip by a particular driver in a particular vehicle – help to approach the theoretical least possible fuel consumption (and thus CO2 emissions), all without compromising the quality of people's and goods mobility. See: http://www.ecomove-project.eu/

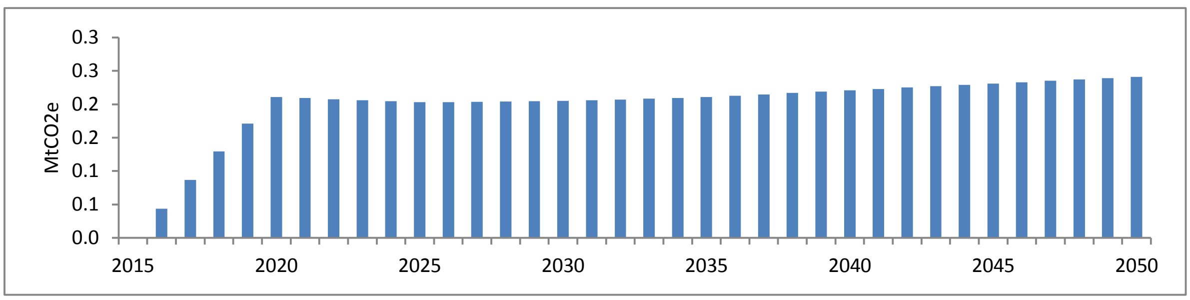
and as such has been applied as a 2 percent efficiency improvement in car activity and 1 percent in HGV activity. The policy has been modelled to reduce the energy consumption as measured in MJ/km. The annual GHG emission savings are presented in the graph below when the policy is implemented as part of the Green package of measures. Annual savings of 0.3 $MtCO_2e$ are forecast by 2050.

Table 19: Summary of Modelling Approach – Eco-Driving

	Modelling Approach
Policy	Eco-driving awareness campaigns and training programs
Implementation timeframe	Full implementation in 2020 with ramp up from 2015
Vehicles Affected	Car, motorcycle and van
Geographical Areas/Road Types affected	All
Impact	Increases driving efficiency
Mechanism	Reduce the energy consumed per km

Source: World Bank.

Figure 39: GHG Emissions Savings – Eco-driving



Source: TRANSEPT.

119. **Freight Measures**. A number of freight sector interventions were identified as potential schemes for consideration. These included freight consolidation centers and vessel management systems. The freight sector represents a significant source of road traffic emissions, reflecting the high polluting nature of the vehicles and the high levels of transport activity undertaken by these vehicles. Logistics therefore represents an area for potential carbon abatement. However, the freight industry has very strong incentive to maximize efficiency, as lower fuel usage leads to cost savings. Given the competitive nature of the logistics industry, operators are typically considered to be best placed to drive efficiency improvements. Government intervention is best directed to areas in which the industry cannot deliver investment, or where market failure is occurring within the competitive environment, such is in the area of air quality for example. Government assistance to enhance efficiency within the freight sector may include investment in consolidation centers or freight hubs linking road with rail for example.

120. Investment in freight hubs and logistics hubs forms part of the General Transport Master Plan, and as such has been included within the baseline. Further proposals regarding the potential for specific

freight investment require more detailed examination than is possible at the strategic level. Given the inclusion of freight investment proposals within the baseline, and the efficacy of the industry in making efficiency savings where they are able to, further freight interventions have not been modelled, with preference placed on other areas of policy in which Government investment can be better focused.

3.6 Urban Planning, Behavioral Change, and Zero Carbon Urban Investment

121. **Integrated Land Use and Transport Planning in Urban Areas**. Romania has seen large changes in residential housing following the post-socialist transition, which have contributed to rising suburbanization.[67] While population growth has not been significant in many cities, this has been compensated by a large reduction in the size of the average household, reflecting a response cramped living conditions in former communist times. Other significant changes to the housing market have been the privatization of the existing housing stock, development of residential mortgages, high demand for residential property from international buyers, and a marked increase in average dwelling unit size. As a result of these changes, there has been (a) a decrease of residential use in the urban core, as commercial uses outbid other activities from central zones, leading to residential depopulation and gentrification; (b) an increased rate of residential suburbanization; and (c) a relaxation of land development controls. The high growth of vehicle ownership seen over the same period in the region has reflected in large part suburbanization, which has been supported by large public investments. Thus, unlike many other developing regions, suburbanization is taking place in the context of slow or negative population growth. On the positive side, suburbanization patterns have tended to be much denser than in the US. Nevertheless, the trend of rapid suburbanization over the last two decades is a worrying one if projected forward.

122. Once a country has developed an urban form characterized by extensive urban sprawl, it becomes exceedingly difficult to control GHG emission growth. This is because low-density development where there is separated land use, as is common in the US, makes a passenger vehicle the only efficient transport option. The population density and vehicle km relationship can be weakened according to the type of land-use policies in place, such as zoning for mixed use, raising density maximums, and eliminating minimum parking regulations. Avoiding the development of a US high-energy model and instead developing one based on more compact, transit served urban city, could reduce transport energy needs by up to three-quarters. From a transportation perspective, urban sprawl has a number of negative effects, apart from increasing VKT. It also makes it more difficult to develop financially viable mass transit systems.

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[67] See Kiril Stanilov (2007), "Housing Trends in Central and Eastern European Cities During and After the Period of Transition", in Stanilov (ed), *The Post-Socialist City: Urban form and Space Transformations in Central and Eastern Europe After Socialism*. Dordrecht: Springer. Turkey was obviously not affected by the post-socialist transition, but has also faced the development of suburbanization.

123. Sustainable Urban Mobility Plans are being developed for a number of cities in Romania[68] and are likely to be looking at the implementation of some or all of these interventions; these plans are expected to be finalized before end 2015. This intervention is outlined in this Report for completeness. However, it is essentially an urban strategy intervention that would form part of an urban package of measures, and is within the remit of the urban report under Component C. Emission impacts and costs of this intervention were therefore not modelled within our project. Integrated land use and transport planning in urban areas essentially involves close consideration of transport requirements when planning development of urban areas. The physical layout and design of a city has a direct impact on daily travel patterns (including travel distance and mode choice) and thus on annual vehicle-km travelled. Many studies have shown that vehicle dependence and transportation energy consumption per capita are far greater for cities with low-density suburban residential areas that are a significant distance from the areas where people work and conduct other significant activities. Using the planning system to reduce the need for long-distance vehicular travel is potentially an effective contributor to minimizing or reducing carbon emissions. A recent World Bank study on GHG emission mitigation in FYR Macedonia[69] identified the following land use planning policies and regulations that could be used to reduce the need to travel and dependence on the private car:

- Developments permitted only where good quality access to public transport, walking and cycling facilities is provided as part of the development.
- New developments that in-fill sites close to city centers and/or refurbish and re-use derelict buildings are encouraged, potentially through regulation or financial incentives.
- Car parking provision in new/refurbished developments is limited to a maximum and developers are encouraged/required to provide high quality alternatives to the car instead.
- New developments are required to complement existing uses in the area or where large developments are planned, they are required to be mixed-use, ensuring that amenities such as shopping, schools and other public services are located near to residential areas avoiding the need to travel further afield by car.

There are many examples of good practice that the Romanian Government could look at. Singapore is often quoted as a good example of a coherent and comprehensive set of land use and development policies aimed at reducing the dependence on motorized vehicles.[70] In Europe, the new development of Hammarby Sjostad forms another good example.[71]

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[68] Including seven larger cities designated as regional urban growth poles (Constanta, Craiova, Ploiesti, Iasi, Brasov, Cluj-Napoca and Timisoara).

[69] World Bank. Support to the Government of Macedonia: Transport sector green growth and climate change analytical work. Mitigation Report prepared by Atkins and iC Consulenten, January 2013.

[70] World Bank (2013). Romania Climate Change and Low Carbon Green Growth Program Transport Rapid Assessment Report, November 2013.

[71] This is the biggest development project in Stockholm - when complete in 2017 it will be home to 24,000 people and workplace for 5000. 3km from the city centre on a 160 hectare brownfield industrial site, the street layout and the mix of land uses is designed to make the streets attractive to pedestrians and cyclists, with traffic and services

124. The cost to the Romanian Government of implementing integrated land use and transport planning would primarily consist of the cost of establishing well-informed, educated and trained planning departments in local governments, together with the administrative cost of implementing any regulations at local or national level. Integrated land use and transport planning could be implemented in a short timeframe, working within existing government structures. Implementation could start immediately, with the aim of all Romanian municipalities fully using the approach by 2018. The main barrier to implementing integrated land use and transport planning would be getting political support and recognition that such an approach is in the long term interest of Romania rather than a 'laissez-faire' approach to planning. Study tours of places—for example through the European Covenant of Mayors program—with good practice may help gain high level acceptance for the intervention.

125. **Investment in Infrastructure for Zero Carbon Modes**. Investment in infrastructure for zero carbon transport modes (walking and cycling) has the potential for reducing carbon emissions by encouraging shift towards those modes. This can result from provision of infrastructure and services that make use of such modes more feasible for more journeys, quicker, more convenient, safer, more comfortable or more pleasant. In the context of this project, we focused on urban infrastructure improvements because urban areas are where there is greatest potential for shifting significant numbers of people to walking and cycling because of the relatively short distances travelled. Infrastructure investment may include investing in packages to improve the quantity or quality of some or all of the following:

- Cycle paths and cycle lanes
- Cycle parking facilities
- Footpaths
- "Pedestrian-ization" of streets
- Pedestrian and cycle crossings

126. A number of European cities have excellent cycling and pedestrian infrastructure and as a result have high levels of cycling and walking embedded in their culture. Well-known examples include Copenhagen, Amsterdam, Utrecht, Groningen and Munich. Many other European cities are currently investing in cycling and walking infrastructure in an attempt to grow their trip modal share. The investment in infrastructure required to achieve modal shift towards cycling and walking depends on local circumstances and the extent of the targeted shift.

127. The city of Bogotá (Colombia) provides an interesting illustration of potential costs and benefits. Here, based on advice from Dutch cycling planners, Euro 178 million was invested in transforming the

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concentrated along the central avenue. The latest modal split figures for Hammarby Sjostad show that 52 percent of trips are made on public transport, 27 percent on foot or by bike, with car journeys accounting for only 21 percent. See: Thriving cities: Integrated land use and transport planning. Report for pteg by Transport for Quality of Life, 2011.

city's cycling infrastructure over a 10 year period from the mid-1990s.[72] This resulted in an increase in cycling trip mode share in the city from 0.9 percent to 4 percent over that period. Taking account of dollar inflation, Euro 178 million in 2000 values (the midpoint of the implementation period) is equivalent to around Euro 232 million in 2011 dollar values. At that mid-point, the population of Bogota was around 6.3 million people, so the investment per person over 10 years was equivalent to Euro 37 per person (2011 values). Based on a similar level of investment per head of population, an investment cost of Euro 75 million is adopted for the 20 largest cities in Romania. Investment in improved cycling and walking infrastructure would require a long term program. However, such a program could in principle be started (subject to availability of funding) in the near future. The main barrier to implementation would be political and public acceptance that the benefits of investment in these modes outweigh any costs arising from reallocating road space or traffic priority away from motorized vehicles.

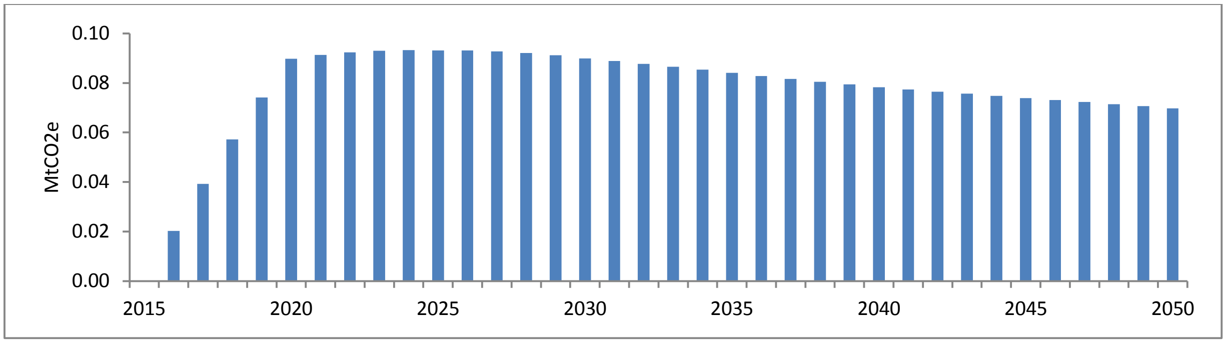
128. *Modelling approach used and GHG benefits*. The investment in walking and cycling implemented in Bogota saw cycling trips increase from 0.9 percent to 4 percent of daily trips within a decade. This scale of increase is considered to be feasible within the context of Romania, as despite climatic differences, the potential for certain trips to be replaced by cycle trips is present. The trips replaced by cycle trips tend to be the shorter distance trips by nature. Overall, a 4 percent shift in urban car trips to walking and cycling was modelled for all major urban areas. The annual GHG emission savings are presented in the graph below when the policy is implemented as part of the Green package of measures. A maximum annual saving of 0.09 $MtCO_2e$ is projected for between 2020 and 2025, however the impact tails off to 0.07 $MtCO_2e$ in 2050 as other polices act to suppress trips.

Table 20: Summary of Modelling Approach – Investments in Zero Carbon Modes (Source: World Bank)

	Modelling Approach
Policy	Investment in Waking and Cycling Facilities
Implementation timeframe	Full implementation in 2020 with ramp up from 2015
Vehicles Affected	Car
Geographical Areas/Road Types affected	Urban areas
Impact/mechanism	4% mode shift in urban car trips to walk/cycle

[72] Cevero, R (2005). Accessible Cities and Regions: A Framework for Sustainable Transport and Urbanism in the 21st Century. University of California at Berkeley Working Paper UCB-ITS-VWP-2005-3. Available at: http://www.its.berkeley.edu/publications/UCB/2005/VWP/UCB-ITS-VWP-2005-3.pdf

Figure 40: GHG Emissions Savings - Investment in Zero Carbon Modes



Source: TRANSEPT.

129. **Investment in public transport infrastructure**. Investment in public transport infrastructure has the potential for reducing carbon emissions by encouraging shift towards that mode. The Romanian General Transport Master Plan (GTMP) that is included in the Business as Usual scenario already includes very significant investment in public transport infrastructure on the strategic transport network, including the national rail system. Investment is also required to maintain and enhance the urban public transport system. It not within the scope of this study to undertake modelling of specific transport infrastructure schemes at the urban level, but the importance of an efficient and well-functioning public transport systems is highlighted here as a prerequisite to ensuring that the modelled strategic policies are effective in achieving the expected levels of carbon mitigation. Without insufficient investment in maintaining and enhancing the urban public transport network, modal shift towards private car will accelerate and the policies which promote modal shift will be less effective without a sufficiently attractive alternative to private modes.

130. Public transport in Bucharest includes a metro system (operated by Metrorex), a tram network, trolley buses, and an extensive bus network (all operated by RATB). In other Romanian cities and towns, public transport consists of buses, minibuses, trolley buses and trams. The city of Brasov took the decision in 2005 to abandon its tram line due to the prohibitive cost of upgrading and maintaining and is focusing on buses and trolley buses. Cluj-Napoca has upgraded its tram system, while other cities have similar plans but lack funding to implement them. Although data is hard to obtain, it is understood that public transport patronage in many Romanian towns and cities is in decline, with a corresponding increase in private traffic levels. For example, in Ploiesti, public transport patronage fell from 7 million trips per month in 2011 to 6.7 million in 2012.[73]

131. Many European cities provide excellent examples of high quality urban public transport infrastructure. The 2011 COST action TU0603 report 'Buses with High Level of Service' presents examples

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[73] Improving energy efficiency in Ploiesti, Romania: TRACE city energy efficiency diagnostic study. World Bank (under the Romania Regional Development Program), undated.

of different aspects of good practice from 35 European cities.[74] The investment in infrastructure required to achieve modal shift from private cars towards public transport depends strongly on local circumstances (including the state of current infrastructure and patronage levels) and the extent of the targeted shift. Modelling of the potential impact of particular public transport schemes at the city level requires a level of detailed city level information and modelling assumptions that was outside the scope of this study. However, investment in improved public transport infrastructure in Romanian cities requires a long term program which must not be neglected as ancillary to the strategic objectives of the GTMP.

132. **Investment in smarter choices/behavioral change programs.** Over recent years there has been an increasing interest in and focus on 'soft' transport policies as a means of changing travel behavior. 'Smarter choices' behavioral change programs seek to provide better information to travelers on the travel choices they have available to them, and in highlighting the potential benefits which considering more sustainable transport modes (e.g. walking and cycling) may bring to them. Schemes and policies which typically fall under the 'smarter choices' banner include: (a) workplace and school travel plans; (b) personalized travel planning, travel awareness campaigns and public transport information and marketing; (c) car clubs and car sharing schemes; and (d) teleworking, teleconferencing and home shopping.

133. Examples of best practice can case study evidence can be found across Europe. In the UK a number of cities have received funding to implement smarter choices programs as part of the Sustainable Travel Demonstration Town initiative and in Scotland, soft policies were trialed in seven cities as part of the Smarter Choices Smarter Places Program. Each of these initiatives involved investment of GBP 15 million spread across the cities, with investment in active travel infrastructure and behavior change activities targeted at achieving an increase in active travel, increased public transport use and reduced emissions. Follow up monitoring of the programs identified statistically significant increases in walking and cycling and a reduction in car trips.

134. In Romania, a Smarter Choices program could be effectively focused on the largest urban areas, such as the twenty cities with over 100,000 population, and designed to complement the investment programs such as the walking and cycling infrastructure investment scheme. Travel planning programs concentrated on the largest employment sites and schools, combined with travel awareness campaigns would enhance the effectiveness of infrastructure investment. A proposed investment budget of Euro 23 million spread across the largest urban areas is proposed, based on similar spend levels to the UK based schemes (not including infrastructure which is covered in other policies here).

135. *Modelling approach used and GHG benefits*. This policy has been modelled as a mode shift for urban trips from car and motorcycle to bus, rail and walking modes. A mode shift of 3.2 percent from car and 1.1 percent from motorcycle have been assumed. These values represent a shift of 5 percent of car

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[74] Buses with High Level of Service: Fundamental characteristics and recommendations for decision-making and research - Results from 35 European cities. Final report – COST action TU0603, October 2011.

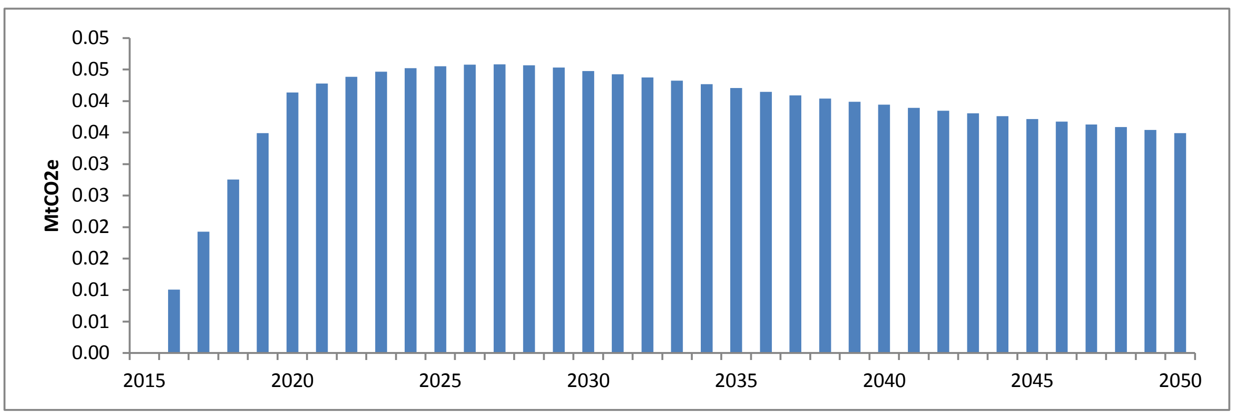
trips and 2.5 percent of motorcycle trips. The trips are reapportioned in equal measure to bus, rail and walk. The annual GHG emission savings are presented in the graph below when the policy is implemented as part of the Green package of measures. A maximum annual saving of 0.05 $MtCO_2e$ is projected for 2025, however the impact tails off to 0.04 $MtCO_2e$ in 2050 as other polices act to suppress trips.

Table 21: Summary of Modelling Approach – Investment in Smart Choices

	Modelling Approach
Policy	Investment in smart choices
Implementation timeframe	Full implementation by 2020 with ramp up from 2015
Vehicles Affected	Car and motorcycle trips shift to bus, rail and walk/cycle
Geographical Areas/Road Types affected	Urban areas
Impact/mechanism	4% mode shift in urban car and motorcycle trips to bus, rail and walk/cycle

Source: World Bank.

Figure 41: GHG Emissions Savings - Investment in Smart Choices



Source: TRANSEPT.

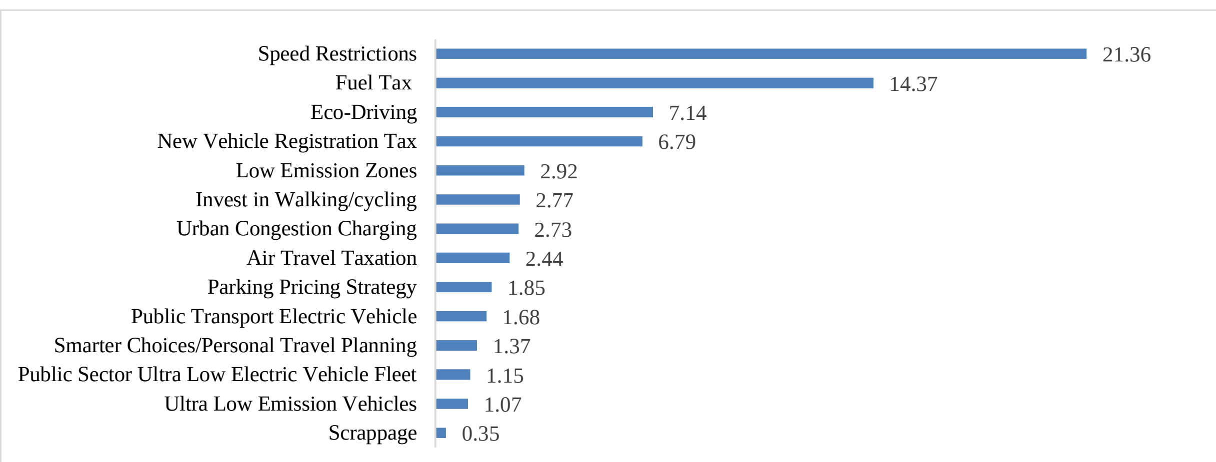
4 MARGINAL ABATEMENT CURVE, GREEN AND SUPERGREEN SCENARIOS

4.1 Introduction

136. The range of potential interventions have been defined and costed and assessed in terms of carbon abatement potential. The measures have been modelled individually to assess their relative mitigation potential and value for money in terms of investment against estimated abatement potential. These metrics sit alongside wider qualitative co-benefits to inform the ranking of those most appropriate for inclusion within the Green Scenario. The interventions performing best in the multi criteria appraisal were included in the Green Scenario, with explanation of why each should be pursued. However, all interventions have been included in the Super Green Scenario in order to assess an upper bound for slow GHG emission growth from the transport sector. No specific pre-defined GHG saving targets were used to constrain the choice of interventions, as a bottom-up approach was adopted. The identified measures have been drawn from a range of policy categories including: (a) pricing instruments; (b) technology; (c) regulatory; (d) operational efficiency; and (e) behavioral change and urban investments.

137. Figure 42 provide a summary of the cumulative abatement results for each intervention over 2015-2050, while the table below provides a breakdown of the abatement potential per intervention in three different time periods. The measures which have the potential to deliver the greatest absolute carbon savings over the course of the modelled period are as follows: (a) the lowering of speed limits (speed restrictions); (b) increasing the fuel tax (as a substitute to more sophisticated road user charging); (c) the implementation of a more progressive first registration tax (Environmental Stamp) promoting the adoption of low emission vehicles; and (d) eco-driving programs which encourage more efficient driving patterns, with advertising campaigns targeted at private car users and training programs focused on the freight and public transport sector.

Figure 42: Cumulative Abatement Potential per Intervention, 2015-2050 ($MtCO_2e$)



Source: TRANSEPT.

Table 22: Carbon Abatement from Interventions ($MtCO_2e$)

Intervention	Action Plan (2015-2022)	Strategy (2015-2030)	2015-2050	% of Total Emissions
Fuel Price	1.032	4.139	14.365	2.08
Scrappage Scheme	0.241	0.331	0.354	0.05
Vehicle Registration Tax	0.071	0.566	6.789	0.98
Parking Pricing	0.191	0.639	1.852	0.27
Urban Cong Pricing	0.050	0.597	2.729	0.39
Air Travel Taxation	0.267	0.757	2.436	0.35
Ultra-low Emission Vehicles	0.019	0.118	1.075	0.16
Public Sector EV	0.020	0.130	1.149	0.17
Bus EV	0.036	0.231	1.678	0.24
Speed Restrictions	2.168	6.288	21.357	3.09
Eco Driving	1.059	2.693	7.140	1.03
Low Emissions Zones	0.229	0.724	2.920	0.42
Investment in Walking Cycling	0.464	1.203	2.774	0.40
Smarter Choices/Soft Measures	0.220	0.582	1.370	0.20

Source: TRANSEPT.

4.2 Marginal Abatement Cost Analysis

138. Having identified the abatement potential for each of the interventions modelled, consideration needs to be given to the most effective areas of investment to achieve emission reduction. Marginal abatement cost (MAC) analysis provides a framework within which to guide investment decisions, identifying the levels of abatement possible and at what level of investment cost. A key component of the MAC analysis is the cost of each intervention, in terms both of capital cost and ongoing operational and maintenance costs. The implementation and ongoing costs of delivering the identified schemes have been estimated using case study evidence and a variety of sources of estimated costs applied to the Romanian context. The scope of the estimated costs are limited to those borne directly by the Government of Romania in terms of capital investment costs and ongoing operational and maintenance costs. The potential costs or operating cost savings borne by the private sector are not estimated or included within the MAC analysis. The basis for the cost estimation has been set out for each intervention in the preceding chapter.[75] Table 23 summarizes the mitigation potential of each intervention against scheme value for money based on the cost per ton of carbon abated. A summary of the qualitative

[75] Costs—capital and operational and maintenance costs—are discounted at a discount rate of 4 percent to provide the net present value (NPV). The abatement cost is hence cost (NPV) divided by total undiscounted cumulative carbon reduction over 2015-2050. The choice was made not to discount carbon savings as the resulting value is an abstract figure which cannot be directly compared back to any graph and would not be easily cross-compared to other literature evidence of abatement costs.

assessment of the wider societal impacts and deliverability issues (barriers to implementation) is also presented where relevant. The MAC can be found in Figure 43.

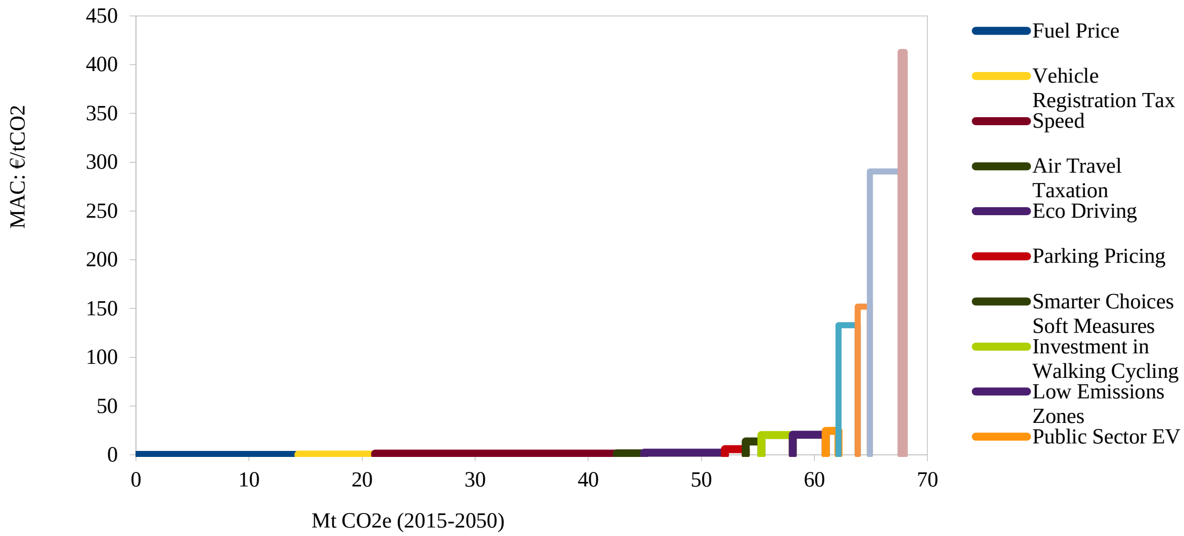
Table 23: Intervention Performance Table

Intervention	**Implementation**	**Investment Cost (Euro million)**	**Cost-Effectiveness (Euro/ton)**	**Co-benefits/Deliverability commentary**
Fuel Tax	2015-2022	0.9*	0.06	Wider economic implications of higher fuel prices. Political resistance to increased taxation.
Scrappage Scheme	2016-2020	164	413	Economic boost to the domestic car industry and dealerships. Improved air quality from lower emissions vehicles.
Vehicle Registration Tax	2015-2022	0.9*	0.13	Economic and equity issues due to increasing the purchase cost of older (imported) vehicles. Potential boost for vehicle manufacturers. Political issues associated with previous tax.
Parking Pricing	2015-2022	19*	5.8	Enhancements to cityscape, urban safety and local air pollution. Barriers to implementation include political resistance and economic impacts on motorists and city commerce.
Urban Congestion Pricing	2022-2030	1,600	291	Air quality benefits. Equity issues. Technical barriers to implementation. Parking pricing a more efficient means of achieving similar results.
Air Travel Taxation	2015-2022	6*	1.4 #	Economic impacts of taxation. Positive equity impacts.
Ultra-low Emission Vehicles	2015-2030	195	152	Significant air quality benefits. Economic benefits to vehicle dealerships and manufacturers. Equity impacts.
Public Sector EV	2015-2030	35	24.5	
Bus EV	2015-2030	277	133	
Speed Restrictions	2015-2022	39	1.1 #	Safety and wider environmental benefits. Significant interest group pressure against reduction in speed limits expected.
Eco-Driving	2015-2022	60	4.8	Economic benefits of reduced fuel consumption. Increased safety.
Low Emissions Zones	2015-2022	114	20.7	Significant air quality benefits. Economic and equity impacts.
Investment in Walking Cycling	2015-2030	70	20.3	Health benefits and wider environmental and cityscape benefits expected.
Smarter Choices/	2015-2022	23	13.7	Health benefits.

* Public revenues also generated by scheme; # particularly low values due to the consideration only of public investment.

Source: World Bank, ITP, TRANSEPT.

Figure 43: Marginal Abatement Cost Curve, 2015-2050



Source: TRANSEPT.

4.3 Development of the Green Scenario

139. The decision on which interventions to include in the Green Scenario were derived from a multi-criteria analysis that took into account the following: (a) scheme investment cost to the government; (b) cumulative emission savings; (c) carbon reduction cost effectiveness; (d) deliverability and economic important; and (e) wider benefits). The performance of each intervention against these criteria are provided in The tables above provide a basis for identifying the schemes which perform well in terms of investment value, and also in terms of required investment cost and potential implementation barriers. The scheme performance is summarized below, ranked by value for money in terms of carbon reduction cost effectiveness. Scheme performance under each criteria has been assigned a rating, based on straightforward three tier ranking as detailed in Table 25.

140. In order to achieve significant levels of carbon abatement, two schemes stand out above others. The implementation of speed restrictions is demonstrated to have significant potential to reduce vehicle emissions levels. Fuel taxation also can make a significant contribution to reducing emissions, through a combination of market forces acting to reduce the demand for travel and also in influencing purchasing decisions towards more efficient vehicles. Both of these policies have significant wider implications for the economy, with costs in terms of increased journey times in the case of speed restrictions and economic burden of higher taxation. In order to make meaningful reductions in carbon emissions in the transport sector, it is likely that at least one of these measures be adopted in some form. The wider costs and benefits will play an important role in determining the most appropriate, but ultimately it is likely that

the political acceptability of one or other measure ultimately determines which may be more politically palatable.

Table 24: Abatement Intervention Performance

Intervention	Discounted Investment Cost	Absolute Emissions Savings (MtCO2e)	Carbon reduction cost-effectiveness (€/ton)	Deliverability/ economic impact	Wider Benefits
Fuel Price Taxation	€0.9m	14.37	€0.06/ton	Challenging	Very high
Vehicle Registration Tax	€0.9m	6.79	€0.13/ton	Moderate	Moderate
Speed Restrictions	€22.6m	21.36	€1.1/ton	Challenging	Very high
Air Travel Taxation	€3.5m	2.44	€1.4/ton	Moderate	Moderate
Eco-Driving	€34.4m	7.14	€4.8/ton	Good	Very High
Parking Pricing	€10.7m	1.85	€5.8/ton	Moderate	Moderate
Smarter Choices/ Soft Measures	€18.8m	1.37	€13.7/ton	Good	Very High
Investment in Walking Cycling	€56.3m	2.77	€20.3/ton	Good	Very High
Low Emissions Zones	€60.4m	2.92	€20.7/ton	Moderate	Moderate
Public Sector EV	€28.2m	1.15	€24.6/ton	Good	Moderate
Bus EV	€222.2m	1.68	€133/ton	Moderate	Moderate
Ultra-low Emission Vehicles	€163.2m	1.07	€152/ton	Moderate	Moderate
Urban Congestion Pricing	€792.8	2.73	€291/ton	Politically Challenging	Moderate
Scrappage Scheme	€146.3m	0.35	€413/ton	Good	Very High

Note: Costs are discounted, using a 4 percent discount rate, while emissions are undiscounted.
Sources: World Bank, TRANSEPT.

Table 25: Criteria for Defining the Performance of Each Intervention (**Source: World Bank)**

Intervention	Good	Moderate	Poor/low
Scheme investment cost	Under Euro 10 million	Euro10-50 million	>Euro 50 million
Absolute Emissions Savings	>10 Mt	2-10 Mt	<2 Mt
Carbon reduction cost-effectiveness	<Euro10/ton	Euro 10-100/ton	>Euro 100/ton
Deliverability/economic impact	Positive impact/easily deliverable	Moderate, some challenges/some negative impacts	Politically challenging/significant economic impact
Wider Benefits	Strong wider benefits	Moderate benefits	Low wider benefits

141. In the near term, whilst politically challenging and economically burdensome in particularly on the lower income households, applying increases in fuel taxation is more practicable. The requirements to change speed restrictions, with the associated awareness campaigns and need for reminder signage and enforcement would involve greater upheaval. It is therefore recommended that fuel taxation be considered as a key tool in achieving significant carbon abatement over the period of the Action Plan and Strategy. Of the 'second tier' intervention measures which may contribute valuable abatement to carbon emissions in absolute terms, the new vehicle registration tax is identified as a tool which can bring significant carbon savings through the influencing of purchasing decisions. Again, this measure has the

potential to create adverse political pressure, even whilst remaining fiscally neutral, and may have negative equity implications in the increased taxation of older and less efficient vehicles. However, as seen in countries across Europe, influencing the make-up of the vehicle fleet at point of purchase is an effective means of encouraging evolution towards a lower emitting vehicle stock. The benefits of this continue to be realized over time, and represent a particularly important opportunity in the face of a high projected growth rate in motorization levels and car ownership.

142. Eco-driving programs also offer significant potential for the reduction in vehicle emissions, and unlike the previous interventions, there are no significant barriers to implementation or adverse impacts. In fact, eco-driving offers significant potential wider benefits in the form of cost savings for motorists and enhanced environmental and safety benefits. Investment costs will vary according to the nature of the program implemented, but studies have highlighted the measures as performing strongly in terms of both overall impacts and value for money.

143. The following interventions perform strongly in value for money terms and should also be considered for adoption within the climate change action plan, and as a feature of the Green Scenario.

- **Smarter choices programs** combined with investment in walking and cycling infrastructure have been demonstrated to lead to modal shift, achieving not only a reduction in emissions levels but also significant wider benefits including health and wellbeing, and decongestion. In cost-benefit analysis, these schemes typically perform strongly, with cost-benefit ratios in excess of 20 by comparison with highway and public transport schemes in the low single figures. This analysis demonstrates that with concerted and sustained investment over the strategy period, emissions savings realized at a reasonable level of cost effectiveness.

- **Parking pricing** is a further market based measure which offers the potential for emissions savings with a high level of cost effectiveness. Indeed, the measure would be expected to offer a stream of revenue which could facilitate some of the investment measures highlighted above. Parking pricing, in conjunction with tightened parking regulation and enforcement, may be considered to be a more cost effective more readily implementable solution to in town congestion instead of urban congestion charging and most European cities are following this strategy in preference to congestion charging; and

- **Air travel taxation** presents a mechanism for exerting some control over the growing demand for air travel at the margins, and also offers a revenue stream which may be put to useful purpose. The implications for the economy need to be considered, but there is are potentially positive equity impacts in what may be expected to be a strongly progressive form of taxation.

144. Based on the analysis of the abatement potential of the identified measures and on the results of wider assessment, the following measures are proposed for consideration within the Action Plan period under the Green Scenario:

- Fuel Price Taxation Increase
- New Vehicle Registration Tax
- Eco-Driving Program
- Smarter Choices/Personal Travel Planning Programs
- Investment in Walking and Cycling Infrastructure
- Parking Pricing
- Air Travel Taxation

145. Of the above measures, the market based policies where the taxation mechanisms already in place require no significant capital investment. The combined undiscounted capital investment of the above infrastructure dependent measures totals Euro 136 million over the timeframe of the Climate Change and Low Carbon Green Growth Strategy under the Green Scenario, but rise sharply for the Super Green Scenario (Table 26). For the Green Scenario, Euro 93 million of investment is profiled to fall within the period of the CC Action Plan, with ongoing investment in walking and cycling measures extending beyond 2022, based on a ten year investment profile. The mitigation impact of the combined bundle of interventions included within the Green Scenario is presented in Figure 44, together with the mitigation of the Super Green Scenario. Note that the impact of the bundle of measures is not identical to the sum of the individual measures due to the inter-relationship between certain policies.

146. The remaining interventions modelled as part of the study have not been considered suitable for inclusion within the Green Scenario, reflecting either the lower value for money based on the MAC analysis, or deliverability challenges. Non-inclusion within the Green Scenario does not however mean that the schemes have no value or that these should not be considered for implementation in Romania based on wider appraisal criteria such as economic impact or local air quality. The high costs of the Super Scenario are driven by the high cost of urban congestion charging scheme, but in terms of initial investment and operating and maintenance costs.

Table 26: Investment Costs of Green and Super Green Scenarios (Euro millions)

Scenario	Undiscounted Investment Cost			Discounted Investment Cost		
	CC Action Plan (2016-2020)	CC and Low Carbon Green Growth Strategy (2016-2030)	Model Period (2015-2020)	CC Action Plan (2016-2020)	CC and Low Carbon Green Growth Strategy (2016-2030)	Model Period (2015-2050)
Green Scenario	93	136	179	79	108	125
Super Green Scenario	885	1,477	2,603	748	1,136	1,562

Note: A 4 percent discount rate was used, in line with other sector reports.
Source: TRANSEPT.

147. The promotion of Ultra Low Emission Vehicles (ULEVs) has a place within government policy, and indeed incentives are currently offered for the purchase of low emitting vehicles both in terms of direct subsidy and as an additional stackable incentive under the existing scrappage scheme. Take-up of electric or plug-in electric vehicles to date has been low, which is likely to be a reflection of the limited existing infrastructure for such vehicles. Large scale investment in charging infrastructure would have the potential to increase take-up. However, this infrastructure has been seen to come at high cost, based on existing technology and the current commercial suppliers operating within this market. The technology is evolving rapidly, and already exposing misallocation of investment based on the approaches adopted by the countries early to provide supporting infrastructure. Equally, the marketplace is changing, and new business models relating to the provision of charging infrastructure are being developed, whether by vehicle manufacturers or by private suppliers identifying commercial potential. As such, it is considered that the high level of investment required to hasten the implementation of supporting infrastructure does not represent best value for money or lead to sufficient emissions reduction savings or wider benefits to merit immediate consideration.

148. Equally, whilst target setting relating to the acquisition of ULEVs within the public sector fleet and the public transport fleet may be considered laudable as a means of promoting and raising awareness about the technology, the cost of the new technology remains high by comparison with the emissions savings achieved, and the technological barriers to effective integration within the fleets are also notable in the near term. Speed restrictions have been rejected in preference to higher fuel duties due to the implementation difficulties, the economic impact and the lack of revenue generated by such a measure. Low Emission Zones are demonstrated to have carbon saving potential, although the driving force behind implementation of such policies is typically local air quality. With its very poor air quality standards, Bucharest would potentially benefit most significantly from such a measure, and the policy should be considered within this context. However, with high implementation and operating costs, technological and enforcement barriers and potential political resistance, the pursuing of such a policy in the short/medium term is not considered cost effective as a means of carbon emissions saving.

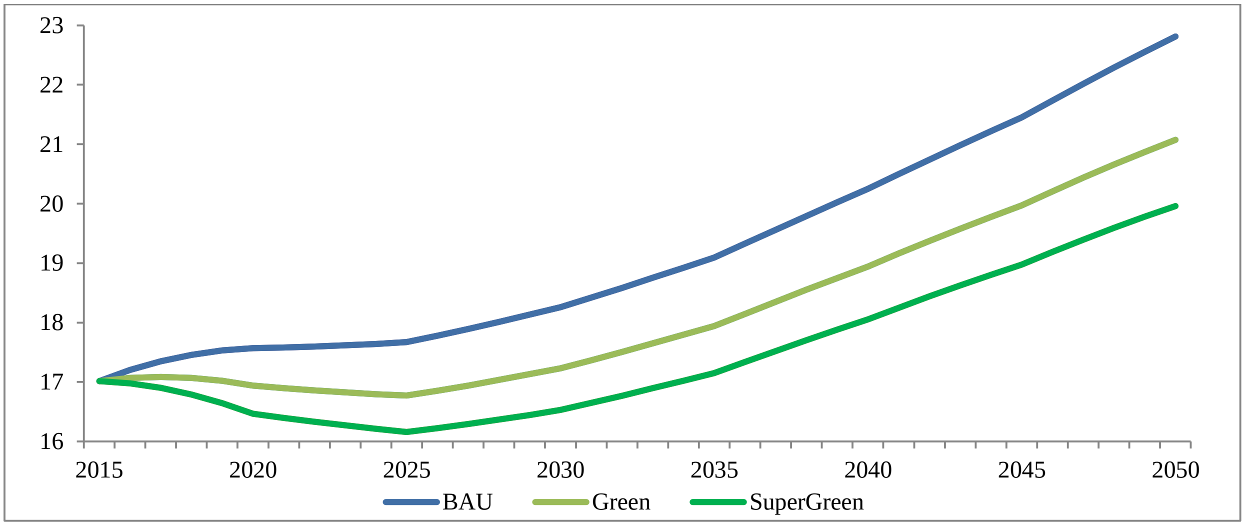
4.4 Conclusion

149. To demonstrate the scale of mitigation achievable under a high intervention or Super Green scenario, the Green Scenario policies as well as policies which were not selected for inclusion within the Green Scenario, but which nevertheless provide GHG emission saving potential amongst wider benefits have been included. The Super Green Scenario therefore represents an all policy modelled scenario. The scale of abatement potential achievable in the Super Green Scenario by comparison with the Green Scenario and the BAU scenario is presented in Figure 44.

150. Under the BAU scenario emissions grow by 34 percent over 2015-2050, while under the Green Scenario emissions growth slows to 24 percent and under the Super Green Scenario growth slows to 17 percent. In all cases GHG emissions from the transport sector rise. These results are in line with many studies which suggest that reducing GHG emissions in the transport sector—as opposed to reducing GHG

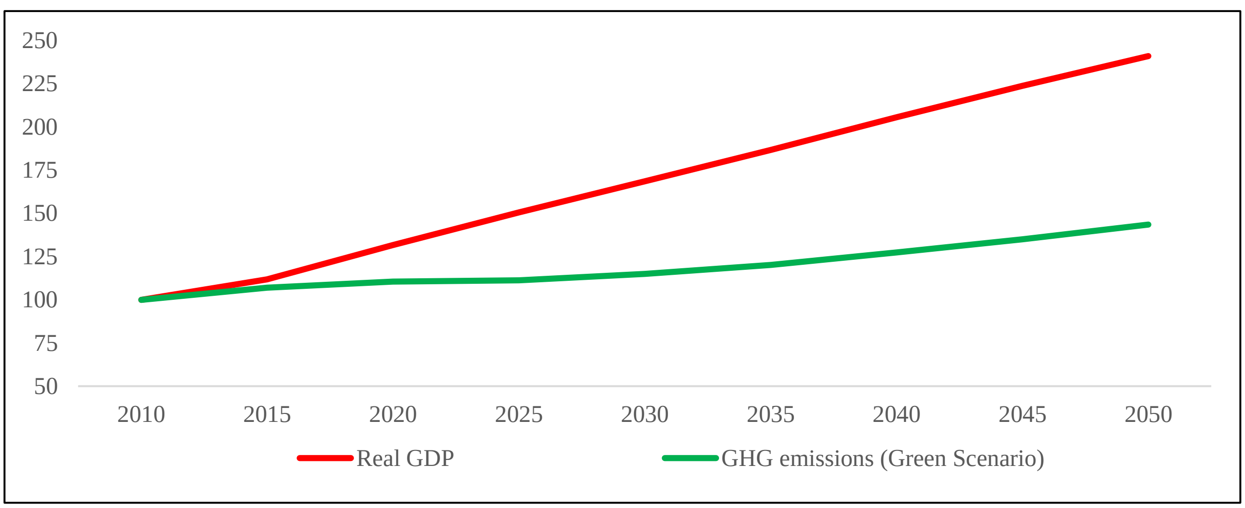
emission growth rate—is difficult in the transport sector. In order to reach a low emission scenario in 2050 Romania's transport sector has to have close to zero emissions, which will need large changes in behavior and technology. However, this growth in GHG emissions has to be seen in the context of a growing real economy. Figure 45 reveals that under a Green Scenario there is a gradual decoupling of GHG emissions from transport with growth in the economy.

Figure 44: Transport Emissions under Alternative Carbon Abatement Scenarios (MtCO2e)



Source: TRANSEPT.

Figure 45: Transport GHG Emissions and Real GDP Trends, 2010-2050 (2010 = 100)



Source: TRANSEPT.

ANNEX 1: TECHNICAL MODELLING NOTE

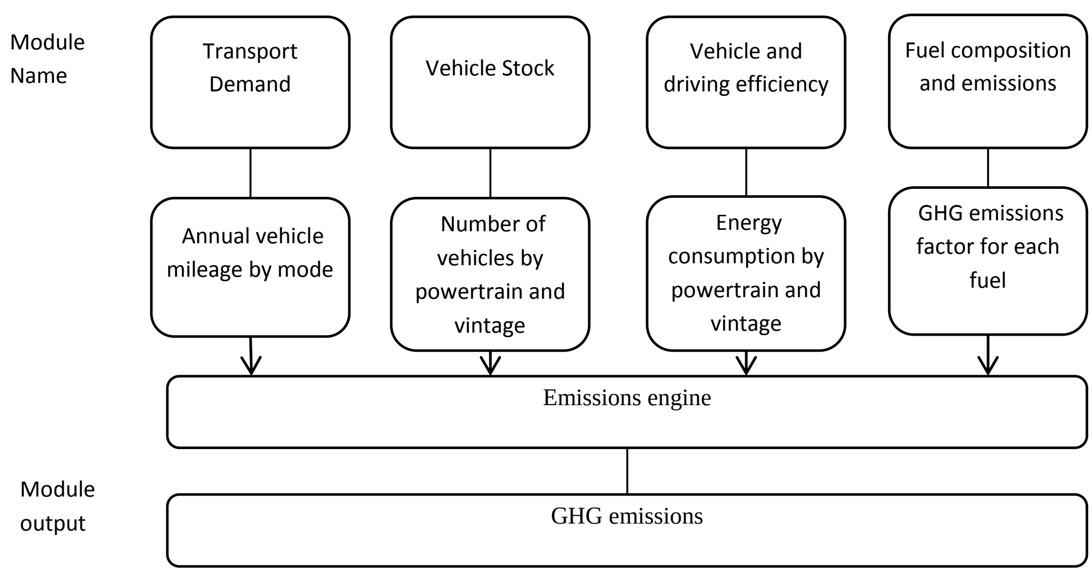
Overview

This technical note sets out the structure of the Romania Transport Emissions Model and the development of the GHG emissions baseline projections. This note identifies what the key datasets are, defines the values used for the BAU scenario, and later benchmarks the resulting GHG emissions of this baseline scenario. The emissions model is comprised of four modules which produce the input matrices for the emissions engine which calculates the GHG emissions. The four modules are:

- Transport Demand
- Vehicle Stock
- Vehicle and driving efficiency
- Fuel consumption and emissions

Each module takes a number of baseline datasets as input and applies the effect of relevant policies to them. The adjusted datasets are then input to the emissions engine which calculates the resulting GHG emissions. The process is outlined in the figure below.

Table A1: Overview of Model



Source: World Bank.

