WPS7697

Policy Research Working Paper 7697

Long-Term Energy Demand Forecasting in Romania

Modeling Approach

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June 2016

Abstract

This study develops an end-use energy demand analysis model for Romania to project energy demand by sector and end-use for 2015–50. The study finds that Romania's energy demand in 2050 would be 34 percent higher than the level in 2013. The industry sector would be the largest final energy-consuming sector, surpassing the residential sector from 2025 onward. The services sector would exhibit the fastest growth of energy consumption in line with the expected structural change from manufacturing to services. Although population in the country is projected to drop by 7 percent in 2050 from the 2013 level, electricity demand would increase by 46 percent over the same period, because of increased household income and the expanded service sector, which is relatively electricity intensive. Still, per capita electricity consumption in Romania will be about half the European Union 28 average. At the end-use level, thermal processes in the industry sector, space heating in the residential and services sectors, and road transportation in the transport sector would be dominant throughout the study period. The study also shows that improvement of energy efficiency in the heating system would be the main channel to cut energy demand in the country.

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Long-Term Energy Demand Forecasting in Romania: An End-Use Demand Modeling Approach[#]

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Key words: Energy demand, end-use modeling, demand forecasting, climate change, Romania

JEL Classification: Q41, Q47

[#] This study builds on the work carried out under 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 World Bank on July 23, 2013. The authors would like to thank Erika Jorgenson, Feng Liu, Jian Xie, Kulsum Ahmad, Mike Toman, Morgan Bazilian and participants of several workshops organized in Bucharest in 2013-2015 period for their valuable comments and suggestions. The authors would also like to thank country experts from Ministry of Environment Waters and Forest (MEMW) and Ministry of Energy (MOE) of Romania, for their constructive comments and invaluable insights in developing EEDA model for Romania. We acknowledge the financial support from the European Union, Romanian Government and the World Bank.

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1. Introduction

Romania, with a population of 20 million, is the eleventh largest economy in the 28 member states of the European Union (EU-28). While the country, like other Eastern European economies, experienced economic downturn in the early 1990s during the political and economic transition, it observed an economic recovery soon in 1993. The entry into the EU in 2007 further accelerated growth, although it was badly hit by the 2009-10 financial crisis. Between 1995 and 2013, Romania's per capita income increased by 73%, more than twice as fast as Germany (28%) and the EU-28 average (30%). Over the past decade, the country's real gross domestic product (GDP) and disposable household income per capita grew on average by 3.5% and 7.2% per year respectively, well above the rate of the EU-28 as a whole (Eurostat, 2015a).[1] Despite the impressive economic growth, the current levels of per capita GDP and energy consumption in Romania fall much below that of most other countries in the EU.

As the Romanian economy expands and households' incomes rise, more energy would be needed to satisfy the growing demand. The average monthly household expenditure on non-food goods, which currently represents 21% of the total expenditure, has increased by twofold (8% per year) between 2005 and 2013 (INS, 2015a). The household ownership of refrigerators grew on average by 5% per year, followed by vacuum cleaners (2.8%), washing machines (2.2%), televisions (1.8%), and passenger cars (1%) during the 2008-2013 period (INS, 2015b). If no action is taken, increasing energy demand will pose a challenge to Romania to comply with its greenhouse gas (GHG) obligations set forth by the EU with its member states.

[1] Despite a major slump in economic growth in 2009 (−7.1%) and 2010 (−0.8%), due to global economic and financial crisis, Romania's real GDP grew on average by 7% per year during 2003−2008 and by 2% per year during 2011−2014.

The EU has set a number of short- and long- term quantitative climate and energy targets for its member countries, notably 20-20-20 climate and energy targets, 2030 framework for climate and energy policies and roadmap for moving to a low carbon economy in 2050. 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. Further, based on the assessment of 2014 national reform and convergence programs for Romania, EU commission recommended energy program that focuses on improving efficiency of industries, thermal insulation of buildings and the rehabilitation of district heating systems (EU, 2014a). There exists only a limited number of empirical studies that examine future energy demand in Romania. A recent report (World Bank, 2014) expects a significant increase in final energy demand (FED), particularly in transport and services sectors. Using econometric techniques, Bianco et al. (2010) estimate long-run GDP and price elasticities of non-residential electricity consumption in Romania and finds that these elasticity values are quite low, i.e., 0.496 (income elasticity) and −0.274 (price elasticity). The sixth National Communication of Romania to the United Nations Framework Convention on Climate Change (MECC, 2013) projects that the country's FED would increase by 28% between 2010 and 2030, and that residential and industry sectors are responsible for over 60% of this increase. Likewise, using PRIMES model, EU (2014b) projects country's FED to grow by 21% between 2010 and 2050, with three-fourth of this increase is coming from industry and transport sectors. Analyzing historical FED over the past decade, ICEMENERG and ANRE (2012) find that country's demand for energy in industry sector has declined, mainly due to shifting away from energy-intensive manufacturing industries, while it has increased in the rest of the sectors, thereby confirming a structural change of the economy. However, these studies lack analysis of

detailed long-term projections of energy demand at sub-sector and end-use levels Understanding of these detailed energy demand evolution is critical in implementing EU recommended energy and climate strategies in the country. In this study, we develop an end-use bottom-up model to examine the long-term energy demand at sub-sector level for Romania.

2. Current Energy Demand Structure in Romania

Romania's total FED was 21.8 Mtoe in 2013. Since 2009, the residential sector surpassed the industry sector as the largest consumer of final energy. The residential sector accounted for 36% of total FED in 2013, reflecting high heating demands in cold climate and an ageing housing stock. The country's share of residential sector in total FED in the same year ranked the highest among EU-28 countries (Eurostat, 2015b). The industry sector including agriculture (31%), transport sector (24%) and the services sector (9%) are the second, third and fourth largest consumers of final energy. In Romania, FED has been in downward trend over the past decade, falling by 12% between 2004 and 2013. This is mainly due to structural changes and declining energy intensity in the industry sector. By fuel types, oil products accounted for 30% of total FED, with more than 76% consumed by the transport sector. Natural gas, mainly used in industry and residential sectors, accounted for 27%, while biomass and renewable wastes accounted for 17%, with more than 85% used in residential sector. Likewise, electricity accounted for 16%, followed by district heat (6%) and coal (3%) in total FED in 2013(EU, 2015).

In per capita terms, country's demand for electricity and energy are still much lower as compared to the respective average values for EU-28. For example, in 2013, Romanians consumed about one-third of electricity to that of Germans and about 37% to that of EU-28 average (Table 1). Likewise, country's per capita FED (1,087 kgoe/capita) is less than half of

Germany and EU-28 average in the same year. In addition, the number of passenger cars per thousand people in Romania was 243 in 2013, much lower compared to Germany (543) and the EU-28 average (491) (Table 1). As economy grows and income rises, the number of passenger cars and transport energy demand is expected to grow in the foreseeable future.

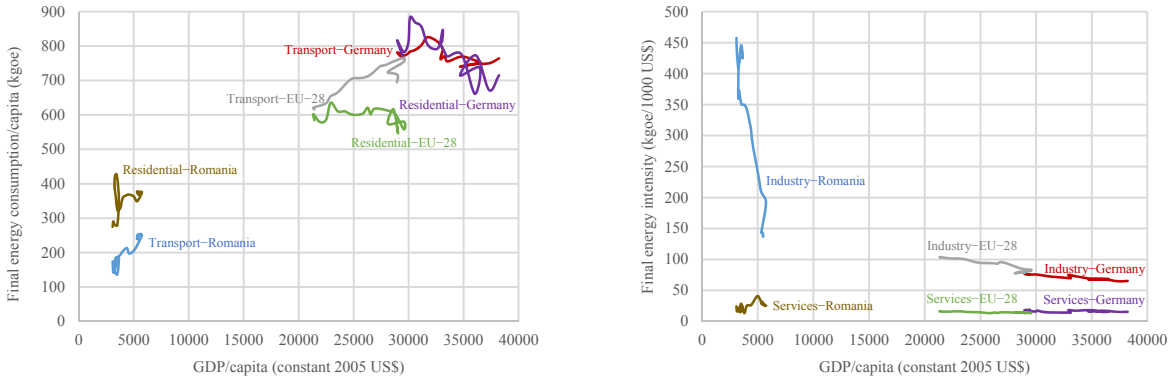

Fig. 1. Relation between income and final energy demand by sector in per capita term (left), and income per capita and final energy intensity by sector (right) in Romania, Germany and EU-28 during 1992-2012 period. *Source*: World Bank (2015) and Eurostat (2015b).

There is strong correlation between the levels of sectoral FED and income. For instance, in per capita terms, FED of both residential and transport sectors and income in Romania is much lower compared to Germany and the EU-28 average during 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-28 average during 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 Romania when compared with high-income countries like Germany and the EU-28 average. More specifically, average final energy intensity of industry in the country declined significantly by 70% during the same period.

Table 1
Overview of selected historical socio-economic and final energy consumption indicators in Romania, Germany and EU-28

	Romania			Germany			EU-28		
	1992	2013	% chg. 92-13	1992	2013	% chg. 92-13	1992	2013	% chg. 92-13
GDP per capita (PPP, constant 2011 US$)	10,366[a]	18,182	75	32,919[a]	43,444	32	25,603[a]	36,925	44
Urban population (%of total)	54	54	0	73	75	3	71	76	7
Final electricity consumption/capita (kWh)	1,818	2,033	12	5,595	6,310	13	4,527	5,450	20
Final energy consumption (FED)/capita (kgoe)	1,192	1,087	-9	2,753	2,649	-4	2,221	2,179	-2
Industry, FED (% of total)	52	29	-44	29	28	-2	31	25	-19
Transport, FED (% of total)	15	24	66	28	29	3	28	32	13
Residential, FED (% of total)	23	35	54	28	27	-2	26	27	1
Services, FED (% of total)	2	8	255	13	16	22	11	14	30
Others, FED (% of total)	8	3	-62	2	<1	-97	4	3	-34
Final energy intensity (toe/million 2010 €)	629	243	-61	165	121	-27	170	129	-24
Import dependency (%)	30	19	-37	55	63	15	46	53	16
Passenger cars per 1000 people	70	235	236	480	543	13	361	491	36
Mean consumption expenditure per HH (€)	1,373[b]	5,514[c]	302	25,228[b]	29,330[c]	16		25,010[c]	

Note: [a] Data from 1995; b data from 1999; c data from 2010.
Source: World Bank (2015) and Eurostat (2015b, c, d).

3. Methodology

Normally two types of techniques are used for energy demand forecasting: an econometric approach, or an end-use accounting approach. The first approach is often used at the aggregated level such as total energy demand. In this approach the statistical relationship between energy consumption and macroeconomic variables, such as GDP is established based on historical data and the same relationship is used to forecast future energy demand. Such an approach is not applicable when detailed energy demand forecasting is needed at the end-use level because long time series of historical data on detailed end-use energy consumption are not available. An end-use accounting model, which does not need time series data, but relies on detailed data for a reference or base year, is normally employed for forecasting end-use energy demand at various sectoral levels.[2] For this study, we also developed an end-use energy forecasting approach for Romania. For a given end-use in a given sector, the main elements of energy demand in our model are activity, structure and intensity. The drivers of future energy demand are the scenarios.

Four energy consuming sectors (residential, services, industry and transport) are considered in the model. The services sector is further divided into 7 sub-sectors by type of buildings: office, educational building, hospital, hotel and restaurant, sport facilities, wholesale and retail store, and others (not classified elsewhere). Industry is divided into 4 sub-sectors: agriculture, construction, mining and quarrying, and manufacturing. The manufacturing sub-sector is further sub divided into 10 manufacturing industry types based on economic activities in the European Community classification (EC, 2008). Transport is further sub-divided into 5 sub-sectors (road, rail, air, inland waterways, maritime and pipeline) based on mode of transportation. The residential sector could be divided between rural and urban types but we did not know due to

[2] For more discussion on energy demand modeling, please refer to Bhattacharyya and Timilsina (2010).

lack of data. The sector, sub-sector and end-use classifications used in the model are presented in Figure 2.

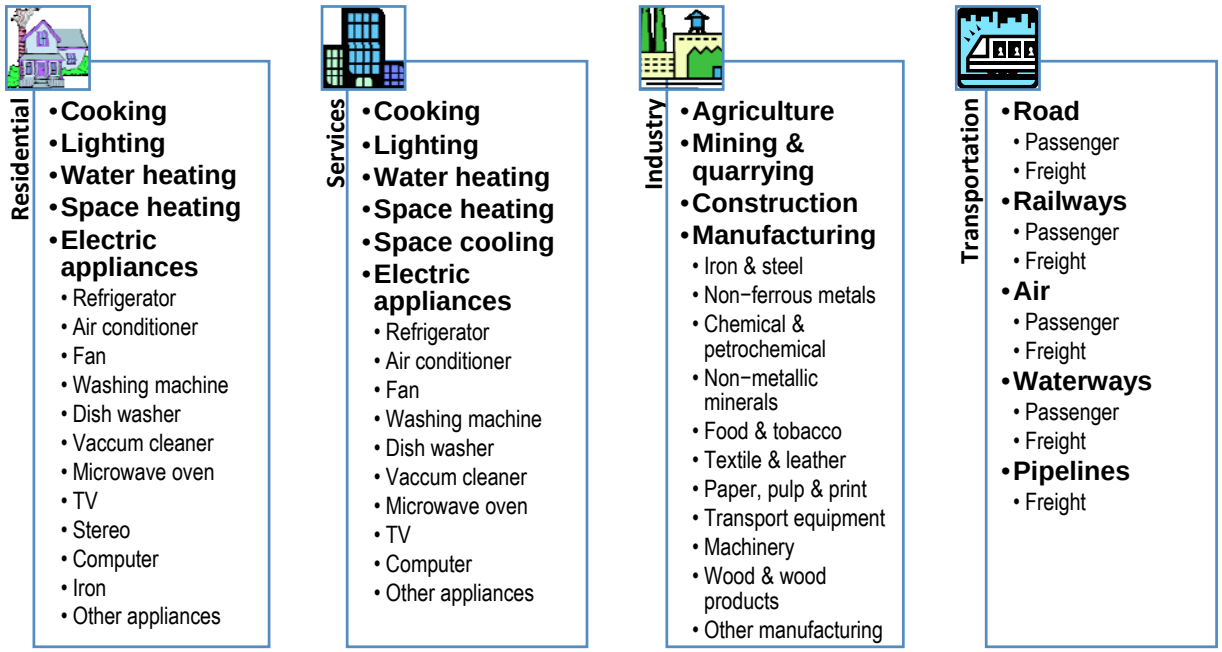

Fig. 2. Simplified classification of sector, sub-sector and end-use classification in Romania.

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. Demand of energy use by each sub-sector and by end-use is calculated using the following general equations:

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

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

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-use, respectively. For example, residential sector end-uses include space heating, water heating, air-

conditioning, cooking, lighting and use of electric appliances. Activity level may be value-added or domestic production for industry sector, domestic demand and commercial floor area for services sector, population, living floor area and ownership of electrical appliances for residential sector, and passenger kilometer (pkm) or ton-kilometer (tkm) for transport sector. Likewise, sectoral structure is the mix of activities within a sector and sub-sectors, such as the share of domestic production in manufacturing industries, and energy intensity is the energy use per unit of activity, such as energy use per domestic production for manufacturing industries. Depending on data availability, breakdown of energy demand by sub-sectors and end-uses for each sector are different. Note that demand for energy is not disaggregated by fuel types. The fuel-mix largely depends on the technological possibilities of supply and their relative prices, which are outside the scope of this paper. However, due to its non-substitutability nature and importance, demand for electricity by sector is calculated separately in FED.