Description of Input Datasets

This emissions model has been developed in a format which ensures as far as possible that it is straightforwardly compatible with the datasets which are used as model inputs. These datasets are discussed in detail below, but include the National Transportation Model, COPERT and Eurostat statistics. Model outputs are also structured to provide relevant output statistics and results which can be compared with other studies. The format of the model outputs have been drawn from the SULTAN emissions model which was used to conduct Europe wide transport emissions modelling work for the European Commission. The model operates using a number of key desegregations including mode, powertrain, fuel used and location type (urban, non-urban, highway)

Table A2: Mode Coverage

Passenger	**Freight**
Car Motorcycle Bus and coach Rail, includes metro and tram Aviation to the EU Aviation to outside of the EU Walk and cycle	Van Medium Truck Heavy Truck Rail Inland Shipping Maritime Shipping

Source: World Bank.

Table A3: Powertrain Specific to Each Mode

Passenger transport					
Car	Bus	Rail	EU Aviation	Int Aviation	Motorcycle
Gasoline Diesel HEV gasoline HEV diesel PHEV gasoline PHEV diesel EV FCEV CNG	Diesel HEV diesel EV FCEV CNG	Diesel CR Eclectic HSR Electric	Short-haul	Long-haul	Gasoline FCEV EV
Freight transport					
Van	Medium Truck	Heavy Truck	Rail	Inland Shipping	Maritime Shipping
Gasoline Diesel HEV gasoline HEV diesel PHEV gasoline PHEV diesel EV FCEV CNG	Diesel HEV diesel PHEV diesel EV FCEV CNG	Diesel HEV Diesel FCEV CNG	Diesel Electric	Diesel CNG	Conventional LNG Conv + wind LNG + wind

Source: World Bank.

Table A4: Fuel Specific to Each Mode

Passenger transport					
Car	Bus	Rail	EU Aviation	Int Aviation	Motorcycle
Gasoline Diesel Electricity Hydrogen LPG CNG	Diesel Electricity Hydrogen CNG	Diesel Electricity	Kerosene	Kerosene	Gasoline Electricity Hydrogen
Freight transport					
Van	Medium Truck	Heavy Truck	Rail	Inland Shipping	Maritime Shipping
Gasoline Diesel Electricity Hydrogen LPG CNG	Diesel Electricity Hydrogen CNG	Diesel Electricity Hydrogen CNG	Diesel Electricity	Diesel LNG	Ship fuel LNG

Source: World Bank.

As mentioned above, a number of datasets belong to each of the four modules. The module holds the baseline values for each dataset as default and applies the effect of the policies to them. The datasets which each module contains are listed in the table below.

Table A5: List of Model Input tables

Model module	**Input table**	**Units**	**Disaggregation**
Demand	Vehicle capacity	Passengers/tons	By mode
	Vehicle load	% of capacity	By mode and location
	Total passenger and freight demand	Million Passenger-kms / million ton-kms	
	Split of demand by location and mode	% of demand	By mode and location
Stock	Total number of vehicles		By mode
	Split of all vehicles in use in 2011 by powertrain	% of vehicles	By mode and powertrain
	Split of new vehicles by powertrain	% of new vehicles	By mode and powertrain
Vehicle and driving efficiency	Energy consumption of all vehicles in use in 2011	Mega Joules/km	By mode and powertrain
	Energy consumption of new vehicles	Mega Joules/km	By mode and powertrain
Fuel	Fuel source of powertrain	% of power used	By mode and powertrain
	GHG direct emissions factor	Kg CO_2e	By mode
	GHG indirection emissions factor	Kg CO_2e	By mode
	Biofuel substitution	% of fuel energy	
	Biofuel GHG life cycle emissions factor reduction	% reduction of GHG emission factors	

Source: World Bank

The data is required for each of the model time horizons which are: 2011 (the base year), 2015, 2020, 2025, 2030, 2035, 2040, 2045 and 2050. The terminology for Mega and million or kilo and thousand are used interchangeably depending on the usual use for each data. A range of data sources were considered to identity the most appropriate baseline values for Romania. These sources include:

- COPERT: a database of road transport demand, stock and emissions– provides Romania specific dataset.
- TREMOVE: a behavior based transport model for the EU - model inputs include Romania specific data
- SULTAN: a transport emissions model for the EU – provides average values for the EU
- Eurostat – provides transport data specific to Romania
- EU Energy, Transport and GHG Emissions, Trends to 2050, Reference Scenario 2013, – used outputs specific to Romania
- Romanian National Transport Model

No single source provides all of the data required for the emissions model because different sources specialize in certain modes and because sources differ on their definitions of mode -for example Eurostat groups some van journeys with passenger cars, while COPERT separates out all van journeys.

Demand Module

Vehicle Capacity

SULTAN provides EU wide average capacity for all modes. The TREMOVE dataset, which is specific to Romania, largely matches that of SULTAN, however does not include every mode and it used different categories for truck. We have taken most values from SULTAN with the exception of inland shipping. The nature of inland shipping in Romania is atypical within the EU because of the heavy use of push and dumb vessels on the Danube.[76]

The average capacity was instead calculated using Eurostat data, by dividing the total tonnage of inland vessels (including dumb) by the number of push vehicles. This provides a value of 4,566 tons which is more than double that of the EU average used in SULTAN of 2,000 tons.[77] Vehicle capacity remains constant across the time horizons.

Table A6: Average Vehicle Capacity

Mode	Chosen value	Source

[76] These vessels can transport much higher loads than the normal barge, a comparison of vessel capacities can be found here:
http://www.binnenvaart.be/en/binnenvaartinfo/scheepstypes.asp.

[77] http://ec.europa.eu/eurostat/web/products-datasets/-/iww_eq_age_loa
http://ec.europa.eu/eurostat/web/products-datasets/-/iww_eq_age.

Passenger transport, average maximum people per vehicle		
Car	5	SULTAN & TREMOVE
Bus	50	SULTAN & TREMOVE
EU Aviation	121	SULTAN
Int. Aviation	350	SULTAN
Passenger Rail	400	SULTAN
Motorcycle	2	SULTAN & TREMOVE
Freight transport, average maximum tons per vehicle		
Van (van and LGV <3t)	1.2	SULTAN
Medium Truck (3-16t)	4	SULTAN
Heavy Truck (16-32t)	15	SULTAN
Inland Shipping	4,566	Eurostat
Maritime Shipping	17,904	SULTAN
Freight Rail	1,000	SULTAN

Source: World Bank

Vehicle Load

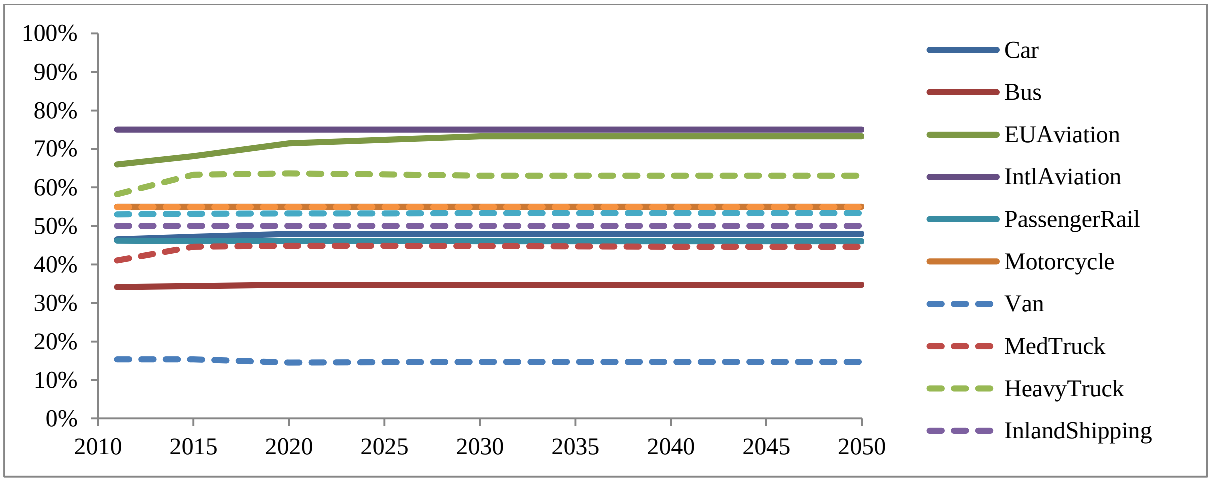
SULTAN and TREMOVE use values for average load from 2010 to 2050 for the EU and Romania respectively. Average loads are all higher in TREMOVE, which is to be expected in Romania. We have therefore used the TREMOVE values for load where available. Table A7 presents the values for load used in 2011 and their source and Figure A1 shows how the chosen profiles vary through time. There are two deviations from the available TREMOVE or SULTAN data:

- The load for passenger rail in TREMOVE appears too high and produces values for rail energy demands much lower than those reported in Eurostat, therefore the load for passenger rail was taken from SULTAN.
- The load of inland shipping provided by SULTAN is probably not typical of Romania because of the unique use of the Danube, we have therefore taken a provision value of 50% which yields levels of energy usage expected by Eurostat.

Table A7: Average Vehicle Load

Mode	Chosen value (2011)	Source
Car	46.5%	TREMOVE
Bus	34.1%	TREMOVE
EU Aviation	65.4%	SULTAN
Int. Aviation	75.0%	SULTAN
Passenger Rail	46.2%	SULTAN
Motorcycle	55.0%	TREMOVE
Van	15.4%	SULTAN
Medium Truck	41.0%	SULTAN
Heavy Truck	58.2%	SULTAN
Inland Shipping	50.0%	Provisional estimate
Maritime Shipping	53.0%	SUTLAN
Freight Rail	54.9%	TREMOVE

Figure A1: Profile of Vehicle Load by Mode (2011 to 2050)



Source: World Bank

Passenger and Freight Demand

Estimations of total transport demand are provided by COPERT, Trends to 2050, TREMOVE and Eurostat. Table A8 compares data from these datasets and presents the chosen values for the base year, 2011. Statistics for road transport demand provided by COPERT and Eurostat differ, however COPERT provides more detailed within the data, for example it identifies demand by location and it separates out more modes. We have therefore taken COPERT values in most cases for road transport. The exception is the demand for heavy trucks, for which COPERT records double the ton-km than Eurostat. One possible reason is that Eurostat data relates only to vehicles registered in Romania, whereas COPERT data might relate to all heavy trucks operating inside Romania. To help benchmark the model we have used the

Eurostat value provisionally as this is the value that would have been used as part of the Trends to 2050 modelling.

Table A8: Total Transport Demand within Romania, 2011

Mode	Eurostat	COPERT	Chosen value	Source and notes
Passenger transport in Million Passenger-kms				
Car	75,000 (Car+MC)	70,593	70,593	COPERT
Bus	11,800	9,052	9,052	COPERT
EU Aviation	6,600	-	5,900	NTM finds 90% flights within EU
Int. Aviation		-	700	
Passenger Rail (Inc. Metro and Tram)	12,200 (of which 7,199 tram/metro)		12,000	Eurostat
Motorcycle	653	329	12,200	COPERT
Walk/Cycle	8,468 (cycle only, from TREMOVE)		8,468	TREMOVE
Freight transport in Million Ton-Kms				
Van	5	2,345	2,345	COPERT
Medium Truck	4,760	5,052	5,052	COPERT
Heavy Truck	21,584	43,108	21,584	Eurostat
Inland Shipping	11,409	-	11,409	Eurostat
Maritime Shipping		-		
Freight Rail	14,719	-	14,719	Eurostat

Source: World Bank

The emissions model requires the total demand to be broken down by location. COPERT provides this data for road transit. For the remaining modes we have used the EU wide averages presented in SULTAN.

Table A9: Split of Demand by Location, 2011

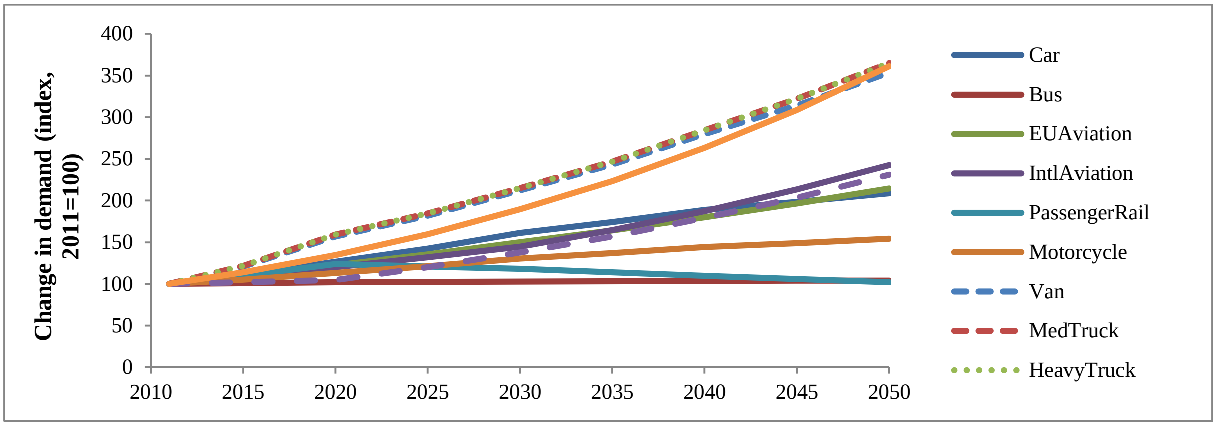
Mode	**Urban**	**Non-urban**	**Motorway**	**Source**
Car	44%	42%	14%	COPERT
Bus	67%	16%	18%	COPERT
EUAviation	0%	100%	0%	SULTAN
IntlAviation	0%	100%	0%	SULTAN
PassengerRail	31%	69%	0%	SULTAN
Motorcycle	72%	17%	11%	COPERT
WalkCycle	97%	3%	0%	SULTAN
Van	37%	37%	26%	COPERT
MedTruck	35%	35%	30%	COPERT
HeavyTruck	35%	35%	30%	COPERT
InlandShipping	0%	100%	0%	COPERT
MaritimeShipping	0%	0%	0%	SULTAN
FreightRail	0%	100%	0%	SULTAN

Source: World Bank

Projected changes to future demand have been taken from the 'Environmental and Economic Scenario' of the NTM. This model forecasts transport demand up to 2040, so the trends were extrapolated to 2050. The NTM only models non-urban and highway trips, therefore the projected growth has only been applied to demand at these locations. This also serves to avoid an overlap with the urban modelling team. Figure

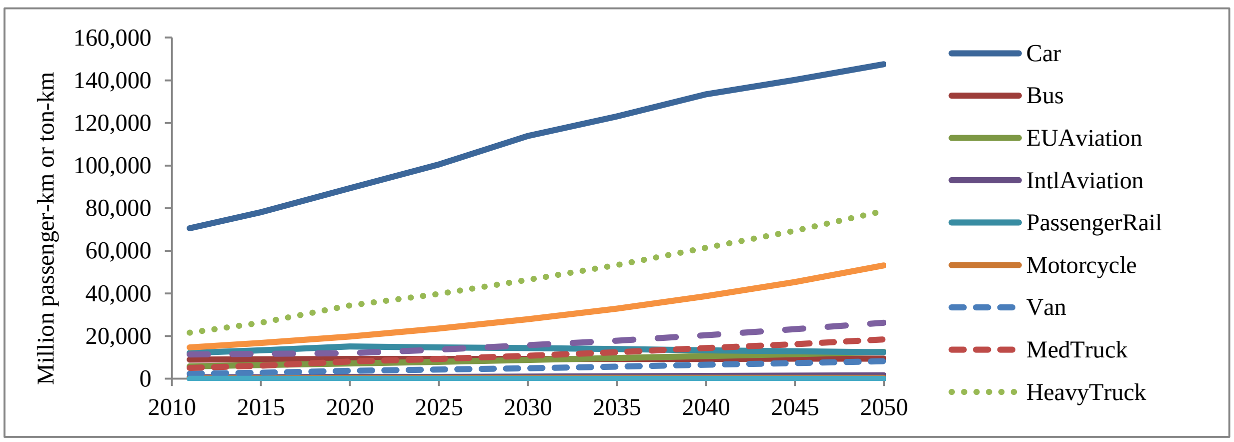
A2: presents the change in demand that is forecast by the NTM, and Figure A3 applies these trends to the demand for transport.

Figure A2: Relative Change in Transport Demand taken from NTM



Source: World Bank.

Figure A3: Projected Transport Demand to 2050



Source: World Bank.

Vehicle Stock Module

Estimates of the total vehicle stock in 2011 are provided by Eurostat and COPERT. The chosen values for 2011 are presented in Table A10 below. Values presented by COPERT and Eurostat often differ. For example Eurostat reports there to be 4,335,000 cars in 2011 compared to 5,284,494 by COPERT. However we have chosen to use COPERT values for most modes because this data explicitly concerns vehicle data.

Table A10: Total Vehicle Stock in 2011

Mode	Chosen value	Source and notes
Car	5,284,494	COPERT
Bus	28,487	COPERT
EU Aviation	50	Eurostat, with 10% of flights external to EU
Int. Aviation	4	
Passenger Rail	794	Eurostat
Motorcycle	166,157	COPERT
Van	565,092	COPERT
Medium Truck	130,564	COPERT
Heavy Truck	209,621	COPERT
Inland Shipping	341	Eurostat
Maritime Shipping		
Freight Rail	926	Eurostat including use of Marfa statistics

Source: World Bank

To project vehicle stock to 2050 we have set the number of vehicles as proportional the change in demand.[78] The split of each mode by powertrain for all vehicles in use in 2011 is presented in Table A11. COPERT provides the most detailed data on the number of vehicles by powertrain, so its values have been used where possible. Eurostat data has been used in conjunction with Marfa, the Romania's rail freight operator, to provide the split between diesel and electric rail locomotives. SULTAN values were used for air and shipping.

Table A11: Split of vehicles by powertrain for all vehicles in 2011

Mode	**Powertrain**	**Split of all vehicles**	**Source**
Car	Gasoline	68%	COPERT
	Diesel	28%	
	LPG	4%	
Bus	Diesel	100.0%	COPERT
EU Aviation	Short-haul	100.0%	SULTAN
Intl Aviation	Long-haul	100.0%	SULTAN
Passenger Rail	Diesel	62.7%	Eurostat & Marfa
	CR Electric	38.3%	
Motorcycle	Gasoline	100.0%	COPERT
Van	Gasoline	33%	COPERT
	Diesel	67%	
Med Truck	Diesel	100.0%	COPERT
Heavy Truck	Diesel	100.0%	COPERT
Inland Shipping	Diesel	100.0%	COPERT
Maritime Shipping	Conventional	100.0%	COPERT

[78] The vehicle lifecycle model is taken from SULTAN, and is based on survival rates which decline with vehicle age. Vehicles drop out of the fleet according to this survival profile, and are replaced in the quantity required to meet the fleet size growth profile.

Freight Rail	Diesel Electric	59.4% 40.6%	Eurostat & Marfa

Source: World Bank

Split of New Vehicles by Powertrain

The powertrain split of all vehicles in 2011 provides the baseline conditions for the model. However a key element for future projections of emissions is the type of vehicles that will be purchased in the future. Values for the powertrain split of new vehicles have been taken from the BAU scenario of the Trends to 2050 scenario set used in SULTAN. Although these projections are not specific to Romania, these are taken presently as the best estimates available. Table A12 presents the split of new vehicles for the decadal time horizons.

Table A12: Split of New Vehicles

Mode	Powertrain	2011	2020	2030	2040	2050
Car	Gasoline	52.5%	55.2%	51.3%	46.4%	44.6%
	Diesel	47.2%	36.3%	32.3%	31.7%	29.6%
	HEV gasoline	-	2.6%	7.4%	10.6%	13.2%
	HEV diesel	-	1.7%	5.0%	7.1%	8.8%
	PHEV gasoline	-	0.01%	0.01%	0.01%	0.01%
	PHEV diesel	-	0.01%	0.01%	0.01%	0.01%
	EV	-	0.00%	0.00%	0.00%	0.00%
	FCEV	-	0.00%	0.00%	0.00%	0.00%
	LPG	0.3%	3.7%	3.5%	3.5%	3.3%
	CNG	-	0.6%	0.5%	0.5%	0.5%
Bus	Diesel	98.2%	98.9%	97.9%	98.7%	98.5%
	HEV diesel	0.2%	0.6%	1.1%	1.3%	1.5%
	EV	0.0%	0.0%	0.0%	0.0%	0.0%
	FCEV	0.0%	0.0%	0.0%	0.01%	0.01%
	CNG	1.5%	0.5%	1.0%	0.01%	0.01%
EU Aviation	Short-haul	100.0%	100.0%	100.0%	100.0%	100.0%
Intl Aviation	Long-haul	100.0%	100.0%	100.0%	100.0%	100.0%
Passenger Rail	Diesel	29.0%	15.0%	1.0%	1.0%	1.0%
	CR Electric	71.0%	85.0%	99.0%	99.0%	99.0%
Motorcycle	Gasoline	100.0%	100.0%	100.0%	100.0%	100.0%
	EV	0.0%	0.0%	0.0%	0.0%	0.0%
Van	Gasoline	36.6%	38.4%	32.3%	33.8%	32.6%
	Diesel	62.8%	56.3%	55.8%	48.6%	44.6%
	HEV gasoline	0.3%	2.2%	5.2%	7.9%	10.5%
	HEV diesel	0.3%	3.0%	6.3%	9.3%	11.9%
	PHEV gasoline	0.0%	0.1%	0.1%	0.1%	0.1%
	PHEV diesel	0.0%	0.1%	0.2%	0.2%	0.2%

	EV	0.0%	0.0%	0.0%	0.0%	0.0%
Medium Truck	Diesel	99.5%	97.6%	95.7%	93.0%	89.9%
	HEV diesel	0.5%	2.4%	4.3%	7.0%	10.1%
	CNG	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy Truck	Diesel	100.0%	100.0%	100.0%	100.0%	100.0%
Inland Shipping	Diesel	100.0%	100.0%	100.0%	100.0%	100.0%
Maritime Shipping	Conventional	100.0%	100.0%	100.0%	100.0%	100.0%
Freight Rail	Diesel	49.0%	40.0%	25.0%	5.0%	5.0%
	Electric	51.0%	60.0%	75.0%	95.0%	95.0%

Source: World Bank

Vehicle and Driving Efficiency Module

The emissions model calculates the total energy used by vehicles of each powertrain. This requires an estimation of the average energy consumption for each powertrain, which is measured in Mega Joules per km (MJ/km). The model uses values presented in the BAU scenario for SULTAN as part of the Trends to 2050 scenario set. SULTAN uses 2009 as its base year instead of 2011, therefore we derived values for the average energy consumption by powertrain for vehicles operating in 2011 by applying historical changes in Romania's vehicle stock from 2009 to 2011.

Table A13: Average Energy Consumption of All Vehicles in Use by Powertrain (2011)

Mode	Powertrain	MJ/km
Car	Gasoline	2.97
	Diesel	2.62
	HEV gasoline	1.73
	HEV diesel	1.64
	PHEV gasoline	1.15
	PHEV diesel	1.11
	EV	0.63
	FCEV	1.06
	LPG	2.71
	CNG	2.57
Bus	Diesel	9.66
	HEV diesel	6.76
	EV	2.90
	FCEV	8.39
	CNG	10.73
EUAviation	Short-haul	166.39
IntlAviation	Long-haul	465.18
PassengerRail	Diesel	43.01
	CR Electric	35.48
	HSR Electric	43.30
Motorcycle	Gasoline	1.13

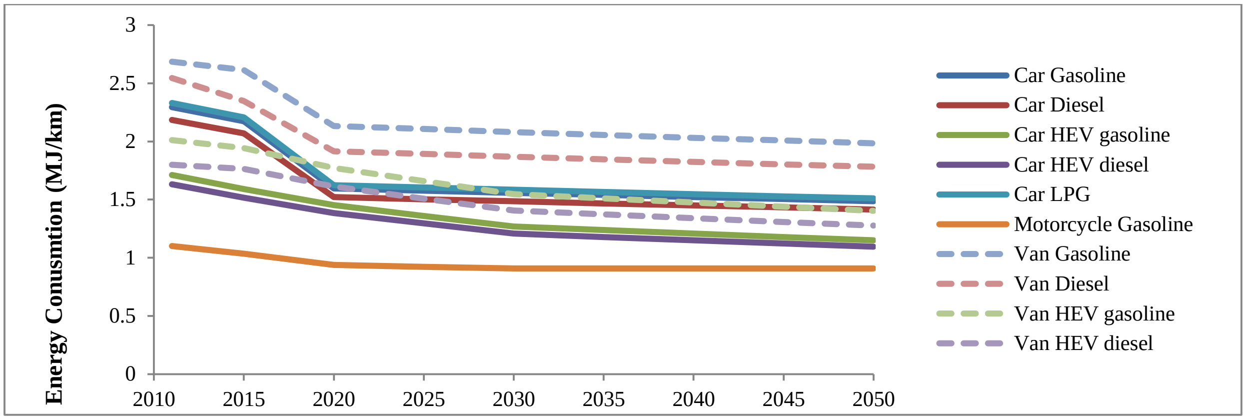
	FCEV	0.19
	EV	0.11
Van	Gasoline	3.49
	Diesel	3.17
	HEV gasoline	2.02
	HEV diesel	1.80
	PHEV gasoline	1.33
	PHEV diesel	1.21
	EV	0.73
	FCEV	1.22
	LPG	2.65
	CNG	2.93
MedTruck	Diesel	4.98
	HEV diesel	3.99
	PHEV diesel	3.12
	EV	1.49
	FCEV	3.01
	CNG	5.67
HeavyTruck	Diesel	12.47
	HEV diesel	11.50
	FCEV	4.15
	CNG	14.09
InlandShipping	Diesel	734.61
InlandShipping	LNG	699.52
MaritimeShipping	Conventional	2413.99
	LNG	2413.99
	Conventional + Wind	1931.19
MaritimeShipping	LNG + Wind	1931.19
FreightRail	Diesel	114.05
	Electric	51.85

Source: World Bank

Energy Consumption of New Vehicles

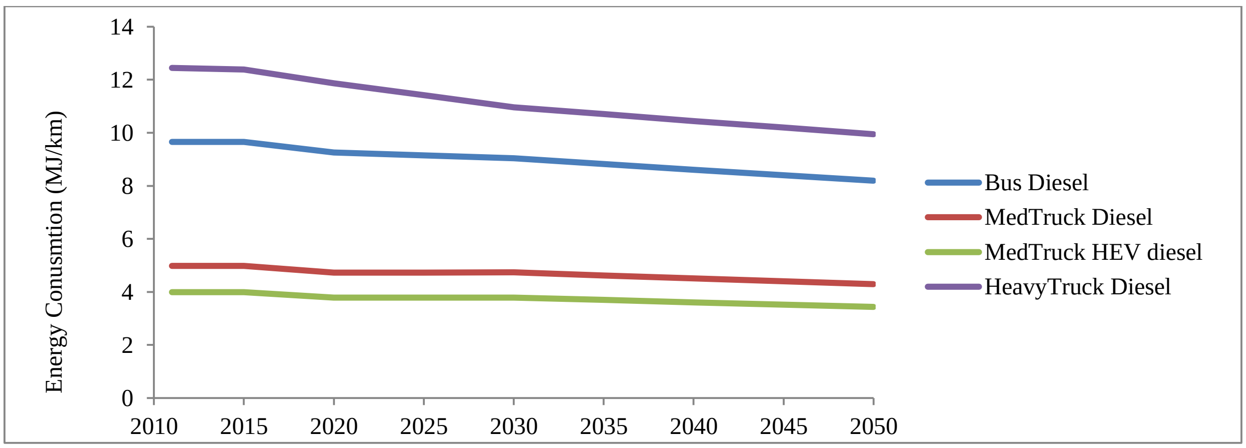
The energy consumption of new vehicles has been taken from the SULTAN BAU scenario. The values for a selection of powertrains by mode are presented in the four graphs below.

Figure A4: Energy Consumption of New Cars, Motorcycles and Vans to 2050



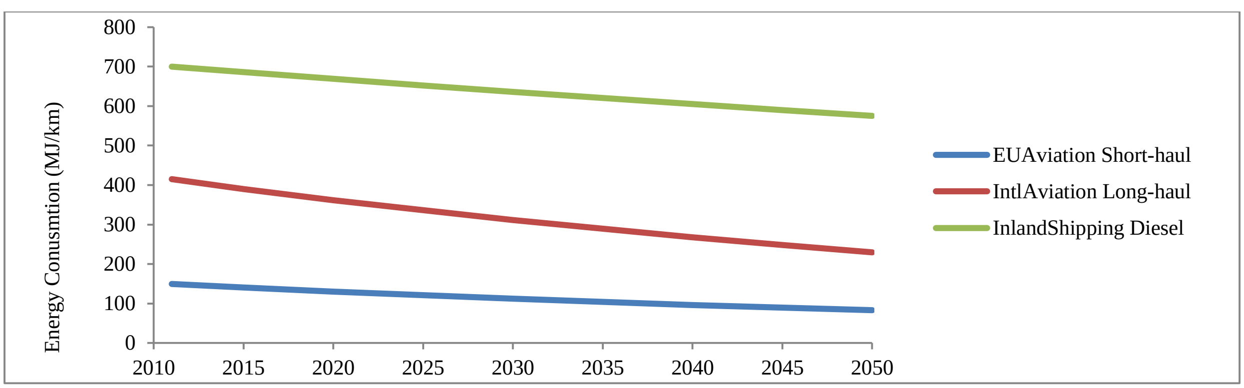
Source: World Bank

Figure A5: Energy Consumption of New Buses, Medium Trucks and Heavy Trucks to 2050



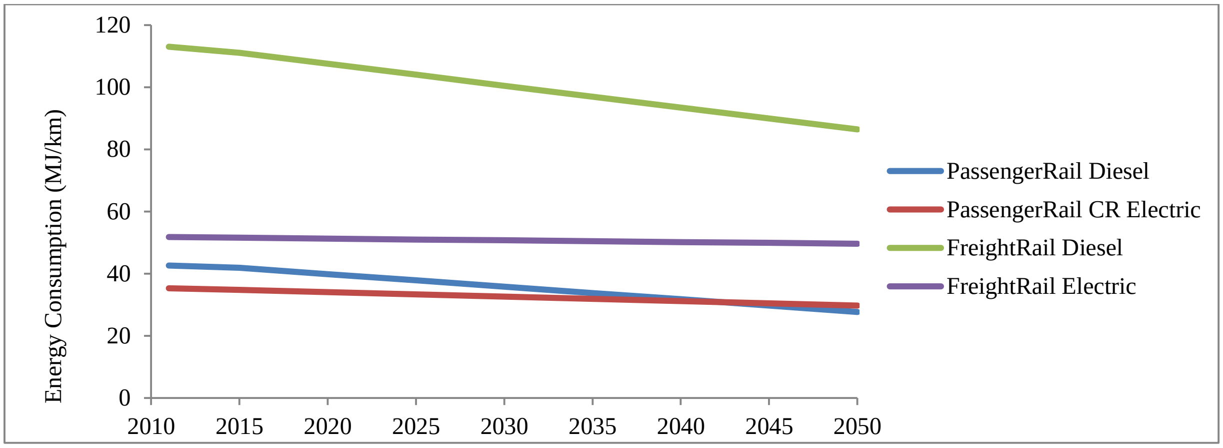
Source: World Bank.

Figure A6: Energy Consumption of New Planes and Inland Ships to 2050



Source: World Bank.

Figure A7: Energy Consumption of New Passenger and Freight Locomotives to 2050



Source: World Bank.

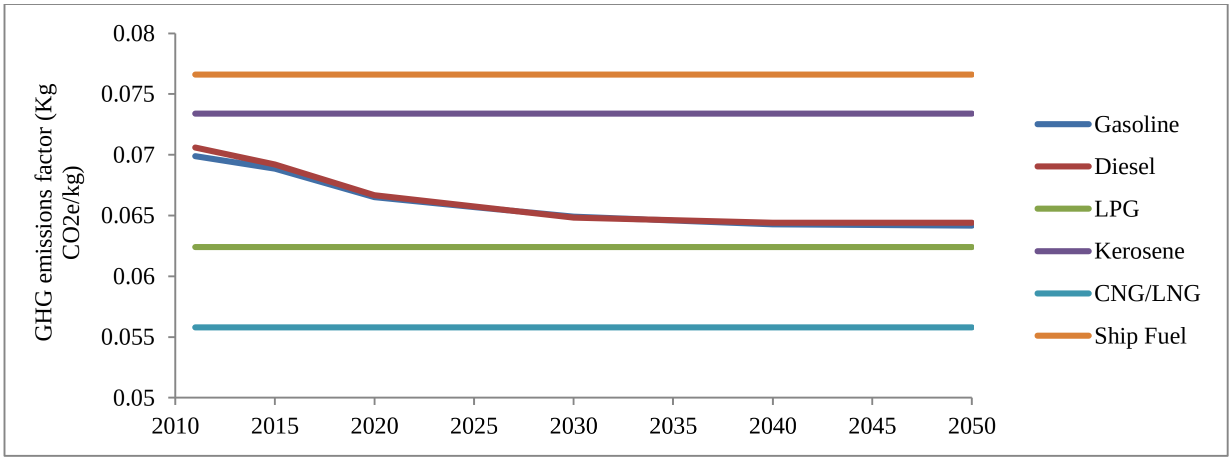
Fuel Composition and Emissions Module

Hybrid vehicles have dual power sources, combining electricity with gasoline or diesel. This model uses a ratio of energy consumption of 70 percent electricity to 30 percent gasoline or diesel. This split follows that used in the SULTAN scenarios. Direct GHG emissions are those produced from the vehicles' exhaust pipe due to combustion of the fuel. As such vehicles running on electricity and hydrogen don't create any direct GHG emissions. The quantity of GHG gasses emitted for each Mega Joule of energy provided is referred to as the emissions factor - this is measured in Kg of CO_2e per Mega Joule ($KgCO_2e/MJ$). The GHG emission factors for each fuel have been provided by the SULTAN BAU dataset.[79] This dataset foresees improvements in the quantity of GHGs emitted over time as shown in Figure A8. The SULTAN dataset

[79] The electricity generation mix has been taken as the EU average mix which is adopted in the SULTAN model, underpinning the Routes to 2050 work. The fuel assumption is incorporated into the model and an indirect emission factor which evolves over time as electricity production becomes cleaner. Emissions factors in kgCO2e/MJ have been modelled as followed: 0.1109 (2011), 0.10258 (2015), 0.09908 (2020), 0.0892 (2025), 0.07939 (2030), 0.06466 (2035), 0.050 (2040), 0.040 (2045), and 0.030 (2050).

actually features slight differences in the emissions factors for fuel used by the different modes, which this model also adopts.

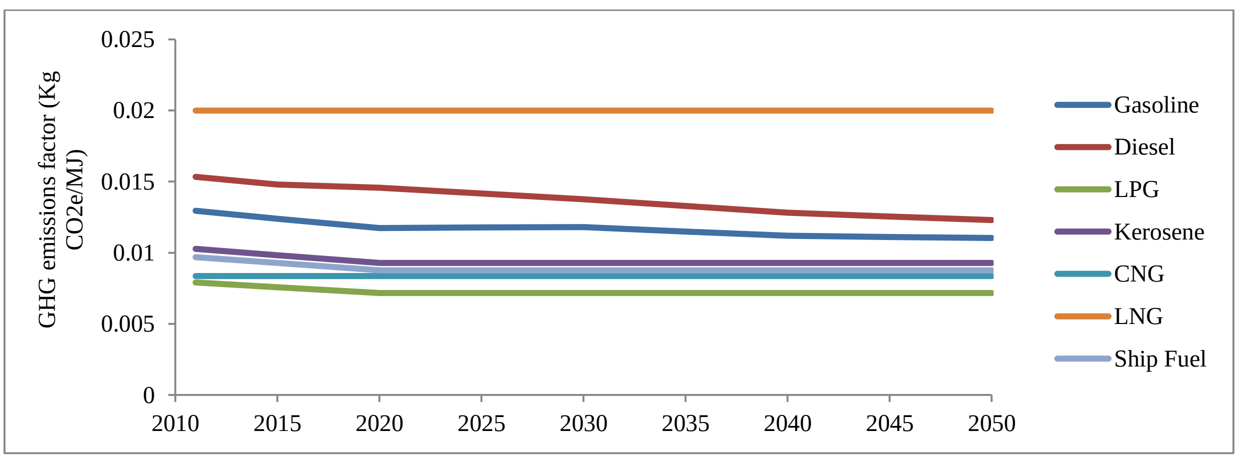
Figure A8: Direct GHG Emission Factor for Each Fuel, to 2050[80]



Source: World Bank

Indirect emissions are those produced in the course of sourcing, refining and transporting the fuel from its source to the vehicle. The source of inspiration was the SULTAN BAU dataset for these values. As supposed to direct emissions, all fuels have indirect emissions associated with them, especially electricity and hydrogen power. The baseline trend in indirect emissions to 2050 is presented in Figure A9 and Figure A10.

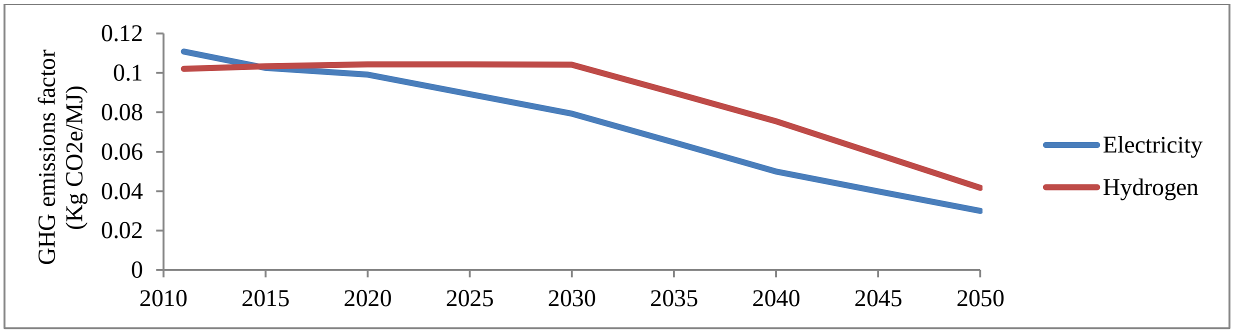
Figure A9: Indirect GHG emissions factor for fossil fuels, to 2050



[80] The direct fuel emission factors were taken from the SULTAN routes to 2050 baseline, based on best estimates of EU-wide fuel emissions factors.

Source: TRANSEPT.

Figure A10: Indirect GHG Emissions Factor for Electricity and Hydrogen Power, to 2050



Source: TRANSEPT.

Biofuel Substitution

Gasoline and diesel sold within the EU contains a proportion of biofuel, at present approximately 3% of gasoline and 5% of diesel is biofuel. Biofuels aim to be carbon natural because the GHG emissions produced when they are burnt are offset by the abstraction of CO_2 from the atmosphere when they are grown. Table A14 presents the projected increase in biofuel as a share of fuel to 2050; this data follows that of the SULTAN BAU scenario. Biofuels are an emerging technology therefore the carbon savings they currently yield are modest at 64% for gasoline and 54% diesel. However as the technology improves we expect these rates to improve into the future, as shown in Table A15. Again this data follows that of the SULTAN BAU scenario.

Table A14: Biofuel Substitution, Measured in % of Energy Substituted, to 2050

Fuel	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Gasoline	3.4%	4.8%	8.0%	9.2%	10.3%	10.7%	11.1%	11.2%	11.3%
Diesel	4.8%	6.7%	10.1%	11.4%	12.6%	12.9%	13.2%	13.2%	13.2%

Source: World Bank.

Table A15: Percent of Biofuel Energy that is Carbon Neutral

Fuel	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Gasoline	64%	67%	72%	73%	75%	78%	82%	83%	84%
Diesel	54%	65%	69%	74%	79%	84%	88%	90%	92%

Source: World Bank.

Benchmarking BAU Results

The emissions model produces three key outputs which are readily benchmarked against existing studies, these are:

- Transport activity - measured in million passenger-kms (Mpkm) or million ton-kms (Mtkm)
- Final energy demand – in kilo ton of oil equivalent (ktoe)

- GHG emissions - in Mega ton of CO_2 equivalent ($MtCO_2e$)

The first point, transport activity, is a key input to the model in the base year however the projection of how transport activity changes from 2011 to 2050 is an important output which requires to be benchmarked against other studies. The following two publications are useful sources of information to benchmark base year (2011) results:

- EU Energy, Transport and GHG Emissions: Trends to 2050, reference scenario 2013
- Eurostat figures, as presented in the Statistical pocketbook for Transport 2013

There is a considerable degree of cross over between these publications. The statistical pocketbook presents Eurostat data tables in an easily understood manner, and the Trends to 2050 study used Eurostat data for its baseline. Both sources are referred to because neither source is complete for the benchmarking task:

- The Trends to 2050 study provides estimates for final energy demand which are not provided by the statistical pocketbook, and
- The statistical pocketbook provides values for 2011, the base year, whereas Trends to 2050 provides data for 2010.

Transport Activity

As expected levels of transport activity provided by Trends to 2050 match those of Eurostat for the year 2010, with the exception of Inland navigation. The reason for the discrepancy with inland navigation is unknown. The activity levels for car and buses used in our emissions model are lower than Eurostat because we have used values from COPERT were possible. This is also the reason why truck activity is slightly higher. Activity levels for all other modes have been taken from Eurostat or Trends to 2050, so they must match.

Table A16: Comparison of Base Year Transport Activity

Source	Trends to 2050	Statistical Pocketbook 2013 (Eurostat)		Emissions Model
Year provided	2010	2010	2011	2011
Passenger transport demand (Mpkm)				
Cars	78,300	75,000	75,000	70,593
Motorcycles		No data	No data	329
Buses and coaches	12,000	12,000	11,800	9,052
Rail passengers	12,600	12,500	12,200	12,200
Aviation	6,600	No data	No data	6,600
Freight Transport Demand (Mtkm)				
Trucks	25,900	25,890	26,350	28,982
Rail	12,400	12,400	14,700	14,719
Inland navigation	6,900	14,300	11,400	11,409

Note: Trends to 2050 and Statistical pocketbook values are rounded to nearest 100.
Source: World Bank.

Energy Demand

The unit for energy which is used in the emissions model is the Mega Joule (MJ) and Peta Joule (PJ). However Trends to 2050 and the statistical pocketbook use kilo ton of oil equivalent (ktoe). 1 PJ is equal to 41.868 ktoe. The base year energy demand from our emissions model matches well the values provided by Trends to 2050 and Eurostat for road based transit. Our model doesn't match so well the rail and aviation values.

Table A17: Comparison of Base year Energy Demand (ktoe)

Source	Trends to 2050	Statistical Pocketbook 2013 (Eurostat)	Emissions Model
Year provided	2010	2011	2011
Car and motorcycles	2,018	No individual values	2,080
Buses and coaches	137		122
Trucks	2,245		2,098
All road transport	4,400	4,500	4,300
Rail – pax and freight	221	300	120
Aviation	272	200	324
Inland navigation	42	100	88
Total energy demand	4,953	5,200	4,832

Note: Statistical pocketbook values are rounded to nearest 100.
Source: World Bank.

GHG Emissions

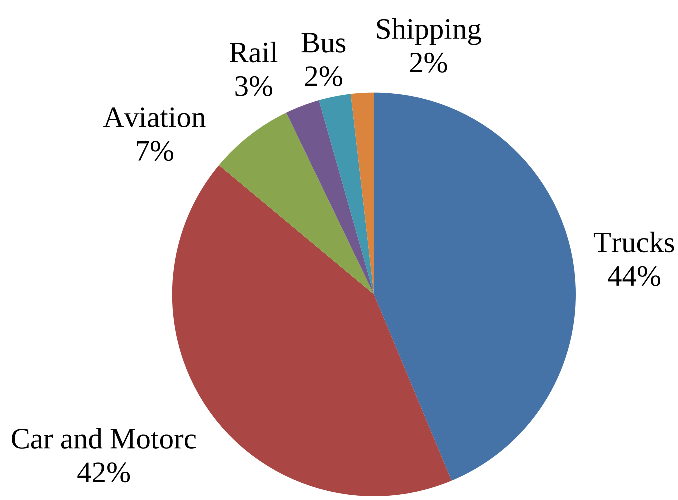
Neither Trends to 2050 nor the Statistical pocketbook provide GHG emission values for our base year, 2011. We have therefore extrapolated our model results backwards from 2011 to 2010 to provide a dataset we can compare. Table A18 shows a close correlation between the results of our emissions model and Eurostat estimations of emissions for 2010 for most modes. Emissions from aviation do appear to be higher in our emissions model. It should be remembered here that TRANSEPT uses Eurostat values for heavy truck activity in place of COPERT values which were twice as high. If we used the COPERT measure of heavy truck activity then this would add on 2.57 $MtCO_2e$.

Table A18: Comparison of Base Year GHG Emissions (MtCO2e)

Source	Trends to 2050	Statistical Pocketbook 2013 (Eurostat)	Emissions Model	
Year provided	2010	2010	2010 (extrapolation)	2011
All road transport	No breakdown provided	14.1	14.0	14.8
Rail – pax and freight		0.4	0.5	0.5
Aviation		0.8	1.1	1.1
Inland navigation		0.3 (incl. 0.1 as international)	0.3	0.3
Total GHG emissions	14.5	15.8	15.9	16.7

Source: World Bank

Figure A11: Modal Share of Transport Related GHG Emissions, 2011



Source: World Bank

We have compared our BAU results to the Trends to 2050 study. This study made projections of transport activity, energy demand and GHG emissions for every European country to 2050.

Transport Activity

The table below compares the projections of transport activity (demand) from our emissions model with Trends to 2050. The projections in our model have been taken from NTM to 2030 and extrapolated thereafter. It should be remembered that we only applied growth in trips to non-urban and highway locations. The key differences in the projections are:

(a) The emissions model forecasts less passenger growth than Trends to 2050, however this is to be expected because our urban trips do not grow (Figure A12).

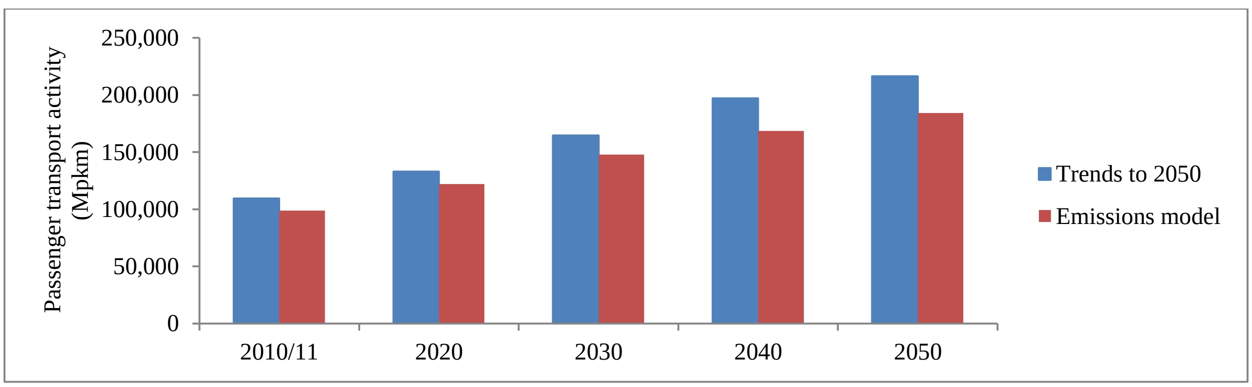
(b) The emissions model forecasts nearly double the growth in freight activity to 2050. This is partly due to the extrapolation of a high rate of growth from 2040 to 2050. The difference in freight activity is presented in Figure A13.

Table A19: Comparison of Transport Activity Projections to 2050

	Trends to 2050					Emissions Model				
Year	**2010**	**2020**	**2030**	**2040**	**2050**	**2011**	**2020**	**2030**	**2040**	**2050**
Passenger transport demand (Mpkm)										
Cars and motorcycles	78,300	91,800	111,100	130,300	139,200	70,922	89,771	114,264	133,863	147,963
Buses	12,000	13,600	15,400	17,100	18,800	9,052	9,240	9,309	9,371	9,426
Rail passengers	12,600	16,400	20,700	25,900	29,000	12,200	15,131	14,417	13,385	12,453
Aviation	6,600	11,100	17,500	23,900	29,600	6,600	8,067	9,860	11,927	14,348
Passenger total	**109,500**	**132,900**	**164,700**	**197,200**	**216,600**	**98,774**	**122,208**	**147,849**	**168,546**	**184,191**
Freight Transport Demand (Mtkm)										
Trucks	25,900	46,700	58,500	65,600	69,000	28,982	46,072	62,242	82,326	105,482
Rail	12,600	16,400	20,700	25,900	29,000	14,719	19,812	27,904	38,778	53,164
Inland navigation	6,900	9,000	10,800	12,100	12,700	11,409	11,964	15,715	20,446	26,344
Freight total	**45,200**	**73,000**	**90,900**	**102,100**	**108,000**	**55,110**	**77,848**	**105,861**	**141,549**	**184,990**

Source: World Bank

Figure A12: Comparison of All Passenger Transport Activity, to 2050



Source: World Bank

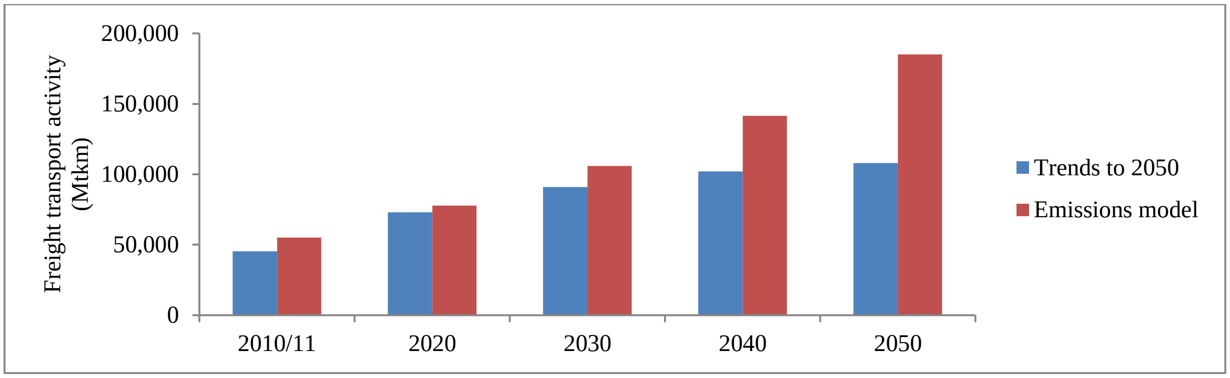
On a mode by mode basis the difference as:

(a) The emissions model forecasts higher growth in car and motorcycle trips, despite no increase in urban trips

(b) The growth in Bus, rail and aviation activity is much smaller in our emissions model compared to Trends to 2050. It could be that Trends to 2050 observes considerable increases in buses and rail use in the urban areas.