In addition to estimating transport energy demand, activity-structure-intensity-fuel (ASIF) framework approach is used for calculating travel demand. The following equations are used:

$$TD_{k,T}(t) = \sum_j TD_{j,k,T}(t) = \sum_j TDD_{j,k,T}(t) \cdot TI_{j,k,T}(t)\,, \qquad j \in T \tag{3}$$

$$TI_{j,k,T}(t) = TI_{j,k,T}(t-n) \cdot \left(1 + R_{j,k,T}(t)\right)^n \tag{4}$$

$$R_{j,k,T}(t) = TE_{j,k,T}(t) + PE_{j,k,T}(t) + RE_{j,k,T}(t) \tag{5}$$

where *TD* is travel demand, *TDD* is transport domestic demand (activity variable), *TI* is transport mobility intensity, *R* is growth rate of overall change in mobility intensity, *TE* is growth rate of travel efficiency improvement change, *PE* is growth rate of population change, *RE* is growth rate of rebound effect change and *T* is transport sector, *t* is time period and *n* is number of period. The small cap subscripts *j* and *k* represent transport mode (e.g., air, road, rail, water or pipeline) and activity type (passenger or freight), respectively. In this framework, travel demand is the function

of mode, mobility intensity, travel efficiency, population change and rebound effect. Passenger travel demand is measured in pkm or number of passengers, and freight travel demand is measured in tkm or ton. In Romania, land transport includes road, rail and pipeline, water transport includes maritime and inland waterways, and air transport includes aircrafts. Excluding pipeline, each of these transport modes are further sub-divided by activity (e.g., passenger and freight). Since road dominates Romania's transportation system, it is further sub-divided by private and public road transport.

4. Data, Scenario Description and Key Assumptions

Required data for the study are grouped under three categories: energy, socio-economic and demographic, and technological data. The primary source of these data are Romania's National Institute of Statistics (INS), EU's Eurostat, the World Bank's World Development Indicators, International Energy Institute (IEA)'s energy balances, and Building Performance Institute (BPIE)'s buildings data. Since none of these publications provide complete dataset, additional dataset are compiled from Ministry of Environment and Climate Change (MMSC)'s sixth National Communication on Climate Change report (MECC, 2013), International Telecommunication Union (ITU)'s Measuring the Information Society 2014 report (ITU, 2014), ENTRANZE project report (Atanasiu et al., 2012) and EU's JRC Scientific and Policy reports (Bertoldi et al., 2012; Pardo et al., 2012) , in particular, for calibrating base year and activity parameters used in projecting energy demand.

The starting year of the analysis is 2013 (base year) and the projection is made through the year 2050 with 5 years of interval starting from 2015. Three scenarios are considered: baseline, low demand and high demand scenarios. These scenarios are differentiated primarily by their

underlying assumptions about socio-economic and technological factors. The baseline scenario takes into account the current trends on socio-economic development, sectoral energy-use patterns and technological progress. It reflects the path of future energy demand given a continuation of current trends and policies.

To illustrate increase in end-use energy demand (optimistic pathway) with respect to the baseline scenario, a high scenario is constructed. This scenario is characterized by the Romanian economy and population growing faster than the baseline scenario. The high scenario also reflects households with high home electric appliances and private vehicle ownership, and more passenger and freight transport mobility. Overall, in this scenario, the general development mode of Romanian economy is optimistic. In contrast, to illustrate decrease in end-use energy demand (pessimistic pathway) with respect to baseline scenario, a low scenario is constructed. In this scenario, economic and population growth are slightly lower compared to baseline scenario. Due to slower economic growth, domestic production and domestic demand are also lower. The selected key driving variables under the baseline and two alternative scenarios are summarized in Table 2.

Table 2
Key driving variables under the baseline, high demand and low demand scenarios for selected years (Index 2013=100, unless otherwise stated)

	Base case			High			Low		
	2020	2030	2050	2020	2030	2050	2020	2030	2050
Population [a]	99	95	90	99	96	91	98	95	87
GDP	127	163	233	133	171	244	122	156	223
Residential effective floor space	103	107	113	105	112	124	102	105	108
Appliances ownership									
Refrigerator/freezer	108	118	140	111	128	160	104	109	120
Washing machine	105	112	126	105	112	126	105	112	126
Television	107	118	138	107	118	138	107	118	138
Computer	142	204	327	142	204	327	142	204	327
Others	112	129	163	112	129	163	112	129	163
No. of residential dwellings with AC	135	189	285	135	190	290	135	187	275
Services buildings floor space	119	143	192	124	156	232	115	131	160
Offices (public and private)	113	132	163	117	144	197	108	120	135
Educational buildings	113	132	163	117	144	197	108	120	135
Hospitals	126	155	227	131	169	273	122	142	188
Hotels and restaurants	113	132	163	117	144	197	108	120	135
Sport facilities	126	155	227	131	169	273	122	142	188
Wholesale and retail trade	119	143	192	124	156	232	115	131	160
Others (n.e.c.)									
Services buildings demolition rate (%)	1.3	2.3	1.0	1.3	2.3	1.0	1.3	2.3	1.0
Services buildings occupancy rate (%)	85	85	85	85	85	85	85	85	85
Industrial domestic production									
Agriculture	107	119	130	111	129	156	103	109	109
Manufacturing									
Iron and steel	98	104	107	99	110	125	92	93	89
Chemical and petrochemical	127	170	279	140	200	371	131	170	267
Non-metallic minerals	115	136	162	115	142	188	107	120	133
Food and tobacco	122	143	189	128	158	231	120	134	165
Textile and leather	122	143	189	128	158	231	120	134	165
Paper, pulp and print	100	107	122	102	115	145	95	97	105
Transport equipment	134	196	311	139	212	371	130	180	261
Machinery	136	204	330	140	221	394	131	187	278
Wood and wood products	122	143	189	128	158	231	120	134	165
Other manufacturing (n.e.c.)	111	135	180	115	140	208	107	118	145
Mining and quarrying	102	111	129	105	119	147	98	101	102
Construction	106	152	235	108	162	278	101	137	197
Transport domestic demand									
Transport (Air)	109	127	201	115	134	211	105	122	193
Transport (Road-Freight)	143	193	286	150	203	301	137	185	275
Transport (Road -Passenger)	112	142	222	118	149	234	108	136	214
Transport (Rail -Freight)	102	121	194	107	127	204	98	116	186
Transport (Rail -Passenger)	116	147	218	122	154	229	111	141	210
Transport (Water - Freight)	97	111	194	102	116	204	93	106	187
Transport (Water - Passenger)	98	113	208	103	119	218	94	108	199
Gas pipeline	112	126	142	117	132	149	107	121	136
Rebound effect	103	107	115	103	107	115	103	107	115

Note: [a] Based on Eurostat's main variant (baseline), high life expectancy variant (high) and low fertility variant (low) population projection.

5. Results and Discussion

5.1. National level final energy demand

In this section, results of FED by sector are discussed under three scenarios. Note that FED is presented in two broad categories: electric and non-electric. In the baseline scenario, demand for electricity is projected to increase by an annual average of 1.3% (Table 3). Industry remains the single largest electricity user, accounting for almost half of total electricity demand over the projected period. By 2050, quantity of electricity demand in services, one of the fastest growing sectors in the country, is projected to be about the same as that of residential sector. Despite transport's share in total electricity demand is small (3.5%) in 2050, this sector exhibits the fastest rate of expansion in percentage terms at an average rate of 2% per year, primarily due to increasing use of electric vehicles.

Table 3
Electricity demand by sector in the baseline scenario, 2013-2050 (ktoe)

	2013	2015	2020	2025	2030	2035	2040	2045	2050
Industry	1,689	1,703	1,869	2,060	2,234	2,393	2,570	2,721	2,867
Residential	1,023	1,035	1,086	1,132	1,170	1,211	1,258	1,303	1,325
Services	685	719	810	880	954	1,035	1,119	1,196	1,276
Transport	96	100	110	122	135	149	164	181	200
Total	3,493	3,557	3,875	4,194	4,493	4,788	5,111	5,401	5,668

However, demand for electricity is markedly different across the scenarios. In high scenario, which reflects optimistic socio-economic development in the country, electricity demand is projected to grow on average by 1.8% per year during 2013-2050, reaching almost 6,681 ktoe in 2050, an increase of 91% from 2013 value. Electricity demand expands much more rapidly in high scenario compared to baseline scenario to a level in 2050 that is 18% higher (Figure 3). In contrast, electricity demand expands much slower in low scenario, which reflects pessimistic

socio-economic development in the country, at an average rate of 0.9% per year to a level in 2050 that is 13% lower from the baseline.

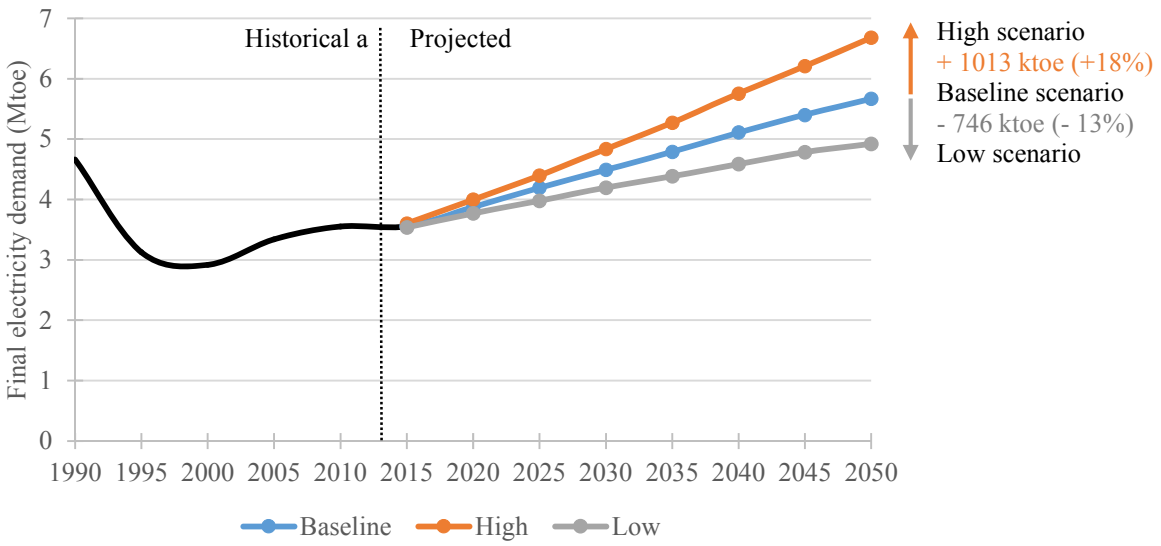

Fig. 3. Historical and projected final electricity demand by scenario in Romania, 1990-2050.
Note: [a] historical data are taken from INS (2015c).

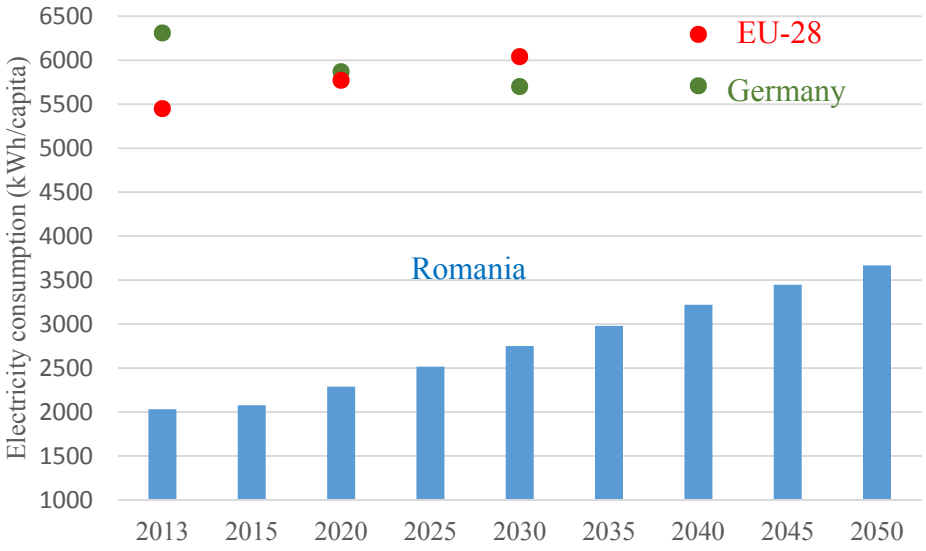

Fig. 4. Final electricity consumption per capita in the baseline scenario, 2013-2050.
Note: Data for EU-28 and Germany are taken from Eurostat (2015b) and IEA (2013, 2014)

As a result of rising demand for electricity and declining population in the country over the projection period, per capita final electricity consumption is projected to increase. For example, in the baseline, it is projected to increase from 2,033 kWh in 2013 to 3,698 kWh in 2050, an increase of 82% (Figure 4). However, the differences in per capita electricity consumption in Romania and other advanced countries in the EU remain very large. In 2040, per capita electricity consumption in Romania amounts to 3,239 kWh, while it is 5,710 kWh in Germany and 6,294 kWh in EU-28 (average). Note that Romania's projected per capita electricity consumption in 2050 is much lower than that of Germany and average EU-28 in 2013. As a reference, if electricity use by each Romanian increased to the 2013 level of German, Romania's electricity use would increase by threefold.

Table 4
Final non-electric energy demand by sector in the baseline scenario, 2013-2050 (ktoe)

	2013	2015	2020	2025	2030	2035	2040	2045	2050
Industry	5,078	5,118	5,507	5,941	6,353	6,723	7,109	7,397	7,669
Residential	6,699	6,691	6,716	6,716	6,676	6,659	6,667	6,670	6,586
Services	1,101	1,164	1,316	1,427	1,541	1,677	1,818	1,946	2,077
Transport	5,182	5,279	5,531	5,740	5,957	6,199	6,452	6,620	6,793
Total	18,060	18,252	19,070	19,824	20,527	21,258	22,046	22,633	23,125

As economy grows, Romania's final non-electric energy demand is also projected to increase. Between 2013 and 2050, total final non-electric energy demand is projected to increase on average by 0.7% per year, reaching 23,125 ktoe in 2050, in the baseline (Table 4). The share of industry in total non-electric energy demand, increases gradually, from 28% in 2013 to 33% in 2050. In contrast, the share of residential in the total non-electric energy demand is slightly declined over the projected period, at an average rate of 0.05% per year, mainly due to declining population. By 2035, industrial non-electric energy demand surpasses the residential sector

mainly due to strong growth in overall industrial production. Despite declining population and improvement in vehicle fuel-economy during the projected period, rising number of motor vehicles and increasing economic activities will lead to rise in demand for energy. Transport sector's non-electric energy demand is projected to increase steadily, from 5,182 ktoe in 2013 to 6,793 ktoe in 2050, an increase of annual average of 0.73%. Although services sector's share in total non-electric energy demand is small (13%) in 2050, this sector has the fastest rate of growth in percentage terms, at an average rate of 1.7% per year reflecting the structural change in the country from manufacturing to service sectors .

Fig. 5. Changes in thermal energy demand by sector in high and low scenario compared to baseline scenario.

The demand for final non-electric energy and travel are quite different across the scenarios. In the high scenario, the changes in industry's non-electric energy demand compared to the baseline scenario, are projected to increase at much higher percentage rate than in other energy consuming sectors. For example, between 2020 and 2050, non-electric energy demand in industry increases from 5% to 23%, while it increases from 4% to 20% in services, 2% to 8% in

residential and 1% to 7% in transport (Figure 5). In the low scenario, changes in the services sector's energy demand is projected to decrease at much higher rate than in other sectors. For example, the thermal energy demand in services decreases from 4% in 2020 to 17% in 2050, while it decreases from 3% to 12% in industry, 1% to 9% in residential and 1% to 4% in transport over the same time period.

Although comparing energy demand forecast between studies is not straightforward, due to different methodologies and assumptions, we have compared our study with EU's *energy, transport and GHG emissions trends to 2050* (EU, 2014b), Ministry of Environment and Climate Change's *sixth national commutation* (MECC, 2013) and the National Commission for Prognosis (CNP)'s *energy balance forecast* (CNP, 2015) for Romania's final energy demand. The comparison suggests some similarities in magnitude of final energy demand. For example, the EU estimate of total FED in 2050 is 27.3 Mtoe compared to our estimate of 28.8 Mtoe. Likewise, EU estimate of total final electricity demand in 2050 is 5.7 Mtoe compared to this study estimate of 5.8 Mtoe. The possible reason for slightly lower EU estimate of final energy and electricity demand compared to this study is the assumption of country's lower economic growth in EU study. Further, the MECC estimate of total FED without any measure (28 Mtoe) in 2030, the latest year reported, is slightly higher compared to this study in the baseline scenario (25 Mtoe), possibly due to higher economic growth assumption. The CNP made projection of FED by sector up to year 2018. For comparison, the CNP's FED estimate of residential (7.8 Mtoe), industry (7.1 Mtoe) and transport (5.5Mtoe) sectors in 2015 is similar to this study in magnitude.