(c) All freight modes see considerably more use in our emissions model compared with Trends to 2050.

Figure A13: Comparison of All Freight Transport Activity, to 2050



Source: World Bank

Energy Demand

Projections for energy demand largely match the growth in transport activity described above. The emissions model see less growth in the energy demand for bus, rail, air, but much larger increases for trucks. Overall our emissions model projects a greater increase in energy demand to 2050 compared to Trends 2050, despite holding urban area activity constant.

Table A20: Comparison of Energy Demand Projections, to 2050 (ktoe)

	Trends to 2050						Emissions Model				
Year	2010	2020	2030	2040	2050		2011	2020	2030	2040	2050
Cars and motorcycles	2,018	1,992	1,952	2,096	2,161		2,080	2,007	1,928	2,017	2,117
Buses	137	152	161	171	183		122	121	118	114	109
Trucks	2,245	3,060	3,221	3,338	3,336		2,098	2,864	3,458	4,274	5,171
Rail passenger & freight	221	282	325	346	334		120	148	163	176	194
Aviation	272	418	524	619	733		324	348	376	401	417
Inland navigation	59	76	89	97	99		88	90	112	137	169
Total	4,953	5,980	6,272	6,668	6,846		4,832	5,578	6,154	7,120	8,177

Source: World Bank

GHG Emissions

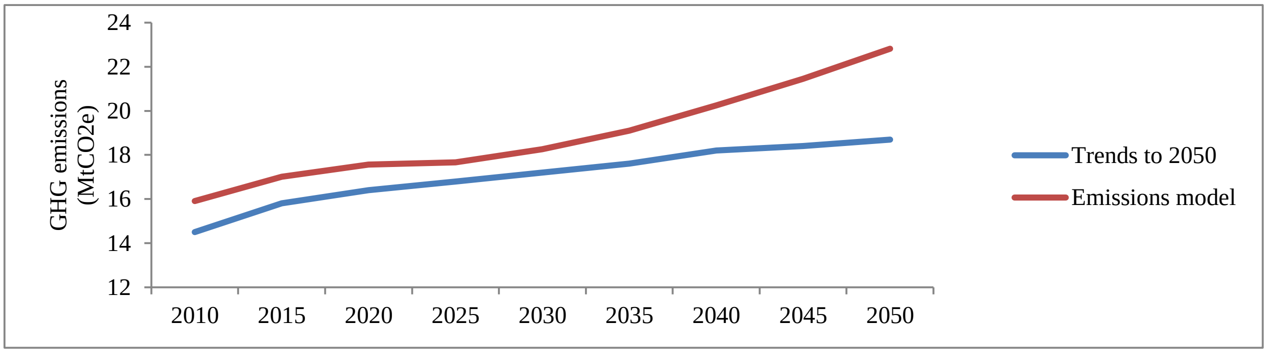
The key output of the Trends to 2050 study is projections of GHG emissions to 2050. It should be noted that the estimation of GHG emissions by Trends to 2050 in 2010 has been revised upwards in the Transport Statistical Pocketbook 2013. This raised the value from 14.5 $MtCO_2e$ to 15.8 $MtCO_2e$. This indicates that the Trends to 2050 model might underestimate emissions overall. Table A10 compares the projections of GHG emissions, which is also presented graphically in Figure A14. Overall our emissions model forecasts a greater growth in GHG emissions to 2050; this is to be expected because our growth in energy demand is higher. The principal driver of higher GHG growth in TRANSEPT is the higher projected vehicle activity levels taken from the National Transport Model. This model represents the planned investment in highway, rail and port infrastructure as well as the underlying drivers of travel demand such as growth in real GDP and car ownership.

Table A21: Comparison of Transport GHG Emissions to 2050 (MtCO2e)

Source	2010	2011	2020	2030	2040	2050
Trends to 2050	14.5		16.4	17.2	18.2	18.7
Emissions model	15.9	16.7	17.6	18.3	20.2	22.8

Source: World Bank

Figure A14: Comparison of Transport GHG emissions to 2050 (MtCO2e)



Source: World Bank.

EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments 2007 - 2013

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Romania Climate Change and Low Carbon Green Growth Program

Output C1.1
Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors

URBAN SECTOR TECHNICAL REPORT: A TECHNICAL ASSESSMENT OF THE ENERGY AND EMISSION IMPACTS OF ALTERNATIVE DEVELOPMENT PATTERNS IN THE BUCHAREST-ILFOV REGION

November 2015

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This report corresponds to “Output C1.1: Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors” in the Advisory Services Agreement on “Romania: Climate Change and Low Carbon Green Growth Program” signed between the Ministry of Environment and Climate Change and the International Bank for Reconstruction and Development on July 23, 2013.

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Abbreviations and Acronyms

AD	Anaerobic digestion
BIMR	Bucharest-Ilfov Metropolitan Region
CO2	Carbon Dioxide
CO2eq	Carbon Dioxide equivalent
CURB	Climate Action for Urban Sustainability
EU	European Union
FDI	Foreign Direct Investment
Gcal	Gram-calorie
GDP	Gross Domestic Product
GHG	Greenhouse gas emissions
GIS	Geographic Information System
GTMP	General Transport Master Plan
IUDP	Integrated urban development plan
KWH	Kilowatt hour
M2	Square meter
MJ	Megajoule
NMT	Non-Motorized Transport
NO_x	Nitrous Oxide
PM	Particulate Matter
PUG	Plan Urbanistic General
RACE	Rapid Assessment of City Emissions model
RAS	Reimbursable Advisory Services
RATB	Regia Autonoma de Transport Bucuresti (Bucharest)
SEAP	Sustainable Energy Action Plan
SO_2	Sulfur Dioxide
SOE	State Owned Enterprise
SUMP	Sustainable Urban Mobility Plan
TPD	Tons per day (of solid waste)
TRACE	Tool for the Rapid Assessment of City Energy
USD	US Dollar

Table of Contents

Section 1: Overview

1.1 Background

1. The urban sector contribution to Component C of the Romania Climate Change RAS consists of a development scenario analysis for the Bucharest-Ilfov Metropolitan Region (BIMR).[1] This analysis has been prepared to provide insights to the Romanian Ministry of Environment, Waters, and Forests (MEWF) on opportunities to change the greenhouse gas emission (GHG) trajectory of Romanian cities, using the Bucharest-Ilfov region as an example.

2. Because Component C of the Romania Climate Change RAS project is focused on understanding the implications of carbon-focused technology and policy interventions in several different sectors, GHG emission reductions are of primary interest in this report. The World Bank team acknowledges that there are many reasons why a city or region may wish to alter current technology use or development patterns, in an effort to reduce vehicle congestion, improve the local business environment, or improve local quality of life. This report seeks to highlight these facts where appropriate, but the report has not been written in a way that prioritizes such a conversation. This could reduce the report's relevance to readers for whom GHG emissions are of secondary importance.

3. This is an important point to make because the World Bank team had limited engagement with local government officials from around the Bucharest-Ilfov region in the early stages of work on this analysis. The analytic design therefore represents the team's expert judgment about how to structure and implement the analysis. In later stages of the team's work, important partnerships were forged with the local teams currently working on the new Bucharest master plan (*Plan Urbanistic General* – PUG) and the new Bucharest sustainable urban mobility plan (See Box 1.1 below) to share information and ideas. Ideally, this analysis will prove helpful to their work, providing insights on issues that are beyond their formal remit.

4. The analysis relies on outputs from the Rapid Assessment of City Emissions (RACE) model developed by Chreod Ltd. and Clean Air Asia, with minor modifications developed by the World Bank team. RACE is a geospatial model that compares population and development, patterns for a city/region under three different scenarios (one baseline + two future) to develop technical estimates of how they differ in terms of energy use, energy spending levels, air quality emissions, and GHG emissions. Given resource and time limitations, the RACE model does not seek to develop estimates of the cost-effectiveness of different interventions. Taking such considerations into account might lead decisionmakers to make different assumptions about where population and development growth should be allocated, how extensive building efficiency upgrades should be, and so on.

[1] BIMR is defined by Eurostat as Bucharest Municipality and Ilfov County.

5. In making GHG emission estimates, it must be emphasized that RACE follows a very different approach than is normally followed in developing a citywide GHG emissions inventory.[2] Such a comprehensive inventory was not possible given the budget and time frame available for this project. A decision was therefore made to use the RACE model's geospatial approach to develop estimates of total electricity demand, thermal demand, and transport-related energy demand in the Bucharest-Ilfov region by assigning energy use values to different land uses. (For example, commercial buildings are assumed to use 128 kWh of electricity and 110 kWh_e of thermal energy per m^2 of floor space. In the transport sphere, each type of land of land use was similarly assumed to generate some number of trips per day. In both cases, these estimates were drawn from the most appropriate local/national/industrial datasets available to the team.) Solid waste-related emissions were calculated separately using the CURB model, another scenario planning tool recently developed by the World Bank/C40/AECOM, and added to the results of the RACE model to allow the team to develop a three-sector portrait of GHG emissions for the Bucharest-Ilfov region.

6. The geospatial land use model on which the RACE energy and transport calculations were based was developed by the World Bank team from a variety of sources. As is the case in many cities, there was no single data repository the team could draw on for georeferenced information on local land use patterns around the Bucharest-Ilfov region, the local road and highway network, population data, building stock data, etc. In many cases, the team manually digitized information based on high-resolution satellite imagery. [Complete information on the modeling approaches used in this analysis can be found in Section 5 and in the technical appendices.]

7. At the end of the day, this report seeks to provide national and local authorities in Romania with insights into how policies affecting the speed and location of growth, the density of urban growth, the type/mix/location of transport infrastructure, the degree of integration between different land uses and transport services, and improved solid waste management practices can influence the long-term economic and environmental sustainability of a city. Recommendations are offered at the end of the report that provide guidance on how the strategies promoted on the future "low carbon" option can be delivered within the current national and local policy environment.

8. Fulfilling the vision outlined by these recommendations will be challenging. Romania currently lacks any formal climate strategy requirement for municipalities, although it does have other planning requirements that can influence land use and development patterns. Unfortunately, there are many policy and planning disconnects between different tiers of government in Romania, allowing local authorities to make decisions that are more reflective of localized concerns or political preferences rather than national or global climate imperatives. These disconnects influence district heating operations around the Bucharest-Ilfov region, the local public transportation system, land use

[2] For example, the Global Protocol for Community-Scale GHG Emissions, the methodology formally endorsed by the Bank, builds estimates by obtaining raw data on fuel/energy use from different sectors for a baseline time period. See http://www.ghgprotocol.org/city-accounting for more information.

permitting decisions, and spatial planning. These topics are all taken up at great length in Section 4 of this report.

1.2 Limitations of the Analysis

9. To complete this assessment, the World Bank team relied on an extensive literature review and in-person semi-structured interviews with a range of ministerial, local government, civil society, academic, and technical experts from the Bucharest region.

10. Data access was a significant issue. In many cases, underlying analytic work does not exist, or it has not been compiled and made available in published form. Although the team did include some native language speakers, language barriers may have affected the team's ability to examine the full array of information available via the internet.

11. Where local data was not available, the team employed national scale data as a proxy, or drew from other European or global datasets as reasonable proxies for the situation in Romania. For example, in the case of trip generation estimate information (i.e., the estimate of how many daily trips are attributable to a specific type of land use), estimates were obtained from a US dataset (US Institute of Transportation Engineers Trip Generation Manual) and then calibrated using the results of the Bucharest and Ilfov Travel Habits survey that was prepared as part of the SUMP. Similar circumstances exist in the estimates used to calculate building energy demand or the impacts of various energy efficiency upgrades. In all cases the team relied on its best professional judgment as to which datasets to use, and how they could be calibrated to represent the situation in Bucharest. However, to the extent these and other estimates are not representative of the true situation in Bucharest, then it may distort calculations of energy demand, energy spending, air pollutant emissions, or GHG emissions.

12. Finally, as was noted above, the models employed in this analysis have been used to estimate the technical potential for change in energy demand, emissions, etc. We have not sought to develop estimates of the cost-effectiveness or local/national political economy of different interventions. Taking such considerations into account might lead decisionmakers to make different assumptions about where population and development growth should be allocated, how extensive building efficiency upgrades should be, and so on. It is for this reason that this analysis should not form the absolute basis for land use or transport planning decisions. Instead, it highlights indicative changes that can be attributed to different policy decisions or estimates of how and where growth will manifest itself around a city. In doing so, we hope to provide insights into the value of strategic planning and efforts to shape development in ways that deliver both local and global environmental gains in a city or region.

Box 1.1: Related Planning Activities in the Bucharest-Ilfov Region

To enhance the Government's ability to absorb EU structure funds for transport projects, the Ministry of Regional Development and Public Administration, with the assistance of the European Commission and the European Bank for Reconstruction and Development, have partnered to support the development of Sustainable Urban Mobility Plans (SUMPs) for Bucharest-Ilfov and the seven other growth pole regions around Romania.

Each SUMP is a strategic plan that seeks to satisfy the mobility needs of people and businesses in cities while simultaneously delivering an improved quality of life. The focus of each plan is on improving access to jobs and services; improving safety and security; reducing pollution, GHG emissions and energy consumption; increasing the efficiency and cost-effectiveness of different transport systems; and enhancing the attractiveness and quality of the urban environment.

Work on the Bucharest-Ilfov SUMP has been underway, and the draft Final Report and Action plan is scheduled to be delivered by the end of June 2015. Work on the SUMP is overseen by AVENSA Consulting, with the active engagement of the Transport, Roads and Traffic Planning Directorate for Bucharest Municipality.

The SUMP is intended to feed into the *Plan Urbanistic General* (PUG), a new master plan for the City of Bucharest. (Although the SUMP necessarily takes account of Ilfov, the PUG is solely focused on development within the city's boundaries.) The purpose of this planning exercise is to redefine and update the previous plan adopted in 2010. As per Romania Planning Law 350/2001, a PUG is both a strategic and a regulatory document, providing the legal basis for urban development activities and investments. The PUG includes several subsidiary studies focused on (1) demographic and economic trends and social, environmental, housing, transport, and public facility needs; (2) a spatial development strategy and associated rules and regulations; (3) the local action plan; (4) the public investment program; and (5) the sustainable urban mobility plan (SUMP).

Work on the PUG began in 2013 under the guidance of a team of planners from the Ion Mincu University of Architecture and Urban Planning in Bucharest and a consortium of private consultants. The PUG is scheduled to be completed in at the end of 2016.

Section 2: Urban Areas in Romania – The Development and Climate Policy Context[3]

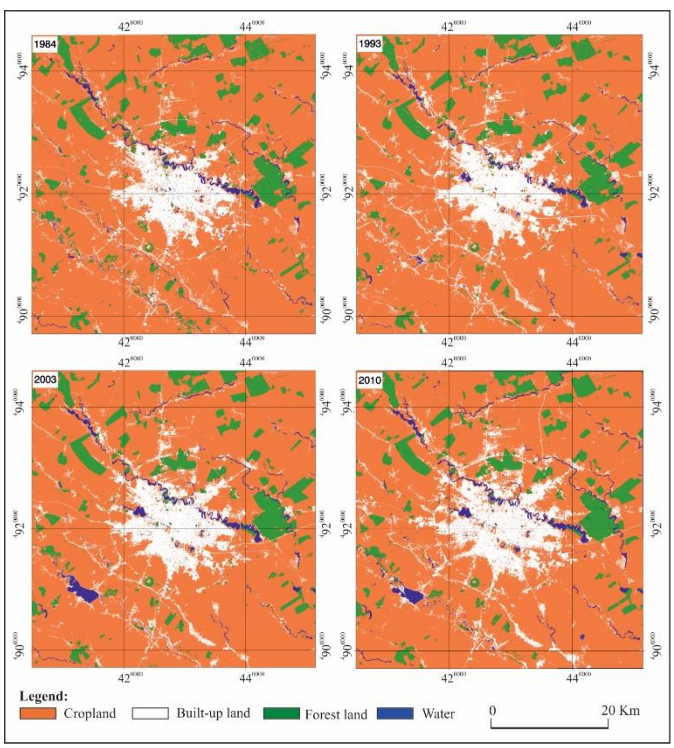
2.1 Overview

13. The official urbanization rate in Romania is roughly 55%, a level that is low compared to other parts of Europe. This rate has remained fairly constant for the past two decades, despite significant population migration out of the country and a strong suburbanization trend in areas immediately on the outskirts of major cities. Because central government demographers still categorize some of these regions outside the urban core as rural, this shift has not yet made its way into the official population statistics. If this were done, the urbanization rate could rise to 65%.[4]

14. For example, population levels in Ilfov County (on the periphery of Bucharest) have increased 69% in the period 1977-2011, jumping from 230,000 to 389,000 people. Figure 2.1 shows how development patterns have changed in Bucharest/Ilfov at different time intervals during this same period.

Figure 2.1: Expansion in Built Up Areas around Bucharest 1984-2010

Source: B Mihai, C Nistor, & G Simion, "Post-socialist urban growth of Bucharest, Romania – a change detection analysis on Landsat imagery (1984–2010)," *Acta Geographica Slovenica, (forthcoming).*



[3] This section excerpts heavily from information contained in an earlier report prepared as part of this same RAS project: World Bank, *Romania Climate Change and Low Carbon Green Growth Program, Component B Sector Report, Urban Sector Rapid Assessment*. January 2014.

[4] World Bank (2009) *World Development Report 2009: Reshaping Economic Geography*. Washington DC.

15. Tables 2.1 and 2.2 detail similar changes in built up area and population density in several other large cities around Romania.

Table 2.1: Changes in Built Up Area of Romanian Growth Pole Cities 1992-2012

Source: World Bank, *Enhanced Spatial Planning as a Precondition for Sustainable Urban Development.* 2013. p 18

	Built Up Area of Selected Cities (in hectares)			Change in Built Up Area
	1992	*2002*	*2012*	*1992-2012*
Brasov	3,511	3,928	4,360	24.2%
Bucharest	20,251	21.497	23,955	18.3%
Cluj-Napoca	4,295	4,410	5,346	24.5%
Constanta	4,258	4,382	4,566	7.2%
Craiova	4,045	4,628	5,152	27.4%
Iasi	3,596	3,966	4,224	17.5%
Ploiesti	3,039	3,120	3,238	6.5%
Timisoara	4,920	5,130	5,568	13.2%

Table 2.2: Changes in Population in Romanian Growth Pole Cities 1992-2012

Source: World Bank, *Enhanced Spatial Planning as a Precondition for Sustainable Urban Development.* 2013. p 15

	Population Density in Built Up Areas (people/hectare)			Change in density
	1992	*2002*	*2012*	*1992-2012*
Brasov	101	73	52	-48.4%
Bucharest	104	90	70	-32.7%
Cluj-Napoca	76	67	58	-23.6%
Constanta	84	71	56	-33.7%
Craiova	76	65	47	-37.6%
Iasi	95	77	62	-34.6%
Ploiesti	83	76	61	-26.7%
Timisoara	69	60	55	-20.6%

16. City and regional planning efforts aimed at managing this growth are governed by Romanian Law 350/2001 that seeks to balance social and economic development across the country. The law also seeks to manage natural resources, protect the environment, rationalize land use patterns in and around cities, and provide coherence to planning activities being carried out by different jurisdictions (local authorities, counties, etc.), each of whom have different, yet occasionally overlapping, sets of responsibilities.

17. Since 2008, national urban policy has also focused around an economic development paradigm emphasizing different types of growth poles' that are to serve as economic engines for the country.

Growth poles are divided into (1) seven large urban centers (plus Bucharest) and their areas of geographic and economic influence; (2) 'urban development poles' consisting of 13 municipalities and towns, and (3) smaller urban centers consisting of towns over 10,000 inhabitants.

18. The growth pole concept identifies a single local authority at the nucleus of the region that is to work collaboratively with other territorial administrative units in its vicinity. Integrated Urban Development Plans (IUDPs)[5] must be developed for each of these regions, elaborating both a local vision and a specific set of projects, timeline, budget, and financing sources designed to deliver that vision.

19. Although they are required to have a common focus, Integrated Urban Development Plans vary widely from city to city, reflecting unique needs and local policy and political preferences.[6] Thus far, they have rarely focused explicitly on climate change considerations, speaking in more familiar, siloed terms focusing on transportation challenges or shortcomings in other environmentally-focused infrastructure, such as waste or water systems. In a recent World Bank report[7] prepared in support of the Romanian government's climate planning work, it was recommended that climate considerations be more explicitly woven into IUDPs to show how sectoral needs link to larger global climate concerns.

20. The logic of doing so is quite obvious. Globally, cities are estimated to be responsible for 2/3 of total energy use and just under 50% of global greenhouse gas (GHG) emissions.[8] However, as has previously been noted in other World Bank reports, the contribution of cities to Romania's overall emission levels are unknown, given the dearth of comprehensive, multi-sectoral, local-scale greenhouse gas emissions inventories by Romanian cities.[9]

21. There is a similar lack of understanding about how Romanian cities will be affected by climate change.[10] Related planning activity has largely taken the form of local disaster plans, which are required by law, although the quality or breadth of these plans is unclear. One contributing factor is that little has been done to statistically "downscale" global climate models to provide a more granular, local picture of how the climate will change in Romanian cities in the coming decades. National climate models do exist, projecting that Romania will get warmer (with strong regional differences)

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[5] The concept of IUDPs was established under the EU Regio's Regional Operating Program Axis 1, seeking to ensure comprehensive, integrated plan development rather than sector-specific approaches.

[6] For example, see *Planul Integrat de Dezolvotare Urbana – Polul de Crestere Brasov* available at http://www.esponusespon.eu/dane/web_usespon_library_files/694/20110317231022_development_strategy_for_bma_extract_from_iudp_brasov.pdf

[7] World Bank, *Romania Climate Change and Low Carbon Green Growth Program, Component B Sector Report, Urban Sector Rapid Assessment*. January 2014.

[8] Marcotullio PJ, A Sarzynski, J Albrecht, N Schulz, and J Garcia. "The geography of global urban greenhouse gas emissions: an exploratory analysis" *Climatic Change* (2013) 121:621–634

[9] World Bank, *Romania Climate Change and Low Carbon Green Growth Program, Component B Sector Report, Urban Sector Rapid Assessment*. January 2014.

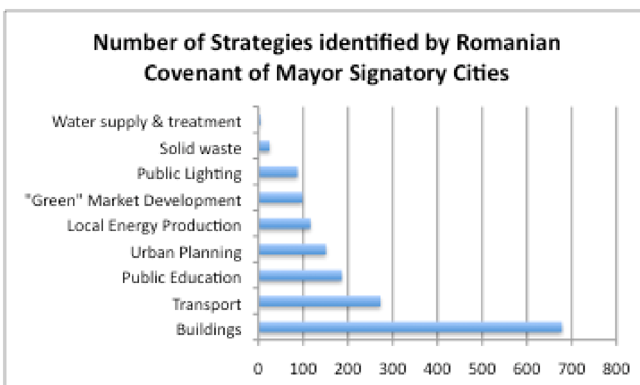
[10] World Bank, *Romania Climate Change and Low Carbon Green Growth Program, Component B Sector Report, Urban Sector Rapid Assessment*. January 2014.

and that both drought and extreme rainfall events are to become more commonplace in the coming century, again with strong regional differences. Such information does little to help a local authority assess what specific actions they should take going forward, however.

22. That is not to say that Romanian cities lack interest in these topics. As of September 2013, there were 60 Romanian communities[11] that had signed on to the European Commission's Covenant of Mayors program, an initiative aimed at promoting sustainable energy use in cities. The Covenant program requires signatories to develop and implement a Sustainable Energy Action Plan (SEAP) within a year of signing on to the program. Although there is a suggested plan format, local authorities have great latitude in terms of which sectors or strategies they choose to focus on in their SEAP. Together, these 60 communities collectively represent a population of roughly 5 million people, or 25% of Romania's population. Signatory communities include Bucharest District 1, Timisoara, Cluj, Brasov, Ploiesti and Arad. The majority of signatories are much smaller, however, with 25 of the 60 signatories having populations of less than 10,000.

23. To date, thirty of these signatories have submitted their SEAP, the majority of which are available for review online. The contents of 29 plans submitted as of July 2013 were analyzed to get a sense of how local authorities choose to prioritize their energy planning efforts.[12] As Figure 2.2 clearly shows, the vast majority of the strategies listed in these plans fall into the buildings and transport sectors, two sectors that typically dominate local energy use.

Figure 2.2: Energy Strategies detailed by Romanian Signatories in their Covenant of Mayors Sustainable Energy Action Plans (as of July 2013)



Source: World Bank, *Romania Climate Change and Low Carbon Green Growth Program, Component B Sector Report, Urban Sector Rapid Assessment*. January 2014.

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11 Covenant of Mayors. Signatories. Reviewed online at http://www.covenantofmayors.eu/about/signatories_en.html?q=Search+for+a+Signatory...&country_search=ro&population=&date_of_adhesion=&status= on September 6, 2013.

12 World Bank, *Romania Climate Change and Low Carbon Green Growth Program, Component B Sector Report, Urban Sector Rapid Assessment*. January 2014.

24. Within these two categories, the strategies most commonly mentioned in the sustainable energy action plans include the refurbishment/thermal rehabilitation of municipal public buildings, energy audits of public buildings and the issuance of energy performance certificates that meet EU requirements, the thermal rehabilitation of residential buildings (i.e. tower blocks), and the installation of photovoltaics on municipal buildings. In the transport realm, plans most commonly focus on modernization of the local public transport system and creation of a bike rental network.

25. Other climate-related planning work has taken place in seven Romanian cities where the World Bank's Tool for the Rapid Assessment of City Energy (TRACE) was deployed to support local energy efficiency planning efforts. TRACE helps local authorities assess their energy use in six key sectors under their control: water, waste, transport, public street lighting, buildings, and the power and heat sector. Cities can benchmark their energy performance against peer cities in each of these categories, receive guidance on which sectors should be prioritized for action, and evaluate which specific policy or technology interventions might be most appropriate in their city. An expert consultant working with local authority staff on data collection and analysis typically carries out a TRACE analysis, but it can be deployed independently by cities with some expertise on energy efficiency matters.

26. Given TRACE's efficiency focus, it does not address a full range of options that cities may consider to lower carbon emissions, such as the use of renewable energy technology or other fuel switching strategies.[13] TRACE is also most useful in addressing sectors over which a local authority has the greatest control – the public bus system, for example, rather than private automobiles – but some of the reports did adopt a broad perspective about the challenges and opportunities facing Romanian cities. Some of the generalizable conclusions from the various TRACE studies are as follows.

2.2 Urban Transport

27. Car ownership rates in Romania are similarly low compared to the rest of the EU, but they too are on the rise, exacerbating existing traffic congestion problems in most cities. Many cities have public transport systems (including buses, trams and trolleys), but declining ridership has made it difficult for system operators to finance those upgrades which might bring riders back to the system. Taxis are plentiful in most Romanian cities, but many of the vehicles are old and not fuel-efficient, mirroring the make-up of the nation's vehicle fleet. Some cities have an age limit for taxi vehicles, but this varies significantly from city to city. Finally, the pedestrian and cycling infrastructure varies greatly in quality and quantity between different towns and cities, and within different city areas.

28. A national General Transport Master Plan (GTMP) was developed but it does not cover urban transport investment and policy interventions. This is because responsibility for urban transport investment generally sits with the municipalities in Romania, under the aegis of the Ministry for Regional Development and Public Administration, rather than with the Ministry of Transport, which

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[13] It is for this reason that the World Bank recently launched a new software tool known as CURB (Climate Action for Urban Sustainability), a comprehensive, multi-sectoral decision support tool with very robust modeling capabilities. It is expected to be rolled out globally over the course of 2015.

has responsibility for the development of the GTMP. Sustainable urban mobility plans (SUMPs) are currently under development in Romania's seven growth pole cities and Bucharest/Ilfov. The Bucharest/Ilfov SUMP process was discussed earlier in Box 1.1.

2.3 Urban Energy Systems

29. Among EU27 countries, Romania has the lowest per-capita energy consumption. Per capita consumption of electricity is particularly low, but significant growth in electricity demand is already occurring, driven mainly by the residential and commercial sectors. Some of this growth is occurring as households move away from their reliance on district heating. District heating systems were once a prominent feature of many Romanian cities, but the 300 systems operating in 1995/96 had declined in number to 83 by 2011. In 16 of the 31 district heating systems with more than 10,000 customers, the number of customers has dropped by more than 50%. In many cities, district heating has become a serious drain on public finances because tariffs for residential consumers are highly subsidized, on average by 50%.

30. Service quality, cost, and concern over high pollution levels are among the primary reasons for declining demand. Most of the old inefficient cogeneration units and heat-only boilers have still not been upgraded or replaced with modern generation equipment, nor are they equipped with adequate burning equipment, resulting in SO_2 and NO_X emissions that exceed EU norms. With an average of 275 tons of CO_2 per Gcal, Romania's district heating producers rank among the most polluting service suppliers in the EU. Heat distribution networks suffer an average of 30% heat and water losses, compared to 5-10% for newer networks. As a result of those inefficiencies, the cost of district heating is about 18-20% higher than in some other EU countries.

2.4 Urban Waste Systems

31. Collectively, the GHG emissions associated with municipal solid waste disposal in Romania total approximately 2% of the country's overall emissions. The majority result from the country's overwhelming reliance on landfilling as its primary waste management strategy. Organic waste entombed in a landfill decays anaerobically, produces methane, a GHG with 25 times the heat trapping potential of carbon dioxide. Very few landfills in Romania have the ability to capture or flare this gas, meaning most methane is released directly to the atmosphere. Organic waste management is a problem given that fully 50% of Bucharest's waste stream consists of food waste and other organic materials.

32. Efforts to divert organic waste material discarded in cities into alternative waste processing methods such as composting or anaerobic digestion (AD) can prevent the problem from getting worse, but Romania's performance to date is quite weak. Recycling rates in Romanian cities are also quite low.

Section 3: Baseline Development Conditions in the Bucharest-Ilfov Region

3.1 General Background

33. Bucharest is the capital of Romania, its financial center, the country's leading industrial and cultural hub, and home to many of Romania's top universities. Located in the south-eastern part of the country, Bucharest is approximately 100 km south of the Carpathian Mountains, 200 km to the west of the Black Sea, and 60 km north of the Danube River. The region's climate is temperate, with hot summers and cold winters.

34. The city is formally known as the Municipality of Bucharest, although it has the same administrative powers as any other Romanian County Council. The city government is headed by a mayor (*Primar General*) and city council (*Consiliu General*). The city is further subdivided into six administrative sectors (*Sectoare*), each with their own mayor and city council. Administrative and political powers are thus shared between the Municipality and the local sector councils, although there is little overlap in authority. In general, The Municipality is responsible for major city infrastructure systems such as the public transport network, major roadways, and the water and sewage system. Sector town halls manage secondary roads, parks, schools, and street cleaning.

35. Ilfov County is managed by a County Council that is responsible for basic public services and the road and transport network outside of the administrative limits of each of the 32 communes located within the County. As is the case with District government above, Communes are responsible for local infrastructure and other government service issues within their boundaries.

36. With a population of 2.3 million, the Bucharest-Ilfov Metropolitan Region ranks 37th in size among all of the metropolitan regions in wider Europe. While Bucharest's population has declined over the past two decades, Ilfov County – the nearly 1600km^2 administrative district that completely envelops Bucharest – grew by 35% from 1992 to 2011. Ilfov County now accounts for more than 17% of the metropolitan area's population, up from 12% in 1992 (Table 1). This population shift has largely resulted from Bucharest residents moving from urban areas into new, single-family residences in suburban areas in Ilfov.

Table 3.1. Population Breakdown of the Bucharest-Ilfov Region.

Source: 1992, 2002, 2011 National Population and Housing Censuses

	1992	2002	2011
Bucharest Municipality	2,067,545	1,926,334	1,883,425
Ilfov County	286,965	300,123	388,738
Bucharest-Ilfov Metropolitan Area	2,354,510	2,226,457	2,272,163
Ilfov County Share (%)	12.2	13.5	17.1

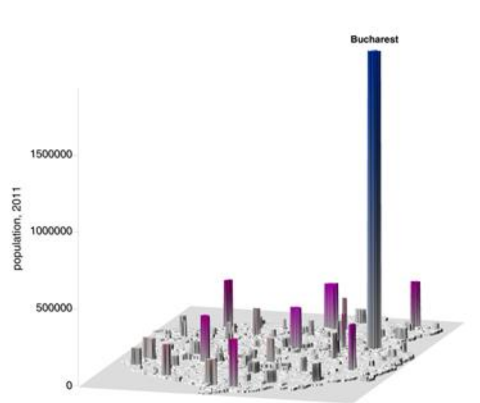
37. Additional relevant baseline information is provided below on a sectoral basis.

3.1 Population, Economic and Land Use Development Patterns – Baseline Conditions

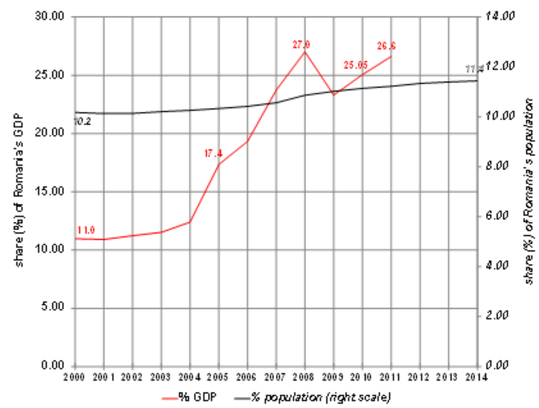
38. The Bucharest-Ilfov region dominates Romania's population and economic landscape (See Figure 3.1). It accounted for over 27% of the country's GDP in 2011, up from 11% in 2000 (See Figure 3.2). Importantly, the region's share of Romania's population increased 10.2% in 2000 to nearly 11.4% in 2011, a share increase that will likely continue over the next few decades (see Technical Annex for more details). This increase is in stark contrast to other cities around the country, where the population has declined significantly (See Figure 3.3).

39. Figure 3.2: Bucharest-Ilfov Region's Change in Share (%) of Romania's GDP and Population

Figure 3.1: Population Distribution in Romania, 2011

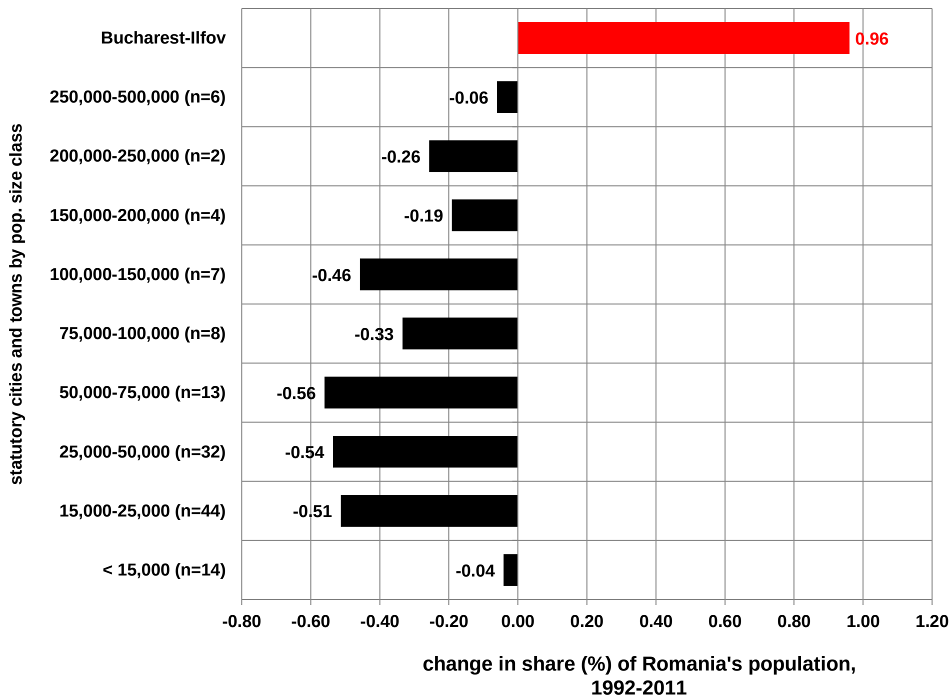


Source: World Bank team calculation based on 2011 Population and Housing Census



Source: World Bank team calculation

Figure 3.3: City Size Class Change in Share (%) of Romania's Population, 1992-2011



Source: National Institute of Statistics (Romania), http://www.insse.ro/cms/en

40. Population distribution within the study area reflects three historical conditions typical of many eastern European cities: lower population densities in the historical core area; high densities in outer clusters of high-rise apartment complexes adjacent to industries, built during the Communist era following the Soviet model; and scattered, low-density suburban sprawl that has evolved since Romania's Revolution in 1989 and the subsequent privatization of land (See Figure 3.4).

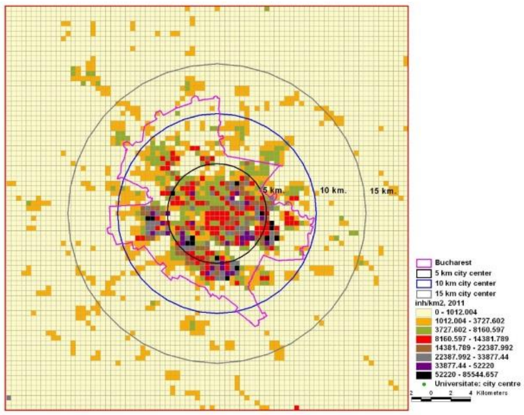
41. Suburban development pressures are strong. Many of the high-rise, prefabricated panel apartment blocks in Bucharest have small units and public spaces have deteriorated over the years due to poor maintenance. With the privatization of land, suburban farmers are now able to sell individual plots for the development of single family homes. Growing incomes enable many Bucharest residents to move to the suburbs even though they continue to have weak public services in terms of schools and commercial facilities.

3.2.1 Building Stock

42. Using the RACE model, building areas have been calculated in all 500 m cells within the study area. The distribution of residential building stock clearly shows these spatial patterns (See Figure 3.5). Suburban low-rise development is occurring at very low densities, generally at 6 dwellings/hectare (See Figure 3.6). Medium-rise residential is largely comprised of 3-5 story walkup apartments in

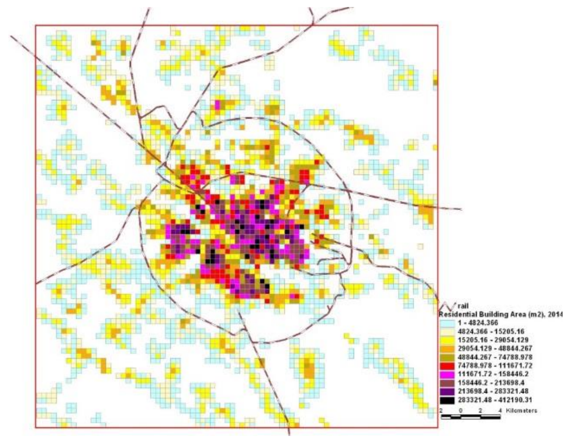
central areas (See Figure 3.7). High-rise residential stock is principally panel blocks built during the Communist era (See Figures 3.8 & 3.9).

Figure 3.4: Population Densities, 2011



Source: World Bank team calculation using 2011 Census data

Figure 3.5: Distribution of Residential Building Stock, 2014



Source: World Bank team calculations

Figure 3.6: Low-rise Suburban Development in Ilfov County (6 dwellings/ha)

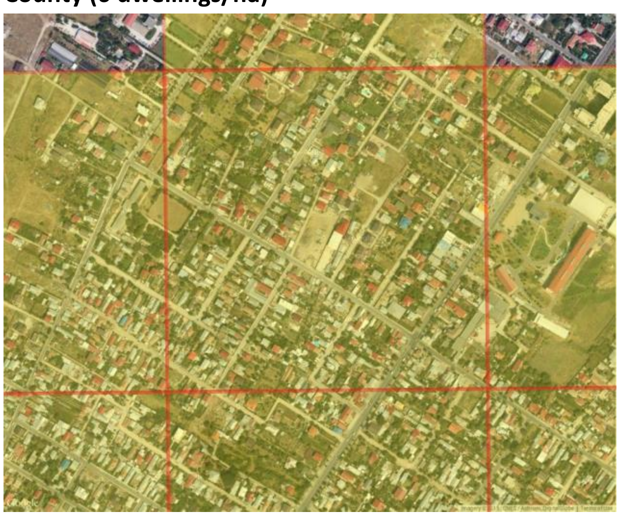


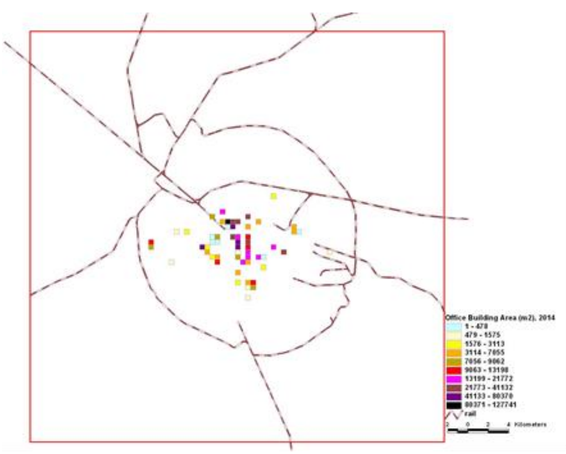
Figure 3.7: Medium-rise Housing in Central Bucharest

Figure 3.8: High-rise Panel Blocks, Drumul Taberei

Figure 3.9: High-rise Panel Blocks, Drumul Taberei

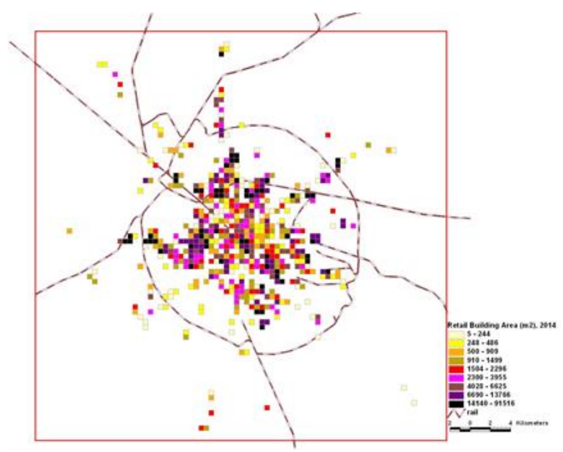
43. Other salient characteristics of Bucharest's building stock are the low quantity of commercial offices and their central location (See Figure 3.10), the large quantity of large-scale retail (big-box) in suburban areas (See Figure 3.11), and the distribution of industrial buildings, clustered around older industries in the inner urban area and more recently scattered in the suburbs (See Figure 3.12). Overall, the distribution of total stock shows a radial pattern driven by proximity to major roads (See Figure 3.13). Building stock by type of use is summarized in Table 3.2.

Figure 3.10: Distribution of Office Building Stock, 2014



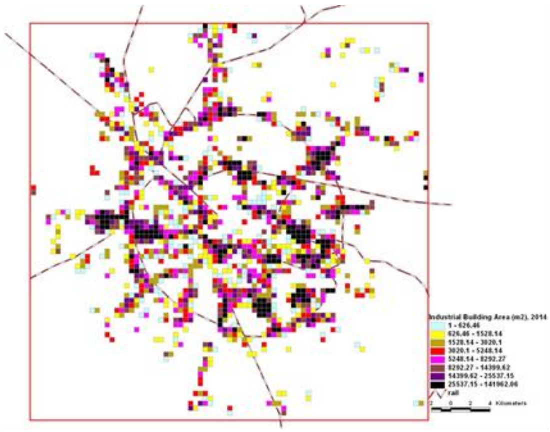
Source: World Bank team calculations

Figure 3.11: Distribution of Retail Building Stock, 2014



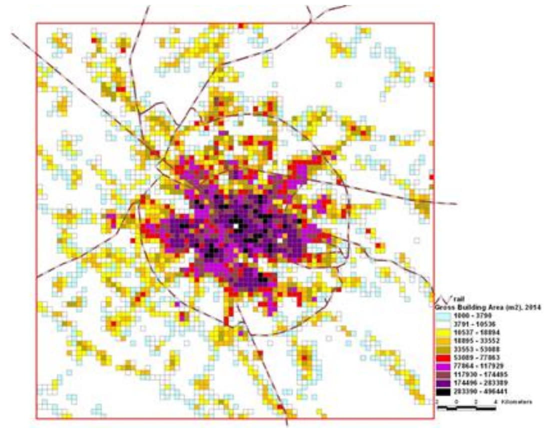
Source: World Bank team calculations

Figure 3.12: Distribution of Industrial Building Stock, 2014



Source: World Bank team calculations

Figure 3.13: Distribution of Total Building Stock, 2014



Source: World Bank team calculations

Table 3.2: Bucharest-Ilfov Region's Baseline Building Stock, 2014

		code	Gross Building Area (m2)	% of total BIMR building area	% of major use	per capita building area (m2/inh)
			2014	POP.		2,217,437
Residential Buildings	low-rise residential	**LD**	38,387,589	30.6	41.7	
	medium-rise residential	**MD**	6,618,788	5.3	7.2	
	high-rise residential	**HD**	15,134,655	12.1	16.4	
	very high density residential	**VHD**	31,911,558	25.5	34.7	
	TOTAL RESIDENTIAL	**R**	**92,052,590**	**73.5**	**100.0**	**41.51**
Commercial Buildings	office high rise	**OHR**	596,218	0.5	68.3	0.27
	office medium rise	**OMR**	167,329	0.1	19.2	0.08
	office low rise	**OLR**	108,943	0.1	12.5	0.05
	sub-total: Office		*872,490*	*0.7*	*100.0*	*0.39*
	large-scale retail	**LR**	3,111,264	2.5	96.3	1.40
	small-scale retail	**SR**	117,944	0.1	3.7	0.05
	sub-total: retail		*3,229,208*	*2.6*	*100.0*	*1.46*
	TOTAL COMMERCIAL	**C**	**4,101,698**	**3.3**	**100.0**	**1.85**
Industrial Buildings	industrial estate	**IE**	15,590,813	12.4	98.7	7.03
	medium-scale industrial	**MI**	203,820	0.2	1.3	0.09
	large-scale industrial	**LI**	0	0.0	0.0	0.00
	TOTAL INDUSTRIAL	**I**	**15,794,634**	**12.6**	**100.0**	**7.12**
Institutional Buildings	government building	**G**	11,464,445	9.2	86.0	5.17
	educational	**E**	744,832	0.6	5.6	0.34
	healthcare	**H**	506,270	0.4	3.8	0.23
	transportation	**TR**	609,076	0.5	4.6	0.27
	TOTAL INSTITUTIONAL BUILDINGS	**IN**	**13,324,623**	**10.6**	**100.0**	**6.01**
Total Buildings	**TOTAL BUILDINGS**	**B**	**125,273,543**	**100**		**56.49**

Source: World Bank team calculations

3.2.2 Economy

44. The Bucharest-Ilfov region's economy is still in transition. There has been a dramatic shift in ownership: 8% of employees worked for the state-owned enterprises in 2012 compared to 25% in 2000; 13% worked for foreign-owned firms in 2011 compared to 5% in 2000[14]. Services now account for more than 76% of employment with higher value-added producer services accounting for 31% of total employment. Manufacturing is still the largest employer (159,800 employees in 2011), but

[14] Bucharest Statistical Yearbook, 2012

decreased by almost 23,000 from 2008 to 2011 (See Figure 3.14). BIMR's manufacturing sector is gradually innovating, but traditional industries (food, apparel, metal fabrication, printing machinery, furniture, tanning/dyeing) still provide the largest share of employment. Exports grew by 69% from 2005 to 2011.

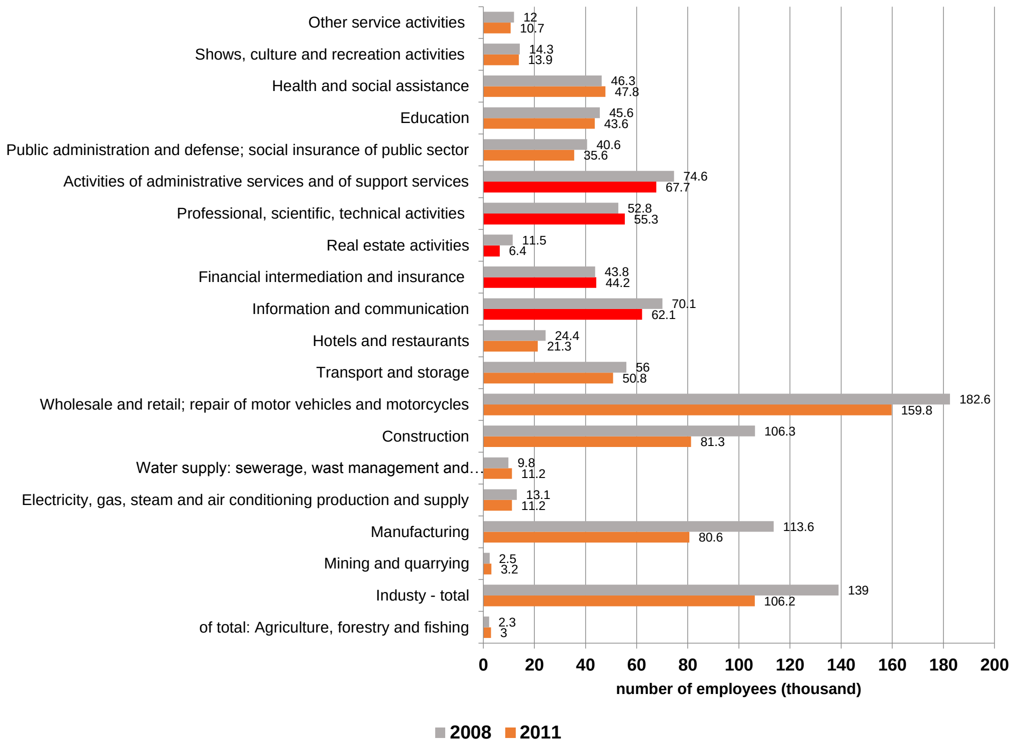


Figure 3.14: Employment by Sectors, 2008, 2011
Source: Bucharest Statistical Yearbook, 2012

45. Per capita GDP in BIMR is 2.5 times the national average. The region's GDP grew by 12.3% between 2010 and 2011[15], and has been high for most of the past 15 years.