5.2. 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 2013, this sector accounted for 35% of total final energy consumption, using natural gas, LPG and solid biomass as the major fuels. In the baseline, residential FED is projected to grow on average 0.1% per year from 2013 to 2050 to reach 7,911 ktoe (Table 5). The residential energy demand varies markedly in the alternative scenarios. For example, it is projected to increase from 7,722 ktoe in 2013 to 8,547 ktoe in 2050 in high scenario, at an average of 0.3% per year, it is projected to decrease (0.2% per year) in low scenario, to reach 7,202 ktoe in 2050. Non-electric energy demand, mainly used for space and water heating, contributes the most in total residential FED in all three scenarios. The contribution of electricity, mainly used for running electric appliances and lighting, is relatively small in total residential FED in all three scenarios.

Table 5
Residential sector end-use energy demand by scenario, 2013-2050 (ktoe)

	2013	Baseline			High			Low		
		2020	2030	2050	2020	2030	2050	2020	2030	2050
Space heating [a]	4,638	4,707	4,777	4,861	4,814	5,023	5,380	4,624	4,551	4,310
Air conditioning	31	42	59	89	42	59	90	42	58	86
Water heating	1,299	1,267	1,201	1,094	1,269	1,207	1,113	1,266	1,193	1,060
Cooking	790	772	731	667	772	735	679	771	727	646
Lighting	218	223	231	244	228	243	270	219	220	217
Electric appliances	746	791	849	955	801	873	1014	782	823	884
Refrigerator/freezer	240	248	256	279	257	278	325	239	235	230
Washing machine	118	120	122	127	120	123	129	120	122	122
Television	176	184	194	210	184	195	214	184	193	202
Computer	28	39	53	79	39	54	81	39	53	76
Other appliances	184	200	223	261	201	224	266	200	221	252
Total	7,722	7,802	7,847	7,911	7,926	8,140	8,547	7,704	7,573	7,202

Note: [a] climate corrected.

At the end-use level, space heating (climate corrected) is by far the largest energy consumer across all scenarios. In the baseline, space heating accounted for 60% of total residential FED in 2013 and it is projected to remain about the same during 2015-2050 period (Figure 6). In contrast, energy demand for water heating and cooking is projected to decline slightly both in absolute and percentage terms during 2015-2050 period. For example, energy demand for these two end-uses is projected to decline on average 0.5% per year in the baseline (Table 5). This is mainly due to the country's declining population and improvement in efficiency of heating and cooking devices during the projected period. It follows the similar trend in alternative scenarios, increasing in magnitude in the high scenario and decreasing in magnitude in the low scenario compared to the baseline scenario.

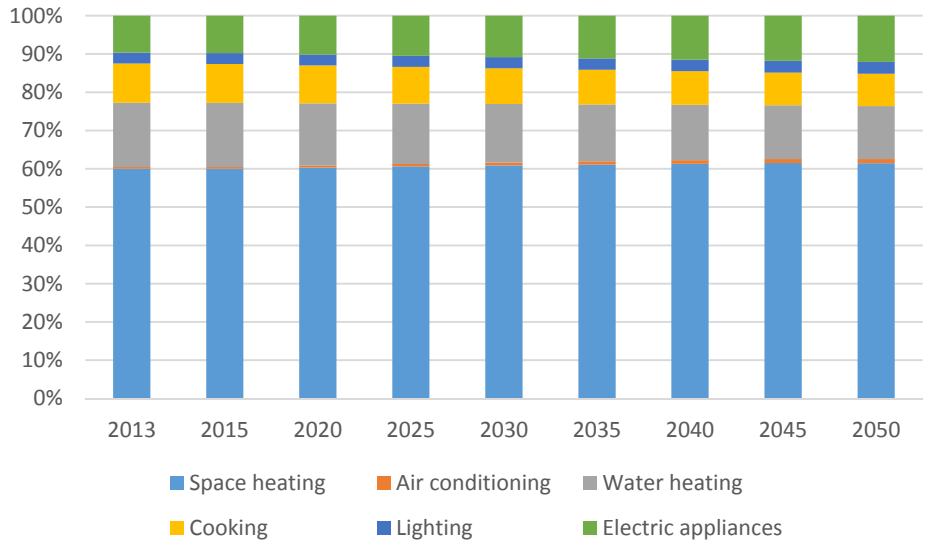

Fig. 6. Percentage share of end-uses in total residential final energy demand in the baseline scenario.

Space heating, followed by water heating and cooking, are the major end-use services in the residential sector. The highest share of energy requirements for 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.[3] Space heating therefore represents the largest opportunity to reduce residential energy demand, for example, by using more efficient heating equipment and by changing energy-mix. For space heating, natural gas and derived heat are commonly used in urban households, while solid biomass fuels including charcoal is commonly used in rural households. In 2013, about half of total energy used for residential space heating came from solid biomass, followed by natural gas (31%) and derived heat (18%) (Eurostat, 2015b). In the same year (2013), 80% of total residential energy is used for heating (space and water heating), 7% is used for cooking and the remaining 13% is used lighting and electric appliances including air conditioning.

As the economy grows and income rises, the use of household electrical appliances and corresponding demand for electricity are also projected to increase. For example, demand for electricity by electric appliances is projected to increase from 746 ktoe in 2013 to 955 ktoe in 2050, at an average rate of 0.7% per year in the baseline. In particular, residential use of refrigerators, washing machines and televisions combined accounts for 72% of electricity demand by electric appliances during the 2015-2050 period. Electricity demand for lighting is projected to increase at a slightly lower rate of 0.3% per year to reach 244 ktoe in 2050. Despite air conditioning's share in total residential energy demand is small (1%) in 2050, this residential end-use has the fastest rate of growth in percentage terms, at an average rate of 2.9% per year in the baseline scenario.

[3] Despite declining population during the 2013-2050 period, demand for heating energy is projected to increase mainly due to increase in size of living floor space in the country. For example, between 2013 and 2050, living floor space is projected to increase on average by 0.3% per year.

5.3. Services sector

The importance of the services sector for Romania's energy policy has grown significantly over the past decade. In 2013, services sector accounted for more than half of country's GDP and about 8% of total FED (INS, 2015c, d). Since 2002, energy demand has increased by 41% as a result of an average growth of 3.5% per year. This sector is also the most heterogeneous sector of the economy that includes wide range of energy consumers. Demand for energy by services is projected to grow at much higher rate than other energy consuming sectors in all three scenarios. For example, services total FED is projected to double from 1,785 ktoe in 2013 to 3,353 ktoe in 2050, at an average rate of 1.7% per year in the baseline (Table 6). Relative to the baseline scenario, it follows higher trends in the high scenario and lower trends in the low scenario.

Table 6
Services sub-sector end-use energy demand by scenario, 2013-2050 (ktoe)

	2013	Baseline			High			Low		
		2020	2030	2050	2020	2030	2050	2020	2030	2050
Space heating	840	1,006	1,179	1,594	1,046	1,287	1,919	968	1,080	1,322
Space cooling	94	113	135	188	117	147	227	108	123	156
Water heating	149	178	208	280	185	227	338	171	191	233
Lighting	231	273	326	437	284	356	527	263	299	363
Others	473	556	647	853	578	706	1,027	535	592	707
Total	1,785	2,126	2,495	3,353	2,210	2,724	4,038	2,045	2,285	2,781

Note: [b] Others include energy demand for cooking (mainly in hotel/restaurant) and electricity for appliances and lighting in public places.

At the end-use level, similar to the residential sector, services sector space heating is projected to account for most of the energy demand. In 2050, the share of space heating in total services FED accounts for 48% in the baseline, followed by others (25%), lighting (13), water heating (8%) and air cooling (6%). At the sub-sector level, excluding energy demand for others, whole sale and retail store, and office buildings combined accounts for more than half of services FED in all three scenarios during the projected period (Figure 7). Hotel and restaurant, hospital,

educational building, sports facility and n.e.c. (not elsewhere classified) sub-sectors account for remaining half of services energy demand in descending order during the projected period.

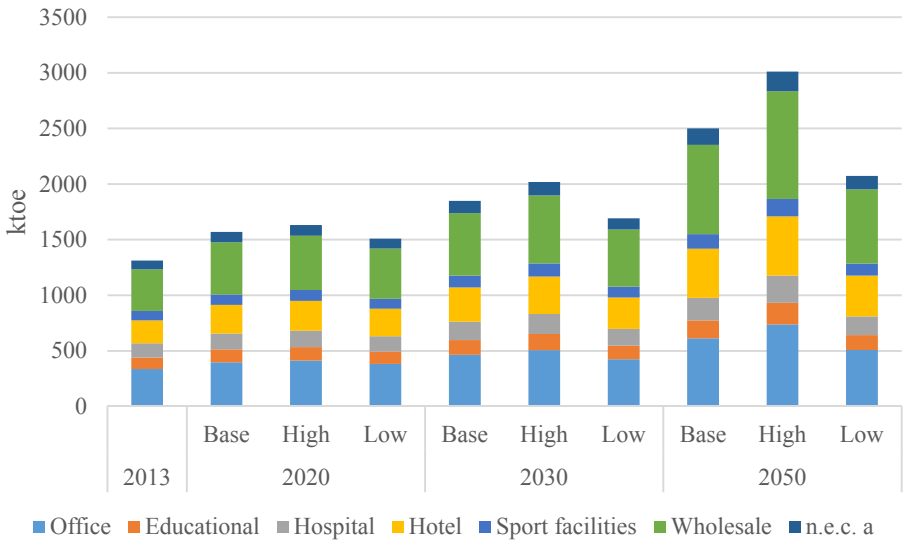

Fig. 7. Services sub-sector energy demand by scenario, 2013-2050.
Note: [a] n.e.c. include institutional buildings, warehouses and other non-specified service industries.

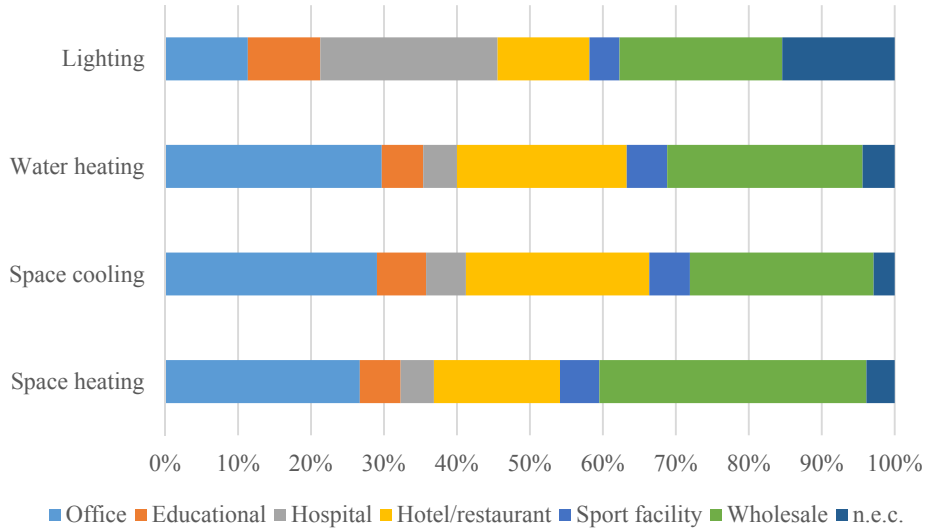

Fig. 8. Services end-use and sub-sector energy demand in the baseline scenario, 2050.

Likewise, in 2050, both at the end-use and sub-sector levels, the share of space heating is projected to account for the highest (37%) in wholesale and retail stores to the lowest (4%) in the

n.e.c. sub-sector (Figure 8). In the case of lighting, it accounts for the highest (24%) in hospitals to the lowest (4%) in the sport facility sub-sector in the baseline. This is followed by water heating, in the range of 4% in n.e.c. to 24% in hotel and restaurant, and space cooling, in the range of 3% in n.e.c. to 29% in offices in 2050.

5.4. Industry sector

Despite a sharp decline in industry's total FED since 1990, Romania remains heavily dependent on energy-intensive manufacturing industries. In 2013, about 87% of industry's total FED is consumed by manufacturing industries. In the same year, close to 70% of total manufacturing energy demand is consumed by a handful of energy intensive industries, such as iron and steel, chemical and petrochemical, and non-metallic minerals (Eurostat, 2015b). 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 are mainly used in chemical and petrochemical industries, and petroleum coke, natural gas and electricity are mainly used in non-metallic minerals industries.

The industry's total FED is projected to increase from 6,767 ktoe in 2013 to 10,536 ktoe in 2050, at an average rate of 1.2% per year, in the baseline (Table 7). Demand for electricity in this sector is projected to increase at much higher rate (1.4% per year) than the demand for non-electric energy (1.1% per year) in the baseline during 2015-2050 period. Note that electricity is used for only electric motors and others, while non-electric (thermal) energy is used for motive, thermal-electric and heat requirements. Relative to baseline scenario, the demand for industrial energy is projected to increase in the high scenario and decrease in the low scenario.

Table 7
Industry sub-sector and end-use final energy demand by scenario, 2013-2050 (ktoe)

	2013	Baseline			High			Low		
		2020	2030	2050	2020	2030	2050	2020	2030	2050
Electric motor	1,013	1,121	1,341	1,720	1,165	1,465	2,094	1,088	1,241	1,487
Agriculture	42	45	48	51	46	52	61	43	44	43
Manufacturing	932	1,036	1,240	1,596	1,078	1,357	1,947	1,006	1,149	1,383
Mining and quarrying	12	12	13	14	12	14	16	12	12	11
Construction	27	28	40	59	29	42	70	27	36	49
Others (electricity)	676	748	894	1,147	777	977	1,396	725	827	991
Agriculture	28	30	32	34	31	35	41	29	29	28
Manufacturing	621	691	827	1,064	718	904	1,298	671	766	922
Mining and quarrying	8	8	9	10	8	9	11	8	8	8
Construction	18	19	26	39	19	28	46	18	24	33
Motive/thermo-electric	537	577	707	916	592	761	1,088	553	644	767
Agriculture	253	268	294	316	277	319	378	258	269	265
Manufacturing	71	85	104	139	88	113	167	82	95	119
Mining and quarrying	20	20	22	25	21	24	29	20	20	20
Construction	193	203	286	436	207	307	514	193	260	364
Thermal energy	4,540	4,817	5,382	6,163	5,029	5951	7633	4,696	5,038	5,440
Agriculture	131	132	136	130	136	148	155	127	125	109
Manufacturing	4,251	4,634	5,286	6,303	4,857	5,867	7,833	4,537	4,969	5,586
Mining and quarrying	3	3	3	3	3	3	4	3	3	3
Construction	156	161	220	316	164	236	373	153	200	264
Total (industry)	6,767	7,376	8,587	10,536	7,695	9,457	12,942	7,185	8,009	9,206

At the end-use level, thermal (heat) energy use is projected to account for most of the energy demand in the industry sector during the projected period in all three scenarios. For example, in 2050, the share of thermal energy in total FED accounts for 64% in the baseline. This is followed by electric motor (16%), others (11%), and motive and thermal-electric power (9%) (Figure 9, right). At the sub-sector level, manufacturing industry is by far the largest end-user in terms of total industry energy use. In 2050, manufacturing industry is projected to account for 86% of total industry energy demand, followed by construction (8%), agriculture (5%) and mining and quarrying (1%) in the baseline (Figure 9, left).

In manufacturing industries, iron and steel, chemical and petrochemical, and non-metallic minerals combined are projected to account for two-thirds of total manufacturing energy demand

through the projection period in the baseline (Figure 10). The other notable manufacture sub-sectors include machinery, and food and tobacco. The share of these two sub-sectors combined in total manufacturing energy demand is projected to increase from 15% in 2013 to 22% in 2050 in the baseline. In absolute values, the top three energy consuming manufacturing sub-sectors are chemical and petrochemical (3,072 ktoe), iron and steel (1,424 ktoe) machinery (1,052 ktoe) and non-metallic minerals (1,015) in 2050.