46. The Bucharest-Ilfov region has several major comparative advantages that will continue to drive its economic growth over the coming decades (more details in Technical Annex). Its economic hinterland is large: within a one-day drive by truck from the center of Bucharest is a population of 11 million; within a two-day drive, the hinterland reaches Budapest, Vienna, Athens, Istanbul and Kiev, a market of 83 million.[16] BIMR has the most educated human capital in Romania: 33% of its working age population has vocational and tertiary education attainment compared to less than 15% in the

[15] European Commission. *Regional Innovation Monitor Plus.* https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/bucharest-ilfov

[16] World Bank team calculation using Eurostat NUTS 3 data.

country's other regions.[17] Supplementing these advantages are labor costs, which are the third lowest in wider Europe (See Figure 3.15).

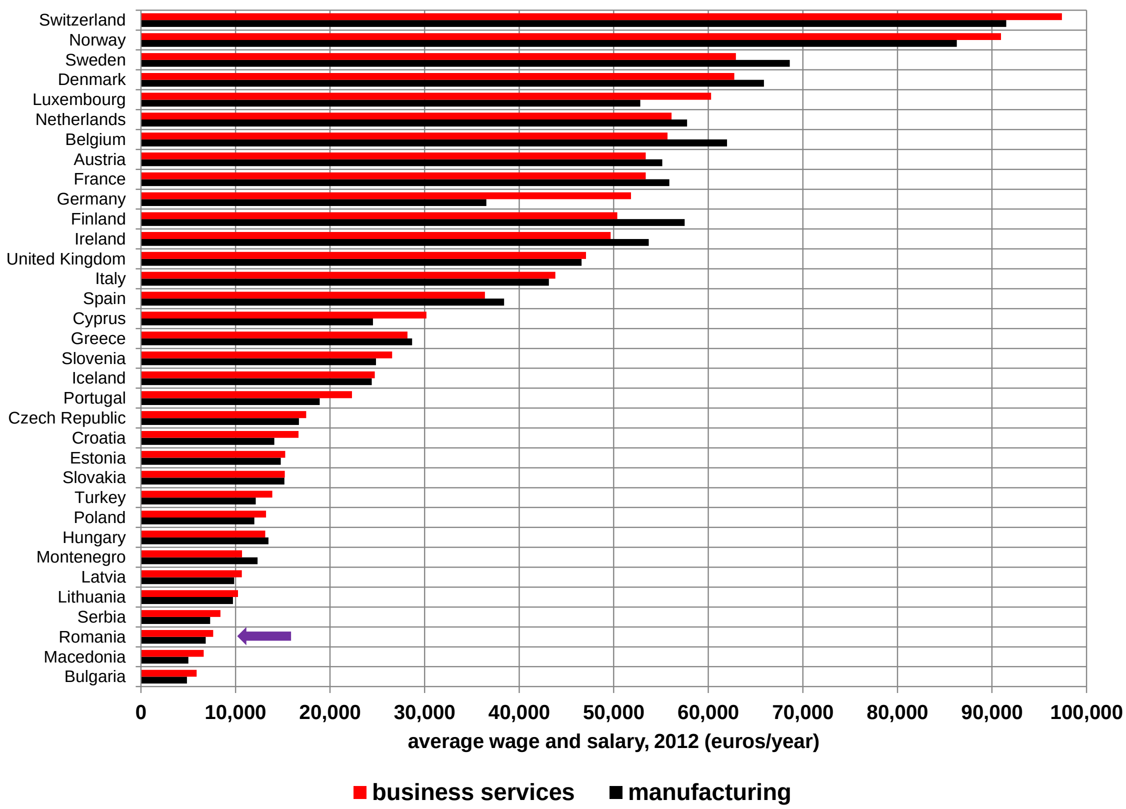


Figure 3.15: Average Annual Wages, Business Services and Manufacturing, 2012

Source: Eurostat. Viewed at http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lc_ncost_r2&lang=en

3.3 Transport Sector – Baseline Conditions

47. Traffic congestion is increasingly a daily part of life in the Bucharest-Ilfov region, particularly in the urban core of Bucharest, at intersections along the main ring roads, and on the main thoroughfares traveling through the city along a north-south axis. A primary contributor to the congestion problem is rapid growth in vehicle ownership rates, which have risen from 152 vehicles per 1000 inhabitants (2006) to 224 vehicles per 1000 inhabitants (2012).[18] [See Figure 3.16]

[17] Eurostat (2015). 'Population with tertiary education attainment by sex and age', [available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=edat_lfse_07&lang=en], and Eurostat (2015), 'Tertiary educational attainment, age group 25-64 by sex and NUTS 2 regions' [available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=tgs00109&lang=en]]

[18] Eurostat, 2012. Motorization Rates. Last update 11/04/2015 http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tsdpc340&plugin=1

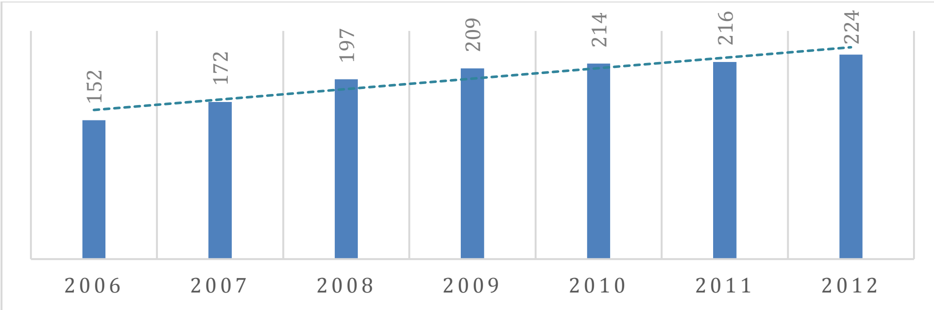


Figure 3.16: Romanian Passenger Car Ownership Rates per 1000 Inhabitants
Source: Eurostat, 2012

48. Contributing to Bucharest's congestion challenge is a lack of adequate off-street parking facilities in the central area. Many drivers ultimately resort to the use of illegal "parasite" [19] spaces on the roadway, narrowing lane space and further inhibiting the flow of vehicles.

49. There are 755km of roadways in Bucharest.[20] Nine radial roads connect at the University Square at the heart of Bucharest, while two partial ring roads circle portions of the city at a distance of roughly 3 km and 5 km from the city center. These roads all carry six lanes or more of traffic. A 2-lane ring road heavily used by freight vehicles completely circles the outskirts of Bucharest.[21]

50. Traffic congestion is a problem despite the fact that the City of Bucharest is well-served by one of the most comprehensive public transport networks in all of Europe. Within Bucharest, the Gara de Nord train station connects the city to a regional and international passenger train network. Riders existing at Gara de Nord can connect to the 4 line, 69km-long, 51-station metro (subway) system with a central city loop and other lines heading along east-west and north-south corridors. Metro stations are located approximately every 1.4km. A 5th metro line is expected to open in 2017. Ridership on the metro system is approximately 500,000 riders/day.

51. Bucharest is also served by much more extensive surface transit system composed of the RATB's (*Regia Autonoma de Transport Bucuresti*) network of 120 bus lines, 24 tram and light rail lines, and 15 trolleybus lines. Ridership on this system is approximately 2.2 million riders/day.[22]

52. The 1000-strong bus fleet serves an incredibly dense transport network, and RATB regularly advertises that most Bucharest residents are never more than a 5 minute walk from a bus stop. The majority of the system's buses were replaced in the past 10 years. RATB also operates the electric tram system which operates on 139km of track in the center of the city. As with the bus network, the majority of the tram fleet has been overhauled in recent years to improve passenger comfort and vehicle

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[19] WSP (2008). *Urban Transport Master Plan – Bucharest, Sibiu, and Ploiesti. Final Report Bucharest.* EuropeAid/123579/D/SER/RO

[20] World Bank team estimate based on GIS analysis of roads shapefile provided by the Avensa SUMP team.

[21] WSP (2008). *Urban Transport Master Plan – Bucharest, Sibiu, and Ploiesti. Final Report Bucharest.* EuropeAid/123579/D/SER/RO. p 96.

[22] RATB. *Statistici 2014*. Viewed at www.ratb.ro/statistici.php on April 26, 2015.

efficiency. The 15 trolleybus lines supplement the bus fleet, operating exclusively along more heavily traveled bus routes.

53. Circumstances in Ilfov County are quite different. There are only 817 miles of roadways in Ilfov County – not much more than Bucharest – but nearly one-quarter of these roads consist of high speed motorways. Bus system access is virtually non-existent, as there are just a few lines serving Ilfov County residents commuting into Bucharest.

54. To develop baseline transport sector assumptions for the RACE model, the team relied on a 2014 travel habits survey[23] developed as part of the current SUMP process and the 2007 mobility household survey[24] used to help craft the last major transport plan for the region.

55. According to the 2014 survey tracking the daily travel patterns Bucharest and Ilfov residents, there are a total of 5.4 million trips in Bucharest and Ilfov every day. This translates into a daily rate of 2.6 trips per capita per day[25] for the entire region.

56. 83% of all trips cover a short distance (<10km). Trips by Bucharest residents alone average roughly 6.3km in length, but as Figure 3.17 makes clear, Ilfov residents tend to travel much longer distances. The average trip distance for the entire Bucharest-Ilfov region is approximately 6.8km.

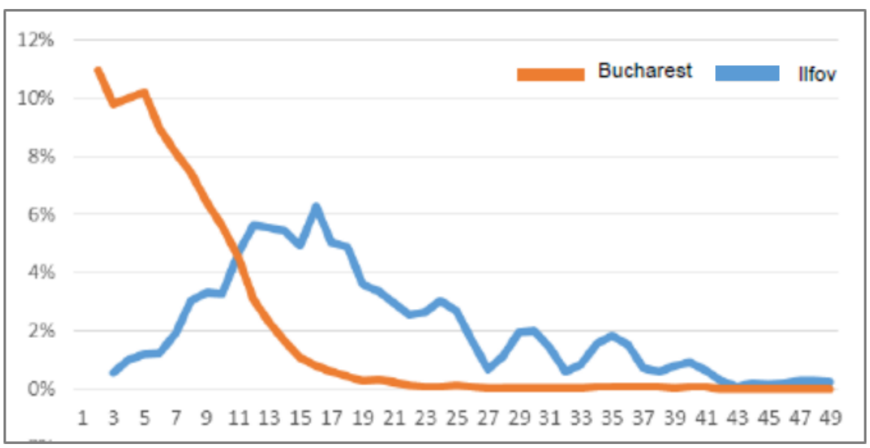

Figure 3.17: Travel Distance for Trips over 1km for Bucharest and Ilfov
Source: AVENSA, Travel Habits Survey 2014

57. 38% of trips in Bucharest and Ilfov are made via automobile. Non-motorized transport (NMT in Figure 3.18 below) is the second most utilized means of transport for daily trips: 31% of trips are made by walking, while 2% of trips are made on a bicycle. The bus is the most-utilized form of public transport, followed closely by the metro.

[23] AVENSA, *Sustainable Urban Mobility Plan Bucharest – Ilfov Conglomeration; Technical Report: Transportation Surveys 2015*
[24] WSP (2008). *Urban Transport Master Plan – Bucharest, Sibiu, and Ploiesti. Final Report Bucharest.* EuropeAid/123579/D/SER/RO.
[25] AVENSA, *Sustainable Urban Mobility Plan Bucharest – Ilfov Conglomeration; Technical Report: Transportation Surveys 2015*

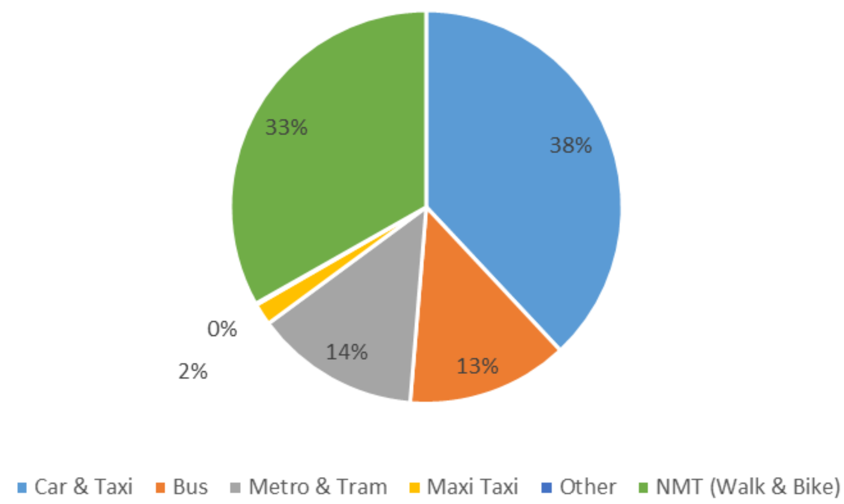

Figure 3.18: Modal Split of Trips in Bucharest-Ilfov Region
Source: AVENSA Travel Habits Survey, 2014

58. The Travel Habits Survey also provided insight into the reason for each trip. The majority of trips (41%) are made by individuals returning home after traveling to another destination. Another 24% of trips involve commuting to work or are otherwise work-related.

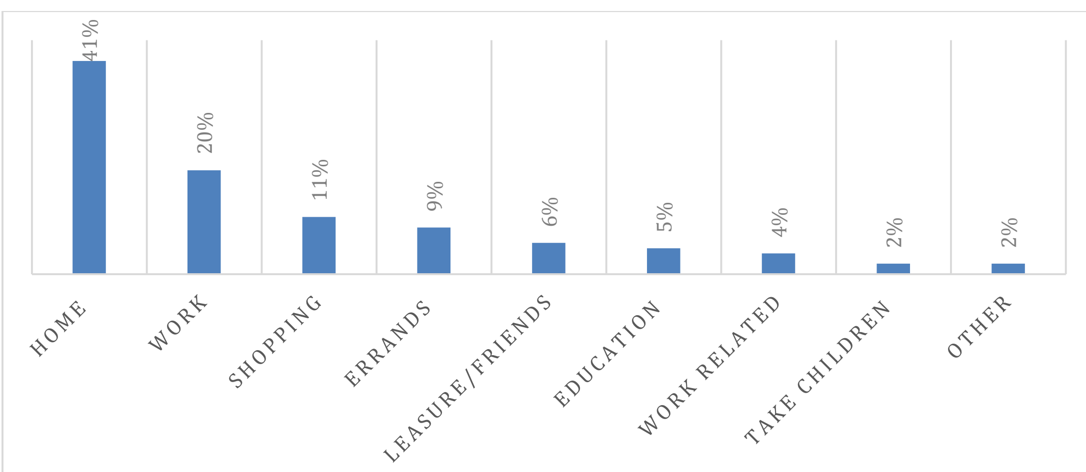

Figure 3.19. Distribution of daily trips in the Bucharest-Ilfov region by type
Source: AVENSA Travel Habits Survey 2014

59. Estimates over the average efficiency of different types of vehicles were calculated based on data provided by one global and one EU-focused datasets. On average, it is 2,85 MJ/km for cars, 9.66MJ/km for buses and for 35.48 MJ/km for passenger rail.

3.4 Energy and Buildings Sector – Baseline Conditions

59. Buildings account for the largest share of energy consumption in Romania at 44% of total demand, followed by industry (30%) and transport (23%). 80% of buildings-related energy demand in Romania occurs in residential buildings.

60. Energy use in buildings is influenced primarily by the thermal efficiency of the building, its size, its age, and its level of use (i.e., 10 hours/day, 5 days/week vs. 24 hours/day, 7 hours/week). Table 3.3 summarizes the thermal and electric efficiency for different building types in Bucharest that form the basis of the building energy calculations in this RACE analysis.

Table 3.3: Energy Consumption by Building type (Romania)

Source: IFC Edge tool[26] (energy) and World Bank team calculations (floor space)

Category	Sub-category	Electricity Consumption (kwh/m²/yr)	Thermal Consumption (kwh/m²/yr)	Average Total Energy Consumption (kwh/m²/yr)	% of total floor space in Bucharest-Ilfov region
Residential	Low density	46.0	257.5	303.5	73.5%
	Medium density	45.5	135.9	135.9	
	High density	46.0	133.8	179.8	
	Very high density	46.0	133.8	179.8	
Commercial	Office	128.0	110.0	238.0	3.3%
	Retail	175.0	81.0	256.0	
Industrial	Industrial	150.0	50.0	200.0	12.6%
Institutional	Government	90.0	210.0	300.0	10.6%
	Education	217.0	200.0	417.0	
	Health	187.0	163.0	350.0	
Infrastructure	Transport	128.0	110.0	238.0	

61. Romania's building stock is fairly old, with nearly 90% of the residential buildings in the country were built before the 1989 Revolution, meaning it was constructed at a time when there were no specific thermal performance standards.[27] Such buildings are unlikely to have much insulation, and have mechanical systems that would be considered unacceptable under today's modern energy or building codes. Buildings around Bucharest are subject to the EU's Building Performance Directive, which requires them to post information about the building's energy performance. The level of compliance with this law in Bucharest is unclear, nor is it known if this has had a significant impact in encouraging owners to upgrade their buildings.

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[26] These values are sourced from the IFC's EDGE Green Buildings Rating Tool and adjusted based on local data from experts at the Romania Green Building Council. They represent average values and there may be significant variation based on building age, usage patterns, and (in the residential sector) income. They are also likely to change significantly over time as new policies to promote building energy efficiency are rolled out in Bucharest. These values form the basis of RACE's baseline building energy model.

[27] BPIE (2014) *Renovating Romania: A Strategy for the Energy Renovation of Romania's Building Stock*. Building Performance Institute Europe.

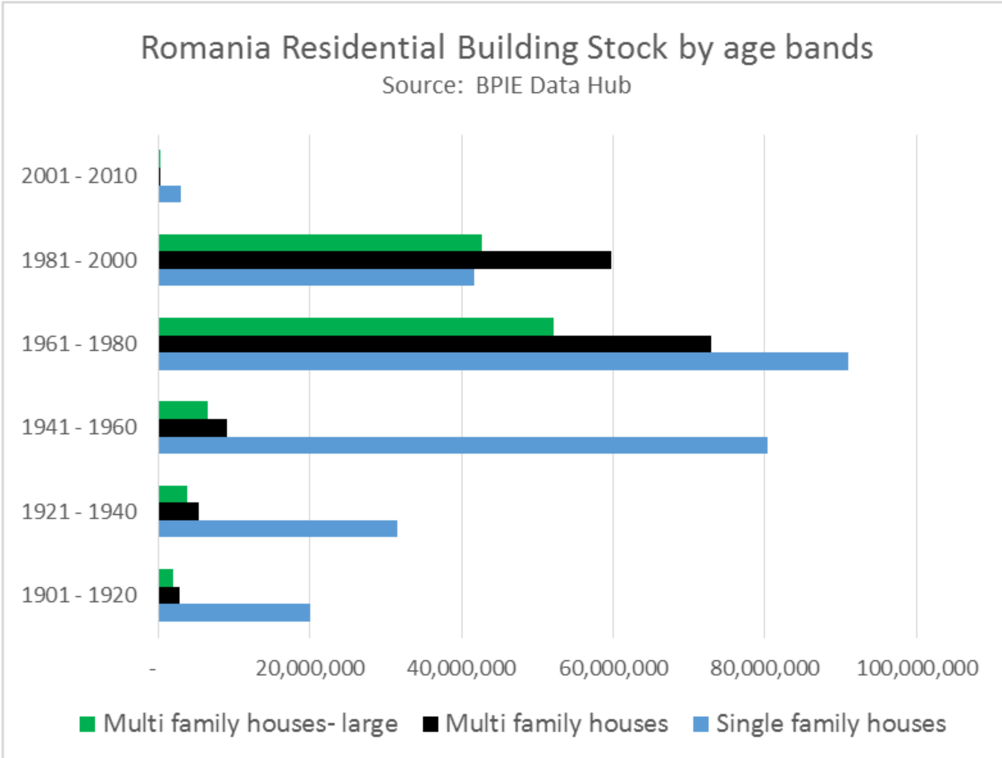

Figure 3.20: Age of Residential Building Stock (Romania)
Source: Building Performance Institute Europe data hub

62. Heating energy constitutes approximately 57% of all energy use in buildings, though the ratio is even higher in residential dwellings. Building heating systems around Bucharest typically involve freestanding boiler units inside the building, or in larger buildings, a connection to a large district heating system. Bucharest's district heating system is vast – the second largest urban system in the world – involving more nearly 4,000 km of distribution pipes and satisfying 72% of the city's thermal energy needs. 8,600 tower block buildings, home to 566,000 apartments and 1.23 million people, are served by the RADET system.[28]

63. The number of customers linked to the system has declined over the years, as has often been the case elsewhere in Romania. Service quality, cost, and concern over high pollution levels have been the primary reasons for declining demand.

64. The RADET district heating system is fired by natural gas (54%), fuel oil (26%), and coal (20%). Standalone units in individual buildings are primarily assumed to burn natural gas. There is no distinction made between fuel sources for standalone units in dwellings in Ilfov; all are assumed to burn natural gas as their primary heating fuel.

[28] Radet (2015). *About Us -- Autonomous Thermal Energy Distribution Bucharest (RADET Bucharest)*. Viewed at http://www.radet.ro/despre.php.

65. The electricity consumed in buildings in Bucharest and Ilfov is assumed to have the same characteristics of the national grid picture, meaning it is heavily dominated by coal and hydropower. (See Table 3.4) Coal use in Romania is considerably higher than in many other European countries.

Table 3.4: Fuel Mix of Romania Electricity Supply (2015)
Source: World Bank team estimates

Fuel type	%
Coal	27.3%
Oil	3.4%
Natural Gas	6.5%
Nuclear	19.0%
Hydro electric	33.4%
Wind	8.1%
Solar	2.2%

66. As noted in Section 4 of this report, energy prices for selected industrial customers and all residential customers are subsidized. Residential rates will not change until 2018 (electricity) and 2019 (natural gas). It is unclear when (or if) district heating rates – which are subsidized at a rate of roughly 50% – will be liberalized. Such subsidies discourage conservation or the use of other energy efficiency measures. Non-industrial business rates were fully liberalized as of early 2015.

67. Energy prices in Bucharest are assumed to be as follows:

Table 3.5 Baseline Energy Price Assumptions
Source: World Bank team estimates

Fuel type	Price
Electricity	$0.13USD/kWh (weighted average of household and industrial rates)
Heating	$0.073/kWh equivalent

3.5 Waste Sector – Baseline Conditions

68. There is limited data available about the full breadth of the solid waste management system in Bucharest and Ilfov County. 2011 data from the National Institute of Statistics disclosed that Bucharest-Ilfov generated a total of 881,000 tons of municipal solid waste, with Bucharest responsible for approximately 86% of that total. Waste generation rates are estimated at between 0.8-0.9 kg/person per day.

69. Little information is available about recycling program performance in the region. Nationally, Romania is reported to recycle only 5% of its total waste stream, with virtually all of the remaining

material ending up in landfills. This low recovery rate is considered quite poor given the high rate of recoverable materials in the waste stream. 45% of the region's waste is considered biodegradable (meaning it could be composted and converted into a useful soil amendment), while another 30% of the waste stream is made up of commonly recycled materials. Table 3.6 presents waste composition estimates for the Bucharest-Ilfov region.

Table 3.6: Waste Composition in Bucharest and Ilfov

Source: National Statistics Agency

Type of material	%
Biodegradable material	45.3%
Paper and cardboard	10.2%
Glass	10.6%
Plastics	3.2%
Ferrous metals	5.6%
Textiles	4.3%
Other inert materials	20.8%

70. Three landfills currently serve the Bucharest-Ilfov region, located in the northwest and southern corners of the region. None of these facilities currently have any methane gas recovery system in place. This is problematic because organic waste entombed in a landfill decays anaerobically, producing methane gas, a GHG with 25 times the heat trapping potential of carbon dioxide. Unless the landfill is properly designed, capturing or flaring the methane via a series of pipes embedded in the landfill, the gas will slowly leak out of the landfill for many years, including long after it is formally closed.

71. Proposals have been floated to develop a large (700,000 tpd) waste-to-energy facility that would combust the region's and convert the waste heat into electricity. There is a possibility it would link to the local district heating scheme in Bucharest, satisfying the heat demand. Whether it would satisfy some or all of the system's heat demand is unknown. The status of this project is unknown.

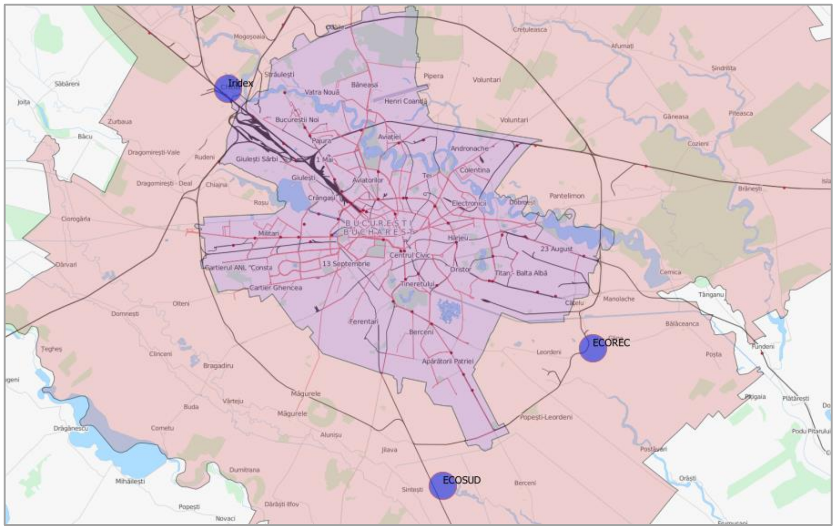

Figure 3.21: Location of Municipal Solid Waste Landfills Serving the Bucharest-Ilfov Region

Source: World Bank team

Section 4: The Challenges of Low Carbon Growth in the Bucharest-Ilfov Region

4.1 Overview

72. The preceding discussion makes clear that while is tremendous opportunity to improve the Bucharest-Ilfov region's environmental performance, there are also many reasons for its current low state of performance that could also inhibit progress in the future. These explanations fall into three main categories: financing challenges, institutional challenges, and market immaturity. Each is addressed in turn below.

4.2 Financing Challenges

73. Several factors have conspired in recent years to limit the amount of resources available to upgrade major infrastructure systems in the Bucharest-Ilfov region. The economic slowdown has hit the region hard, with exports to the rest of Europe slowing considerably. Foreign direct investment (FDI) has generally been good for the Bucharest region – ten years ago 60% of the country's total FDI went to the Bucharest region – but by 2010, FDI levels had dropped by nearly 80%,[29] a situation from which Bucharest is still recovering. The slowdown in the real estate market also has obvious implications in terms of the tax resources available to the Municipality for major infrastructure projects.

74. Another critical factor has been Romania's difficulty in absorbing European Union Regional Operating Program funds for which it was eligible: as of the end of March 2015, the absorption rate for the period 2007-2013 was 49%. (The Government has the ability to apply for and receive these funds until the end of 2015, and this figure will likely increase.) Between2007-2009, however, the absorption rate was 0%, as there was considerable ramp-up time to train staff, prepare portfolios of projects, develop the necessary legal framework and regulations, etc. One of the goals of the SUMP work currently underway is to explicitly focus on strategies that will increase the drawdown of EU resources for improved transport systems. Similarly, much of the World Bank's recent RAS work has focused on helping the Government of Romania develop the analytic foundation to support its request for funding support in the new Operating Program period.

4.3 Institutional Challenges

75. It is unclear to the extent which Romania's lack of a formal urban climate strategy has played a role in minimizing the type of low carbon planning activity analyzed in this study. On the one hand, issues of traffic congestion, diminished air quality, and excessive energy spending are by themselves justification for cities to take action, as evidenced by the fact that 60 Romanian communities have voluntarily opted to create Sustainable Energy Action Plans under the auspices of the city-focused Covenant of Mayors program.

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[29] CJ Pen and M Hoogerbrugge, *Economic Vitality of Bucharest*. European Metropolitan Network Institute (EMI). 2012.

76. In other countries, formal climate planning rules have been established mandating the development of local climate action plans. This is not the case In Romania, with high level climate policy statements typically speaking only terms of the types of sectoral or infrastructure changes that are necessary to reduce GHG emissions. Until there is greater clarity about who is responsible for planning or implementing these changes – meaning whether local authorities are given a formal role in crafting the solution – the policy ambiguity means local authorities can continue to engage on these issues in ways that are more reflective of local considerations rather than national or global imperatives.

77. Policy and planning disconnects between different tiers of government or Ministries with overlapping functions have proven to be a major impediment to the resolution of several major infrastructure challenges facing the region. Examples can be found in all sectors:

    a. Two different regulatory agencies are responsible for policies relevant to district heating systems across Romania.

    b. The metro (subway) system in Bucharest is operated by METROREX under Ministry of Transport control, while the surface transport system (trams, bus and trolley) is managed by RATB (*Regia Autonoma de Transport Bucuresti*), which is under city control.

    c. Although there is a single set of zoning rules for the entire city (derived from the rules and regulations component (*Plan de Reglemetari*) of the PUG's spatial strategy), a building permit is granted by different authorities (either Bucharest Local Council or District Local Council) depending on the type of planning guidance covering the project – either the Zonal Urban Plan or Detailed Urban Plan.[30] For permits on projects within any of Bucharest's "protected areas" and for projects covered by Zonal Urban Plan rules, Bucharest Municipality has approval authority. On such projects, in addition to Local Council approval, each project must also obtain approval from seven different technical departments within City Hall or at different government Ministries.

    d. In the planning sphere, there three plans, all with overlapping concerns: (1) a PUG for Bucharest managed by the Municipality; (2) a spatial plan for Ilfov County (*Plan de Amenajare a Teritoriului Judetean – PATJ*) managed by the Bucharest-Ilfov County Council/Authority: and (3) a Regional Development Plan and Regional Development Strategy managed by the Bucharest-Ilfov Regional Authority.

78. Lack of transparency by different government agencies is also a challenge. There is little public access to information about the building stock in Romanian cities, and there are no reports published to date comparing the Energy Performance Certificate[31] scores (*Certificat de Performanta Energetica – CPE*) across cities, despite the fact that the law has been fully implemented as of 2011. Were such information available, local authorities could more easily compare building upgrade strategies or set priorities among different types of buildings.

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[30] Law 350/2001 stipulates the Urban Zonal Plan (*Plan Urbanistic Zonal - PUZ*) shall apply should a project cover one or more parcels/lots modifying the zoning restrictions referring to floor-to-area ratio limits, height limits, minimum lot size, etc.). The Detailed Urban Plan (*Planul Urbansitic de Detaliu – PUD*) covers all other projects.

[31] Required by the EU Energy Performance of Buildings Directive 2002 2002 (2002/91/EC) and its Recast (2010/31/EU)

4.4 Market Immaturity

79. One of the key changes the Romanian government had to make as part of its accession into the European Union was an agreement to move away from tightly regulated (and subsidized) energy prices to a system that was more market based. As of last year, businesses must now pay market rates for electricity and gas, but energy prices for selected industrial customers and all residential customers remain subsidized. Energy-intensive state-owned enterprises (SOEs) continue to receive preferential electricity and gas prices. State and local subsidies for residential district heating cover roughly 50% of residential customer costs. Household energy prices will not be fully liberalized until January 2018 (electricity) and January 2019 (gas) respectively, reducing the incentive to adopt energy saving measures. No timeline has been given for removing district subsidies.

80. In addition to influencing energy demand, low prices have meant the market for energy efficiency-focused firms and expertise has been slow to develop. That should change in coming years, either through firms in other European countries targeting the Romanian market, or through more home-grown endeavors. Trade groups such as the Romania Green Building Council are becoming more active, although membership rates remain quite low.[32]

[32] Interview with Steven Borncamp, Romania Green Building Council. July 2014.

Section 5: Overview of the Rapid Assessment of City Emission (RACE) Model

5.1 Overview

81. RACE is a geospatial model that calculates transport and other energy demand based on population and land use patterns in a city. RACE was originally developed for use on an Asian Development Bank-sponsored project looking at the energy and emission impacts of alternative development scenarios in several fast-growing cities in Southeast Asia. Because of obvious climatic differences, the model has been adapted to address circumstances unique to Romania. Solid waste management has also been added to this version of the model.

82. By changing assumptions about current and future land use patterns, the design and location of different public transport system options, the energy and emission factors assigned to different land use patterns in a city, and the solid waste management system design, it is possible to compare a "baseline" scenario with one or more alternative scenarios in terms of:
    a. Total energy demand
    b. Total energy spending (in real terms)
    c. Total energy-related air quality emissions (PM_{10} and NOx)
    d. Total energy-related CO_2 emissions

83. RACE thus provides local authorities with insights into how policies affecting the speed and location of growth, the density of urban growth, the type/mix/location of transport infrastructure, the local waste infrastructure, and the degree of integration between different land uses and transport services can have on the long-term economic and environmental sustainability of a city.

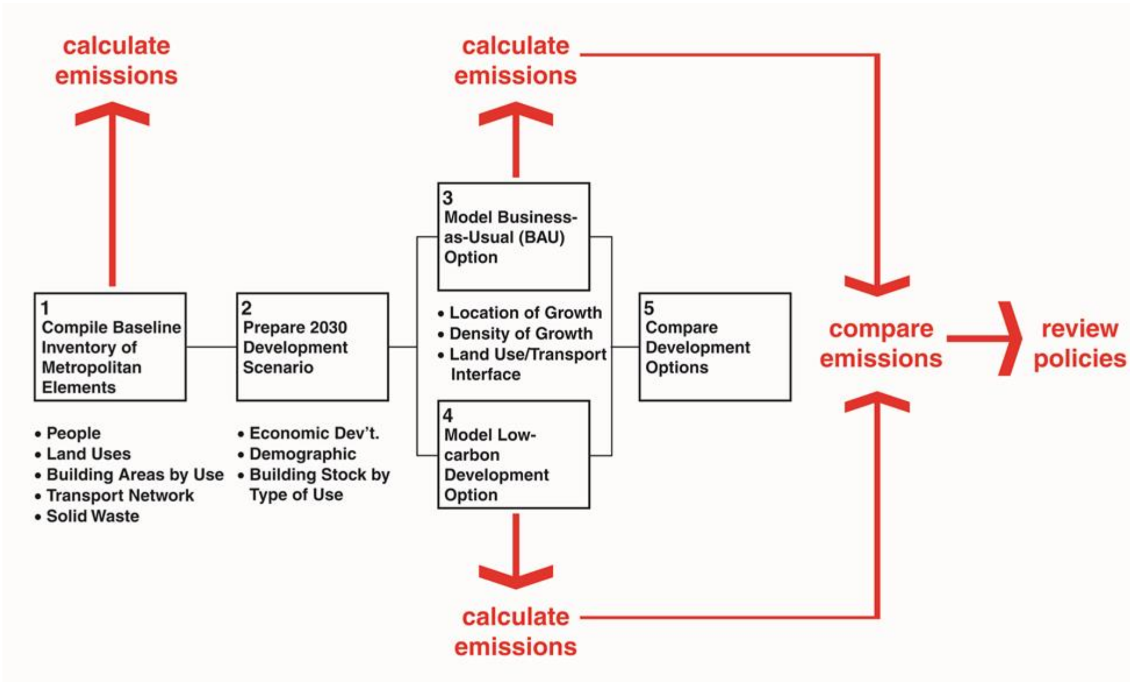

Figure 5.1: Overview of the RACE model
Source: Chreod Ltd.

84. The remainder of this section summarizes the five primary steps involved in applying the RACE model to the Bucharest-Ilfov region. [See Figure 5.1]

5.1.1 Step 1 – Compile Baseline Inventory of Metropolitan Elements

85. A geospatial model like RACE presumes access to georeferenced digital information on different land uses around a city/region. Ideally, the information will be granular enough to distinguish between similar functions (e.g., low rise vs high rise residential buildings) as well as developed and undeveloped land. Road networks must be digitally represented in the model, along with different types of public transport networks and waterways. The elevation and footprint of individual buildings must be captured, to allow for three-dimensional estimates of each building's size. Granular population data and information about the level and type of economic activity occurring in a given area are other important pre-requisites of the model.

86. This can be a tall order even in highly developed cities, much less in cities where there is no legacy of GIS-based analytics or data tracking. In the case of the Bucharest-Ilfov region, there was no single resource the World Bank team could go to for digitized information on local land use patterns, the location of roads or highways, population data, or building stock data. The team had to pull the dataset together from a variety of different sources, and in many cases, manually digitize information using high resolution satellite imagery. This was achieved as follows:

   a. *Land use and building areas*: Leveraging datasets available through OpenStreetMap and by using GIS to manually digitize the shape and dimensions of individual buildings based on high resolution satellite imagery, the team was able to develop a comprehensive land use map covering the entire city of Bucharest and Ilfov County. Building heights and uses were derived from field studies and online-analysis of geo-referenced photographs. See Figures 5.2 and 5.3 for digital imagery of the new land use maps developed for this project. Table 5.1 reflects the building type categories used as part of this mapping exercise.

b. *Population*: Census-tract level digital shapefiles and population figures from the 2011 national census were obtained for the entire City of Bucharest. For Ilfov County, 2011 census data is only available at the Commune level.

c. *Transportation networks*: The current road GIS shapefile for the Bucharest-Ilfov region was obtained from Avensa, the consultant leading the work on the Bucharest Sustainable Urban Mobility Plan. The local rail network GIS shapefile was obtained from OpenStreetMap, while the public transport network was manually created using GIS and digital images of the system.

d. *Business activity*: Enterprise address and employment data was obtained from the 2012 Bucharest Statistical Yearbook and then georeferenced by the World Bank team. This information has been used to help develop maps of where different types of business activity are currently located around the region.

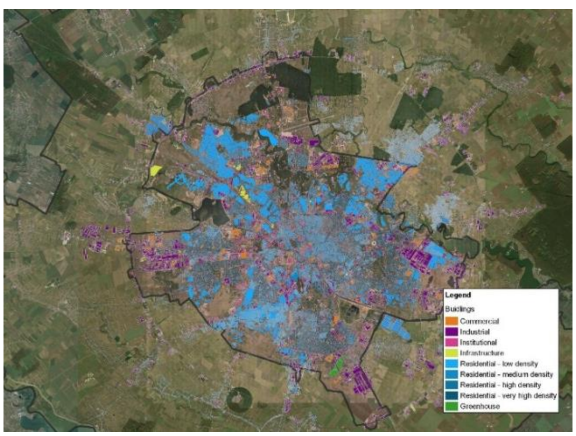

Figure 5-2: Buildings in Bucharest-Ilfov County
Source: World Bank team

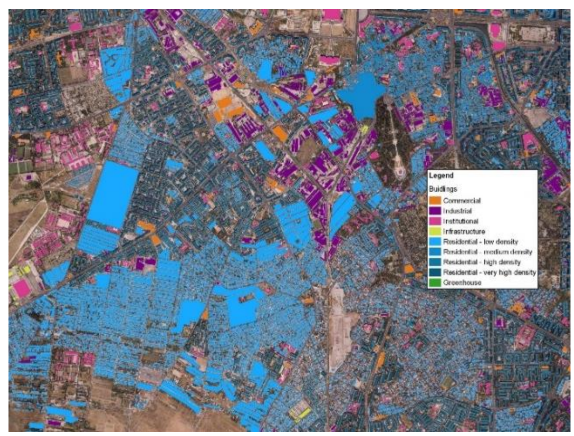

Figure 5-3: Close up of buildings in Bucharest
Source: World Bank team

Building Class Categories utilized in the RACE model – Table 5-1

Building Type	# Floors	Spatial Characteristics
Residential		
▪ *Low rise*	1-2	Single family dwellings
▪ *Medium rise*	3-5	Row, terrace, walk-up apartments
▪ *High rise*	6-10	Apartment building
▪ *Tall high rise*	>10	Apartment high rise

Mixed-use		
▪ *Small-scale*	1-5	e.g., shop houses/office/residential
▪ *Large-scale*	>5	e.g., retail/ office/ residential complex
Commercial		
▪ *Office high rise*	>10	Generally fully-serviced office block
▪ *Office medium rise*	5-10	Older, partially-serviced (e.g., air-conditioned with elevator)
▪ *Office low rise*	1-4	
▪ *Large scale retail*	1-6	e.g., shopping mall, department store, big box stores
▪ *Small scale retail*	1-3	Shops and restaurants
Industrial		
▪ *Industrial estate*	1-4	Purpose-built, multiple occupants
▪ *Medium-scale industrial*	1-2	Single occupant factory, warehouse
▪ *Large scale industrial*	1	Major industry, e.g., steel, petrochemicals
Institutional		
▪ *Government building*	1-10	Offices, legislative, executive, judicial
▪ *Educational*	1-5	Schools, institutes, universities
▪ *Health*	1-10	Hospitals, clinics

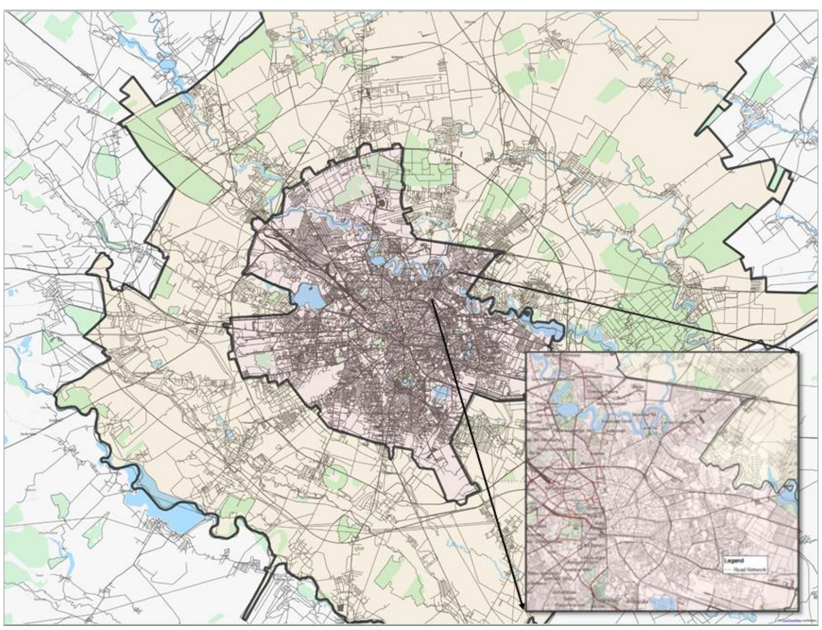

Figure 5-4: Road network for Bucharest and Ilfov County

Source: Avensa/Bucharest SUMP team

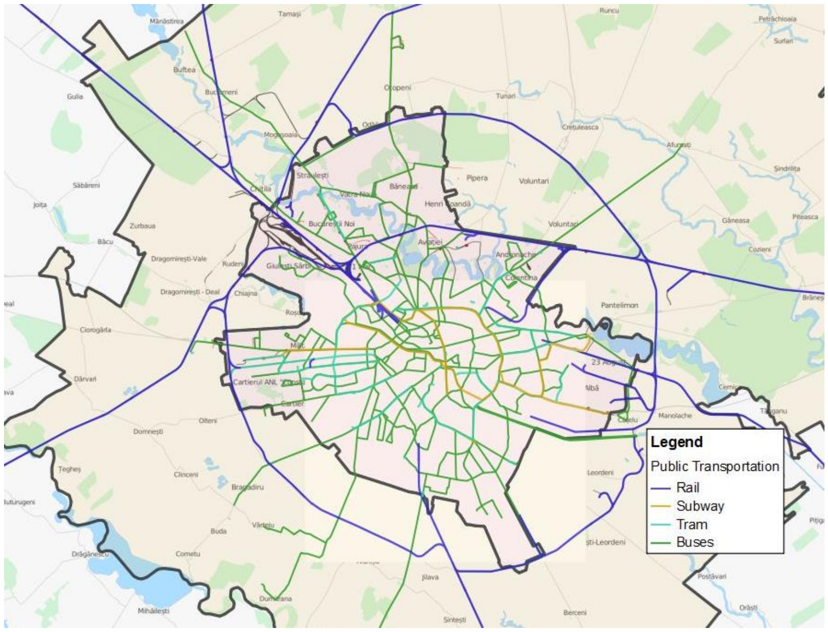

Figure 5-5: Public Transportation Network for Bucharest and Ilfov

Source: World Bank team

87. Once the spatial model was fully developed, population, land use, and business activity information was then reallocated by superimposing a 500m x 500m grid scale over the entire Bucharest-Ilfov study region. This technique is commonly employed in GIS analyses to help remedy the fact that data is often available at wildly disparate scales (e.g. building scale vs. census tract vs. specific addresses, etc.) Using the grid scale based approach, data attached to an individual cell or to an aggregation of cells is more easily extractable for analysis in a relational database or a spreadsheet (as is the case with the RACE model.). [See Figure 5.6 for a depiction of the 500m x 500m grid overlay applied to the Bucharest-Ilfov study area.]

88. Step 1 is completed once the data is transferred into the RACE spreadsheet model, and energy and emission factors are applied to develop Baseline estimates of current energy demand, energy spending, GHG and air quality emission levels for the Bucharest-Ilfov region. Solid waste management system parameters are also entered into the analysis at this point, as the various disposal options are not necessarily spatially linked. This information serves as the starting point for the scenario analysis.

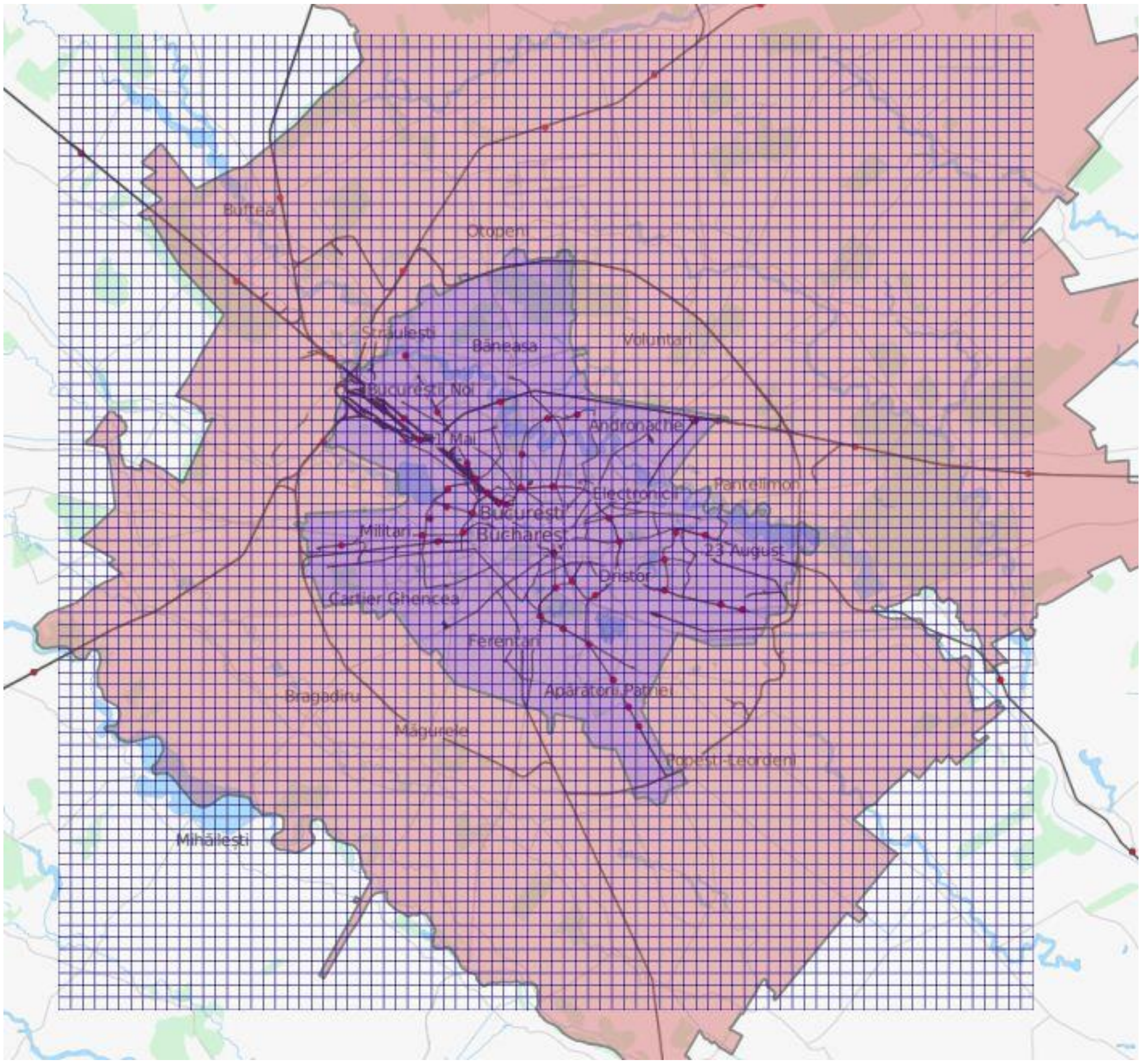

Figure 5.6: 500m x 500m grid overlay on Bucharest-Ilfov study area
Source: World Bank team

5.1.2 Step 2 – Prepare 2050 Development Scenario

89. The future development scenarios modelled in RACE posit assumptions about future demographic and economic conditions likely to exist in the city/region. In making these calculations, the scenario must explicitly address the pace of expected growth and shifts in the city's reliance on manufacturing value chains (i.e. from low to high value-added manufacturing) and in consumer and product services. Population growth estimates must be compared to other cities in the country or region to ensure credibility. Collectively, these assumptions drive estimates of future demand for industrial, commercial, and residential building stock, which RACE then uses to calculate emissions.