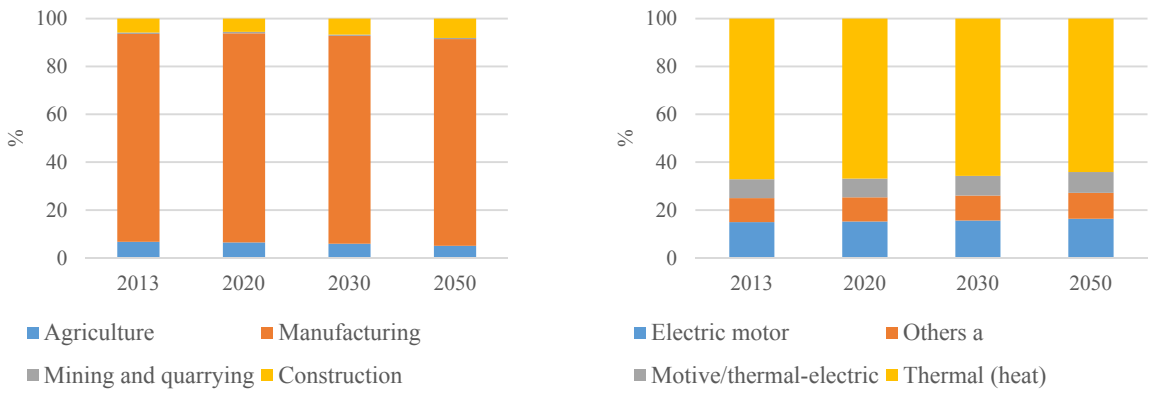

Fig. 9. Share of sub-sector (left) and end-use (right) industrial energy demand in the baseline scenario.
Note: [a] Others include electricity for lighting, electric appliances, electro-chemical process, electro-thermal process and refrigeration.

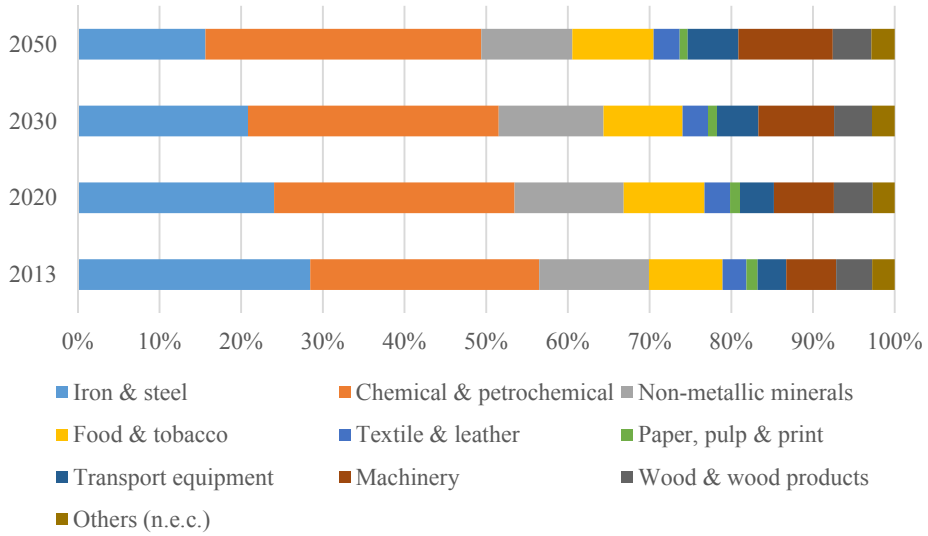

Fig. 10. Industrial manufacturing sub-sector final energy demand in the baseline scenario, 2013-2050.

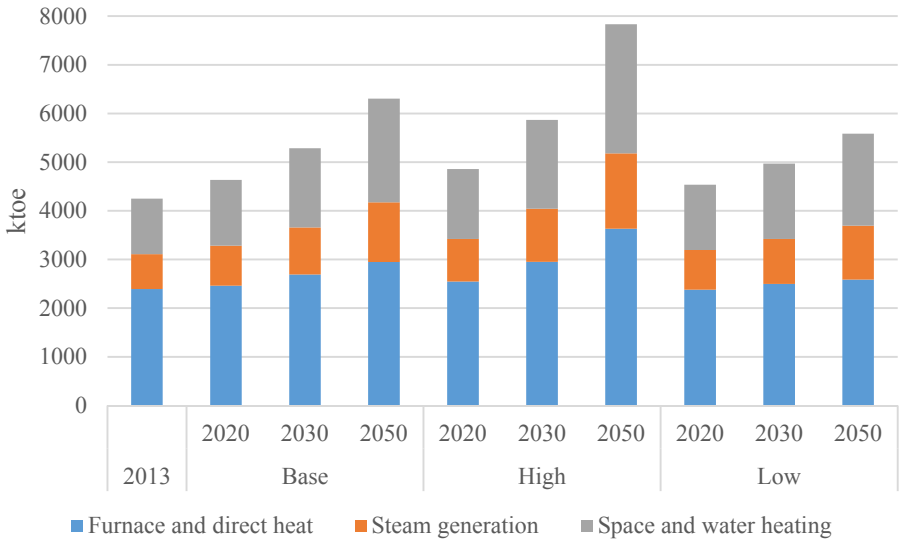

Fig. 11. Industrial manufacturing thermal energy demand by scenario, 2013-2050.

In the industry sector, three temperature intervals are considered to describe the quality of thermal energy demanded by the manufacturing industries. 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 processes such as washing, rinsing and space heating in agriculture, mining and quarrying, and construction sub-sectors, is relatively small. In 2050, the share of these three sub-sectors combined in total thermal energy demand is projected to be only 6.6%, about 449 ktoe in the baseline (Table 7). In the case of manufacturing industries, the demand for furnace and direct heat (high temperature) is projected increase from 2394 ktoe in 2013 to 2948 ktoe in 2050, an increase of 0.6% per year (Figure 11). However, its share in total thermal energy demand is projected to decrease from 56% in 2013 to 47% in 2050, mainly due to increase in the share of space and water heating (low temperature) in total thermal energy demand in the baseline.

5.5. Transport sector

Improvement of transportation remains very high on the policy agenda in Romania. In 2013, Romania's transport energy demand is 5,278 ktoe or 24% of total FED. Despite decrease in country's total FED, energy use in transport has increased steadily (1.3% per year) over the past decade, mainly due to a surge in passenger and freight road traffic. In 2013, 90% of Romania's energy demand in the transport sector comes from road transportation and this share remains about the same over the projected period in all scenarios. The remaining transport energy demand is consumed mainly in air and rail transportation. Despite vehicle technology and fuel-economy improvements, transport energy demand is projected to increase during 2013-2050 period. Between 2013 and 2050, it is projected to increase by an average 0.8% per year to reach 6,993 ktoe in 2050 in the baseline, compared to on average 1% and 0.7% per year in high and low scenario, respectively (Table 8). Unless significant policy measures are adopted in promoting increasing use of mass transit system such as railways, road will remain the main transportation mode in the foreseeable future. As a consequence, this will put pressure on demand for oil and associated negative air pollution impact.

Table 8
Transport sub-sector final energy demand by scenario, 2013-2050 (ktoe)

	2013	Baseline			High			Low		
		2020	2030	2050	2020	2030	2050	2020	2030	2050
Air	211	215	232	313	218	240	336	214	228	301
Road	4,766	5,118	5,508	6,211	5,189	5,696	6,684	5,082	5,416	5,987
Rail	255	263	304	393	267	314	423	262	299	379
Inland waterways	42	41	44	71	41	46	77	40	43	69
Pipeline	4	4	4	6	4	4	6	4	4	5
Total (transport)	5,278	5,641	6,092	6,993	5,720	6,301	7,526	5,602	5,990	6,741

Over the past decade, demand for passenger travel has been steadily increasing, while demand for freight travel has been declined slightly in the country. Since 2004, total passenger

movement from road, rail and inland waterways combined has increased on average by 2.6% per year, while freight movement has decreased on average by 0.3% per year. The decline in country's freight movement over the past decade is mainly due to slump in economic growth in 2009 and 2010. However, as economy grows and the number of motorized vehicles increases, the passenger and freight travel demand is projected to increase over the 2013-2050 period. For example, excluding air and maritime transport, the passenger travel demand is projected to increase on average by 1.4% per year, reaching 174 Gpkm in 2050, and the freight travel demand is projected to increase on average by 1.3% per year, reaching 98 Gtkm in 2050 in the baseline (Table 9). Compared to baseline scenario, it follows the similar trends with higher travel demand in the high scenario and with lower travel demand in the low scenario.