90. Transport infrastructure assumptions are necessary to construct "accessibility indices" for each 500m grid cell across the region. These indices measure the relative accessibility of each cell to the city center or other areas of anticipated economic growth, thereby defining the areas most likely to attract development activity.

91. Based on the 2050 development scenario, at least two different spatial growth options can be constructed to accommodate the projected population and building stock requirements: a Business-as-Usual option and a Low Carbon option. These options articulate different visions for the location of growth, the density of growth, the land use mix of growth, and the extent to which these land uses are integrated with the city's transport infrastructure.

5.1.3 Step 3 – Model Business-as-Usual (BAU) Option

92. The BAU Option reflects recent spatial patterns of development in the city/region: the land use mix is assumed to remain relatively segregated, i.e., large residential areas with little or no formal employment spaces; growth driven by changes in population levels and/or economic expansion continues to focus on suburban and peri-urban areas (with little, if any growth distributed to the core and inner city areas) based on the assumption that land values and resettlement costs are lower in the suburbs. 500m grid cells with building densities higher than the city average are also excluded as growth areas. Finally, the BAU option assumes little attempt is made to link development growth to public transport systems in the region.

93. With these assumptions in mind, growth is then distributed around the city using GIS, factoring in accessibility indices that prioritize available marketable land and recent growth trends. Once this is done, it is possible to recalculate energy demand, energy spending, and emissions for the region. (Note: the process for distributing growth in the Bucharest-Ilfov BAU option is outlined in greater detail in Section 6.)

94. Any changes in the solid waste management system structure (compared to the baseline period) are also accounted for at this time.

5.1.4 Step 4 – Model Low Carbon (LC) Option

95. The Low Carbon option presumes very different growth parameters than the BAU Option. The density of future growth is modeled far higher in strategic locations with the best accessibility to the city core and to employment areas. The land use mix in the Low Carbon Option is more varied. High-density clusters of mixed use development are proposed, minimizing the need for travel to places of work, education, commerce, and recreation. Because growth is concentrated in areas with the best accessibility, there is tight integration of land uses with transport infrastructure. In preparing the Low Carbon Option, changes to transport routes or the creation of new transit nodes can be proposed to improve land use-transport integration and facilitate even higher density development. Solid waste management system options known to increase a city's carbon performance are also changed in the model.

96. Energy demand, energy spending (in real terms), and emission levels are then calculated for the new configuration.

5.1.5 Step 5 – Compare Development Options

97. By comparing the energy and emission impacts of different development options, local and regional authorities can identify the types of policies that affect, sometimes in unexpected ways, the long term economic and environmental sustainability of their city. Action plans can then be prepared to comprehensively review and – where appropriate – adjust these policies to minimize emissions.

Section 6: Key Findings – Alternative Development Scenarios for the Bucharest-Ilfov Region

6.1 Overview

98. Section 4 provided a baseline picture of Bucharest's population, economic and land use patterns, in addition to a brief overview of key urban sectors including transport, buildings, and solid waste. This section looks at how current trends might change over time and the implications for energy use, energy spending, carbon emissions, and other pollutants.

99. Two scenarios are presented: a Business-as-Usual case in which current trends (with minor modifications) are projected to 2050, and a Low Carbon Development pathway, in which the city/region takes proactive measures to promote smart urban development through a mixture of land-use planning and action to reduce emissions from buildings, transport and solid waste.

100. The following sections outline the key assumptions and results of the different development options. A more detailed summary of the methodology and underlying assumptions can be found in the Appendices

6.2 Option 1: Business-as-Usual (BAU)

6.2.1 Summary of Key Features

101. The BAU scenario presumes continued low density development on the periphery of Bucharest, with no integrated transport and land use planning leading to inefficient urban form. While energy use and associated emissions continue to increase as a result, growth is offset by a number of encouraging trends in transport and buildings that take place even in the absence of strong local action.

6.2.2 Spatial Development

102. The BAU option assumes the continuation of low-density growth of residential, office and industrial development. For residential development (which accounts for the majority of both floor space and energy use) BAU assumes the continuation of recent market trends for residents in high-rise Communist-era apartment blocks to move to single-family homes in the suburbs around Bucharest. Consequently, low-rise's share of total residential building stock grows from 42% in 2014 to 60% in 2050.

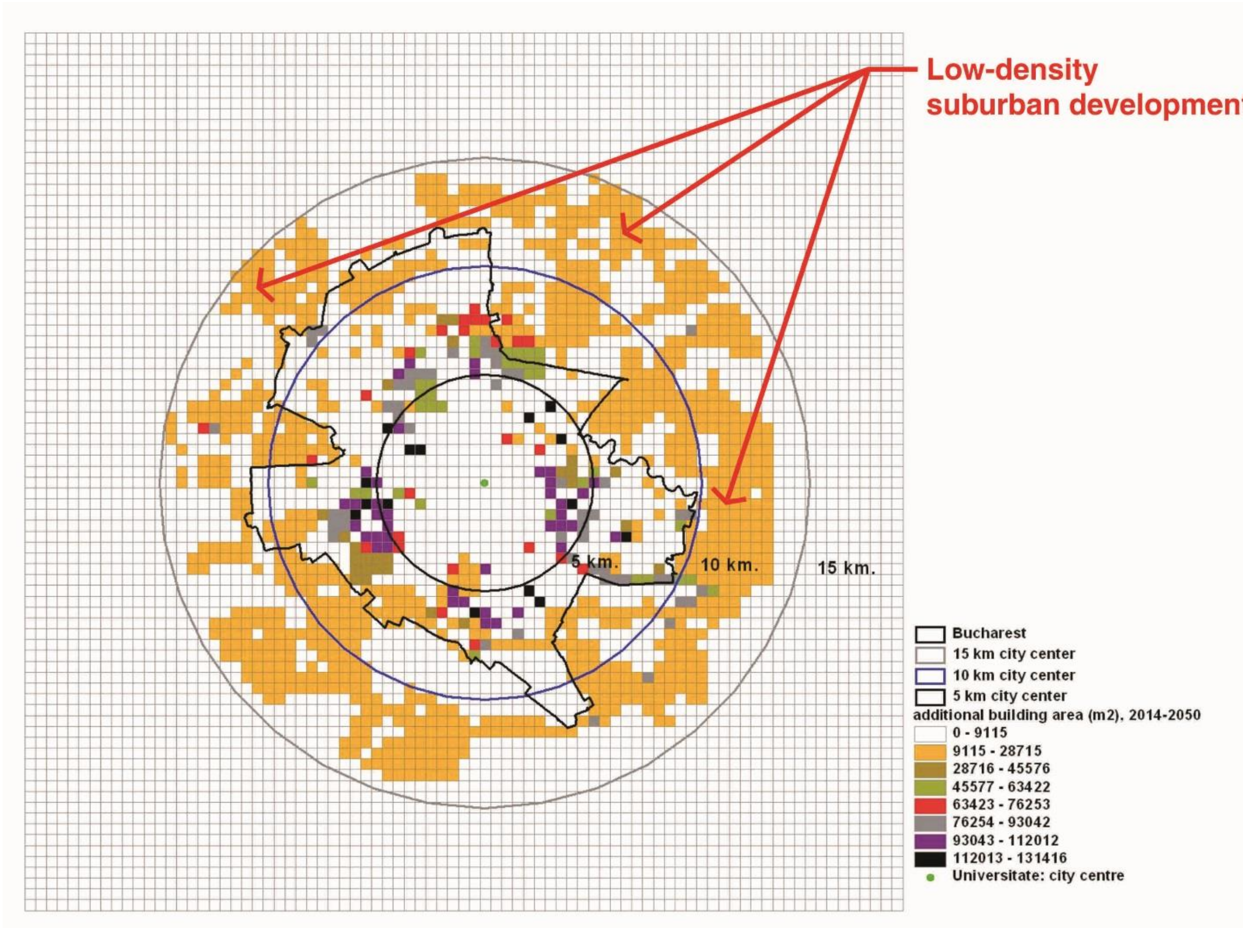

Figure 6.1: Distribution of New Building Stock under BAU Option
Source: World Bank team

103. The resulting spatial distribution of new building stock under BAU is shown in Figure 6.1. Because there is insufficient land to accommodate low density residential growth within Bucharest, the BAU scenario involves extensive suburbanization in the ring 10-15 kms from the center of the city. Given the absence of public transport in this outer ring, residents would need to rely on private vehicles for journeys to work, education, shopping, and recreation. Indeed, the BAU scenario is notable for its lack of integration between new development and public transit (trams, buses and metro).

6.2.3 Results

104. In the business-as-usual (BAU) scenario, overall energy use and associated emissions continue to increase out to 2050. While this is to be expected given the low density development and lack of coordination with transport planning, what is most surprising is the slow rate of growth in GHG emissions. Even as demand for energy continues to increase between 2014 and 2050 as a result of the demographic and spatial trends outlined above—including an 30% increase in population and building area— carbon emissions grow much less rapidly (9%) over the same period. (See Figure 6.2) This is explained by a number of positive trends in transport, buildings, and solid waste.

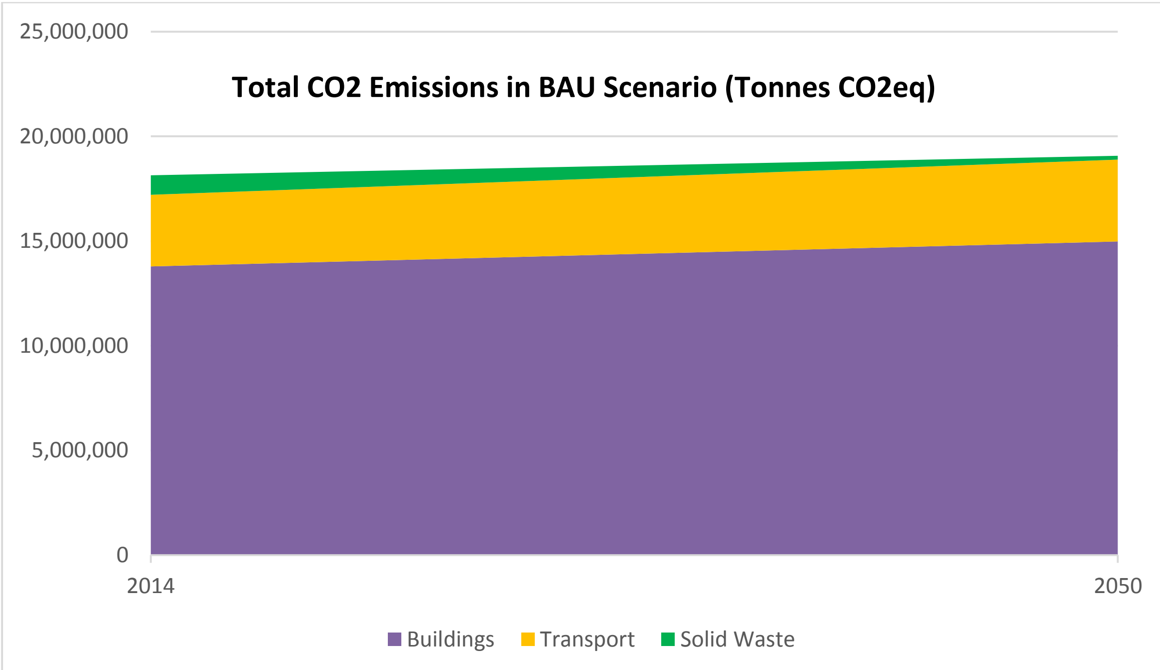

Figure 6.2: Total Emissions of Carbon Dioxide Equivalent in the Business-as-Usual Scenario
Source: World Bank team

105. First in the building sector, despite a 30% increase in total building floor area—including a move to lower density buildings which are typically characterized by higher energy usage per square meter—overall building energy demand increases at half that pace (15%) because of anticipated improvements in building efficiency.

106. As described in the baseline chapter of this report, the majority of Romania's buildings were constructed pre-1989 and have significant room for efficiency gains. The BAU scenario assumes that the rate of renovation of the existing building stock continues at its current pace of 1% per year, with energy savings from retrofits assumed to be a conservative 15%. Given current EU policies targeting efficiency in the built environment, it is assumed all new buildings come with moderate energy savings of 45% compared to existing building stock.[33]

107. Total GHG emissions from buildings are also affected by changes in the carbon intensity of Romania's electricity grid as coal-fired plants are largely replaced by natural gas facilities.[34] Even as the proportion of non-fossil fuels in the electricity generation mix declines (63% in 2015 to 60% in 2050) largely as a result of no growth in generation from either nuclear power or hydroelectricity, switching from coal to less carbon-intensive natural gas results in sizable reductions in emissions associated with electricity consumption. The thermal efficiency of buildings in the Bucharest-Ilfov region is also

[33] These assumptions on the rate and depth of change are informed by BPIE (2014). *Renovating Romania*. Building Performance Institute Europe.
[34] Assumptions here follow those used by the World Bank's Component C RAS Project energy modeling team.

expected to increase thanks to anticipated reductions in technical losses from the district heating system (from 15% to 13%).

108. A similar story is foreseen in the transport sector. Due to a combination of rising incomes, low density development, and lack of coordination between land use and transport planning, the number and average length of trips increase as people move to the suburbs, and speeds decrease as a result of increased congestion. (Trip speed is an important contributor to emissions, with slower speeds indicating increased incidence of vehicle idling.) From 2014 to 2050, the number of trips increases by 30% and average trip length increases 8%.

109. At the same time, however, increasing vehicle kilometers travelled are offset somewhat by macro trends that lie largely outside the purview of local government. First, all vehicle classes will experience efficiency gains[35] (40% in private vehicles and almost 20% in buses) as a result of current EU directives on fuel efficiency combined with natural replacement rates that see an increase in Euro III/3 and up vehicles and a decrease in less-efficient older models. Moreover, 2014-2050 sees a trend towards a cleaner fuel mix, with particularly notable growth in LPG consumption in private cars.[36] In the absence of coordinated land-use and transit policy, it is assumed in the BAU scenario that modal split will stay the same.

110. In the solid waste sector, emissions[37] increase along with population and income growth, similar to other sectors.[38] While waste composition is assumed to remain constant over the time period, management of waste is expected to change in line with current trends. As with buildings and transport, no aggressive local action is assumed under the BAU scenario. Rather, acknowledging the existing policy environment, it is anticipated that rates of recycling and biodegradable waste diversion in Bucharest would reach half the levels mandated by EU targets, except in the case of paper recycling where local performance already exceeds EU standards. Emissions from solid waste are relatively small, however, and constitute just 5% of the region's projected emissions in 2050.

111. In summary, the noteworthy thing about the Business-as-Usual scenario is that even in the absence of strong local action, the natural replacement rates of buildings and vehicles combined with a changing fuel mix lead to emissions growth that is slower than one might expect given the 30% growth in local population and building stock. This is no excuse for complacency, however. In order to meet national and EU-wide emissions targets, more will have to be done at the local level to

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[35] Assumptions here follow those used by the World Bank's Component C RAS Project transport modeling team. See World Bank (2015) *Romania Climate Change and Low Carbon Green Growth Program- Component C Transport Mitigation Report: Transport Sector Rapid Assessment* for discussion of these estimates.

[36] Assumptions here follow those used by the World Bank's Component C RAS Project transport modeling team. See World Bank (2015) *Romania Climate Change and Low Carbon Green Growth Program- Component C Transport Mitigation Report: Transport Sector Rapid Assessment* for discussion of these estimates.

[37] Expressed here in tonnes of CO2 equivalent.

[38] For detailed description of solid waste assumptions and methodology using the CURB Tool: Climate Action for Urban Sustainability, please see Annex. It is important to note that emissions here refer only to those associated with waste management rather than collection and transport. Also worth noting is the fact that these emissions are not affected by Bucharest's spatial development.

promote compact development. Nor are GHG emissions the only reason for more proactive interventions on the part of local government—high-density mixed use development can also improve local livability, air quality, and attractiveness to business. The Low Carbon development scenario presented below attempts to quantify some of these benefits.

6.3 Option 2: Low Carbon Development

6.3.1 Key Features

112. The Low Carbon Development scenario prioritizes dense development, coordination of land use and transit, proactive local action to reduce energy consumption in buildings and transport and change local solid waste practices, and assumes ambitious national initiatives to promote clean power and cleaner vehicles.

6.3.2 Spatial Development

113. Compared to the BAU scenario, spatial development in the Bucharest-Ilfov region under the Low Carbon option exhibits less sprawl, higher densities, mixed-use, and a coordination of transit and spatial planning.

114. The LC Option reduces the share of low rise residential development from 60% in BAU to 30% in 2050. (This is the current rate in Budapest and Bonn, and higher than in Bratislava.) The amount of medium density's share stays the same at 10%. The most significant change is in the shift in share of high rise residential development from 15% to 30%, and of very high density from 15% in BAU to 35% in the LC Option.

115. Embracing the principles of high density and mixed use, LC presumes that retail becomes more dispersed in high density communities, reducing the need to travel to shops. Consequently, large-scale retail's share of total retail drops from 98% in BAU (and 96% in baseline) to 70%. Small scale retail's share increases from 2% in BAU to 30% in the Low Carbon option.

116. As in BAU, the Low Carbon Option assumes that 100% of industrial development is in industrial estates; spatially, these are concentrated in 2 large industrial parks strategically located close to rail and expressways. For institutional buildings, the LC scenario assumes a drop in government buildings' share from 86% to 75%, accounting for e-government reforms that reduce the need for building space. Education's share of building space increases from 6% to 10%, reflecting a qualitative improvement in space per student. The amount of land allocated to healthcare facilities increases from 4% in baseline and BAU to 10% in the LC, reflecting a growing demand from an aging population. Transportation's share grows slightly from 4.6% in the baseline to 5%, reflecting an increase in the number of metro stations and hubs by 2050.

117. Above all, the Low Carbon option strives to be realistic, attempting to improve on existing patterns rather than aiming for an idealistic but unachievable vision of compact growth. As such, the low

carbon scenario does not introduce any gross building area density that exceeds the highest cell density existing in Bucharest in 2014. The intention is not to create a Singapore or Hong Kong but rather to increase the efficient use of urban land in the Bucharest-Ilfov region and reduce travel distances.

118. Spatially, growth is concentrated in a number of strategic areas (see Figure 6.3 and Appendices reflecting a high degree of land use planning. The LC Option creates two major new sub-centers with high densities and a mix of residential, office, and retail uses. Very high density residential is distributed in the immediate vicinity of metro stations, reflecting a strong coordination of transport and land use planning.

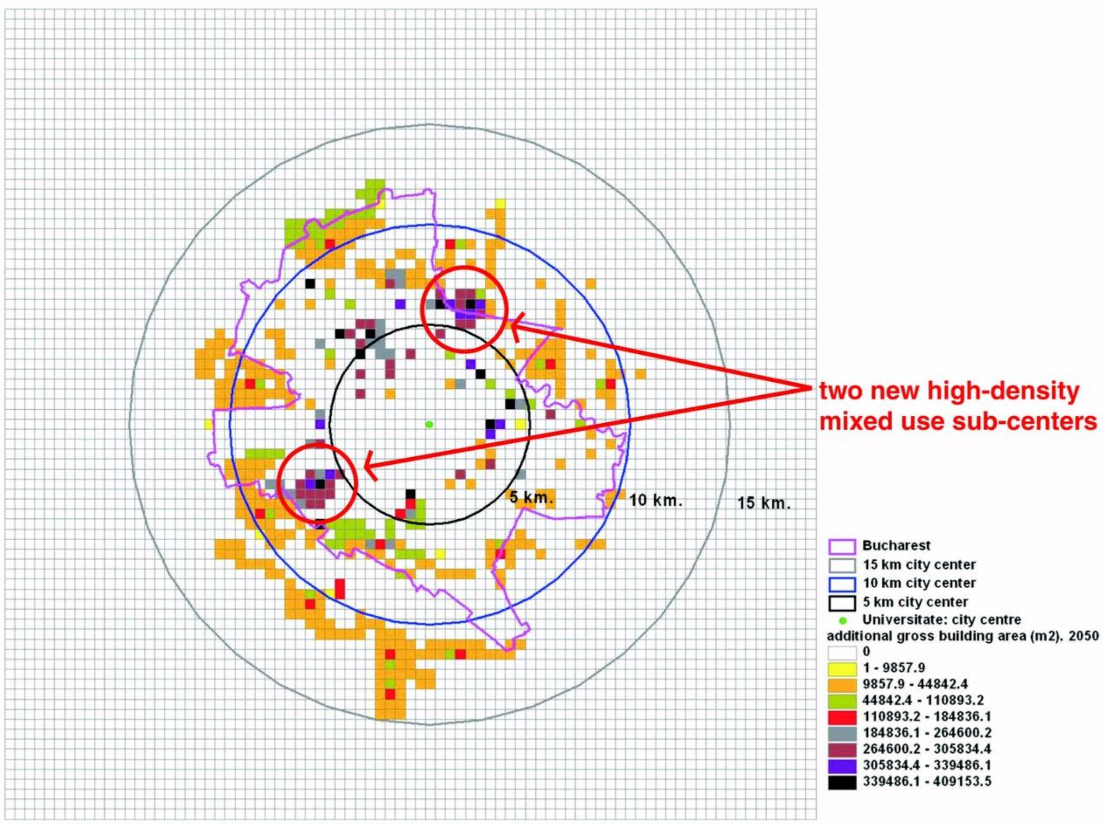

Figure 6.3: Distribution of New Building Stock under Low Carbon Option, 2050
Source: World Bank team

6.3.3 Results

119. Perhaps unsurprisingly, proactive spatial planning leads to significant improvement in energy use, energy spending, and emissions—even though the gross building area remains the same as in the BAU option. The scenario leads to carbon emissions reductions of 37% relative to a Business-as-Usual pathway, with buildings-related energy use delivering three-quarters of that savings.

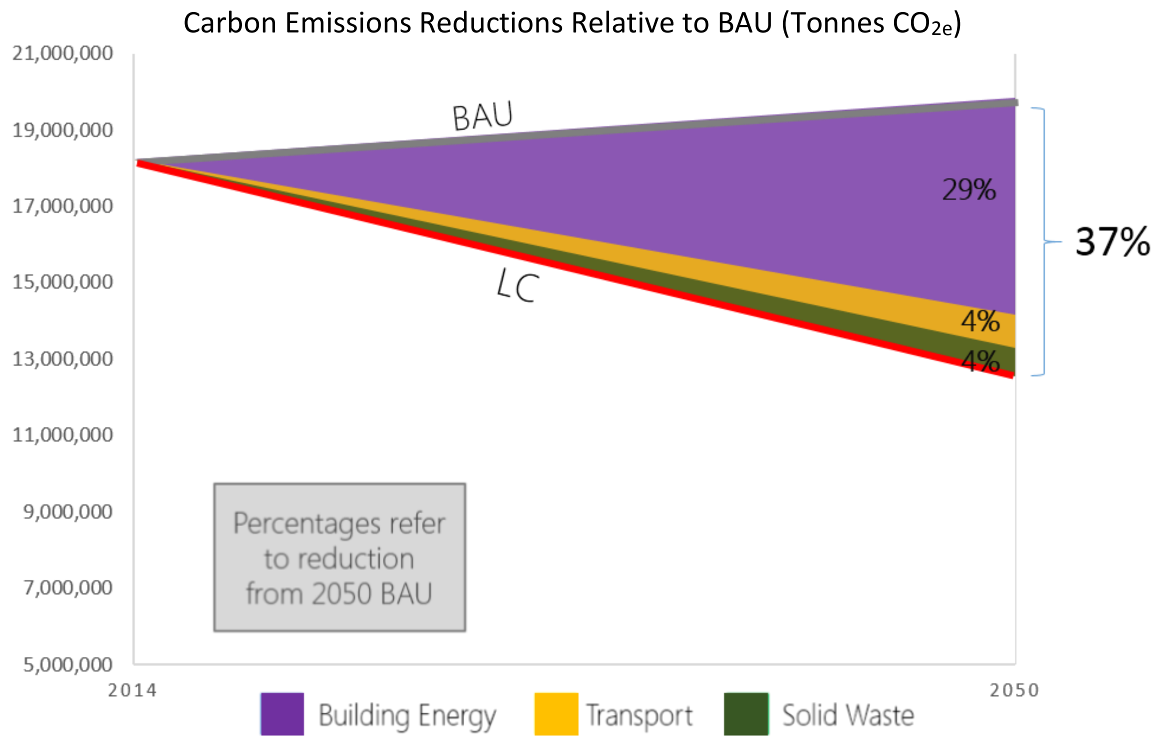

Figure 6.4: Carbon Emissions Reductions under Low Carbon Scenario Relative to BAU, 2050
Source: World Bank team

120. The benefits of the Low Carbon scenario are not limited to global climate change, however. Reduced energy use cuts total energy spending by $1.4 billion USD per year in real terms. Moreover, there are benefits to local air quality across the city with a 39% reduction in particulate matter (PM_{10}) and 35% reduction in nitrous oxide (NOx) emissions.

121. In the buildings sector alone, energy savings lead to a reduction in energy spending totaling $956 million USD per year by 2050. Significantly, thermal energy savings relative to the BAU scenario amount to as much as $632 million USD. Given that retail prices for heating are set by the government, it is likely that most of these savings will accrue to the municipal budget—an important saving given the large burden of subsidizing thermal energy use in Bucharest.

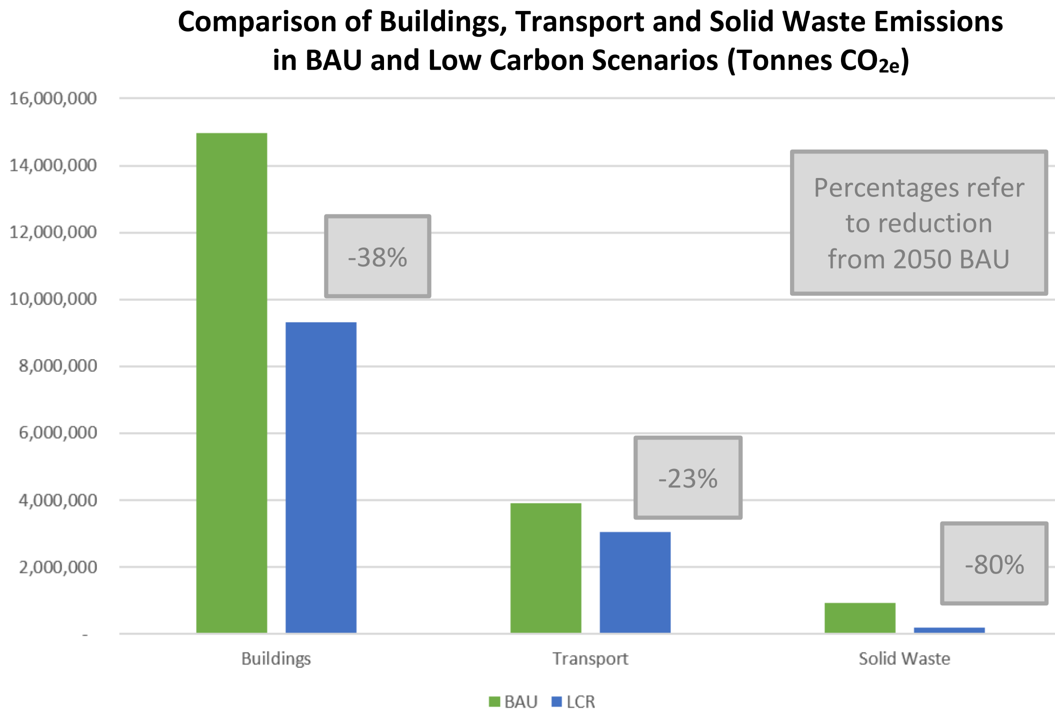

Figure 6.5: Comparison of Buildings, Transport and Solid Waste Emissions in BAU and Low Carbon Scenarios (Tonnes CO_{2e})
Source: World Bank team

122. As in the BAU scenario, actions outside of city control are an important part of the equation. For example, under the Low Carbon scenario, fossil fuels are expected to account for just 14% of electricity generation by 2050—most of which (10%) is natural gas.[39] This is achieved primarily through increases in nuclear, hydropower and wind generation, which respectively make up 32%, 25% and 16% of electricity generation mix in 2050. Transmission and distribution losses are also reduced from 12% to 9%. .

123. Other reductions in building-related emissions are expected to be achieved through an increase in the proportion of higher density buildings (which have a lower kWh/m^2 footprint) and actions by both local and national government to increase the rate and depth of building energy efficiency above and beyond the BAU case. While not specifying the precise policies that would be needed to achieve reductions at scale, this analysis assumes that new buildings use 75% less energy on a per m^2 basis than Bucharest's current building stock. Renovations of this stock are expected to proceed at a rate of 1.5% per year during 2015-2025 and 2.75% per year thereafter, delivering a 45% reduction in energy use on a per m^2 basis. On the supply side, technical losses in the district heating system are reduced from 15% to 10% in this model (i.e. a 33% improvement). The following Section discusses policy options for achieving the reductions this analysis suggests may be possible in the Bucharest-Ilfov region.

[39] *Romania Climate Change Study: Energy Sector Investment*, World Bank, March 2015

124. In the transport sector, new spatial patterns lead to reductions in the number and length of trips relative to BAU, in addition to decreased traffic congestion. As a result, transport emissions are 23% lower than the BAU scenario, with a total (real) saving in energy spending amounting to $440 million USD per year by 2050. Moreover, a particulate matter (PM_{10}) emissions decline by 39% and nitrous oxide (NOx) emissions decline by 16% relative to the Business-as-Usual scenario. These improvements in local air quality, along with improvements in urban mobility, can make Bucharest a much more attractive and healthier place for people to live and work.

125. The biggest difference between this scenario and BAU is the attention to land use planning. In particular, development of high density buildings and mixed uses around transit nodes is reflected in a changed modal split, with a 9% increase in public transportation and 3% increase in non-motorized transit. In addition to changes related primarily to spatial patterns, the low carbon option assumes a suite of measures to promote reduced vehicle kilometers travelled, mode shift, and improvements to vehicle stock and efficiency. In contrast to the BAU scenario, these can include a wide array of actions that can be implemented locally in Bucharest, including changes in on-street parking rules or pricing, congestion pricing in the central business district, procurement of electric vehicles in public fleets and investments in walking and cycling infrastructure. Others, such as subsidies for ultra-low emission vehicles, are more suited to national action.[40]

126. While its relative contribution to region-wide emissions is low, under the Low Carbon scenario the solid waste sector shows a greater reduction proportionate to its BAU development trajectory than any other sector. An 80% reduction in emissions relative to Business-as-Usual is achieved by assuming Bucharest-Ilfov meets all EU targets with regards to recycling and biodegradable waste diversion (see Appendices), a significant improvement over today's baseline practices. Emission reductions are driven primarily by a reduction in methane, which is achieved through a combination of composting (assumes food and yard waste diversion of 65% as per EU targets) and the capture of 100% of the methane emissions from local landfills.

[40] These assumptions draw on the work of the World Bank's transportation team. See World Bank, *Romania Climate Change and Low Carbon Green Growth Program- Component C Transport Mitigation Report: Transport Sector Rapid Assessment,* 2015.

	Comparison to Baseline Circumstances	
	Business-as-Usual scenario	Low Carbon Development scenario
Annual CO_{2e} Emissions	+18%	-29%
Annual Energy Consumption	+17%	-17%
Annual Energy Spending	+17%	-19%
Annual PM_{10} Emissions	+34%	-18%
Annual Total NOx Emissions	+21%	-20%

Table 6.1: Changes in Key Metrics Relative to Current Baseline Conditions in Bucharest
Source: World Bank team

6.4 Summary

127. While this analysis is not meant to be prescriptive, by illustrating the impact of different patterns of spatial development, combined with changes to building performance, vehicle efficiency, solid waste management and the overall urban fuel mix, it does begin to point to priority areas for government intervention.

128. There are already encouraging signs for the Bucharest-Ilfov region. Even without strong local action, energy use and carbon emissions in the BAU scenario do not grow as fast as might be expected thanks to a combination of EU and national policies that, together with increased market penetration of new technologies, helps to reduce the energy and carbon intensity of growth through better buildings, better vehicles, and a cleaner energy mix.

129. The Business-as-Usual scenario is not something to aspire to, however. As Table 6.1 clearly shows, the BAU scenario involves increases in *every* key metric: air quality and GHG emission levels, energy demand, and energy spending. The Low Carbon scenario delivers the exact opposite, aching reductions in each of these areas. Moreover, high-density, walkable, mixed use development characterized by higher usage of public transit and lower levels of air pollution can have benefits which are less easy to quantify—for public health, economic development, and overall livability.

130. Delivering the Low Carbon scenario will not be easy, however. In contrast to BAU trends, the low carbon pathway demands strong local leadership to steward Bucharest to a low carbon future. The purpose of this section has not been to recommend specific policy interventions, but rather to contrast the implications of two different models of development in terms of land use, energy consumption, emissions, cost savings and air pollution. The next section of this report suggests a range of more concrete options for the government to begin translating the Low Carbon scenario presented here to action on the ground.

Section 7: Policy Recommendations/Next Steps

7.1 Policy Recommendations

131. In this analysis, the Low Carbon option has focused on policy and technology changes that go far beyond the Business-as-Usual conditions likely to be achieved as a result of current and planned EU policy mandates, Romanian government policies, or general market trends. Delivering these changes will take considerable financial resources and political will on the part of a range of stakeholders. Other analyses prepared as part of the World Bank's Climate Change RAS work have documented many of the macro-level changes that must be undertaken by different Romanian government ministries to increase the level of funding available for different projects, decarbonize the national energy supply, and improve coordination between planning efforts at the national, regional, county, and local levels. Those changes will not be recapped here.

132. Instead, the recommendations included here focus more directly on initiatives Bucharest Municipal Government, District governments in Bucharest, and Ilfov County and Commune officials should consider. These recommendations fall directly within the policy remit of these tiers of government. Recommendations are broken out on a sectoral basis, although some general cross-sectoral administrative recommendations are included as well. Note that these recommendations avoid reference to specific interventions that will improve the efficiency of different infrastructure systems or types of buildings, as such choices can necessarily be made only after further technical review by trained experts.

Table 7.1 Policy Recommendations

Sectoral Focus	Policy Recommendations	Type of Policy Initiative
Cross-sectoral	*<u>Data collection training, dissemination, and use</u>*: Expand the amount of land use, building stock, and building and transport-related energy use data systematically collected and made available for public use. Local authority staff should be trained on data collection strategies and methods of analysis (including GIS).	Administrative and policy reform
	<u>Guidance</u>: Convene multi-stakeholder coordinating group to ensure policy coordination on land use and transport policies and investments	Administrative and policy reform
	<u>Improve metropolitan governance and management</u>: Evaluate, with all affected stakeholders, mechanisms to improve coordinated and integrated strategic planning, development monitoring and control, and delivery of	Administrative and policy reform

	metropolitan public services at the scale of the metropolitan region (including land use planning, public transport, and environmental management.)	
	Improve management of suburban growth: Design, enact as a statutory instrument, and enforce a growth management strategy for the metropolitan region that limits uncontrolled suburban sprawl and resulting consumption of agricultural land and forests.	Administrative and policy reform
Land use	*Promote mixed land use*: Adopt mixed land use policies, where different types of land use (housing, shops, offices, other urban amenities) are interspersed rather than segregated, thus providing more convenient access to goods/services and employment opportunities. Mixed land use policies are recognized for their ability to reduce the use of motorized transport.	Land use policy reform
	Up-zoning: Change the floor-to-area (FAR) ratio allowed on certain land parcels or in certain neighborhoods, thus increasing the level of population or economic activity that can be accommodated. Note: these changes must be made to take into account the carrying capacity of local streets, sidewalks, and parking areas to ensure they do not become overloaded.	Land use policy reform
	Transit-oriented development: A variation on upzoning by specifically targeting these changes in the vicinity of high-capacity transit nodes, thereby increasing the size of the population likely to make use of the mass transport system. Note: these changes must be made in close coordination with relevant transport agencies to ensure that transit system capacity (overall, or at specific nodes) does not become overwhelmed by higher rates of usage.	Land use policy reform
Land use + Transportation	*Preferential lane space for public transport/high occupancy vehicles*: Dedicated lane space can ensure that high occupancy vehicles are not adversely affected by slow moving vehicles. Interest in public transport use typically increases if it is seen as a time-saving option compared to private vehicles.	Roads policy reform
	Creation of Pedestrian-only zones: Designating core city areas as pedestrian-only zones can reduce demand for motorized vehicles.	Land use and roads policy reform

	Parking policies: On-street parking takes up scarce lane space that could be used to facilitate vehicle movement around the city. Different parking policies (e.g., variable rate pricing with higher rates during peak travel period, on-street parking bans or time-based restrictions) should be considered for important thoroughfares. Land use policies can also be amended to promote the creation of more off-street parking. On the periphery of the city, Park and Ride facilities should be established at the end of high capacity transit lines to encourage the use of public transportation when entering Bucharest. (Such systems are critically needed if congestion pricing programs are established in the urban core. See below.)	Roads policy
	Completion of Ring road(s): The incomplete nature of the ring roads around Bucharest leads through traffic to drive through the city center, competing with local traffic and increasing congestion levels.	Roads policy
Traffic management policies	*Congestion pricing*: Congestion pricing is a mechanism whereby users of scarce public goods – such as road space in the center of a large city – are charged for their use of that good. The pricing strategy seeks to influence demand by dissuading individuals unwilling to bear this cost burden. Typically, congestion pricing in cities is limited to heavily trafficked areas; drivers entering must pay a toll to enter that area. Congestion pricing programs presume that effective alternatives (such as public transit) exist to allow individuals to enter that area at no or low charge.	Roads policy
District heating systems	*District heating system upgrades*: Conduct or require strategic reviews of local district heating systems to identify cost effective efficiency upgrade opportunities. Systems can also be analysed for the possible use or integration of low(er) carbon energy sources.	Engineering analysis
Building efficiency	*Property Assessed Clean Energy (PACE) finance*: PACE systems create a revolving loan fund that can be tapped to support energy efficiency upgrades. Property owners can apply for these funds, which are then paid off via a surcharge on their energy bill (typically at a rate equivalent to the energy savings the upgrades deliver to the building.) Because the loan is attached to an individual property rather than the owner of the property, when the property	Public finance

	is sold/transferred the loan obligation is immediately transferred as well. PACE programs can be capitalized by private investors or other municipal finance strategies.	
	Green Mortgages: Green mortgages typically enable borrowers to obtain larger mortgages (or preferred rates) because their properties have been certified as meeting minimum efficiency standards. The monthly savings on energy spending can thus be transferred to allow the borrower to afford higher monthly mortgage payments. Local authorities can partner with and promote the Romania Green Building Association's new green mortgage program that provides preferential rates to property owners buying or investing in more efficient buildings.	Public finance
	Point of Sale Efficiency Upgrades/Audits: These requirements seek to bring older buildings closer to the energy performance of new buildings. These requirements must be satisfied before a property can be sold, transferred from one occupant to another, or renovated beyond a certain limit. To ensure that the retrofit burden does not become excessive, such policies typically cap the total cost of required improvements at some fraction of the sale or rental price. These requirements mesh well with EU-imposed building performance disclosure requirements, because underperforming properties can easily be identified.	Energy policy
	Energy Efficiency capacity building programs: Local authorities can create programs to improve local knowledge of building efficiency upgrade opportunities. These programs can be run centrally out of City Hall, or support can be given to relevant community-based organizations in a strong position to influence/inform the public.	Energy policy/ education

7.2 Relevance of this Analysis to Other Romanian Cities

133. As this analysis has found, strategies that promote more compact city design, transport-oriented development (and other policies resulting in changes in modal-split), upgrades to more efficient vehicle stock, and policies promoting building efficiency upgrades can deliver sizable reductions in annual energy spending and emission levels.

134. Romanian cities considering this type of assessment are encouraged to keep several things in mind before moving forward. First, although some of the more technical assumptions (e.g. the CO_2

emission and other air quality emission factors for different fuel types, estimates of vehicle efficiency, estimates of energy demand/m^2 for different building types) used in the Bucharest analysis will generally be relevant in other Romanian cities, much of the model is necessarily based on local data and estimates of a particular city's future growth prospects. In the growth pole cities, where SUMPs are under development, or other master plans (PUG or IUDPs) are already available, much of this type of information may be readily available.

135. The digitized land use map detailing the size, location and type of building will likely be the most difficult dataset to obtain. Local university researchers or others may have different data sets that can be built upon; it may also be possible to purchase datasets from private firms specializing in geospatial information. Cities pursuing this route are encouraged to evaluate the quality of this information before they purchase it, as the World Bank's team found some datasets that purported to include all buildings actually did not do so.

136. Second, as with any complex model, training on use of the various models used in this analysis is required. The World Bank team included a range of modeling and sector specialists, all of whom added value to the analysis because of their ability to evaluate the appropriateness of certain assumptions built into the model or make decisions about how and where development will occur around the Bucharest-Ilfov region. For this reason, other cities/regions seeking to replicate this analysis will require one or more experts to be trained on both RACE and CURB, and would benefit from an in-house working group of local experts who can provide counsel and feedback on different modeling decisions.

137. Finally, the fundamental limitations of the RACE model were outlined above in Section 1.2 and users are encouraged to keep these points in mind when evaluating its results. Models seeking to forecast economic development, population, land use, and technology trends decades into the future may make errors, and it is for that reason that this analysis should not form the basis of significant specific land use or transport planning decisions. Instead, RACE should be used to obtain insights into indicative changes in energy demand, energy spending, and emission levels that can be attributed to different policy decisions or strategic changes in how and where growth should be directed around a city. In doing so, RACE highlights the value of strategic planning in delivering both local and global environmental and economic gains in a city or region.

7.3 Next Steps

138. As part of Component C of the Romania Climate Change RAS project, the World Bank team has committed to providing training on the use of the different models employed in this analysis to Ministerial level staff, local government officials, and other key stakeholders involved in relevant planning efforts around Romania. This trainings took place during the summer of 2015.

139. Georeferenced information developed as part of this project will also be made available for public use, likely via OpenStreetMap, a global open-source data platform that was the source of some of the baseline land use information informing this analysis. By making this information widely

available, the Bank team hopes to enable improved planning work by those involved in the SUMP and PUG development efforts, as well as creating new platforms for inquiry and innovation by students, civil society organizations, and others interested in using this information in ways that can improve quality of life and advance low carbon development of the Bucharest-Ilfov region.

EUROPEAN UNION

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Structural Instruments 2007 - 2013

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Romania Climate Change and Low Carbon Green Growth Program

Output C1.1
Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors

WATER SECTOR TECHNICAL REPORT

November 2015

THE WORLD BANK
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This report corresponds to Output C1.1: “Report Summarizing the Results and Findings of the Sectoral Analysis and Baseline of Selected Sectors” in the Advisory Services Agreement on “Romania: Climate Change and Low Carbon Green Growth Program” signed between the Ministry of Environment and Climate Change[1] and the International Bank for Reconstruction and Development on July 23, 2013.

1 Now named Ministry of Environment, Waters and Forests

Contents

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Introduction

1.1 OBJECTIVE AND MOTIVATION FOR THIS ANALYSIS

The prospect of climate change represents a major challenge to the water resources and agriculture sectors in Romania for three important reasons:

The type of climatic change that most threatens water resources and agriculture is expected to be more severe in this region. According to the United Nations (UN) Intergovernmental Panel on Climate Change, by the end of the century Eastern Europe and Central Asia is projected to have a temperature increase above the global mean, increased frequency of extreme climatic events, and a decrease in precipitation in already dry areas.

Water resources and agriculture are a highly climate-sensitive economic sector, and key characteristics of Romania make their water resources agricultural sectors particularly vulnerable to these changes. A changing climate, with warmer temperatures and lower precipitation, is already impacting agriculture and livestock in Romania. The economic effects of climate change on agriculture include direct yield impacts which are the most easily estimable as well as ripple effects across sectors and markets dependent on agriculture and water resources.

Some work has been done to both assess climate challenges and increase resilience to climate change in Romania, but there is a need for focused and rigorous analysis of a menu of green growth and climate adaptation options to ensure actions are taken in this area.

In response to this challenge, the World Bank and Romania are partnering on a Green Growth and Climate Change Analytic and Advisory Support Program, part of an 'umbrella' program of analytic work and non-lending technical assistance, which has focused in many World Bank client countries as a mechanism to assess the economic costs and benefits of a shift to greener growth taking into account projected climate change; to prioritize for implementation a set of actions for improving economic conditions and environmental sustainability; and to provide focused decision-support tools and capacity building to enable continued progress in these areas. These principles are being implemented in Romania as part of the World Bank's Climate Change Reimbursable Advisory Service (RAS) Program at the request of the Government of Romania, through its Ministry of Environment, Waters and Forests.

A series of Rapid Assessments has been completed under component B of this program as of the end of 2013. In the water sector, the purpose of the Rapid Assessment was to assess the climate change impacts on water resources in Romania from an integrated, multi-sectoral perspective, and to recommend priority actions for addressing the identified risks and opportunities. Recommended priority actions were presented in the context of consideration for possible financing under the Operational Programs funded by the European Structural and Investment Funds (ESIF) in the 2014-2020 planning horizon.

An enhanced water and agriculture sector analysis is an integral component of the broader Program – work which is the subject of this report. The water sector is here defined to include water related impacts on agriculture (especially irrigation), energy (mainly hydropower) and municipal and industrial water supply. The analytical work builds on but mostly expands and replaces existing work from two completed

EU-supported, multi-country/multi-year assessments: 1. Climate Change and Variability: Impact on Central and Eastern Europe (or CLAVIER, http://www.clavier-eu.org/), completed in 2009; and 2. Central and Eastern Europe Climate Change Impact and Vulnerability Assessment (CECILIA - http://www.cecilia-eu.org/), completed in 2010.

The purpose of this report is to describe the methodologies and present results of the water sector analysis, which is an integral component of the broader Program. In addition, this report addresses a set of non-water sector agricultural sector investments, such as use of improved varieties and optimization of agricultural inputs, which could enhance crop yields.

This water sector analysis therefore addresses four policy-relevant issues not addressed in prior work: (1) the possible adaptive responses by farmers to climate change and the resulting marginal impact on agricultural production; (2) projected impacts on hydropower energy production under the modeled development and climate scenarios; (3) trade-offs between alternative water uses (for irrigation, energy and municipal and industrial use); and (4) potential investment options in irrigation and hydropower infrastructure and the resulting costs and (marginal) impacts on agriculture and energy production.

The framework for the water analysis incorporates the following elements: (1) suggested combinations of climate and policy scenarios to be used in the analysis; (2) the modeling tools to be used, the level of detail in data input planned, the sources of data, and other necessary information to understand the character of the outputs; and (3) the outputs that the water sector analysis produces that can serve as inputs to the macro-economic analyses conducted under the broader program.

1.2 THE WATER AND AGRICULTURAL SECTORS IN ROMANIA

Water Resources Availability and Demands[2]

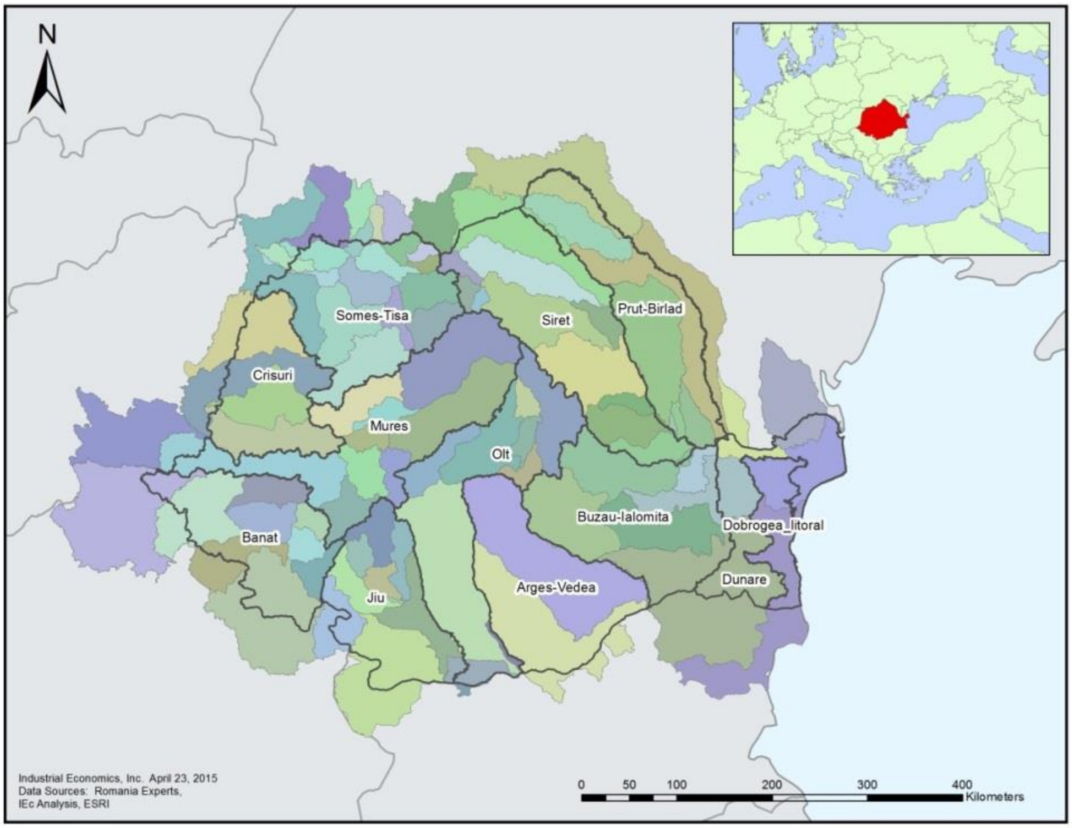
The total surface water potential of Romania amounts to 125 Billion Cubic Meters (BCM)/year, with the internal river basins contributing 40 BCM and 85 BCM available from the Danube basin. The groundwater potential is estimated at 10 BCM/year. The utilizable fraction of the total (surface and ground) water resources, as defined by the existing capacity to extract and use water, is 40 BCM/year. In contrast the total water demand stands at 7.2 BCM/year.

With a population of approximately 20 million, the average water availability in Romania amounts to approx. 2000 cubic meters per capita per year.3 While this value is above the threshold generally defined for water stress (1700 cubic meter per capita per year), it is lower than the average value for Europe (approx. 4500 cubic meters per capita per year), and underscores the need for good management to ensure resource conservation and sustainability.

2 Data presented in this section is derived from the World Bank's Integrated Water Resources Rapid Assessment Report, finalized in November 2013 as part of the Advisory Service Agreement between Ministry of Environment and Climate Change and the International Bank of Reconstruction and Development, Beneficiary: Ministry of Environment and Climate Change, except where otherwise noted.
3 Source: World Bank databank, www.data.worldbank.org

There is a significant inter-annual variation in water resources availability. In the driest years the water availability has fallen to 20 BCM. There is also a significant variation within Romania, with the basins of Jiu, Arges-Vedea, Buzua-Ialomita, Siret, Prut-Barlad, and Dobrogea-Littoral facing the most serious water scarcity (see Figure 1-1 for a map of Romania with basins indicated).

Figure 1-1. River basins in romania



Source: World Bank Team and Industrial Economics

The current water demand comprises of industry (67%), agriculture (18%), and municipal (15%). The water demand has steadily decreased since the 1990s, because of structural changes in economy, including reduction in industrial activity, shut-down of economically unviable irrigation schemes, introduction of metering and tariffs in domestic water supply, and reducing system losses. The total demand, in terms of volume of water made available to users, has decreased from approx. 20 BCM/year in the early 1990s to approx. 8 BCM/year now. As a result there is currently a degree of over-capacity in the system at the national level. The actual water consumption in 2012 was 6.5 BCM. and for 2014 was 6.3 BCM.

Irrigated area in Romania has decreased from 2 million ha in the late 1980s/early 1990s to approx. 0.8 million ha (considered irrigable with functional infrastructure), as economically unviable schemes were closed down In fact, the land under irrigation has remained below 300,000 ha for the past 5 years. The corresponding water demand has reduced from about 8 BCM to 1 BCM per year. While the overall situation appears good because of over-capacity, there are areas of water scarcity in many basins where summer droughts are a significant concern.

About 70% of the water supply for domestic use is sourced from surface waters, compared to 95% dependence on surface waters for industrial supply. From a quantitative perspective, a majority of the basins have no serious problems in ensuring sufficient volume for water for meeting the domestic and industrial demands. However, as the current report finds (see Chapter 3 below), some basins may face supply reliability challenges during the summer months, especially in dry years.

Romania's hydropower potential is estimated at 36 TWh/year, and currently the total installed hydropower capacity amounts to 6,400MW. Hydropower generation accounts for 32% of Romania's total electricity generation, and 16% of the total energy use. The Government intends to decommission/modernize some of the high-emission and obsolete thermal power plants, and therefore plans on a modest increase in hydropower generation capacity. While hydropower is not a consumptive user of water, operations rules for hydropower facilities constrain and are constrained by water uses in other sectors. Therefore the proposed new hydropower facilities would need to be planned taking into account the existing and anticipated future water uses in all sectors. In the basins where scarcity already arises in summers of dry years, hydropower production will be adversely affected for a short duration, as it was in the dry year of 1990. These constraints can be alleviated to a large extent by careful systems planning and operations optimization, and by accounting for the anticipated climate change impacts in the operations planning for these as well as existing facilities.

Almost 60% of the water bodies in Romania meet the EU Framework Directive’s water quality designation of good ecological status/potential, which is based on multiple elements of quality (biological, physio-chemical, and specific pollutants).

Sectoral Uses of Water

Agriculture: Irrigated area in Romania has decreased from 2 million ha in the late 1908s/early 1990s to approx. 0.8 million ha (considered irrigable with functional infrastructure), as economically unviable schemes were closed down In fact, the land under irrigation has remained below 300,000 ha for the past 5 years. The corresponding water demand has reduced from about 8 BCM to 1 BCM per year. While the overall situation appears good because of over-capacity, there are areas of water scarcity in many basins where summer droughts are a significant concern. The situation will become more serious as the impacts of climate change become more pronounced, the most salient being increase in temperatures and reduction in water availability across all of Romania. Addressing this challenge will require adoption of climate-resilient agriculture, and updating of the basin plans while taking climate change impacts into account, to re-assess the sustainable levels and modes of irrigation in the water-scarce basins.

Industrial Water Supply and Domestic Water Supply/Sanitation: As noted above, about 70% of the water supply for domestic use is sourced from surface waters, compared to 95% dependence on surface waters for industrial supply. There are regional exceptions, however - for example, almost 95% of the supply for the city of Constanta (Litoral area- interconnected supplying water system) is being sourced from groundwater, which is being pumped from significant depths 25-55m). A number of cities in Banat and

Moldova regions also face water scarcity in summer months. These cases stand apart from most of the other urban areas in Romania (and especially from Bucharest), which have multiple sources offering significant buffer supplies and a high degree of reliability. As mentioned above, groundwater accounts for almost 30% of the domestic water supply, which could be further stressed under increased incidence of nitrate pollution, but according to the annual assessment of the monitored state of quality of groundwater bodies there is no increase in the percentage of the drilling works with exceeding of the nitrogen dioxide concentrations in groundwater. Additionally, Romania has had a Nitrate Action Plan in place since 2013, as required by the European Commission Nitrate Directive, due to its location upstream from a eutrophicated waterbody (the Black Sea).

Hydropower: Romania's hydropower potential is estimated at 36 TWh/year, and currently the total installed hydropower capacity amounts to 6,400MW. Hydropower generation accounts for 32% of Romania's total electricity generation, and 16% of the total energy use. While coal and other fossil fuels remain the primary source of energy and electricity generation for Romania, the share of renewable sources of energy is large, increasing and higher than EU average. The Government intends to decommission/modernize some of the high-emission and obsolete thermal power plants, and therefore plans on a modest increase in hydropower generation capacity. While hydropower is not a consumptive user of water, operations rules for hydropower facilities constrain and are constrained by water uses in other sectors. Therefore the proposed new hydropower facilities would need to be planned taking into account the existing and anticipated future water uses in all sectors. In the basins where scarcity already arises in summers of dry years, hydropower production will be adversely affected for a short duration, as it was in the dry year of 1990. These constraints can be alleviated to a large extent by careful systems planning and operations optimization, and by accounting for the anticipated climate change impacts in the operations planning for these as well as existing facilities. Furthermore, the development of new hydro infrastructure will need to ensure that the environmental impacts are managed in compliance with the requirements of the EU Water Framework Directive.

1.3 ORGANIZATION OF REPORT

The remainder of this report is organized as follows. Section 2 describes the overall framework of the study, included climate and policy scenarios analyzed, modeling tools and data sources used in this analysis, and key elements of the investment analysis, emphasizing refinements to the previous work. Sections 3 and 4 present the results of the two main components of the analysis: 1) Water and agriculture sector modeling of water availability and crop yields; and 2) Economic implications of these analyses in terms of hydropower production and agriculture sector revenues. An appendix provides the reults of sensitivity analyses on water allocation priority and other model runs.

2. Methods

2.1 OVERVIEW OF APPROACH

As noted above, the water and agriculture sector analyses address four policy-relevant issues: (1) the possible adaptive responses by farmers to climate change and the resulting marginal impact on agricultural production and incomes; (2) projected impacts on energy (mainly hydropower) production under the modeled development and climate scenarios; (3) trade-offs between alternative water uses (for irrigation, energy, and municipal and industrial use); and (4) economic implications of climate change and green growth investments suitable for incorporating in economy-wide modeling of Romania's macroeconomic future. Attention was focused in the study on the agricultural sector to align the analysis with Romania's current water sector investment priorities. Although the industrial sector has larger current water withdrawals than agriculture, most of the industrial demand is focused on thermal electric power plant cooling water, for which detailed data on specific locations of use is not currently available. As a result, the data available for industrial water demand is too aggregated at present for this study to complete an effective representative analysis. Work under the RAS continues to focus on enhancing the rapid assessment; rigorous modeling of water resource availability and crop yields; coordination with the macroeconomic modeling team to ensure that the results can be incorporated in a Romania-wide economic model; and transfer of the methods, data, and results to local institutions to support future work.

The Project Team has proposed to rely on a suite of models and analytic steps to generate estimates of the impact of future climate change under various green growth development scenarios for the water resource sector. Figure 2-1 below presents the sequencing of models and other analyses employed to achieve this goal. The models and analyses applied in this report cover a time frame spanning the next 35 years which necessarily implies some limitations in projections. The impact of climate change on water resources availability and demands is directly linked to uncertain estimations of rainfall by General Circulation Models (GCMs), and subsequently, river flow volumes.

GCMs lie at the beginning of the modeling chain. These models take as inputs quantities of greenhouse gases emitted and produce climate outcomes through time and across space as a function of these emissions and initial conditions. Our team identified three GCM/emissions combinations to use for this step, representing a low/medium/high outcome for climate impacts based on various indicators of water availability, water demand, and aridity that combine temperature and precipitation outcomes (briefly described in Section 2.3 below). The base case climate scenario assumes no climate change.4

4 Note that the approach used here relies on experiments with General Circulation Models (GCMs). Comments from the Romanian National Meteorological Administration suggest that it might be preferable to use results of Regional Climate Models (RCMs), because while the GCM spatial resolution is suitable for large-scale analysis, for regional studies a finer resolution can be justified (e.g., that from RCMs like those from CORDEX program (COordinated Regional Climate Downscaling EXperiment). While the overall approach here can be modified to accept alternative climate inputs, such as those from RCMs, and RCMs could be used in a follow-up activity by local counterparts, an

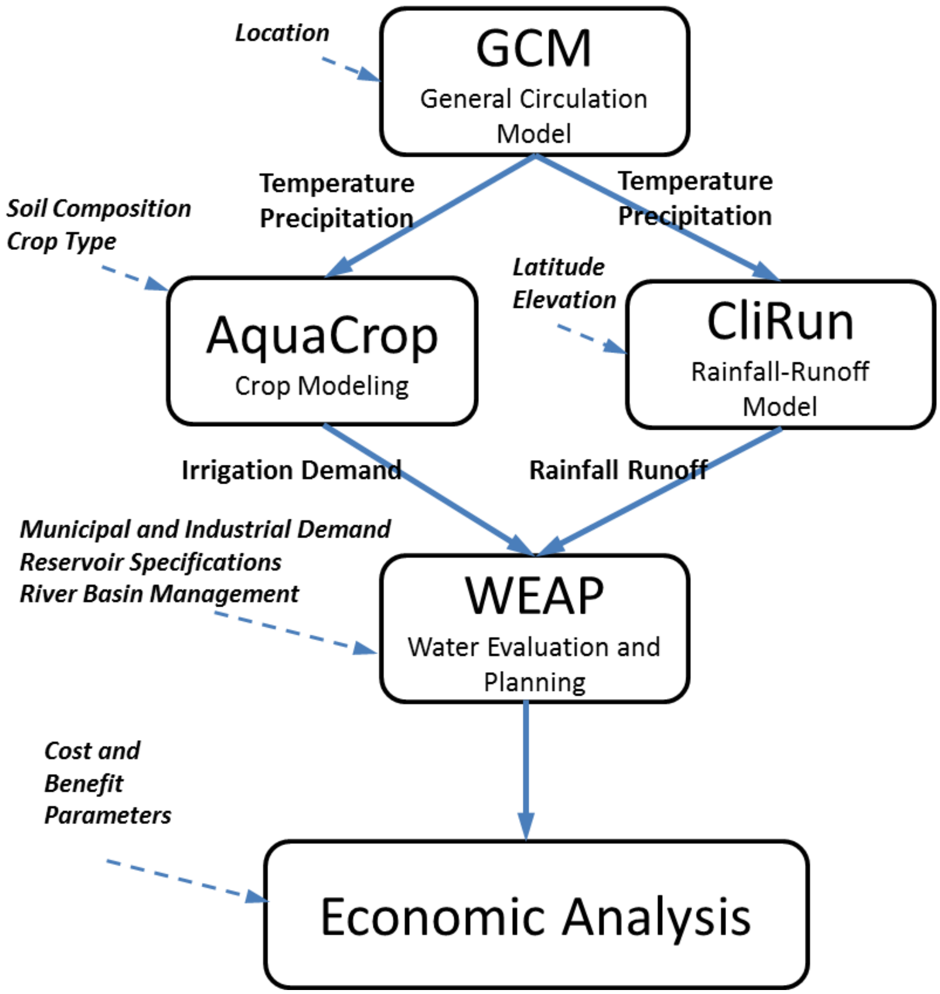
Next, climate data is fed to the CliRun hydrologic model to produce streamflow runoff estimates, and to the AquaCrop model to produce crop yield and irrigation demand estimates. The crop yield analysis focused on the nine crops in Romania with the largest 2012 production value (Wheat, Maize, Sunflower Seeds, Tomatoes, Alfalfa (Lucerne), Barley, Soybean, Sugarbeet, and Potatoes). Along with other hydrologic system inputs and non-irrigation sector water demand estimates, the runoff and irrigation water demand estimates are then incorporated into the Water Evaluation and Planning (WEAP) tool, where water storage, hydropower potential, and water availability are modeled based on their interaction with the temporal and spatial climate and demand characteristics of the river basin being modeled. To refine estimates of crop yield in irrigated areas, the unmet demand for irrigation water from WEAP is fed back into the crop modeling process.

Finally, the WEAP hydropower generation and AquaCrop crop yield results will be analyzed for their economic implications for the region, using custom tools developed for this work. The economic analyses include benefit-cost analysis of adaptation options, and country-wide productivity estimates for hydropower and agricultural yields that will be incorporated in the macro-modeling framework.

The ongoing analyses the Project Team is developing remain significantly limited by the extent of the available information. The most significant shortcomings of this analysis pertain to summary nature of data that is available to characterize water demand nodes within each of the major basins. The Project Team worked closely with Romanian water resource institutions, most notably ANAR and INHGA, to provide enhanced characterizations of these data throughout the project process.

RCM approach was not adopted for this work. Further, it is important to remember that while RCMs can provide data at increased spatial resolutions, it is not always clear that they provide a more reliable signal for climate change than GCMs – in other words, they can reflect spurious precision. Both GCMs and RCMs are difficult to evaluate because model skill assessed relative to historical results may not reflect predictive accuracy under a fundamentally changed atmospheric physics such as that induced by climate change. Nonetheless, we welcome further experiments with this approach using more highly resolved climate, runoff, and water demand projections, as that information becomes available.

Figure 2-1. Sequencing of Analytic Tools for the Water and Agriculture Sector Analyses



2.2 POLICY SCENARIOS FOR THE ANALYSIS

The World Bank and project partners agreed that the overall project examines one baseline and two adaptation investment scenarios, applied to all sectors within the scope, defined as follows:

A baseline scenario which includes the impact of a changing climate process. In the water sector, incorporating climate change entails taking into account the effect of higher temperatures and lower rainfall on the demand for irrigation and municipal water, and the effects of climate on water supply for all demand sectors (irrigation, hydropower, thermal cooling for electric power production, and municipal and industrial uses). This scenario incorporates a water infrastructure investment portfolio that effectively holds constant existing hydropower and irrigation infrastructure deployment, but evaluates their performance relative to current conditions.

A Tier 1 Adaptation scenario where adaptation measures to climate change are taken across water-using sectors. This scenario implies additional investment in agricultural sector productivity. As such it does not affect water use, but it does affect costs and revenue outcomes in the agricultural sector, relative to the baseline.

A Tier 2 Adaptation scenario which consists of additional investments in irrigation system rehabilitation beyond the currently irrigated lands, and an expanded suite of climate change adaptation investments in the agriculture sector.

The specific set of options for the water sector is outlined in Table 2.1 below.

Table 2.1. Summary of Water and AGriculture sector Green Growth Policy Scenarios

Green Growth Scenario	Characteristics of Scenario	
	Climate Change Assumptions	Water and Agriculture Sector Investments
Baseline	Current climate, plus low, medium, and high climate change scenarios – implies increased irrigation water demand as a result of climate change, as well as crop yield reduction or gain as estimated by AquaCrop modeling. Economic analysis uses only the medium climate change scenario	All current and planned thermal and nuclear plant deployment All current and funded or in construction future hydropower plants and associated storage Current but no additional reservoir construction Irrigation capacity, use, and efficiency at current levels
Tier 1	Same as Baseline	Improved fertilizer application in the agriculture sector (as described in more detail in Chapter 4), which results in yield increases for rainfed crops. Improved varieties (for rainfed) and extension to support farmer training in their use. In both cases, these measures are applied over approximately 530,000 ha, identified as areas of current medium agricultural production with potential for high production
Tier 2	Same as Baseline	Extended application of improved fertilizer and varieties as in Tier 1, but applied over approximately 2.1 million ha, also identified as areas of current medium agricultural production with potential for high production Expand irrigation by approximately 430,000 ha, an approximately 5 times increase current

Green Growth Scenario	Characteristics of Scenario	
	Climate Change Assumptions	Water and Agriculture Sector Investments
		irrigation, in areas identified as "viable" for irrigation expansion (as described further in section 2.3, Step 7 below).

2.3 MODELING CHANGES IN IRRIGATION DEMAND, RIVER RUNOFF, AND ROMANIA'S WATER SYSTEM UNDER CLIMATE CHANGE

Overall, there are seven steps in our development of the impact methodology for this assessment: (1) establish climate and river runoff baselines; (2) develop climate projections; (3) model crop yields and irrigation demand; (4) model rainfall runoff; (5) model changes in water availability and hydropower generation across Romania; (6) adjust irrigated crop yields based on unmet irrigation demand from WEAP; and (7) conduct economic analyses of alternative climate-policy scenarios and develop inputs to the macro-economic analyses.

Step 1: establish climate and river runoff baseline

In this assessment, the baseline climate and runoff data that underpin the future projections reflect a significant spatial refinement upon prior work. Figure 2-2 shows the 11 catchment areas/ river basins and 91 subbasins investigated in this analysis, along with locations of the 26 hydrological gaging stations, irrigated areas, and major hydropower facilities. World Bank team developed a climate and runoff baseline for the 91 subbasins in Romania.

Temperature and Precipitation Baseline

The climate data for each basin in this assessment consists of daily monthly historical temperature and precipitation observations that were provided by the Romanian National Meteorological Administration (NMA, or Administratia Nationala de Meteorologie. During the August 21 to 22, 2014 mission to Bucharest, WB team met with Ms. Elena Mateescu of NMA to discuss information needs. NMA subsequently provided information on the agrometeorological and meteorological data available:

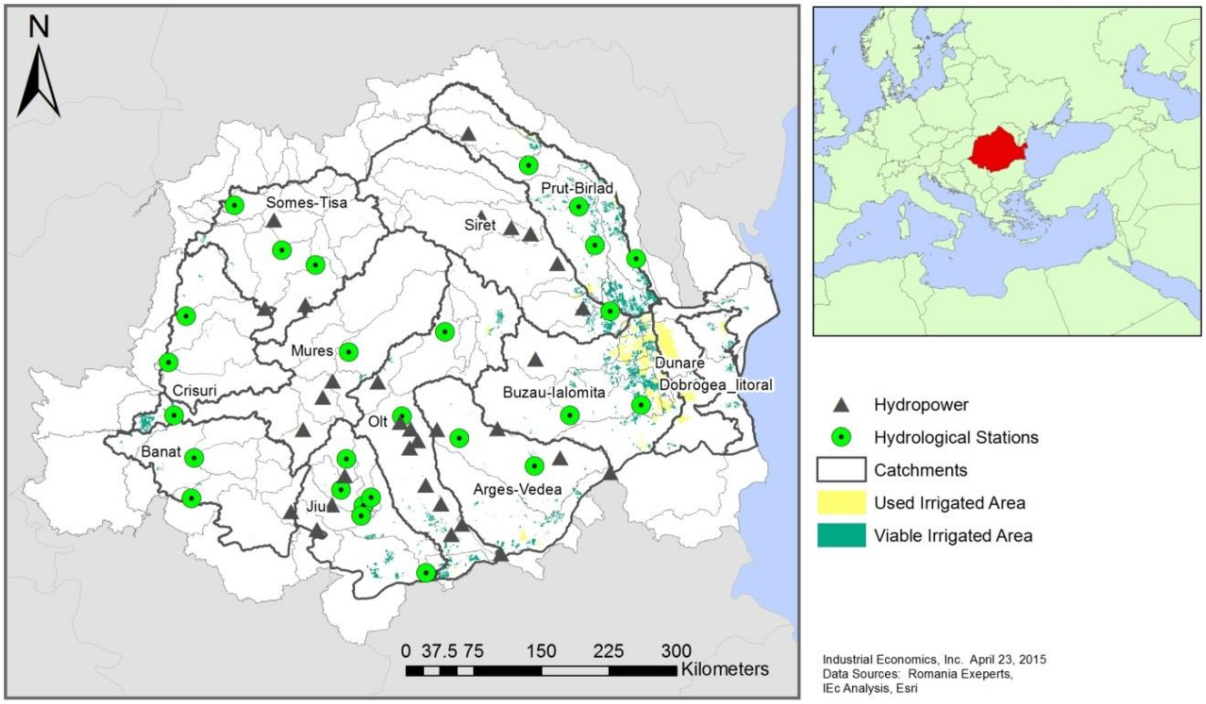
Station agrometeorological data. Available for 55 stations from 1970 to present, and includes reporting of soil moisture and crop phenology.

Station meteorological data. Available for 160 stations, daily from 1960 to present, with data gaps filled using modeling. Data for 23 of these stations are freely available, and are provided annually to WMO.

Gridded meteorological data. NMA has developed a gridded 10km x 10km dataset using the 160 stations of Romania, which is available on the NMA website for download (approximately 1 GB) with a password from NMA. These data include precipitation, tmax, tmin, humidity, and atmospheric pressure, are available daily from 1961 to 2013, and were developed using a model to fill in spaces between stations.

WB ultimately relied on the most useful and efficient to use product, the gridded meteorological data.

Figure 2-2. River Basins, hydrological Stations, used and viable Irrigated Areas, and major hydropower facilities in romania



Source: World Bank team and Industrial Economics analysis of NMA and ICPA Bucharest data

River Runoff Baseline

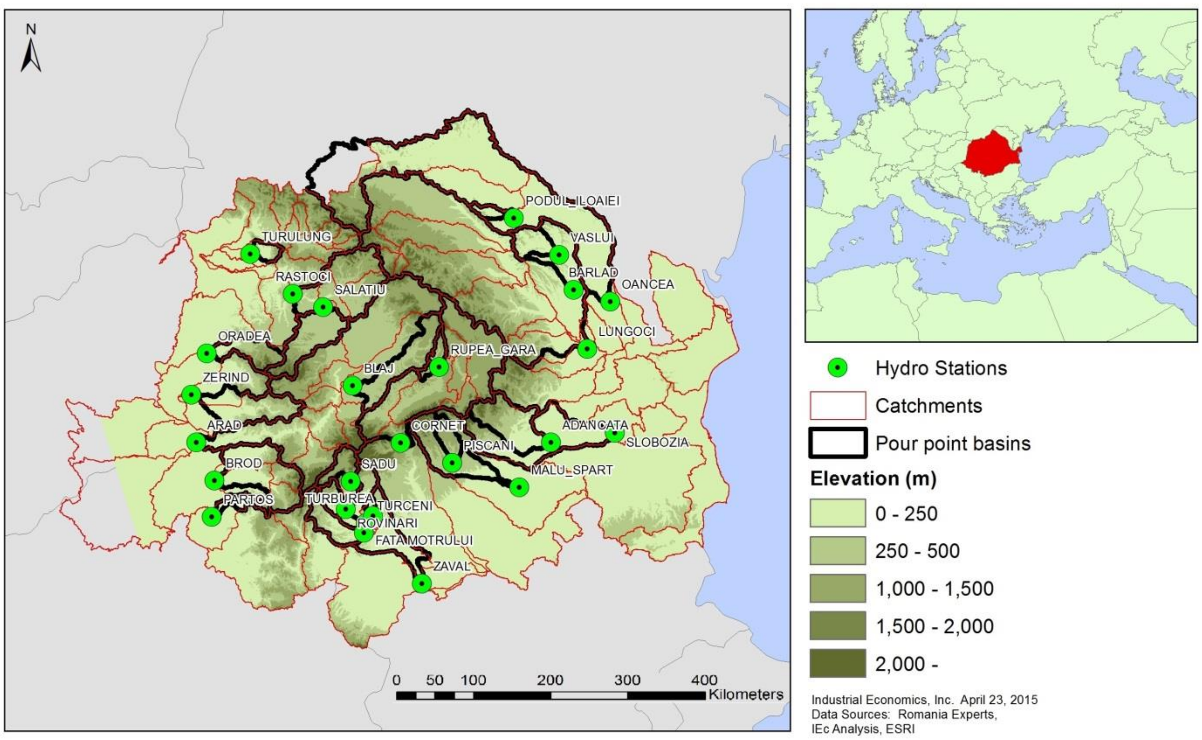
The baseline runoff record for the 91 subbasins was generated based upon two sources: (1) 1990 to 2012 monthly runoff data that were provided by ANAR and INHGA for available river runoff gaging stations, and (2) gridded runoff data from the Global Runoff Data Center (GRDC). The GRDC dataset is a composite runoff database that combines simulated water balance model runoff estimates with monitored river discharge (Fekete et al. 2002).[5] This data set consists of average monthly runoff values for each cell at a 0.5˚ by 0.5˚ global land grid. As discussed below, the GRDC data were used to develop runoff records for any subbasins that were not spatially covered by the station data.

The first step in making the translation from the available runoff records to the 91 subbasins was to develop “pour point basins” using the runoff station locations. To do so, we employed a GIS algorithm to identify the geographic area where rainfall would runoff to each of the stations, based on topography (i.e., the area “upstream” of each of the points). If one upstream pour point basin was spatiallynested within another downstream basin, both the flow and the area of the upstream basin were subtracted from the downstream basin, to avoid double counting. This procedure ensures that the runoff

[5] Fekete B, Vorosmarty C and Grabs W 2002. High-resolution fields of global runoff combining observed river discharge and simulated water balances, Global Biogeochemical Cycles, 16:3 15-1 to 15-10.

components of each basin are spatially allocated to the proper rainfall catchment area. Next, data for the pour points were translated to subbasin-level monthly runoff estimates based on the intersection of pour point and basin boundaries according to a GIS analysis. Prior research has suggested that in high snowfall areas, there is a strong positive relationship between elevation and precipitation accumulation (e.g., Osborn 1984).6 As a result, rather than translating runoff from the pour point basins to the subbasins based on area weighting alone, we also incorporated information about the precipitation profile across Romania into the translation. For each subbasin that overlapped with a pour point basin, runoff was estimated by weighting the runoff in any overlapping pour point areas by the precipitation volume in those overlapping areas. This process generated a time series of 1990 to 2012 observed runoff estimates for 57 of the 91 subbasins. The pour point basins generated from station data are presented in Figure 2-3.

Figure 2-3. River gaging stations and corresponding "pour point basins"



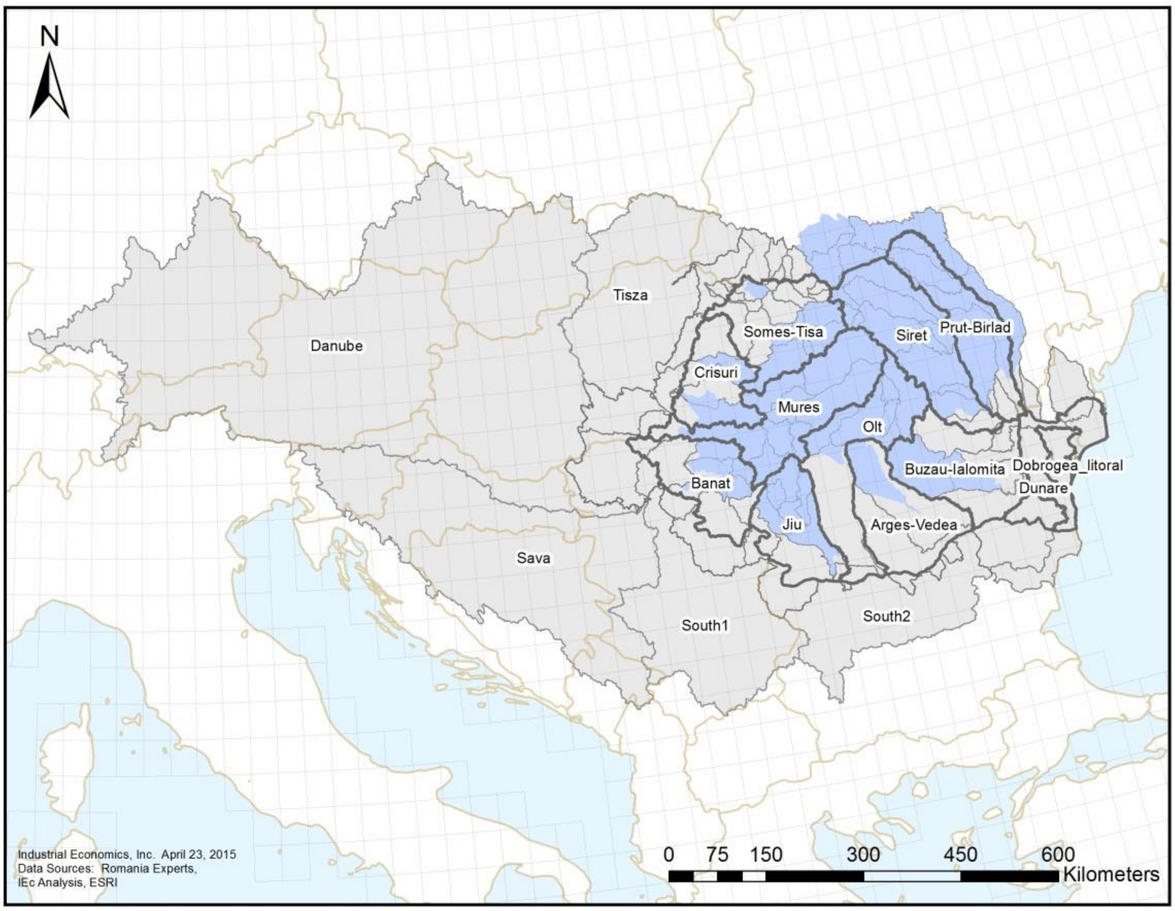
Source: World Bank Team and Industrial Economics analysis

For the remaining 34 subbasins that fall outside of the gauging station pour point basins, we relied solely on the GRDC data. This involved spatially averaging the 0.5˚ by 0.5˚ degree gridded runoff data to the resolution of the subbasins using a GIS algorithm. To ensure that the effect of climate change on river flows from the upstream Danube was appropriately captured, an additional five subbasins of the Danube,

[6] Osborn, H. 1984, "Estimating Precipitation in Mountainous Regions," Journal of Hydraulic Engineering, Vol. 110, No. 12.

upstream of Romania, were included in the analysis. The baseline runoff data for these additional catchments were also developed by spatially weighting GRDC data. Figure 2-4 provides an overview of the 91 subbasins, the five upstream basins, the 11catchment areas/ river basins of the River Basin Administrations (RBA) basins, and the pour point basins. The colored regions within Romania's boundaries are the pour point catchments, and the light gray lines delineate the 91 subbasins of Romania and the five upstream catchments.

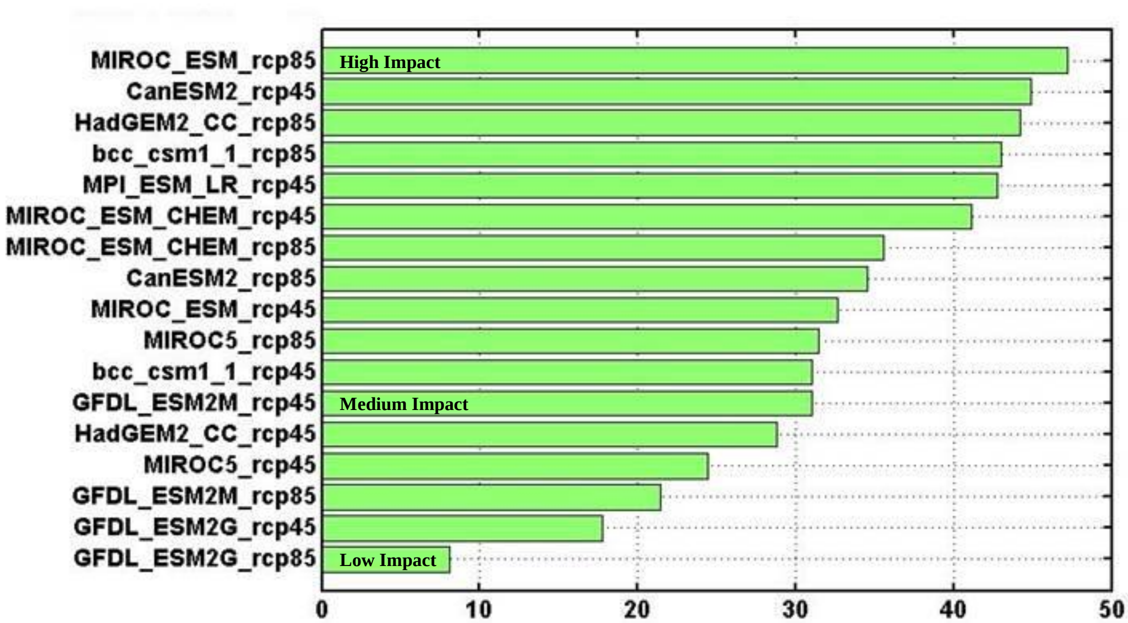
Figure 2-4. Romanian Internal and Relevant Upstream Basins Used in the Runoff Analysis



Step 2: Develop future climate scenarios

The baseline climate data are combined with projections of changes in temperature and precipitation obtained from GCMs to create daily and monthly time series of future climate from 2015 to 2050. In this assessment, we developed three climate scenarios (low impact, medium impact, and high impact). These climate scenarios were developed for Romania based on the most positive, the median, and most negative changes in irrigation water requirements for maize, estimated by running the crop model through 2050 across 17 available combinations of GCMs and Reference Concentration Pathway (RCP) scenarios employed by the IPCC in the First Assessment Report. These results for all 17 models are presented in Figure 2-5. The climate scenarios chosen are presented in Table 2-2.

Figure 2-5. percent deviation in maize IWR from base, for 17 AR5 models



Source: World Bank Team and Industrial Economics analysis

Table 2-2. Climate Scenarios Used to Develop Future Climate for Romania

climate scenario	Global general circulation model basis for the scenario	relevant ipcc Emissions scenario
High Impact	Model for Interdisciplinary Research on Climate (MIROC) ESM	RCP 8.5
Medium Impact	Geophysical Fluid Dynamics Laboratory (GFDL) ESM2M	RCP 4.5
Low Impact	Geophysical Fluid Dynamics Laboratory (GFDL) ESM2G	RCP 8.5

Source: World Bank Team and Industrial Economics analysis

Importantly, these projections represent three possible futures selected to span the range of climate outcomes projected by the nine models and 17 GCM/emissions scenario combinations described above. Although these 17 projections may adequately span the range of modeled climate change futures, each projection is only one of many possible sequencings of temperature and precipitation arrival times. In addition, the issue of needing to consider historical variability is discussed further in the recommended next steps of this report.

The spatial disaggregation component of the BCSD methodology involved translating the series of GCM outputs to a higher resolution (0.5 x 0.5 degree), and then bias correcting those spatially disaggregated outputs using the 0.5 x 0.5 degree Princeton dataset. This mathematical process of spatial disaggregation has the advantage of being analytically efficient, but because it does not consider underlying topography or other physical system characteristics, the approach introduces some unavoidable uncertainty to the spatial resolution of the resulting BCSD projections.

This study adopts a scenario based approach to climate change projections. An alternative approach might use climate projections to estimate probabilities of individual climate futures. Work is actively progressing in this area, but requires great care, for three reasons: 1. The uncertainty associated with emissions scenarios requires judgments about the probabilities of future economic and energy use pathways, which was not possible for this work; 2. Uncertainty in the effect of GHG emissions on climate outcomes, from GCM projections, must account for the fact that the models are not necessarily independent from each other, but rather interrelated in a variety of ways, and that the models are sampled in different numbers in the IPCC archives, which must also be accounted for; 3. Probability weighting of model outcomes on the basis of "model skill" assessments, as suggested by some analysts, is as yet not widely accepted in the climate science community, in part because skill in "back-casting" climatic conditions does not necessarily imply accuracy in climate forecasts. Our approach is designed to reflect a broad range of plausible climate futures, consistent with IPCC-reported representations of climate futures, which are extensively peer reviewed. For an analysis such as this, which is not designed to generate new climate science but instead to evaluate climate impacts and adaptation options, the scenario approach is appropriate.

Step 3: model crop Yields and irrigation demand

Next, basin-level climate outcomes are fed into the AquaCrop model and converted to changes in crop yields and irrigation water demands. Based on FAOSTAT information on gross production value, we evaluate the following crops: alfalfa (lucerne), barley, soybean, maize, sugarbeet, sunflower, potato, tomato, and winter wheat. In 2012, these nine crops covered more than half of the total production value of crops in Romania. Data specifying average historical crop yield and irrigation demand provided by our Romanian counterparts will be used to calibrate AquaCrop outputs to observed data.7

In Table 2-3, we outline the strategy for crop modeling scenarios. In column A are the nine crops, and in column B are the 11 catchment areas/ basins. A "model farm" is used for each of the 108 crop-basin combinations. Each model farm is then run for 8 scenarios, consisting of combinations of 4 climate

[7] Importantly, the AquaCrop modeling assumes simplified behavioral relationships for farmers; that is, our modeling assumes that farmers do not pursue adaptive responses to lessen the impacts of climate change or reduced water availability. For example, planting dates are fixed. The purpose of this assumption is to separate the assessment of impacts from the assessment of possible benefits from CC adaptation, and in particular, from the benefits of Green Growth policy options that might be pursued to facilitate CC adaptation.

scenarios (3 climate change projection scenarios plus the reference climate) (column C) and two water use regimes (rainfed and irrigated). In total, 864 simulations were run for the baseline (no CC adaptation) crop yields.

Step 4: model runoff

To model changes in runoff, WB employ CLIRUN, which is a two-layer, one-dimensional infiltration and runoff estimation tool that uses historic runoff as a means to estimate soil characteristics. First, CLIRUN is calibrated for the river basins using ten years of the monthly baseline runoff dataset described above. The remaining years of the historical dataset were used for validation. Once calibrated, we used CLIRUN to simulate future runoff in each of the river basins with the precipitation and PET projections under the three climate change scenarios.

Step 5: model changes in romania's water system

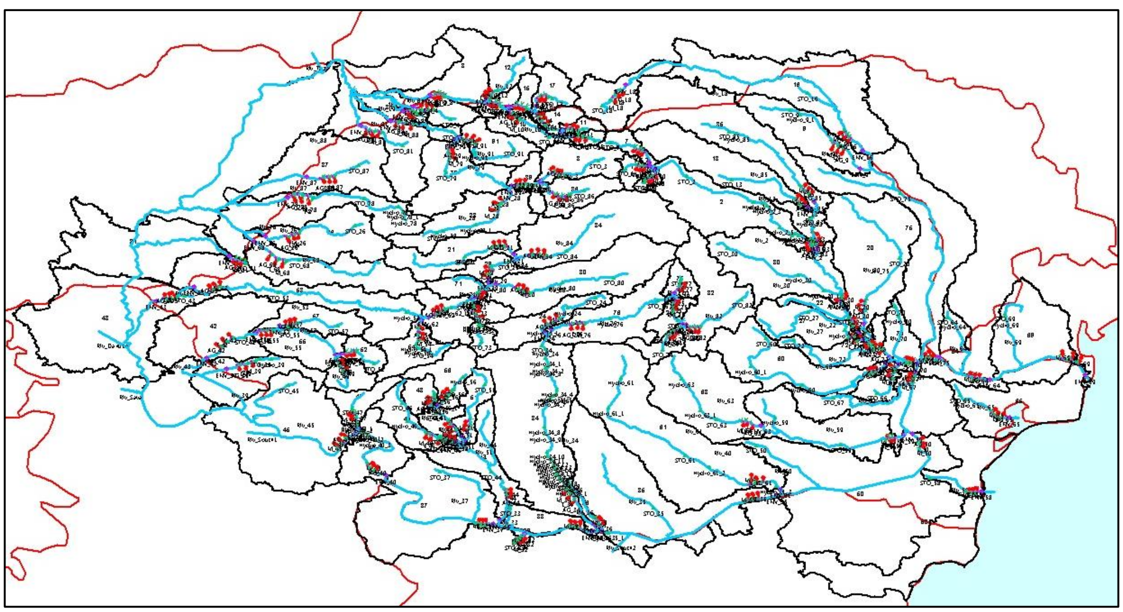
Next, the Water Evaluation and Planning (WEAP) tool is used to evaluate the potential interactions between growing municipal and industrial (M&I) water use, irrigation demands, hydropower demands, and environmental flows under each climate-policy scenario. To generate aggregate irrigation water demands, we employed crop-level information on irrigated acreage across Romania that was provided by our Romanian counterparts for each of the Romanian counties. For each scenario, WEAP generates a time series of surface water availability (runoff), reservoir storage, hydropower, and major water demands in Romania in order to allow investigation of intersectoral competition between water demands. In particular, this assessment focuses on projected interactions between changes in water availability and growing demand for water in the hydropower and irrigation sectors as investment plans are implemented. The analysis projects perturbations, or "shocks," to hydropower production and irrigated crop yields resulting from these conflicts from 2015 to 2050 across Romania. No assumptions are made about cross-border effects – we effectively assume static upstream water demand. Figure 2-6 shows a schematic of the Romania WEAP.

Table 2-3. Crop modeling Scope and Strategy

Type	A Crop types	B Basins	C Climate scenarios	D Irrigation/ Rainfed
Classes	1. Alfalfa 2. Barley 3. Soybean 4. Maize 5. Sugarbeets 6. Sunflower 7. Potatoes 8. Tomatoes 9. Winter Wheat	1. Jiu 2. Prut-Birlad 3. Olt 4. Dobrogea-litoral 5. Somes-Tisa 6. Banat 7. Dunare 8. Arges-Vedea 9. Siret 10. Buzau-lalomita 11. Mures 12. Crisuri	1. Baseline 2. Low 3. Median 4. High	1. Irrigated 2. Rainfed
Number	9	12	4	2
	Total dimensions (A*B*C*D) = 864			

Source: World Bank Team and Industrial Economics analysis

Figure 2-6. weap Schematic for the 91 basins of romania

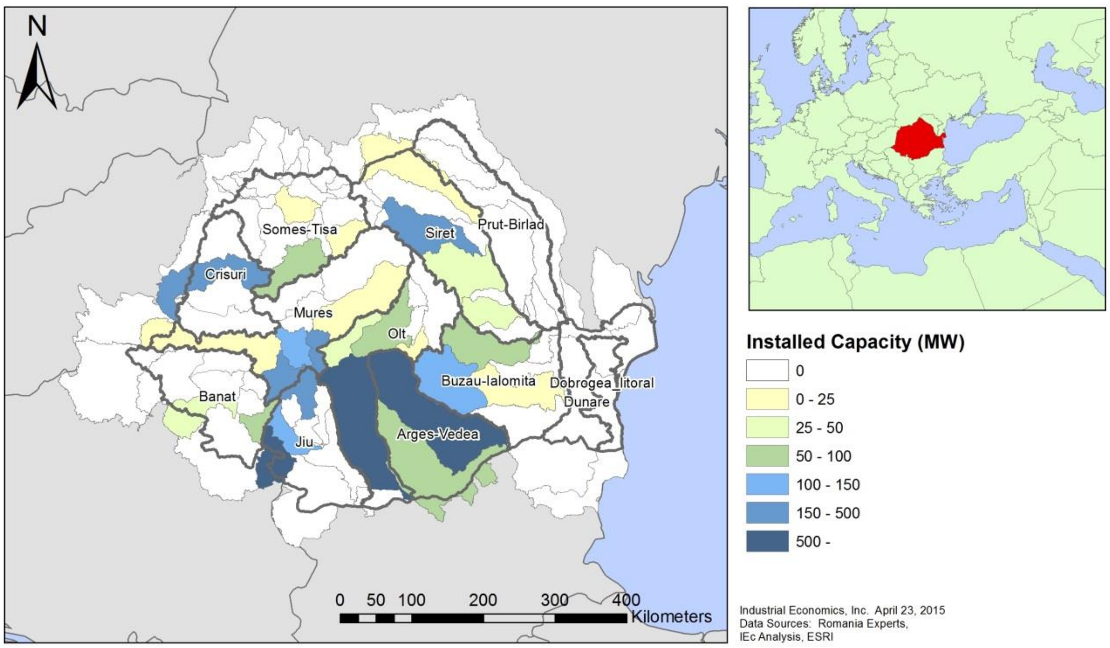


Source: World Bank Team and Industrial Economics analysis

Computations are performed on a monthly time scale for 36 years for two scenarios of economic growth, namely, (i) a reference case; and (ii) a full build-out scenario. The climate and policy scenarios are characterized by unique inflows and growing irrigation demand. The output runoff projections from

CLIRUN are used as the available runoff in WEAP. Municipal and industrial (M&I) sources also withdraw water from available runoff, and are projected based on estimates from ANAR and INHGA.8 Hydropower production and irrigation capacity is based on information provided by Romanian sources on the locations of dam sites and the storage volumes associated with existing hydropower construction projects. Environmental flows are set at the 10th percentile (q90) of simulated natural flows in each of the 91 subbasins based on work conducted by Smakhtin and others, who suggest that these flows are sufficient to maintain riparian health in "fair" condition.9 For reference, Figure 2-7 shows the resulting hydropower capacity for the 91 subbasins. Outputs from the WEAP tool that are employed in this analysis include hydropower generation at each facility and unmet water demands at each irrigation and M&I location.

Figure 2-7. Installed Hydropower Capacity by Basin



Source: World Bank Team and Industrial Economics analysis

Step 6: adjust irrigated crop yields based on unmet irrigation demands from weap

As a final step in evaluating impacts of the climate and policy scenarios on crop yields, the results of the crop and water impact analyses can be combined to evaluate how crop yields may be affected by reductions in basin-level water availability. To adjust crop yields produced in AquaCrop for changes in irrigation water availability projected by WEAP, information from the Food and Agricultural Organization

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[8] Municipal water demand is assumed to be proportional to population. Demand within each river basin is calculated by multiplying the basin's population within each of five demographic categories (large city, city, town, rural, and tourists) by supply norms for the five categories.

[9] Smakhtin, V., Revenga, C. & Doll, P. 2004a A pilot global assessment of environmental water requirements and scarcity. Water Int. 29, 307–317. (doi:10.1080/02508060408691785)

(FAO) on irrigated crop sensitivity to water availability can be combined with basin-level water deficits from WEAP. This approach employs crop response factors from FAO, which are estimates of the elasticity of crop yield with respect to irrigation water application (i.e., the percentage change in crop yield in response to a one percent change in water application). Details of this approach are provided in World Bank 2012.[10]

In this Romania analysis, however, the results for unmet irrigation water demand show relatively small shortfalls for irrigated agriculture, even with the implementation of the Tier 2 investments in expanded irrigation (shortfalls are on the order of 10-15%). Further, the current level of precision of the model does not yet conclusively support the finding of significant unmet demands for irrigation – while we used the currently best available data, further spatial and temporal detail on water demands, particularly for the industrial sector, are needed to support this finding. As a result, we did not conduct Step 6 in this analysis, but leave it for a possible follow-up activity for local counterparts, the details of which can be demonstrated at the June 2015 capacity building workshop, when the models will be fully transferred to local counterparts.

Step 7: conduct economic analysis and develop inputs to the macro-economic analyses

Finally, the WEAP hydropower generation and water balance results are analyzed for their economic implications in Romania. The economic analysis relies on the following macro-economic and demographic variables:

Macro-economic variables: These include future GDP (annual data) and sector distribution as well as terms of trade (relative price trajectories at a minimum for energy, agricultural products and agricultural inputs). IEc has developed some of these inputs in prior work, based on global projections made by the International Food Policy Research Institute (IFPRI).

Demographic variables: These include overall population growth, rural to urban migration, and migration from Romania to the "rest of the World".

For defining land use area by crops and regions, the economic analysis relies on:

Geocoded spatial data on irrigated area across Romania, categorized by use (actual and viable), as well as data of total harvested areas and yields for the time series 2008-2012 and, separately, for the single year 2005, categorized by administrative area and crop, as provided by Dr. Catalin Simota of the National Research and Development Institute for Soil Science, Agrochemistry, and Environment.

Data on total harvested area across the world, categorized by crop and water supply (irrigated and rainfed), were provided in the Global Agro-Ecological Zones (GAEZ) dataset, developed by the Food and Agriculture Organization of the United States (FAO) .

GIS analysis and spatial weighting techniques were used to distribute the irrigated area provided by Dr. Simota across regions and crops using spatial data from GAEZ. Rainfed land per region and crop was then

[10] Crop response factors are based on information presented in FAO Irrigation and Drainage Paper 56: Table 24, Seasonal Yield Functions. Accessed on May 24, 2012 from http://www.fao.org/docrep/x0490e/x0490e0e.htm.

calculated as the difference between irrigated and total area. This process was repeated for actual irrigated land (irrigation under baseline and Tier 1) and viable irrigated land (Tier 2).

Enhanced fertilizer and improved varieties are distributed spatially based on an evaluation of rainfed crop yield potential and arable hectares by locality provided by Dr. Catalin Simota. Improvements are distributed by prioritizing localities with midlevel yield potential in order to increase the total high potential area, and summing up to the regional level. Once region level totals were established, enhanced fertilizer application is distributed among all crops in proportion to their rainfed area within the region, and improved varieties is similarly distributed between grain maize, winter wheat, and tomato according to their relative rainfed areas within the region.

Revenue Calculations

Using modeled yield data provided by AquaCrop outputs and the area data described above, production figures are calculated by multiplying the yield (crop, region, year, and land type specific) by the corresponding area11, all using values calculated for the medium climate scenario (GFDL45) through 2050. The production data was bias corrected against observed production figures (an average of 2010-2012 values categorized by region and crop). Observed production was calculated using data of areas and yields for the time series 2008-2012 and 2005, categorized by administrative area and crop, provided by Dr. Catalin Simota. In the baseline (no investment) scenario, land types include rainfed and actual irrigated. In Tiers 1 and 2, land types also include enhanced fertilizer application and improved varieties. The actual irrigated land used in Tier 1 is substituted with viable irrigated area in Tier 2 to represent rehabilitated irrigation systems.. The bias corrected production data is then multiplied by 2012 crop prices to generate yearly revenue figures per land type, which are then summed over each region. All crop prices, except alfalfa are available from FAOSTATS12. Alfalfa prices are calculated by dividing the Eurostat 2012 revenue13 from fodder crops by the production data provided by Dr. Catalin Simota, and converting to US dollars using the 2012 exchange rate.

Cost calculations

Costs for each of the investment options are estimated using information from a broad range of prior IEc agricultural adaptation projects for Eastern Europe and Central Asia14, and adjusted based on local information provided by Dr. Catalin Simota. The cost of improved varieties is assumed to only include extension services, and research and development (as estimated in prior agricultural adaptation projects).

[11] Marginal yields for enhanced fertilizer and improved varieties were used in this calculation, so that, for example, an area that received enhanced fertilizer would be multiplied by the crop-region rainfed yield, and then by the additional yield above rainfed modeled for fertilized areas.
[12] Available at http://faostat3.fao.org/download/P/PP/E
[13] Available in Eurostat table “agr_r_accts”
[14] See for example, Nicolas Ahouissoussi, James E. Neumann, and Jitendra P. Srivastava (eds), 2014. Building Resilience to Climate Change in the South Caucasus Region’s Agricultural Sector. (World Bank: Washington, DC), and William R. Sutton, Jitendra P. Srivastava, and James E. Neumann (eds). 2013, Looking Beyond the Horizon: How Climate Change Impacts and Adaptation Responses Will Reshape Agriculture in Eastern Europe and Central Asia. ISBN 978-0-8213-9768-8. (World Bank: Washington, DC).

Improved variety seeds are assumed to be provided in coordination with CGIAR at no cost to farmers. Actual costs for this improvement may be higher than those assumed in this analysis, but as the current analyses show negative net present benefit for improved varieties investment in most regions, increased costs will not meaningfully alter the results. Irrigation rehabilitation costs are estimated based on the average rehabilitation cost of four systems in Romania.15 Enhanced fertilizer costs are derived by estimating current fertilizer expenditure, and calculating the cost of increasing fertilizer use to the best practice application rate.16 These costs are then multiplied by the areas identified in the previous section to calculate annual costs per region and investment. Costs are presented in present value in the economic implications chapter, where a discount rate is assumed to be 5%, over 2015 to 2050.

3. Analysis and findings – Effects of climate change and Green Growth investments on water availability and crop yields

Applying the framework and tools described in Chapter 2, we developed results for the following: (1) changes in mean annual runoff (MAR) resulting from changes in climate, from the CLIRUN model; (2) changes in irrigation demands, from the AquaCrop model; (3) changes in unmet water demand for irrigation, and M&I, and changes in hydropower production, from the WEAP tool; and (4) changes in rainfed and irrigated crop yields, from the AquaCrop model results, adjusted using irrigation water availability results from the WEAP tool. This chapter summarizes these results by the 91 subbasins and the eight administrative regions of Romania.

As described in chapter 2 above, results are presented for three future periods (2020s, 2030s, and 2040s), three climate change scenarios, and two investment scenarios. Then WB evaluated how climate change impacts are addressed by various targeted water investment options. We aggregate hydropower generation estimates to the subbasin level. Locations of the 12 basins and 91 subbasins are shown in Figure 3-1. The three climate scenarios described in Chapter 2 are refered to henceforth in short form as GFDL-8.5 (low impact), GFDL-4.5 (medium impact), and MIROC-8.5 (high impact).

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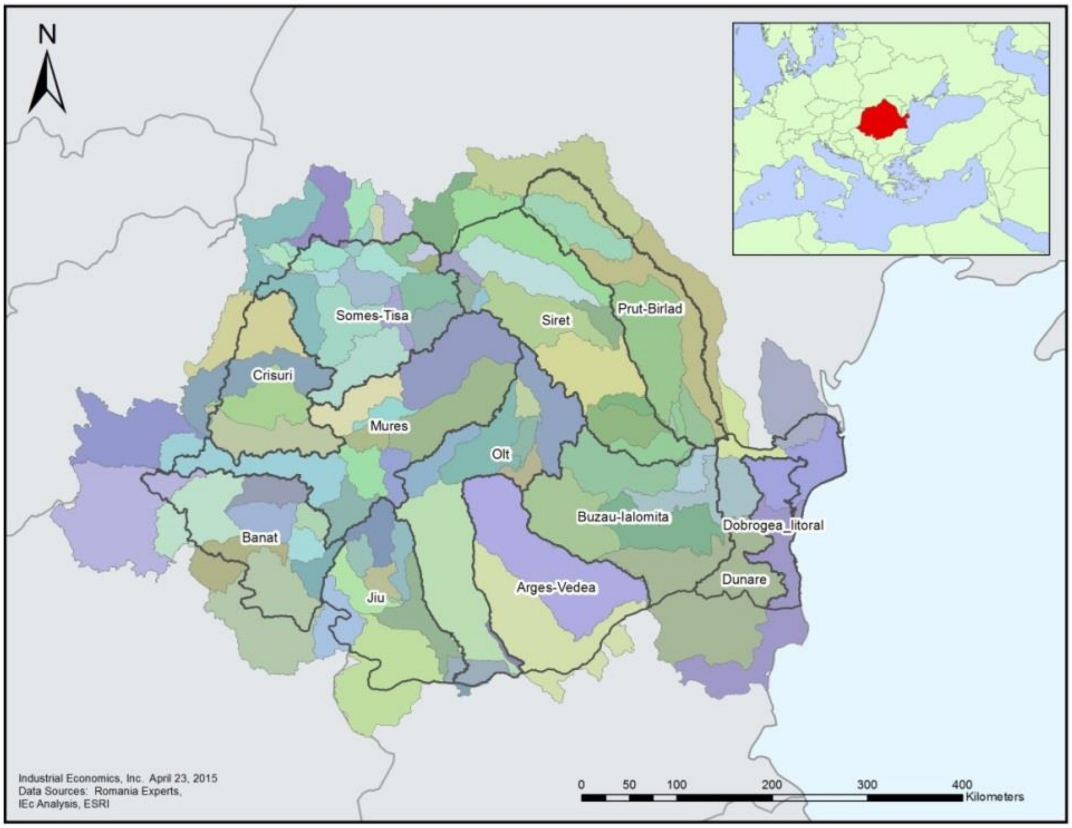
[15] Dr. Simota provided these costs, citing the report "Rehabilitation and Reform for irrigation systems", by Fridman Mek at. for the Ministry of Agriculture and Rural Development (2011). The average per hectare cost for four principal infrastructure systems presented in the report are used in this economic analysis.

[16] Using Eurostat data on Romanian expenditures on fertilizers and soil improvers from 2010-2012, and cultivated area over the same time period, provided by Dr. Catalin Simota resulted in a $108/HA current expenditure. Assuming a cost of $2.68/kg for fertilizer (found in the National Rural Development Plan 2014-2020), the current application rate is estimated at 40.7 kg/HA. To reach the best practice application rate of 110 kg/HA,(based on the Code for Good Agriculture) 69.3 kg/HA is applied at a cost of $2.68/kg, for a total cost of $185.57/HA.

Figure 3-1. river basins in romania

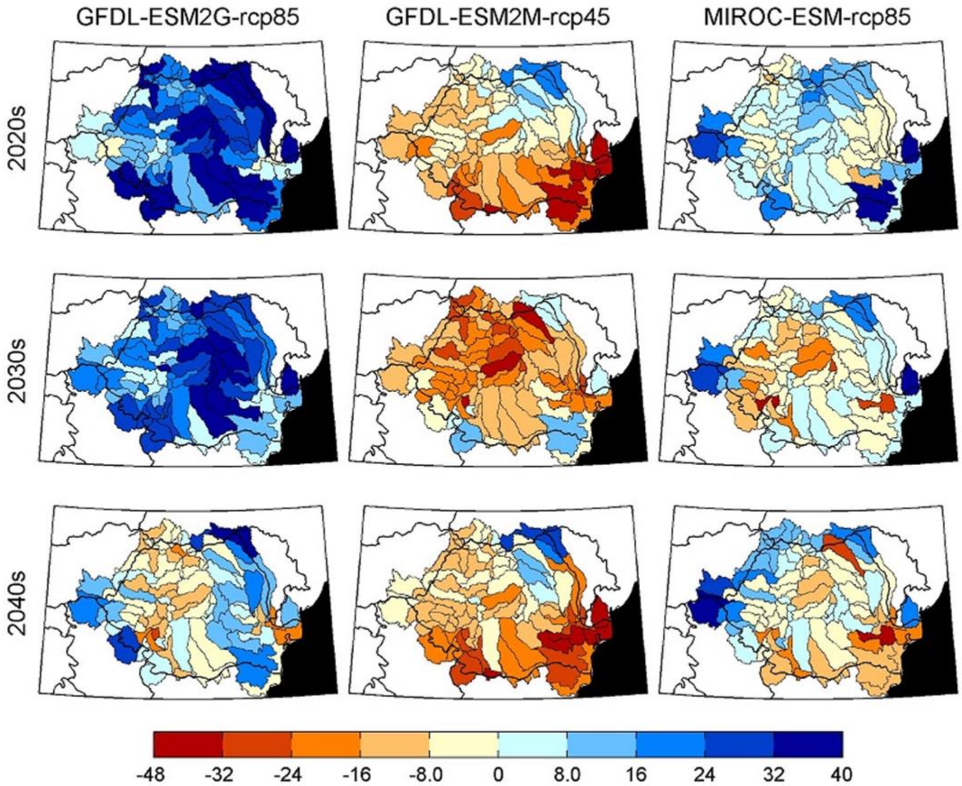


3.1 CLIMATE EFFECTS ON WATER AVAILABILITY

The first component of our approach involves estimating changes in water availability, measured as mean annual runoff. The results in Figure 3-2 below present the changes in mean annual runoff (MAR) by basin for the 2020s, 2030s, and 2040s, reflecting CLIRUN analyses for the three scenarios of future climate change described in Chapter 2. The results show that climate change will have a mostly positive effect on runoff under the GFDL-rcp85 model, but a generally negative effect under the other two models, particularly in the 2040s. In the 2020s, the changes in annual runoff in Romania range from a decrease of 7 percent to an increase of 20 percent. By the 2040s, the changes are dampened somewhat when summarized at the national scale, but universally negative, ranging from reductions of 0.7 percent to 8 percent.

As seen in Figure 3-2, MIROC-8.5 (high impact) actually demonstrates a wetter percent change in annual runoff than GFDL-4.5 (medium impact). It is important to remember that the high, medium and low impact scenarios were developed for Romania based on the irrigation water requirements for maize. But a scenario with the highest irrigation water requirements for maize does not equate to that scenario producing the highest impact in the case of other metrics. The scenarios chosen do not represent the extreme impacts for every metric, but as a group the three scenarios do capture a broad view of the potential range of climate change in Romania.

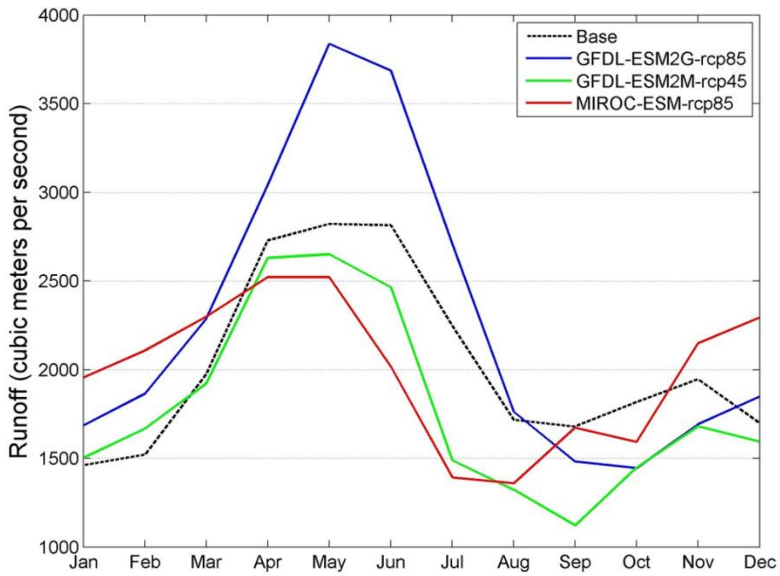
Figure 3-2. Percent Change IN ANNUAL RUNOFF by CLIMATE SCENARIO, and Time Period



Source: World Bank Team and Industrial Economics analysis

For illustration of projected changes in monthly flows, Figure 3-3 shows total mean monthly runoff across the 91 subbasins under both the 1961-2000 baseline and under the three climate change scenarios between 2031 and 2050. During the primary growing season months (April to September), runoff changes range from a 30 percent reduction to a 30 percent increase. Importantly, the majority of months under two of the scenarios show falling runoff throughout the growing period, suggesting threats to irrigation water availability.

Figure 3-3. sum of mean monthly runoff across the 91 subbasins, baseline (1961-2000) versus the three climate projections (2031-2050)

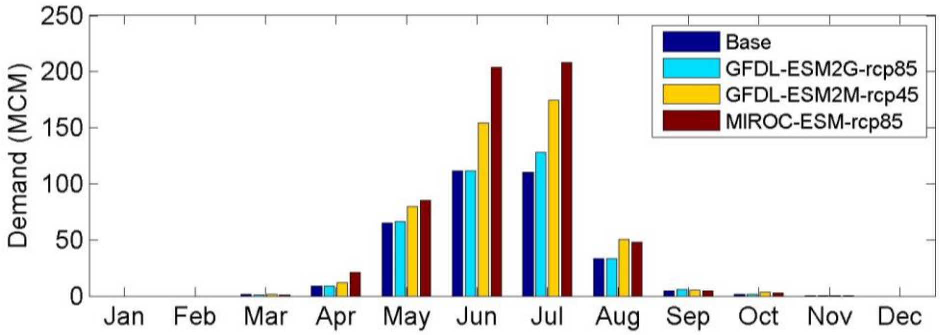


Source: World Bank Team and Industrial Economics analysis

3.2 CLIMATE EFFECTS ON IRRIGATION WATER DEMAND

Climate change will affect demands for irrigation water, as higher temperatures and more variable precipitation cause changes in crop water demand and the availability of rainfall. Figure 3-4 provides an overview of the impacts of climate change on aggregated irrigation water demand across Romania. Each of the climate change scenarios shows rising irrigation water requirements due to the uniformly increasing temperature effect. Under the MIROC-8.5 scenario, there is over a doubling of requirements in the more arid months between the baseline and the 2021-2050 period.

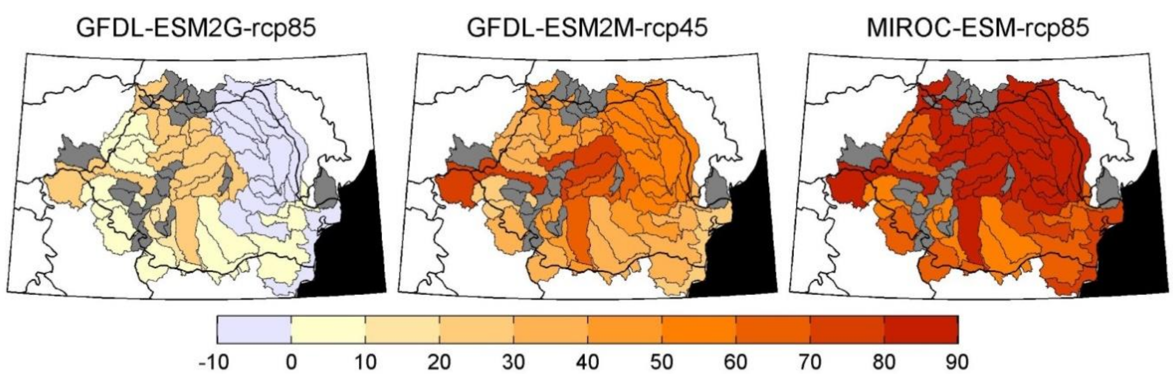
Figure 3-4. Monthly irrigation water demand under the baseline (1961-2000) and each climate scenario (2021-2050)



Source: World Bank Team and Industrial Economics analysis

Figure 3-5 provides the spatial variation of changes in irrigation water requirements between baseline demands and the 2021-2050 period, under each of the three climate change scenarios. Although demands fall in the eastern part of the country under the GFDL-8.5 scenario, in the two other scenarios all subbasins show demands increasing between 10 and 100 percent.

Figure 3-5. PERCENT CHANGE from baseline IN ANNUAL IRRIGATION WATER DEMAND by subbasin and climate scenario under the tier 2 policy scenario, 2021-2050



Source: World Bank Team and Industrial Economics analysis

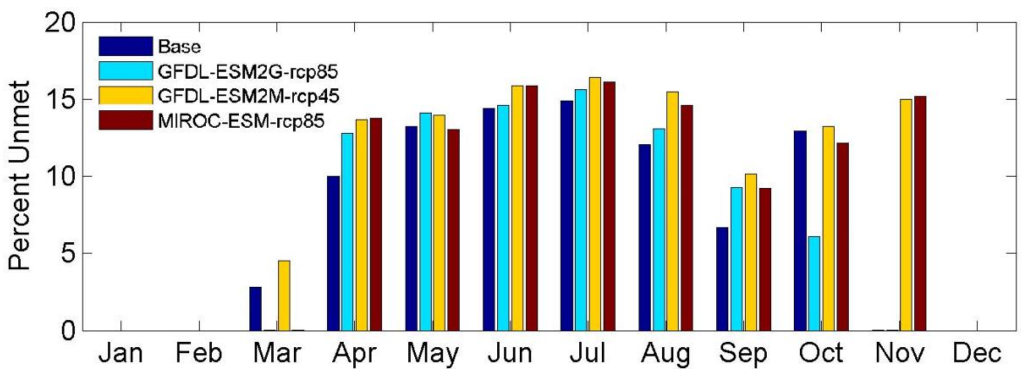
3.3 CLIMATE EFFECTS ON WATER BALANCE AND IMPLICATIONS FOR IRRIGATION, MUNICIPAL DEMAND, INDUSTRIAL DEMANDS, AND HYDROPOWER

In the WEAP tool, we combine the water supply results from CLIRUN, the irrigation water demand results from AquaCrop, and the current and planned hydropower and M&I uses from Romanian government projections to generate estimates of the average irrigation demand met for each subbasin, the average M&I demand met for each subbasin, and the average hydropower generation by subbasin. These results are presented for the baseline and each of the climate scenarios, and in the case of irrigation, for both the no investment and Tier 2 investment policy scenarios. These results reflect an assumption that, where conflicts for water supply may arise across sectors, municipal demands are given first priority, environmental demands are given second priority, industrial demands are given third priority, agricultural irrigation demands are given fourth priority, and hydropower demands are given last priority. The WEAP model therefore satisfies water demands in this order for each month of the simulation, until and if available water is exhausted.

Unmet Irrigation Demands

Results for mean monthly unmet irrigation demand under the baseline and climate change scenarios (through 2021-2050) are presented in Figure 3-6 below. Due to rising crop water demand, unmet irrigation demands increase in the majority off months for all scenarios, starting at between 5 and 14 percent under the baseline between April and September, and rising to between 9 and 17 percent under the climate change scenarios.

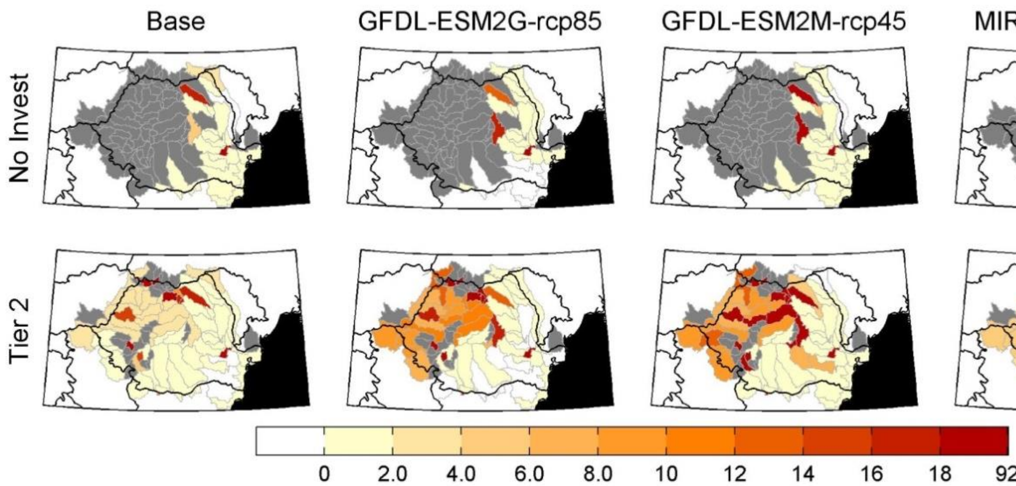
Figure 3-6. percent unmet demand irrigation water demand under the baseline (1961-2000) and each climate scenario (2021-2050), Tier 2 policy scenario



Source: World Bank Team and Industrial Economics analysis

Figure 3-7 presents the unmet demands over space under each of the climate scenarios, the no investment policy scenario, and the Tier 2 investment policy scenario, which includes a large expansion of irrigated areas. Gray in a particular subbasin indicates that no irrigated agriculture exists under that policy scenario. The majority of unmet irrigation water demands occur in the western part of Romania, and severe unmet water demands are confined to only a few subbasins. These subbasins should be the target of more concentrated data gathering to confirm whether such large unmet demands would be anticipated in those areas.

Figure 3-7. UNMET IRRIGATION WATER DEMAND AS PERCENTAGE OF TOTAL IRRIGATION WATER DEMAND by basin, climate SCENARIO (projections 2021-2050), and policy scenario

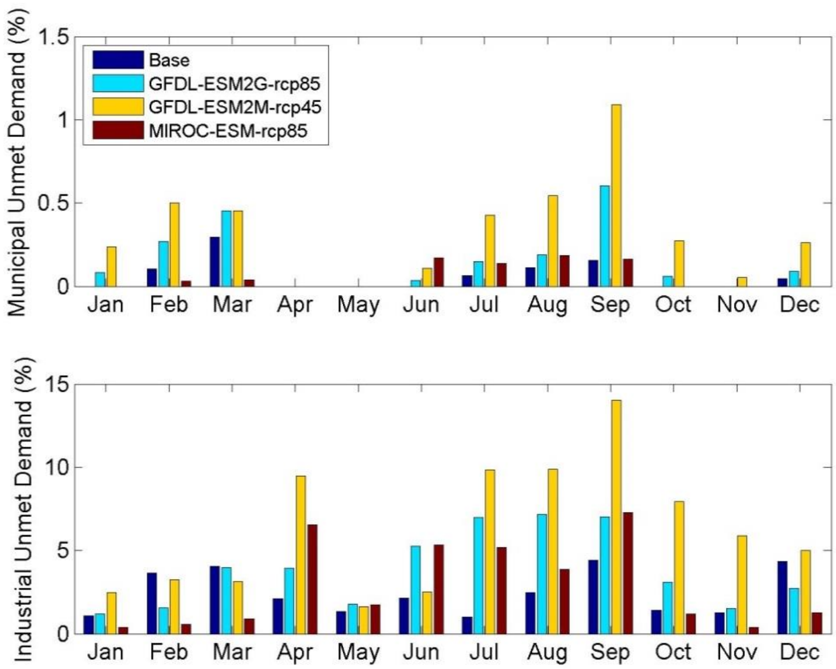


Source: World Bank Team and Industrial Economics analysis

Unmet Municipal and Industrial Demands

Figure 3-8 presents the percentage of mean monthly municipal and industrial demand that is unmet, according to the WEAP model, under the no investment policy and each of the climate change scenarios. Unmet municipal demands are fairly modest, ranging from zero to approximately 1 percent under the GFDL-4.5 scenario. On the other hand unmet industrial demands are quite significant, particularly considering that industrial demands constitute approximately 75 percent of the total water withdrawals of the country. Under baseline conditions, unmet industrial demands are fairly constant over the year, and remain under 5 percent. Under the GFDL-8.5 scenario, on the other hand, unmet demand reach nearly 15 percent in September, suggesting that these industrial activities may be adversely affected by climate change without CC adaptive efforts.

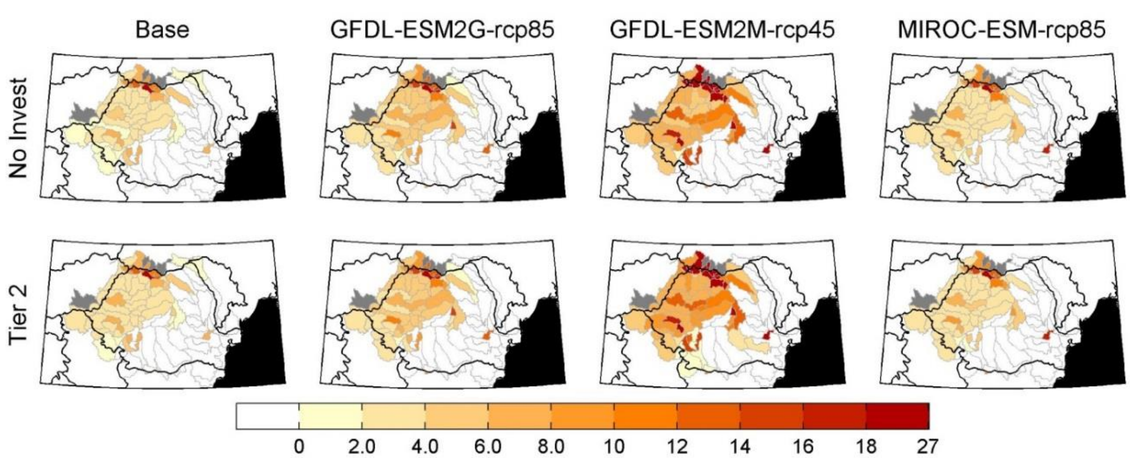
Figure 3-8. percentage of municipal (top) and industrial (bottom) demand that is unmet under the baseline (1961-2000) and three climate scenarios (2021-2050)



Source: World Bank Team and Industrial Economics analysis

Figure 3-9 presents maps of unmet industrial water demands across the 91 subbasins, under each climate scenario and the two investment scenarios. Unmet demands are as high as 25 percent in some subbasins, and as observed above, increase significantly between the baseline and three climate scenarios. Note that the difference between unmet industrial demands under the two policy scenarios is minimal, primarily because industrial water use is a higher priority use in WEAP than irrigation withdrawals.

figure 3-9. UNMET Industrial WATER DEMAND AS PERCENTAGE OF TOTAL IRRIGATION WATER DEMAND by basin, climate SCENARIO (projections 2021-2050), and policy scenario

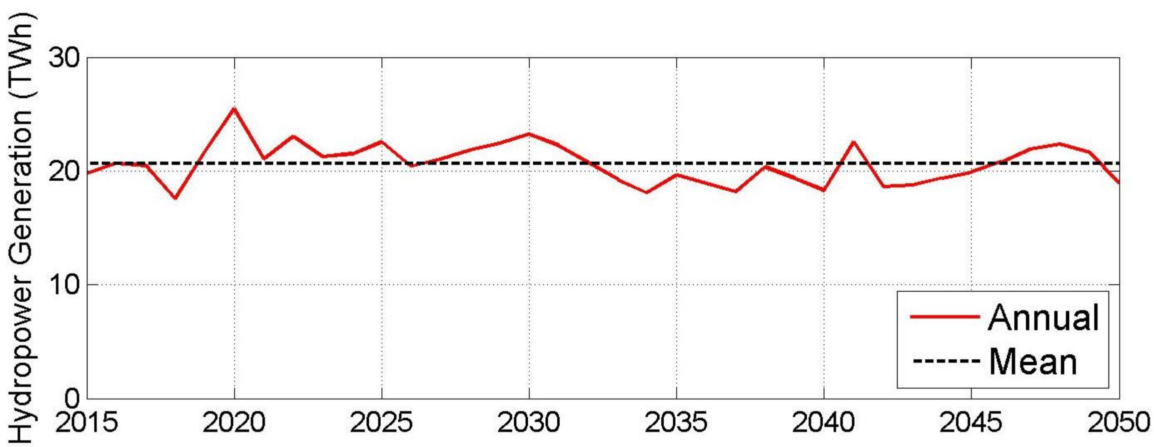


Source: World Bank Team and Industrial Economics analysis

Hydropower Generation

At 19 TWh annually, hydropower generation accounts for approximately one third of total electricty generation in Romania, and is therefore an essential component of energy security in the country.17 Using data from ANAR and INHGA, the WEAP model includes 52 facilities and 21 "lumped" facilities in a representation of the hydropower system of the country. Figure 3-12 provides the annual time series of hydropower generation simulated within WEAP, over the 2015 to 2050 period under the baseline climate scenario. The dashed line is the average over the period at 21 TWh per year, which is very close to the observed average value of 19 TWh. Figure 3-13 presents the effect of climate change on mean annual generation under each of the future periods.18 River runoff increases in the GFDL-8.5 scenario in the 2020s and 2030s (see Figure 3-2 above), and these are reflected in projected increases in hydropower generation in those decades. Generation declines under the other seven scenario-decade combinations, most significantly in the 2030s and 2040s under GFDL-4.5 scenario where hydropower production falls by nearly 10 percent. Also of significance is that all three climate scenarios show a decrease in hydropower production in the 2040s, suggesting a more robust finding that substitutes will likely be needed to fill in this shortfall.

Figure 3-12. Annual projected hydropower generation under the baseline No climate Change scenario, 2015-2050

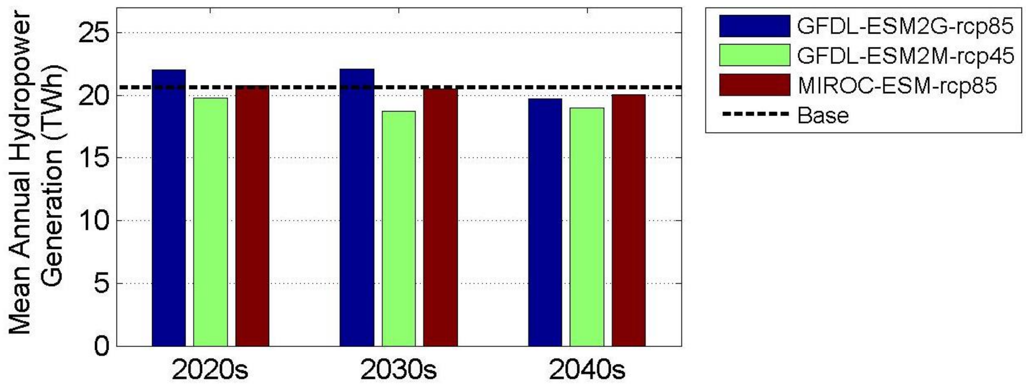


Source: World Bank Team and Industrial Economics analysis

[17] Lehner, B., G. Czisch, and S. Vassolo. Europe's Hydropower Potential Today and in the Future. Accessed from http://www.usf.uni-kassel.de/ftp/dokumente/kwws/5/ew_8_hydropower_low.pdf on April 10, 2015.

[18] Note that hydropower results are only presented under the "no investment" policy scenario, as differences between generation under the no investment versus Tier 2 policy scenario were minimal. The effect of the Tier 2 irrigation expansion is minor because (a) most of the expansions are anticipated to occur in basins with lower levels of existing hydropower capacity and (b) the consumptive use of projected irrigation represents a small portion of the overall water budget of Romania.

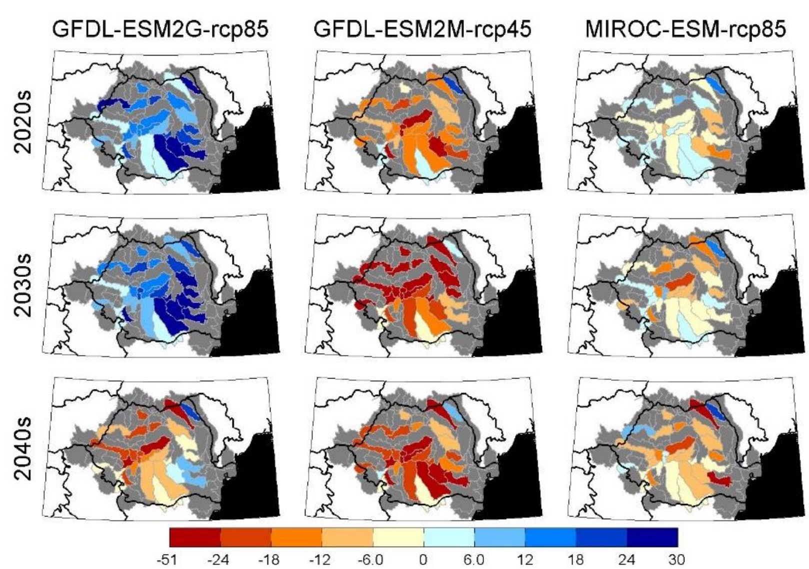
Figure 3-13. mean annual hydropower generation in the 2020s to 2040s under each climate scenario



Source: World Bank Team and Industrial Economics analysis

The general pattern observed in Figure 3-13 above is reflected in the spatial pattern of changes in Figure 3-14 below (subbasins shaded in gray have no existing hydropower capacity). The largest increases occur in the GFDL-8.5 scenario, and the largest decreases occur in all three decades under the GFDL-4.5 scenario and then in the 2040s across all three climate scenarios. Within individual subbasins, decadal average hydropower generation is projected to fall by a maximum of 50 percent in some basins and scenarios, and increase by a maximum of 30 percent in other basins and scenarios.

Figure 3-14. PERCENT CHANGE IN MEAN ANNUAL HYDROPOWER GENERATION under each time period and climate change scenario



Source: World Bank Team and Industrial Economics analysis

3.4 CLIMATE EFFECTS ON CROP YIELDS

Climate change affects crop yields through changes in soil moisture, direct temperature effects on crop growth, and changes in the evapotranspiration requirements of the crop, among other effects. As described in Chapter 2, the AquaCrop model was employed to evaluate these effects together and estimate the changes in yields of nine crops over the catchment areas/ basins of Romania. In the tables below, these yield effects have been aggregated to the eight administrative regions in the country that are the focus of the remaining Chapters of this report. Tables 3-1 and 3-2 present the percentage changes in rainfed and irrigated yields from baseline conditions under the GFDL-4.5 climate scenario by crop, administrative area, and time period. Appendix A provides these irrigated and rainfed results for the GFDL-8.5 and MIROC-8.5 scenarios. Table 3-1 suggests that rainfed yields will generally decline under the GFDL-4.5 scenario, and that the effect is exacerbated over time, although certain crops such as maize, barley, and winter wheat tend to perform well in some regions. The crops affected most negatively by climate change are sugarbeets, potatoes, and tomatoes, and the regions that are projected to experience the largest declines are South-East, South-Muntenia, and Bucharest-Ilfov.

TABLE 3-1. PERCENT CHANGE IN rainfed CROP YIELDs by crop, administrative area, and time period under the GFDL-4.5 scenario

Period	Crop	Change in Rainfed Yields under GFDL-ESM2M-rcp45							
		North-West	Center	North-East	South-East	South-Mutenia	Bucharest-Ilfov	South-West Oltenia	West
2020s	Maize	1.6%	2.4%	2.2%	0.0%	-1.9%	-2.1%	1.1%	2.0%
	Barley	5.2%	5.4%	5.7%	4.1%	2.6%	2.5%	3.6%	2.6%
	Potato	2.5%	-2.1%	-3.4%	-7.1%	-8.6%	-8.8%	-3.3%	2.4%
	Soybean	2.8%	1.2%	0.3%	-2.6%	-3.2%	-3.4%	0.5%	3.1%
	Sugarbeet	9.3%	1.9%	-1.2%	-14.5%	-14.0%	-14.3%	1.9%	9.3%
	Sunflower	1.0%	-0.1%	-0.7%	-3.4%	-4.3%	-4.4%	-0.7%	1.0%
	Wheat	14.4%	10.5%	13.3%	1.5%	2.5%	2.5%	9.1%	14.9%
	Tomato	3.9%	-0.1%	-1.6%	-6.1%	-5.4%	-5.5%	0.4%	4.4%
	Alfalfa	8.7%	3.3%	4.5%	0.3%	-3.5%	-3.7%	1.4%	7.6%
2030s	Maize	7.2%	6.9%	4.9%	-3.4%	-9.4%	-9.9%	-1.7%	1.3%
	Barley	8.4%	8.0%	8.8%	5.1%	3.3%	3.2%	5.0%	6.6%
	Potato	-15.1%	-18.3%	-15.0%	-15.0%	-17.4%	-17.4%	-19.3%	-18.3%
	Soybean	-3.3%	-5.2%	-4.3%	-6.7%	-8.9%	-9.0%	-8.1%	-6.9%
	Sugarbeet	-15.9%	-21.2%	-21.4%	-28.9%	-32.4%	-32.8%	-26.2%	-23.6%
	Sunflower	-2.7%	-4.3%	-3.6%	-9.0%	-14.3%	-14.7%	-9.2%	-7.1%
	Wheat	6.9%	1.1%	-0.9%	-7.0%	-8.9%	-9.1%	-3.2%	0.2%
	Tomato	-11.9%	-15.0%	-13.2%	-14.1%	-15.7%	-15.7%	-16.2%	-16.0%
	Alfalfa	-3.2%	-10.3%	-6.0%	-7.0%	-12.0%	-12.1%	-13.5%	-10.3%
2040s	Maize	8.4%	8.9%	4.4%	-4.1%	-10.9%	-11.7%	1.6%	6.2%
	Barley	10.8%	11.5%	10.9%	6.8%	5.2%	5.0%	8.6%	8.9%
	Potato	-6.3%	-13.5%	-12.4%	-15.8%	-19.1%	-19.3%	-16.6%	-7.9%
	Soybean	1.4%	-1.9%	-3.0%	-6.6%	-9.6%	-9.8%	-5.7%	-0.1%
	Sugarbeet	-3.6%	-13.2%	-15.6%	-25.8%	-35.9%	-36.9%	-19.6%	-2.4%
	Sunflower	0.3%	-2.0%	-4.5%	-9.9%	-15.1%	-15.7%	-7.2%	-1.0%
	Wheat	20.3%	14.7%	7.6%	-13.2%	-17.4%	-18.3%	8.3%	20.6%
	Tomato	-2.3%	-8.9%	-9.7%	-14.9%	-18.8%	-19.1%	-12.4%	-3.5%
	Alfalfa	9.6%	1.0%	2.3%	-0.7%	-5.4%	-5.6%	-2.4%	6.1%

Source: World Bank Team and Industrial Economics analysis

Table 3-2, on the other hand, suggests that irrigated yields will tend to improve under climate change. This finding indicates that if water stress is removed by irrigating, then the direct temperature effects of climate change may have a positive effect on future crop yields. The largest positive gains are in winter wheat, alfalfa, maize, and barley, while sugarbeets and tomatos are projected to experience the largest declines. As a result of this general finding, the primary investment option considered in Tier 2 was a signicant expansion of irrigated areas. By moving from rainfed to irrigated hectares, farmers become much more resilient to the effects of climate change.

TABLE 3-2. PERCENT CHANGE IN irrigated CROP YIELDs by crop, administrative area, and time period under the GFDL-4.5 scenario

Period	Crop	Change in Irrigated Yields under GFDL-ESM2M-rcp45							
		North-West	Center	North-East	South-East	South-Mutenia	Bucharest-Ilfov	South-West Oltenia	West
2020s	Maize	1.4%	2.5%	2.5%	-1.8%	1.5%	1.5%	1.8%	1.6%
	Barley	4.7%	5.4%	5.2%	4.8%	4.2%	4.2%	4.1%	2.0%
	Potato	0.3%	0.2%	0.2%	0.0%	0.0%	0.0%	0.1%	0.2%
	Soybean	1.6%	1.8%	1.6%	1.2%	1.1%	1.0%	1.2%	1.4%
	Sugarbeet	0.3%	-2.8%	10.9%	-12.8%	-12.3%	-11.8%	19.0%	1.6%
	Sunflower	0.7%	0.8%	0.7%	-0.3%	0.5%	0.5%	0.5%	0.7%
	Wheat	9.7%	9.6%	10.7%	10.5%	9.3%	9.2%	8.8%	8.7%
	Tomato	0.1%	2.3%	-7.0%	-2.2%	-0.1%	-0.3%	12.9%	0.6%
	Alfalfa	8.9%	11.9%	12.4%	9.6%	7.5%	7.3%	8.5%	7.2%
2030s	Maize	10.0%	10.0%	7.7%	1.2%	3.4%	3.2%	5.5%	6.9%
	Barley	8.2%	8.2%	9.6%	7.0%	5.4%	5.3%	5.7%	6.7%
	Potato	0.1%	0.1%	0.1%	0.0%	-0.1%	-0.1%	0.0%	0.0%
	Soybean	2.9%	2.9%	2.4%	1.3%	0.8%	0.8%	1.4%	1.9%
	Sugarbeet	4.6%	-3.6%	13.7%	-10.4%	-10.9%	-10.1%	16.6%	5.8%
	Sunflower	2.3%	2.3%	1.5%	0.1%	0.4%	0.4%	1.0%	1.4%
	Wheat	14.8%	14.3%	15.5%	14.6%	13.0%	12.9%	13.2%	13.7%
	Tomato	-0.1%	2.3%	-10.0%	-3.2%	-0.1%	-0.3%	12.9%	0.2%
	Alfalfa	21.9%	23.1%	20.4%	14.6%	11.6%	11.2%	15.1%	16.2%
2040s	Maize	17.9%	19.1%	14.4%	-0.7%	5.7%	6.2%	10.6%	13.1%
	Barley	13.7%	14.7%	7.9%	8.9%	8.9%	8.7%	10.3%	11.6%
	Potato	-6.5%	0.3%	0.2%	-0.1%	-0.3%	-0.3%	0.0%	0.1%
	Soybean	-0.6%	5.3%	4.1%	2.2%	1.5%	1.4%	2.8%	3.6%
	Sugarbeet	-3.3%	9.5%	-0.2%	6.9%	3.9%	3.8%	28.9%	7.9%
	Sunflower	-13.1%	3.5%	2.2%	-2.7%	0.5%	0.5%	0.9%	-11.9%
	Wheat	31.1%	23.7%	24.3%	23.3%	21.2%	21.1%	21.8%	24.4%
	Tomato	-10.0%	1.0%	-24.2%	-7.6%	-0.6%	-0.8%	12.6%	0.1%
	Alfalfa	42.5%	47.0%	42.4%	31.3%	26.2%	25.6%	31.6%	34.4%

Source: World Bank Team and Industrial Economics analysis

3.5 GREEN GROWTH INVESTMENT EFFECTS ON UNMET WATER DEMANDS AND CROP YIELDS

Lastly, we considered several investment options that may increase Romania's resilience to climate change. The physical performance of these investments is described here, and they are examined from an economic perspective in Chapter 4. Broadly, in the agricultural sector we evaluated investments that would improve farm-level rainfed and irrigated yields (e.g., improved crop varieties), and in the water sector, we considered investments that would decrease water withdrawals through demand management approaches.

Green Growth Investments in the Agricultural Sector

For the agricultural sector, the AquaCrop model was used to explicitly evaluate the potential yield improvements that could be generated through a number of improved farm-level investments. These included:

Adopting improved, drought tolerant, crop varieties

Converting from rainfed to irrigated

Improving soil drainage

Improving soil aeration

Optimizing fertilizer application

Optimizing the timing of irrigation water application

Except in the case of converting from rainfed to irrigated and optimizing irrigation water timing, each of these options was analyzed in AquaCrop for both irrigated and rainfed areas. We found that the most promising alternatives from a yield improvement perspective were: (1) improving crop varieties, (2) optimizing fertilizer application, and (3) converting from rainfed to irrigated. As a result, the first two options are at the center of the Tier 1 investment policy, and all three options are the focus of the Tier 2 policy.

The yield improvements generated from improved varieties and fertilizer application are presented in Table 3-3 for each crop and administrative region. These are presented for the GFDL-4.5 scenario in the 2040s, and improved varieties are presented for rainfed crops only, while optimizing fertilizer application is presented for each. Improved rainfed crop varieties generate between 0 and 10 percent yield benefits for rainfed crops, whereas optimizing fertilizer application can produce anywhere from a 4 percent to a 70 percent yield improvement, depending on crop, region, and whether the farm is rainfed or irrigated.

TABLE 3-3. PERCENT CHANGE IN CROP YIELDs by crop, administrative area, and green growth investment under the GFDL-4.5 scenario, in the 2040s

Investment	Crop Type	Changes in Yields (tonnes/ha) under Medium Scenario (GFDL-ESM2M-rcp45)							
		North-West	Center	North-East	South-East	South-Mutenia	Bucharest-Ilfov	South-West Oltenia	West
Improve Crop Varieties -- Rainfed	Maize	0.7%	1.2%	2.2%	6.3%	9.6%	10.0%	3.1%	1.2%
	Barley	0.0%	0.1%	0.6%	2.1%	2.8%	2.9%	0.4%	0.2%
	Potato	2.7%	2.4%	2.6%	3.0%	3.2%	3.2%	2.4%	2.6%
	Soybean	1.7%	2.2%	2.2%	3.1%	3.5%	3.5%	2.9%	2.5%
	Sugarbeet	1.8%	2.2%	2.1%	N/A	N/A	6.5%	3.6%	2.3%
	Sunflower	1.5%	1.9%	1.3%	2.2%	2.1%	2.0%	2.5%	2.0%
	Wheat	1.0%	1.3%	1.9%	6.1%	8.7%	9.1%	2.1%	1.2%
	Tomato	2.6%	3.0%	3.1%	3.9%	3.9%	3.9%	3.7%	3.6%
	Alfalfa	3.7%	3.5%	3.7%	3.6%	3.7%	3.7%	3.6%	3.5%
Optimize Fertilizer Application -- Rainfed	Maize	50.9%	48.2%	44.9%	28.8%	21.9%	21.0%	32.0%	47.6%
	Barley	51.7%	50.8%	48.5%	40.2%	38.6%	38.3%	47.8%	51.4%
	Potato	22.1%	22.2%	21.4%	17.6%	17.3%	17.2%	19.8%	21.4%
	Soybean	43.1%	41.4%	40.4%	32.6%	30.6%	30.3%	35.4%	40.2%
	Sugarbeet	42.3%	42.5%	43.5%	N/A	N/A	20.3%	35.0%	40.1%
	Sunflower	50.1%	45.8%	42.1%	25.2%	14.7%	13.5%	28.3%	45.4%
	Wheat	12.9%	15.5%	25.6%	66.5%	81.2%	84.1%	26.1%	12.9%
	Tomato	37.3%	34.0%	33.1%	19.4%	15.0%	14.5%	24.4%	32.7%
	Alfalfa	7.0%	6.6%	7.0%	4.7%	4.1%	4.1%	5.2%	6.0%
Optimize Fertilizer Application -- Irrigated	Maize	N/A	62.1%	61.7%	67.8%	61.2%	N/A	62.1%	N/A
	Barley	N/A	52.4%	52.8%	51.7%	52.2%	N/A	50.2%	N/A
	Potato	N/A	34.1%	34.1%	34.3%	34.7%	N/A	34.1%	N/A
	Soybean	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Sugarbeet	N/A	75.3%	62.0%	103.5%	92.4%	N/A	74.8%	N/A
	Sunflower	N/A	63.1%	63.2%	70.0%	63.5%	N/A	63.2%	N/A
	Wheat	N/A	62.8%	62.6%	62.3%	62.4%	N/A	62.7%	N/A
	Tomato	N/A	56.9%	64.3%	56.6%	53.6%	N/A	56.4%	N/A
	Alfalfa	N/A	18.3%	18.1%	18.7%	18.7%	N/A	18.5%	N/A

Source: World Bank Team and Industrial Economics analysis

Green Growth Investments in the Water Resources Sector

For water sector investments, we focused primarily on water demand management rather than supply augmentation alternatives. According to ANAR and INHGA, additional storage options are not currently a focus of policymakers in Romania. Consequently, we considered improved irrigation efficiency, M&I delivery efficiency, and municipal water use efficiency as possible investment options to alleviate water shortages. Irrigation efficiency options considered included both conveyance improvements (e.g., lining irrigation canals), and field level improvements such as converting from flood to sprinkler irrigation. M&I efficiency improvements would focus on repairing leaking delivery systems and potentially installing leak prevention systems.

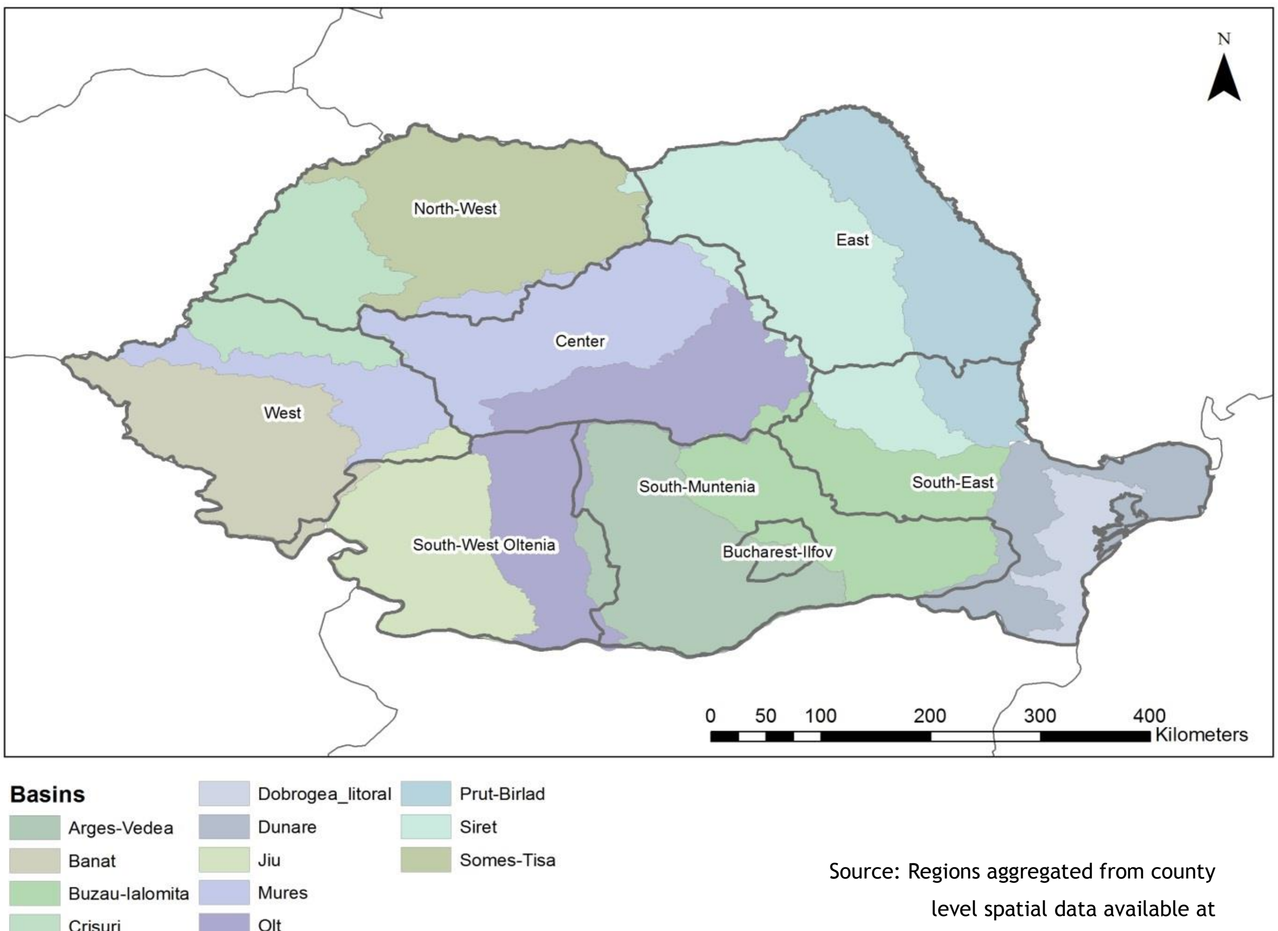
We identified several subbasins that have significant unmet demands in the irrigation and/or industrial sectors according to the WEAP analysis, and then built these improvements in irrigation and M & I delivery efficiency into the WEAP model within these subbasins. Next, we ran the WEAP model with these improvements to determine whether unmet demands in any of the sectors declined significantly. We found that the reductions in unmet demands (or alternatively, improvements in supply reliability) resulting from these investments were fairly minimal, primarily because the existing unmet demands in the system occur during years when extremely low flows occur are dedicated wholly to meet minimum environmental flow requirements. If little or no water is available to be used consumptively, then decreasing withdrawal requirements through efficiency improvements will have limited effect. More effective alternatives may include increased basin storage, inter-basin transfers, conjunctive use between surface water and groundwater, or improved reservoir management practices. A challenge to this analysis was the availability of only aggregated data. The reductions in unmet demands with improvements in irrigation and M & I delivery efficiency could be more significant if more specific data were available.

4. Analysis and Findings - economic implications FOR THE AGRICULTURAL SECTOR of Investments for Green Growth Scenarios

In this chapter, we present the economic implications of two green growth investment scenarios, referred to as Tier 1 and Tier 2 investment scenarios, on the agriculture and hydropower sectors of Romania, against the medium climate change scenario (GFDL45). Although the sectors are likely to experience gains under the Tier 1and Tier 2 investment scenarios, the results vary by region and investment choices.

The map below shows the intersection of the twelve basins presented earlier and the eight development regions referred to in this chapter. The eight regions presented in this map are the eight Development Regions. These regions are based on aggregation of the 41 counties of Romania, and recognized by Eurostat as an appropriate spatial unit for reporting economic information. The agricultural data provided by Dr. Catalin Simota at the National Research and Development Institute for Soil Science, Agrochemistry, and Environment were presented at this regional resolution.

FIGURE 4-1. ROMANIAN DEVELOPMENT REGIONS AND BASINS



Source: Regions aggregated from county level spatial data available at http://gadm.org/country.

Basin data provided by ANAR and INHGA.

4.1 GREEN GROWTH INVESTMENT SCENARIOS

Economic impact analyses are presented for two green growth investment scenarios. Tier 1 investments include enhancing crop varieties for grain maize, winter wheat, and tomato; and increasing fertilizer application to all modeled crops on about a half a million hectares of current rainfed agricultural land. Tier 2 applies those same two improvements across about two million hectares of land, and converts 430 thousand hectares of equipped irrigated land to actual irrigated agriculture, based on the viability of irrigation in the area. Current estimates do not include analysis of improvements in water storage, or unmet demand due to increased irrigation, which could impact results. Unit and annual costs of each green growth investment sector analyzed are presented in Table 4-1.

TABLE 4-1. GREEN GROWTH INVESTMENT SCENARIOS

Tier 1	Hectares	Cost/HA	Annual Cost (MM $USD)
Increased fertilizer application	536,302	$185.00	$99
Enhanced crop varieties	536,302	$30.00	$16
Tier2	Hectares	Cost/HA	Annual Cost (MM $USD)
Increased fertilizer application	2,167,518	$185.00	$401
Enhanced crop varieties	2,167,518	$30.00	$65
Rehabilitated irrigation	434,397	$690.00	$300

Source: World Bank Team and Industrial Economics analysis

4.2 AGRICULTURAL BASELINE CONDITIONS AND IMPROVEMENT SCENARIO DESCRIPTIONS

The economic analysis involved modeling production by crop and estimating revenue by multiplying production by crop price for each of the nine modeled crops19. The modeled production figures were calibrated based on data of areas and yields for the time series 2008-2012 and 2005, categorized by administrative area and crop, provided by Dr. Catalin Simota. 2012 crop prices were utilized in the revenue calculations20. As Figure 4-1 shows, agricultural revenues see a slight downward trend over time when no additional green growth investments are made.

[19] Modeled crops are grain maize, barley, potato, soybean, sugar beet, sunflower, winter wheat, tomato, and alfalfa.

[20] Crop prices per tonne were gathered for Romania from FAO PRICESTAT. The alfalfa price, which was not available from FAO PRICESTAT (http://faostat3.fao.org/download/P/PP/E), was calculated based on production figures provided by Dr. Catalin Simota and revenue figures available from Eurostat (agr_r_accts).

FIGURE 4-1. Trends in AGRicultural revenue: Observed and modeled

* Observed baseline data are 2010-2014 averages based on Eurostat agricultural output data, using the average 2012 Euro to US Dollar exchange rate. Note that 2012 was a low year for production due to drought. Missing data for specific modeled crops in 2014 were imputed using the weighted average of the proportion of yearly total crop revenue contributed by the crop from 2005-2013, with recent years receiving higher weight.

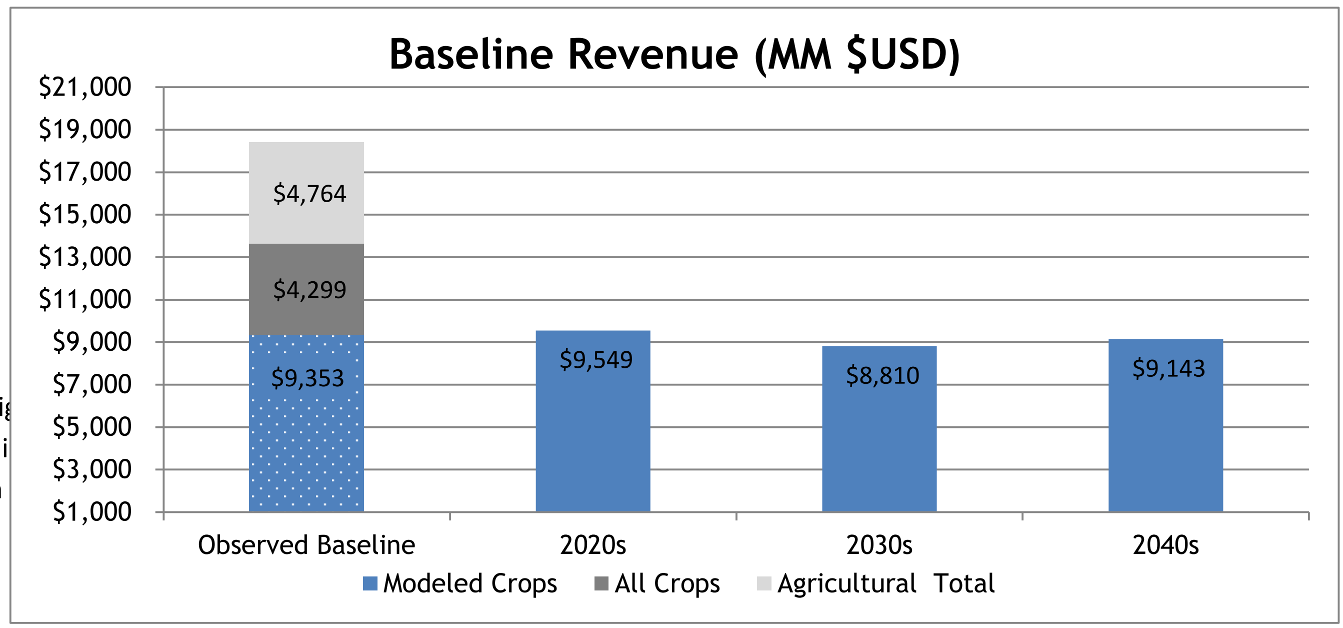


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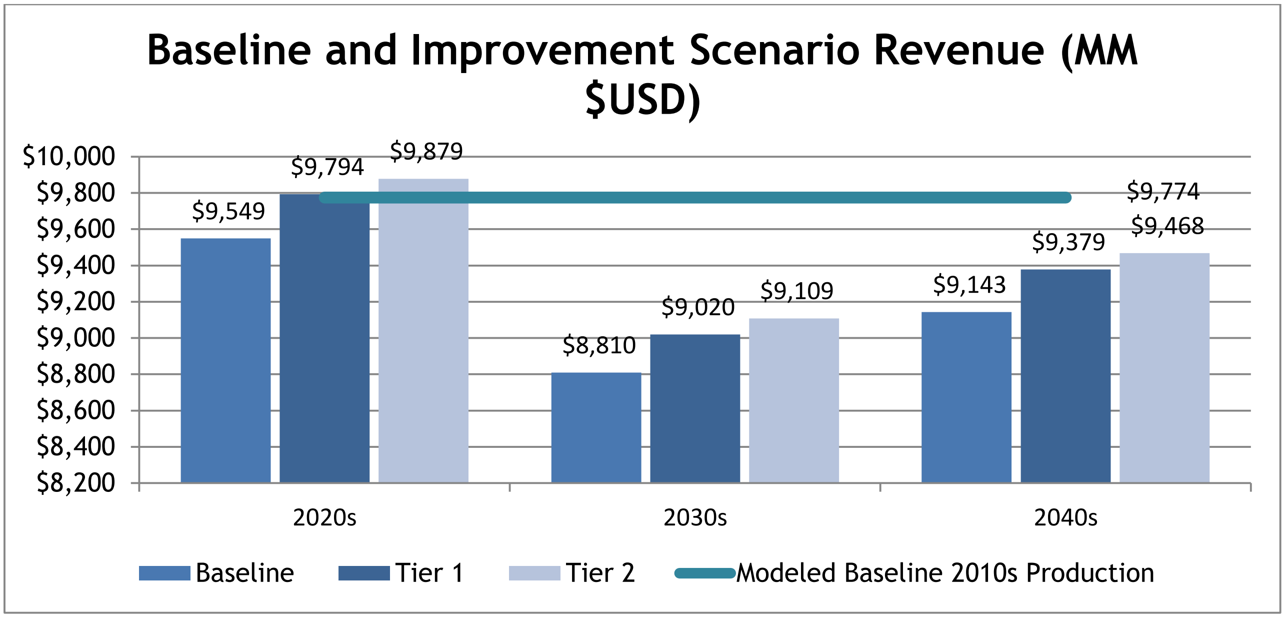
FIGURE 4-2. BASELINE AND GREEN GROWTH INVESTMENT REVENUES



Source: World Bank Team and Industrial Economics analysis

4.3 ECONOMIC IMPLICATIONS FOR THE AGRICULTURAL SECTOR

Table 4-2 converts the yield effects on agriculture presented in Chapter 3 into revenue effects, aggregated across rainfed and irrigated crops for each region under the medium climate scenario. Era level average revenues under the baseline scenario (no additional investment) are presented for the 2020s, 2030s, and 2040s, alongside percent changes in these revenues under the Tier 1 and Tier 2 investment scenarios. Baseline revenues vary based on the crop mix, modeled yields, and area under harvest in each region. In all instances, investment scenario revenues increase relative to baseline revenues. Under the Tier 2, agricultural revenues increase more dramatically due to the broader set of investments that are considered in the scenario.

TABLE 4-2. PERCENT CHANGE IN value of Romania's crop production in each Region under TWo tier scenarios and time periods, medium climate scenario

	2020s			2030s			2040s		
	BASE REVENUE ($USD MM)	PERCENT CHANGE		BASE REVENUE ($USD MM)	PERCENT CHANGE		BASE REVENUE ($USD MM)	PERCENT CHANGE	
REGION		TIER 1	TIER 2		TIER 1	TIER 2		TIER 1	TIER 2
Nord-Vest	$1,108.55	3.44%	15.06%	$1,024.77	3.03%	13.42%	$1,125.25	3.11%	13.70%
Centru	$1,068.98	1.20%	4.74%	$946.31	1.09%	4.63%	$1,040.20	1.13%	4.64%
Nord-Est	$1,607.10	2.77%	8.91%	$1,520.34	2.45%	8.35%	$1,562.85	2.54%	8.67%
Sud-Est	$1,615.07	0.32%	5.95%	$1,567.00	0.32%	7.17%	$1,523.56	0.35%	8.35%
Sud-Muntenia	$1,894.97	4.33%	16.98%	$1,750.15	4.49%	18.40%	$1,679.71	5.15%	21.21%
Bucuresti-Iflov	$89.48	1.62%	2.12%	$81.01	1.75%	2.38%	$77.85	1.83%	2.54%
Sud-Vest Oltenia	$1,076.05	0.69%	12.17%	$953.68	0.62%	12.73%	$1,032.92	0.60%	11.71%
Vest	$1,088.61	4.90%	16.06%	$966.71	4.22%	14.79%	$1,101.16	4.48%	14.96%
TOTAL	$9,548.80	2.56%	11.38%	$8,809.97	2.39%	11.45%	$9,143.50	2.57%	12.13%
Note: Value in constant 2012 $USD									

Source: World Bank Team and Industrial Economics analysis

To compare the value of these agricultural investments, Table 4-3 reports the present value revenues and costs above baseline (at a 5 percent discount rate), and the net present value (NPV) of the investments for each region under the Tier 1 and Tier 2 scenarios, by investment option. Enhanced fertilizer application and rehabilitated irrigation investments have positive net present values, while improved crop varieties are negative in both Tier 1 and Tier 2 scenarios. Overall NPV values for Romania under the Tier 1 and Tier 2 scenarios are $2.3 billion and $17.4 billion, respectively. Table 4-4 presents the benefit cost ratio of the investments in each region. Again, it is clear improved varieties investments have the lowest ratios across all regions, while enhanced fertilizers and rehabilitated irrigation investments show larger ratios in all regions.

TABLE 4-3. net present value of agricultural investments under green growth, medium scenario 2015-2050

REGION	TIER 1 ($USD MM)								
	Enhanced Fertilizer			Improved Varieties			Total		
	PV REVENUES	PV COSTS	NPV	PV REVENUES	PV COSTS	NPV	PV REVENUES	PV COSTS	NPV
Nord-Vest	$640.9	$236.3	$404.6	$17.2	$38.3	$(21.1)	$658.1	$274.7	$383.5
Centru	$226.2	$80.7	$145.4	$5.4	$13.1	$(7.7)	$231.6	$93.8	$137.7
Nord-Est	$785.6	$304.7	$480.9	$21.5	$49.4	$(27.9)	$807.1	$354.1	$452.9
Sud-Est	$88.3	$46.0	$42.3	$8.2	$7.5	$0.8	$96.5	$53.5	$43.0
Sud-Muntenia	$1,349.3	$657.3	$692.0	$ 150.7	$106.6	$44.1	$1,500.0	$763.9	$736.1
Bucuresti-Iflov	$24.0	$9.2	$14.8	$4.1	$1.5	$2.7	$28.1	$10.7	$17.5
Sud-Vest Oltenia	$121.4	$60.8	$60.6	$6.5	$9.9	$(3.4)	$127.9	$70.7	$57.3
Vest	$861.0	$328.7	$532.3	$34.5	$53.3	$(18.8)	$895.5	$382.0	$513.5
TOTAL	$4,096.8	$1,723.8	$2,373.0	$248.1	$279.5	$(31.4)	$4,344.9	$2,003.3	$2,341.6

REGION	TIER 2 ($USD MM)											
	Enhanced Fertilizer			Improved Varieties			Rehabilitated Irrigation			Total		
	PV REVENUES	PV COSTS	NPV	PV REVENUES	PV COSTS	NPV	PV REVENUES	PV COSTS	NPV	PV REVENUES	PV COSTS	NPV
Nord-Vest	$2,801.0	$1,032.8	$1,768.2	$75.2	$167.5	$(92.3)	$256.3	$99.7	$156.7	$3,132.5	$1,299.9	$1,832.5
Centru	$873.1	$311.7	$561.4	$20.9	$50.6	$(29.7)	$406.6	$159.3	$247.3	$1,300.7	$521.6	$779.0

Nord-Est	$2,450.2	$950.4	$1,499.8	$67.0	$154.1	$(87.2)	$1,802.7	$877.9	$924.8	$4,319.8	$1,982.4	$2,337.4
Sud-Est	$554.9	$289.3	$265.6	$51.7	$46.9	$4.8	$5,541.5	$2,272.5	$3,268.9	$6,148.0	$2,608.8	$3,539.3
Sud-Muntenia	$4,773.4	$2,325.2	$2,448.2	$533.0	$377.1	$156.0	$2,678.7	$850.6	$1,828.1	$7,985.1	$3,552.9	$4,432.3
Bucuresti-Iflov	$28.5	$10.9	$17.6	$4.9	$1.8	$3.2	$14.5	$4.2	$10.3	$47.9	$16.9	$31.1
Sud-Vest Oltenia	$1,969.4	$985.9	$983.4	$105.4	$159.9	$(54.5)	$1,836.8	$640.6	$1,196.2	$3,911.5	$1,786.4	$2,125.1
Vest	$2,778.3	$1,060.6	$1,717.7	$111.3	$172.0	$(60.7)	$928.7	$302.8	$625.9	$3,818.3	$1,535.4	$2,282.9
TOTAL	$16,228.7	$6,966.9	$9,261.8	$969.4	$1,129.8	$(160.4)	$13,465.8	$5,207.6	$8,258.2	$30,663.9	$13,304.3	$17,359.6

Source: World Bank Team and Industrial Economics analysis

TABLE 4-4. BENEFIT CoST RATIO for agricultural investments under the green growth scenarios, medium Climate scenario between 2015 and 2050

REGION	TIER 1 ($USD MM)			TIER 2 ($USD MM)			
	Enhanced Fertilizer	Improved Varieties	Total	Enhanced Fertilizers	Improved Varieties	Rehabilitated Irrigation	Total
Nord-Vest	2.71	0.45	2.40	2.71	0.45	2.57	2.41
Centru	2.80	0.41	2.47	2.80	0.41	2.55	2.49
Nord-Est	2.58	0.43	2.28	2.58	0.43	2.05	2.18
Sud-Est	1.92	1.10	1.80	1.92	1.10	2.44	2.36
Sud-Muntenia	2.05	1.41	1.96	2.05	1.41	3.15	2.25
Bucuresti-Iflov	2.61	2.78	2.64	2.61	2.78	3.47	2.84
Sud-Vest Oltenia	2.00	0.66	1.81	2.00	0.66	2.87	2.19
Vest	2.62	0.65	2.34	2.62	0.65	3.07	2.49
TOTAL	2.38	0.89	2.17	2.33	0.86	2.59	2.30

Source: World Bank Team and Industrial Economics analysis

4.4 ECONOMIC IMPLICATIONS FOR THE HYDROPOWER SECTOR

Because of the limited capacity for expansion in the hydropower sector, economic implications of climate change are presented as historic hydropower facility production projected under no climate change and medium scenario climate change. Table 4-5 presents the percentage changes in annual hydropower revenues across all Romanian facilities, assuming a range of 2.6-7.4 cents per kilowatt-hour wholesale price of electricity in Romania throughout the study period (see footnote on Table 4-5). This wholesale price represents the replacement cost of electricity in Romania were hydropower generation to decrease, but for this analysis the measure is static and does not adjust to other macro- and micro-economic conditions that could alter the absolute or relative price of electric energy. Price is multiplied by yearly modeled production, and averaged over each decade to get the average era revenues presented below.

TABLE 4-5. PERCENT CHANGE IN value of ROMANIA's Hydropower production under No climate change and medium climate scenario

Decade	NO CLIMATE CHANGE (millions USD)		MEDIUM SCENARIO CLIMATE CHANGE (percent change)
	low	high	
2020s	$573.91	$1,615.46	-10.42%
2030s	$516.59	$1,454.11	-4.01%
2040s	$529.47	$1,490.37	-8.96%
*Low and high wholesale electricity prices from GDF SUEZ Energy Romania 2012-2014, converted from Lei to USD using the average 2012 exchange rate.			

5. Recommendations and Next Steps

The results presented in this report suggest that climate change can present a substantial risk to agricultural production, irrigation, municipal and industrial water uses, and hydropower generation at current facilities in Romania, but that those effects can be addressed at least partially by following a green growth investment plan. Implementing a program for Romanian irrigation infrastructure, in particular, can counteract the effects of climate change in most places and provide additional benefits to increase productivity beyond current levels. These investments do not eliminate climate change risks to water-dependent sectors, but the combined effect of multiple investments has great potential for supporting green growth in Romania. In addition, the work presented here demonstrates that it is critical to consider climate change when choosing among investment options and green growth development pathways.

In this chapter, we present a summary of those Green Growth investments and investment packages that provide the best return for Romania. We also outline a series of additional steps that should be taken by the Government of Romania water resource institutions as follow-up to this work, in order to develop a refined investment plan.

5.1 RECOMMENDED PRIORITY GREEN GROWTH INVESTMENT PACKAGES

The results in in Chapters 3 and 4, taken together, suggest that the greatest investment potential exists for optimizing agronomic inputs, including fertilizer inputs, and rehabilitating irrigation infrastructure to restore irrigation production to certainly currently rainfed areas.[21] The agricultural productivity measures would require a significant investment in high-quality extension services, as well as increased and/or subsidized availability of fertilizers, with the payoff being a significantly increased crop yield. The highest investment payoffs for these measures are in the South-Muntenia, Northeast, and Northwest Development Regions. In general, fertilizer programs show strong returns to investment throughout Romania, and for best results could be targeted for those farms of medium size (roughly 10 ha), to ensure that the measures encourage consolidation of the smallest farms while also avoiding providing an unnecessary subsidy to the largest farms, which are already quite productive.

The results for enhanced varieties are interesting, as in many basins the modeled response to enhanced varieties is low, yielding negative net present values and benefit-cost ratios less than 1 for this investment. The exceptions are in South Muntenia, Bucharest-Ilfov and Sud-Est, where net present values for investment in varieties are positive, and where benefit-cost ratios for this investment are between 1.4

[21] For practical reasons, the economic analysis in Chapter 4 focuses on only one of the three climate scenarios used in this report – the medium climate change scenario. The time and resources allotted for this project did not allow for additional economic and investment analysis of the other two scenarios. We encourage the Romanian institutions receiving the data and models from this work to conduct additional analysis of investment performance under multiple climate scenarios, with the goal of assessing the robustness of the investments to uncertainty in future climate. The project team notes that temperature change forecasts are similar across the three scenarios, but that future rainfall, runoff, and potential evapotranspiration could vary across scenarios (as indicated in Chapter 3), which may affect some of the investments analyzed here.

and 2.7. The South Muntenia region crops, which are characterized by a high concentration of maize, are most responsive to an investment in new varieties. Wheat in these regions are also highly responsive to new varieties, increasing yields by approximately 10 percent. Other regions' crops (and crop mixes) are far less responsive to a change in varieties. This clearly suggests that a targeted approach to new varieties – focused on the South Muntenia region, but also on maize production in selected southern regions – is likely to be most successful.

It is also clear that expanded irrigation has a very high potential for a positive investment payoff, provided water is available for the irrigation sector. The highest NPV results for irrigation investments are indicated in the Southeast and South-Muntenia regions; high NPVs were also found for the Northeast and West regions. The NPV results largely track with the spatial distribution of areas found to be "economically viable" for irrigation system restoration and rehabilitation, a determination that was made in a prior study, referenced in Chapters 2 and 4 above. What this study adds, however, is an assessment of the potential revenue gains to irrigated agriculture, relative to current rainfed yields, with full consideration of the effects of climate change over time. The method reflects no spatial differentiation of rehabilitation costs – detailed analysis is left to subsequent project-scale feasibility studies. Yet both the NPVs and the benefit-cost ratios do reflect spatial variation in the returns to irrigation investment. These suggest that returns are likely to be strong in all regions – the lowest B-C ratio of 2.05 is in the Northeast region, which reflects good investment potential – but that the best returns are likely in the South Muntenia, Bucharest-Iflov, and West regions, which all indicate B-C ratios of more than 3 for irrigation investments. Further analysis can be readily conducted to assess the robustness of this result across a range of climate scenarios (the results in Chapter 4 focus on the medium scenario), or using alternative climate input such as those from Regional Climate Models, to which NMA has access.

It is also worth noting that the Tier 1 investments of about $100 million annually (as estimated in Chapter 4) would be a manageable increase from 2013 levels of agricultural sector support of 1 billion EUR direct payments, and 1.3 billion EUR of rural development expenditures. By contrast, the roughly $750 million annual expenditure for Tier 2 investments would represent a substantial increase from current spending and would quickly exhaust the National Rural Development Program (NRDP) 2014-2020 financial allocation for irrigation infrastructure, which is over 400 million EUR, or about 65 million EUR annually.

5.2 REALIZING THE BEST GREEN GROWTH OUTCOMES: SOME SUGGESTED NEXT STEPS

In addition to providing insights on specific packages of Green Growth investments, this study has also developed a set of transferable tools for water sector investment analyses which will be delivered to local counterparts of the Ministry of Environment, Waters and Forests as well as ANAR, INHGA, and other nominated local stakeholders. This tool can be usefully applied to further assess the irrigation and other water and agriculture investment options, both individually and in combination with water use efficiency options. It can also be used to assess multi-sectoral strategies that may have water use implications – for example, as described further below, a shift from fossil fuel-based thermoelectric power generation to wind power, if such as shift were to be viewed as favorable, has the potential implication of reduced water use, an implication which could be assessed within the scope of this study, if it were both consistent with Romania's energy sector planning and important to Romania's water sector future.

The tools developed here are appropriate and well-suited for the types of analyses conducted and the recommendations made – but additional work is needed if the tools are to be used for both ongoing water resource planning and to assess more specific agriculture, irrigation, and water use efficiency investments. Some important limitations need to be recognized in interpreting the results, especially the WEAP results, as indicated below, and some data gaps should be addressed to support further work:

Planning scale of the WEAP analysis: The WEAP tool is a planning tool, which means it reflects a spatial, temporal, and management resolution that is less granular than tools that focus on the operation of individual elements of water infrastructure, such as hydropower dams, irrigation schemes, or municipal water supply systems. The planning scale is particularly appropriate for identifying potential conflicts for water use, incorporating forecasts of demand and supply, and setting priorities among alternative investments. However, a planning scale analysis cannot reflect the full range of complexities in national water systems, espeically for complex countries such as Romania. For example, the umet demands forecasted for the industrial sector are based on highly aggregated industrial sector data; with more highly resolved data inputs, which could be tested in the context of the remaining capacity building activities of this project, a clearer picture of persistent unmet demands might be demonstrated.

Water allocation priorities: The WEAP system, as configured in this analysis, reflects relatively course schemes for setting priorities for water allocation among potentially competing uses. The priority scheme operates as a decision-rule, and does not reflect the possibility of more refined management approaches that have a seasonal, temporary, or conditional nature, and that might therefore be deployed to better optimize the allocation of water in basins where supply is insufficient to meet the full range of competing demands. In particular, the level and seasonal timing of environmental flow requirements need to be carefully considered in all future work.

Forecasting versus current situation: When interpreting the WEAP and other results in this paper, it is important to note that this study is focused on forecasting the future water system in Romania. All scenarios analyzed here – the baseline, Tier 1, and Tier 2 investments – incorporate the effects of future climate change. In particular, an analysis of currently unmet water demands (if any) across the range of current historical interannual variability might be a useful supplemental analysis to pursue, with the objective of providing some context in which to view the range of forecast future outcomes, with climate change, that are modeled in this study.

Evaluation of model and results uncertainties. Any modeling exercise involves some degree of uncertainty – a forecasting exercise, in particular, can only be evaluated based on comparision or calibration of the models to current conditions. Where possible, the approach adopted here attempted to evaluate model robustness. Five results in particular are worth highlighting:

AquaCrop comparisons of modeled to measured crop yields showed good agreement for all crops but barley, where the modeled yield undestimates actual yields;

To ensure greater reiliability, modeled yields were bias-corrected to reflect differences between modeled and measured yields,in each Development Region, as described in Chapter 2 – this procedure should increase the reliability of the results;

The CliRun rainfall-runoff model was calibrated to measured runoff data, and achieved R2 values of between 0.35 and 0.83;

Hydropower production estimates from the WEAP model show good agreement between measured and modeled production, as indicated in Chapter 3. Certainly better results could be achieved with more highly spatially resolved data, which appears not to be currently available.;

Importantly, it was beyond the scope of the current analysis to evaluate the potential role of historical climate variability on infrastructure performance. Such an evaluation would: (1) put in context the magnitude of climate change impacts presented in this report and (2) allow for an evaluation of infrastructure performance under both climate change and variability. To conduct such an analysis, a statistical technique such as bootstrapping would be used to generate a range of alternative historical and projected precipitation and temperature time series, which would then be used to simulate a set of alternative river runoff, crop yield, and irrigation water demand series.

This water sector analysis has addressed four policy-relevant issues not addressed in prior work: (1) the possible adaptive responses by farmers to climate change and the resulting marginal impact on agricultural production and revenues; (2) projected impacts on energy (mainly hydropower) production under the modeled development and climate scenarios; (3) trade-offs between alternative water uses, for irrigation, energy, and industrial use; and (4) potential investment options in irrigation infrastructure and agriculture sector adaptation, and the resulting costs and marginal impacts on agriculture and energy production. The results developed here, as well as the tools transferred to local counterparts, can have lasting benefits for evaluation and prioritization of a broad range of water and agriculture sector investment options.

The big picture realization of this analysis is that Romania, which already faces the difficult problem of allocating scarce water among multiple users, will face a larger challenge in the future as some demands increase, and as water supplies decrease. The suite of investments analyzed in this study and recommended for adoption can make a substantial improvement in the water and agriculture sectors. These investments, while broad in scope, cannot hope to be comprehensive. Additional thinking will be needed on several fronts to better manage water. 22

To provide a simple example, addressing unmet water demands in the baseline and, in particular, in the Tier 2 investment scenario will likely require additional water efficiency measures if water-dependent industries are to continue to grow. As indicated Chapter 3 of this report, the forecast for unmet industrial demands in particular are quite significant, and overall industrial demands constitute approximately 75 percent of the total water withdrawals of the country. Investment in reducing abstractions in the

[22] Water demand for irrigations was severely reduced due to financial reasons (subvention cuts) in 2010. Additional analyses of these types of scenarios might therefore be relevant to current policy decision-making.

industrial sector is a potential option for meeting the unmet demands. These abstractions could potentially be reduced using closed cycle water cooling systems in thermal power plants, as opposed to once-through systems. Baker et al. 2014 studied the impact of renewable energy futures on cooling water use in the United States, and a principle finding of the study was that a shift to closed cycle technology would lead to a decrease in water withdrawals while at the same time an increase in water consumption. 23 A systems approach is needed to assess the tradeoff between decreased abstraction and increased consumption related to implementation of these types of technologies in Romania. The CLIRUN/WEAP system used in this report is an effective tool for this assessment but currently needs improvements in spatial and temporal resolution of thermal electricity plant withdrawals and return flows to produce a credible assessment of potential investments.

The WEAP system, however, can also be used to assess multi-sector strategies. Another relevant finding by Baker et al. is that compared to the nonrenewable fossil-based technologies (gas, coal, nuclear), renewable technologies (geothermal, biopower, retrofitted coal, solar, wind) generally are less water-intensive, leading to overall reductions in water abstraction. An interesting extension of the WEAP system used in this report would be to assess the tradeoff between water abstraction and consumption with increased use of renewable technologies, which could represent a key aspect of the overall Green Growth platform.

The point of the example is that multiple measures, including investment as well as water allocation agreements, also can and should be considered as part of an overall water management plan for the country. This type of thinking, and studies such as this one, can hopefully contribute to a better understanding of these tradeoffs and move the country toward a better rationalization of water use and allocation that supports economic growth and development for decades to come.

[23] Baker, Jonathan, et al. "Quantifying the impact of renewable energy futures on cooling water use." JAWRA Journal of the American Water Resources Association 50.5 (2014): 1289-1303.

APPENDIX A: IMPACTS OF CLIMATE CHANGE ON CROP YIELD UNDER THE GFDL-8.5 AND MIROC-8.5 SCENARIOS

TABLE a-1 percent change in rainfed yields under the GFDL-8.5 scenario by crop, period, and administrative region

Period	Crop	Change in Rainfed Yields under GFDL-ESM2G-rcp85							
		North-West	Center	North-East	South-East	South-Mutenia	Bucharest-Ilfov	South-West Oltenia	West
2020s	Maize	7.9%	7.2%	5.8%	3.4%	3.4%	3.3%	4.9%	6.3%
	Barley	2.8%	2.9%	3.4%	3.0%	2.5%	2.4%	1.9%	0.2%
	Potato	3.0%	1.7%	3.2%	4.8%	8.4%	8.7%	3.6%	2.1%
	Soybean	3.8%	3.5%	3.7%	3.5%	5.0%	5.2%	3.6%	2.9%
	Sugarbeet	6.9%	6.2%	9.0%	14.5%	25.5%	26.6%	11.6%	6.5%
	Sunflower	2.8%	2.0%	1.8%	1.3%	2.4%	2.5%	2.1%	2.1%
	Wheat	10.9%	11.8%	17.1%	22.7%	31.6%	32.6%	15.3%	12.2%
	Tomato	3.8%	2.7%	4.5%	6.0%	10.4%	10.8%	5.4%	2.2%
	Alfalfa	19.2%	16.3%	18.5%	17.6%	19.0%	19.2%	14.3%	14.3%
2030s	Maize	4.8%	4.7%	4.3%	2.4%	-1.0%	-1.3%	2.3%	3.4%
	Barley	5.1%	4.5%	4.0%	2.7%	0.6%	0.4%	2.6%	4.0%
	Potato	0.9%	-1.0%	3.4%	5.8%	3.8%	3.8%	-0.9%	-2.0%
	Soybean	2.7%	1.6%	2.5%	2.7%	1.4%	1.4%	0.6%	0.7%
	Sugarbeet	4.0%	0.8%	3.7%	9.5%	8.0%	8.2%	-0.4%	-3.5%
	Sunflower	1.7%	0.7%	1.2%	0.6%	-2.8%	-3.1%	-1.2%	0.1%
	Wheat	9.8%	6.6%	9.6%	15.7%	15.1%	15.3%	5.8%	6.2%
	Tomato	3.8%	0.8%	3.9%	6.0%	4.2%	4.3%	1.1%	1.0%
	Alfalfa	9.6%	9.4%	14.8%	17.5%	15.0%	15.0%	9.0%	4.8%
2040s	Maize	10.0%	10.1%	7.7%	-1.1%	-6.6%	-7.1%	2.4%	7.5%
	Barley	7.5%	7.8%	7.7%	3.5%	1.3%	1.1%	4.9%	6.6%
	Potato	-6.5%	-10.8%	-6.5%	-12.7%	-16.0%	-16.1%	-14.6%	-9.2%
	Soybean	2.2%	0.2%	1.0%	-5.0%	-7.6%	-7.8%	-3.9%	-0.2%
	Sugarbeet	-2.0%	-9.4%	-4.9%	-25.4%	-31.7%	-32.2%	-18.6%	-7.3%
	Sunflower	1.9%	0.4%	0.8%	-7.1%	-12.2%	-12.7%	-5.5%	-0.2%
	Wheat	9.4%	6.0%	9.0%	-6.7%	-13.1%	-13.6%	0.5%	10.1%
	Tomato	-3.5%	-6.5%	-3.2%	-12.1%	-15.4%	-15.6%	-9.9%	-5.3%
	Alfalfa	7.5%	1.4%	6.2%	-1.4%	-6.2%	-6.4%	-4.5%	2.8%

Source: World Bank Team and Industrial Economics analysis

TABLE a-2 percent change in rainfed yields under the MIROC-8.5 scenario by crop, period, and administrative region

Period	Crop	Change in Rainfed Yields under MIROC-ESM-rcp85							
		North-West	Center	North-East	South-East	South-Mutenia	Bucharest-Ilfov	South-West Oltenia	West
2020s	Maize	12.7%	12.1%	7.6%	-0.3%	-1.6%	-1.9%	6.4%	9.1%
	Barley	9.4%	9.1%	9.2%	7.3%	7.0%	7.0%	7.1%	8.6%
	Potato	-0.5%	-3.4%	-9.2%	-13.1%	-10.4%	-10.4%	-4.3%	-1.2%
	Soybean	3.8%	2.7%	-0.6%	-4.7%	-3.5%	-3.6%	1.0%	2.7%
	Sugarbeet	6.0%	1.7%	-7.7%	-18.5%	-10.9%	-10.9%	3.9%	8.7%
	Sunflower	2.5%	1.8%	-1.8%	-7.7%	-6.8%	-6.9%	-0.3%	1.0%
	Wheat	16.1%	13.4%	11.2%	7.5%	15.6%	16.2%	15.8%	17.0%
	Tomato	0.1%	-1.3%	-7.7%	-11.2%	-5.9%	-5.8%	-0.3%	0.8%
	Alfalfa	24.1%	18.7%	10.3%	4.1%	3.6%	3.3%	12.5%	19.2%
2030s	Maize	14.7%	14.0%	8.4%	-7.1%	-8.8%	-9.2%	3.7%	9.6%
	Barley	9.6%	10.1%	7.7%	4.2%	3.8%	3.7%	7.2%	7.4%
	Potato	-11.0%	-13.3%	-19.1%	-21.0%	-18.0%	-18.0%	-13.9%	-13.1%
	Soybean	-0.8%	-1.7%	-6.5%	-10.1%	-9.1%	-9.2%	-5.0%	-3.8%
	Sugarbeet	-10.9%	-14.0%	-27.4%	-34.5%	-26.0%	-25.9%	-16.1%	-17.9%
	Sunflower	1.0%	-0.5%	-4.6%	-16.0%	-15.3%	-15.5%	-5.5%	-1.8%
	Wheat	3.4%	1.4%	-6.5%	-12.7%	-5.0%	-4.8%	2.1%	2.1%
	Tomato	-11.9%	-12.4%	-19.7%	-21.3%	-15.6%	-15.4%	-11.6%	-13.6%
	Alfalfa	19.4%	16.4%	7.8%	4.0%	4.3%	4.1%	9.7%	12.6%
2040s	Maize	14.1%	10.9%	6.8%	-14.9%	-27.1%	-28.3%	-8.4%	3.3%
	Barley	13.4%	13.6%	12.5%	5.7%	3.1%	2.8%	8.4%	10.8%
	Potato	-14.6%	-21.9%	-26.0%	-28.9%	-30.0%	-30.3%	-23.5%	-18.4%
	Soybean	-3.0%	-6.7%	-9.6%	-15.2%	-17.7%	-18.0%	-11.5%	-7.5%
	Sugarbeet	-19.0%	-27.7%	-39.6%	-52.5%	-53.2%	-53.9%	-33.9%	-26.4%
	Sunflower	-3.1%	-7.8%	-9.4%	-25.0%	-34.5%	-35.4%	-19.2%	-10.7%
	Wheat	8.7%	4.3%	-3.4%	-24.0%	-25.1%	-25.8%	-0.5%	6.4%
	Tomato	-16.4%	-20.8%	-24.4%	-29.4%	-31.1%	-31.4%	-23.3%	-19.5%
	Alfalfa	24.8%	14.0%	6.5%	1.0%	-4.0%	-4.5%	6.6%	16.1%

Source: World Bank Team and Industrial Economics analysis

TABLE a-3. percent change in irrigated yields under the GFDL-8.5 scenario by crop, period, and administrative region

Period	Crop	Change in Irrigated Yields under GFDL-ESM2G-rcp85							
		North-West	Center	North-East	South-East	South-Mutenia	Bucharest-Ilfov	South-West Oltenia	West
2020s	Maize	7.6%	6.8%	5.6%	-2.0%	-1.0%	-1.2%	4.0%	5.7%
	Barley	3.1%	2.8%	2.4%	1.6%	0.5%	0.5%	1.5%	0.8%
	Potato	0.2%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%
	Soybean	2.7%	3.0%	2.4%	1.4%	1.1%	1.1%	1.7%	2.1%
	Sugarbeet	1.7%	2.1%	9.5%	2.5%	-6.7%	-7.0%	12.9%	2.5%
	Sunflower	0.2%	1.9%	1.5%	1.1%	0.6%	0.6%	1.0%	0.3%
	Wheat	10.2%	8.0%	7.9%	8.0%	7.4%	7.3%	7.7%	7.3%
	Tomato	-0.1%	2.5%	-3.8%	-0.9%	0.5%	0.3%	13.2%	0.5%
	Alfalfa	12.2%	11.7%	11.1%	7.3%	5.2%	5.1%	7.8%	9.3%
2030s	Maize	4.6%	4.7%	4.2%	-2.2%	-1.5%	-1.7%	3.3%	3.5%
	Barley	5.3%	5.2%	4.0%	2.9%	2.5%	2.5%	3.9%	4.9%
	Potato	0.2%	0.2%	0.1%	0.0%	-0.2%	-0.2%	0.0%	0.1%
	Soybean	1.9%	2.2%	1.9%	1.2%	0.7%	0.7%	1.3%	1.5%
	Sugarbeet	1.1%	0.6%	9.5%	1.0%	-8.7%	-9.0%	9.2%	1.5%
	Sunflower	-1.3%	1.3%	1.2%	1.6%	0.6%	0.6%	0.8%	-0.5%
	Wheat	12.0%	8.8%	8.3%	8.3%	8.2%	8.2%	8.6%	8.5%
	Tomato	-0.1%	2.5%	-2.9%	-0.8%	-0.1%	-0.3%	13.0%	0.5%
	Alfalfa	8.5%	9.8%	8.4%	6.9%	5.9%	5.8%	7.5%	7.1%
2040s	Maize	10.0%	10.2%	8.0%	-6.0%	-5.2%	-5.6%	6.4%	7.7%
	Barley	7.7%	8.4%	8.2%	5.9%	4.8%	4.7%	5.6%	6.2%
	Potato	0.2%	0.2%	0.1%	0.0%	-0.2%	-0.2%	0.0%	0.1%
	Soybean	3.8%	4.1%	3.1%	1.8%	1.4%	1.4%	2.3%	2.9%
	Sugarbeet	4.3%	5.2%	13.2%	-1.2%	-13.4%	-13.9%	6.4%	4.5%
	Sunflower	-3.0%	2.4%	1.7%	-0.5%	0.5%	0.4%	1.2%	-1.3%
	Wheat	16.5%	13.2%	13.3%	12.5%	11.6%	11.5%	11.9%	12.7%
	Tomato	-0.1%	2.0%	-9.2%	-3.2%	-0.6%	-0.8%	12.8%	0.5%
	Alfalfa	19.7%	22.0%	18.6%	14.1%	11.7%	11.5%	15.2%	16.0%

Source: World Bank Team and Industrial Economics analysis

TABLE a-4 percent change in irrigated yields under the MIrOC-8.5 scenario by crop, period, and administrative region

Period	Crop	Change in Irrigated Yields under MIROC-ESM-rcp85							
		North-West	Center	North-East	South-East	South-Mutenia	Bucharest-Ilfov	South-West Oltenia	West
2020s	Maize	13.0%	12.9%	10.5%	-1.5%	4.2%	4.6%	7.8%	9.8%
	Barley	8.9%	8.6%	5.7%	5.4%	4.9%	4.8%	6.1%	7.8%
	Potato	-3.3%	0.3%	0.3%	0.1%	0.1%	0.1%	0.1%	0.1%
	Soybean	1.8%	4.1%	3.6%	2.1%	1.6%	1.5%	2.2%	3.0%
	Sugarbeet	1.5%	5.2%	4.1%	7.6%	3.0%	2.9%	25.6%	5.0%
	Sunflower	-5.2%	3.2%	2.3%	-1.2%	1.1%	1.0%	1.4%	-3.6%
	Wheat	17.4%	11.9%	11.8%	11.2%	9.8%	9.7%	11.1%	13.1%
	Tomato	-4.0%	2.1%	-14.7%	-4.2%	0.4%	0.2%	13.3%	0.7%
	Alfalfa	26.7%	27.5%	25.6%	17.7%	13.5%	13.1%	18.6%	21.5%
2030s	Maize	15.5%	16.2%	12.4%	-0.8%	5.0%	5.4%	9.3%	11.5%
	Barley	10.9%	11.2%	4.8%	6.5%	6.6%	6.5%	8.2%	9.1%
	Potato	-5.5%	0.2%	0.1%	-0.1%	-0.2%	-0.2%	0.1%	0.1%
	Soybean	0.4%	4.5%	3.4%	1.9%	1.4%	1.3%	2.4%	3.0%
	Sugarbeet	-1.6%	7.5%	1.4%	6.8%	3.0%	2.9%	27.0%	6.3%
	Sunflower	-6.4%	3.2%	2.2%	-1.9%	0.8%	0.7%	1.1%	-6.6%
	Wheat	24.9%	19.1%	18.4%	17.6%	16.0%	15.9%	17.6%	20.3%
	Tomato	-7.4%	1.6%	-21.4%	-6.5%	-0.2%	-0.4%	12.9%	0.2%
	Alfalfa	34.5%	37.7%	33.4%	24.7%	20.4%	20.0%	25.6%	28.2%
2040s	Maize	17.9%	19.1%	14.4%	-0.7%	5.7%	6.2%	10.6%	13.1%
	Barley	13.7%	14.7%	7.9%	8.9%	8.9%	8.7%	10.3%	11.6%
	Potato	-6.5%	0.3%	0.2%	-0.1%	-0.3%	-0.3%	0.0%	0.1%
	Soybean	-0.6%	5.3%	4.1%	2.2%	1.5%	1.4%	2.8%	3.6%
	Sugarbeet	-3.3%	9.5%	-0.2%	6.9%	3.9%	3.8%	28.9%	7.9%
	Sunflower	-13.1%	3.5%	2.2%	-2.7%	0.5%	0.5%	0.9%	-11.9%
	Wheat	31.1%	23.7%	24.3%	23.3%	21.2%	21.1%	21.8%	24.4%
	Tomato	-10.0%	1.0%	-24.2%	-7.6%	-0.6%	-0.8%	12.6%	0.1%
	Alfalfa	42.5%	47.0%	42.4%	31.3%	26.2%	25.6%	31.6%	34.4%

Source: World Bank Team and Industrial Economics analysis