Table 9
Travel demand by transport mode by scenario, 2013-2050 (Gpkm, Gtkm) [a]

		2013	Baseline			High			Low		
			2020	2030	2050	2020	2030	2050	2020	2030	2050
Road	passenger public	20.7	21.6	23.6	30.8	22.7	24.8	32.3	20.7	22.7	29.5
	passenger private	80.4	82.4	89.9	135.9	86.5	94.4	142.7	79.1	86.3	130.4
	freight	34.0	38.8	44.1	57.5	40.7	46.3	60.3	37.2	42.4	55.2
Rail	passenger	4.4	4.8	5.4	6.9	5.1	5.7	7.2	4.6	5.2	6.6
	freight	12.9	12.4	13.6	18.4	13.0	14.3	19.3	11.9	13.0	17.6
Waterways	passenger	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.01	0.02	0.02
	freight	12.2	11.6	12.9	21.5	12.2	13.6	22.6	11.1	12.4	20.6
Pipeline	freight	0.8	0.9	1.0	1.0	0.9	1.0	1.1	0.9	0.9	1.0
Air	passenger	10.7	11.1	11.7	16.3	11.6	12.3	17.1	10.6	11.2	15.7
	freight	0.03	0.03	0.04	0.05	0.04	0.04	0.06	0.03	0.04	0.05
Maritime	passenger	0.05	0.06	0.07	0.08	0.06	0.07	0.09	0.06	0.06	0.08
	freight	43.6	52.0	62.7	83.6	54.6	65.8	87.8	49.9	60.2	80.3

Note: [a] Passenger and freight travel demand for air and maritime are expressed in million passenger and million ton.

In Romania, road transport dominates both passenger and freight travel demand in the past and this trend is projected to continue during the projected period. For example, the road passenger travel demand is projected to grow on average by 1.4% per year, to reach 167 Gpkm

in 2050 from 101 Gpkm in 2013 in the baseline (Table 9). More specifically, private passenger travel demand dominates road transport. Roughly 80% of road passenger travel demand is projected to be met by private passenger vehicles (mainly cars) in the baseline (Figure 12). The remaining 20% of total road passenger travel demand is projected to be met by public passenger vehicles (mainly buses and mini-buses). The share of railways and inland waterways in total passenger travel demand is relatively small compared to passenger travel by road transport in the country. In 2050, the share of railways and waterways combined accounts to only 4% of total passenger travel demand in the baseline scenario. In addition to lack of railway infrastructure, the projected decline in population and rising incomes over the study period will most likely limit the increase of passengers travel by railways.

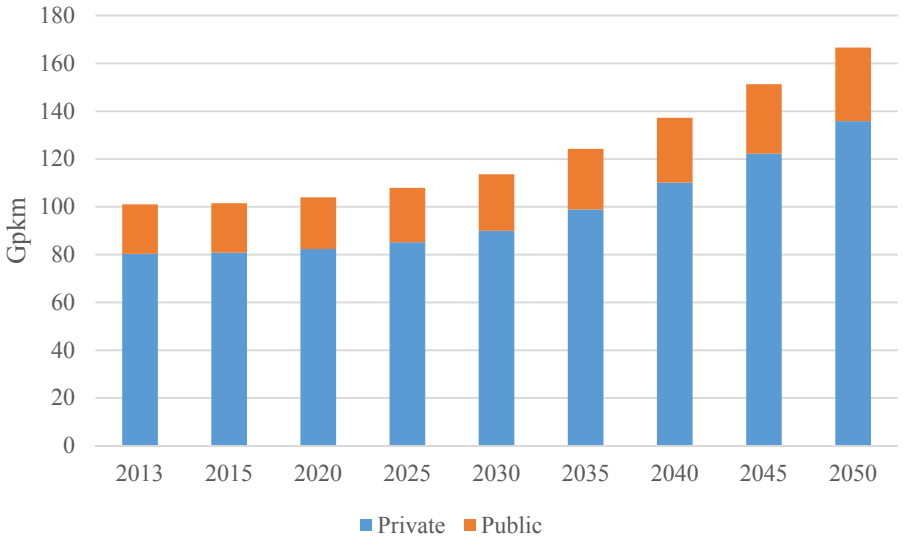

Fig. 12. Road passenger transport travel demand in the baseline scenario.

Unlike passenger travel demand, freight travel demand is evenly distributed among different transportation modes. In the freight transport, road remains the main transport mode during the projected period. For example, the share of road freight in total freight travel demand ranges from 57% in 2013 to 62% in 2030 and then decline slightly to 58% in 2050 (Figure 13). Road

freight is followed by railways, inland waterways and pipeline during the projected period. These figures reflect, among others, the relative importance of passenger and freight transport in the country. While passenger travel patterns are more closely related to personal wealth and lifestyle changes, freight transport activities are closely connected to overall economic activity.

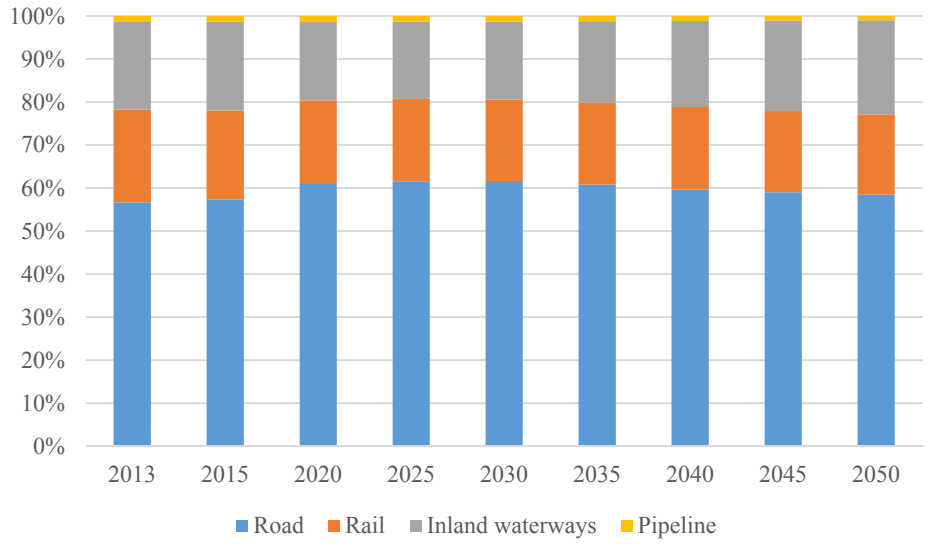

Fig. 13. Share of freight transport demand by transport model in the baseline scenario.

In recent years, both air passenger volumes, measured in number of passengers, and air freight volumes, measured in tons, grew steadily, closely connected to the country's economic growth rate. It is projected that the trend will continue over the projected period. For example, air passenger volumes is projected to grow at an average rate of 1.1% per year during 2013-2050 to 17 million passengers in 2050, while air freight volumes is projected to grow at 1.4% per year over the same period to 55,000 tons in 2050 (Table 9). Maritime follows a similar trend as that of air transport during the projected period.

6. Concluding Remarks

Using an end-use accounting model, this study projects sector-wise energy demand by end-uses and travel demand by transportation modes over the next 35 years. Although there is considerable variation in demand for energy between sectors, sub-sectors and end-uses, the country's overall FED is projected to increase from 2013 (base year) to 2050. The outlook for FED differs to some degree across the three scenarios. In the baseline scenario, total FED grows at an average annual rate of 0.8% through 2050, rising from 21.6 Mtoe in 2013 to about 28.8 Mtoe in 2050. Demand grows slightly faster in the high scenario, by 1.2% per year, but slows to 0.5% per year in the low scenario, owing to in part to slower economic growth. As a result of the growing economy and rising income, the market for electric services and the stock of electronic devices and electric appliances are expected to continue to grow in the country. This will lead to faster projected rates of growth in demand for electricity than the total final energy in all scenarios. In the baseline scenario, electricity demand grows by 1.3% per year and it meets 20% of final energy needs in 2050, up from 16% in 2013. However, the difference in per capita electricity consumption in Romania and EU member countries remains very large. In 2040, per capita electricity consumption in Romania amounts to 3,239 kWh, while it is 5,710 kWh in Germany and 6,294 kWh on average in EU-28.

At the sector level, the residential sector is presently the largest energy consuming sector in the country, accounting for a little more than one-third of total FED, followed by the industry, transport and services sectors. Interestingly, the share of Romanian residential energy demand in total FED in 2013 is the highest among all EU-28 countries. However, growth in energy demand across the sectors varies widely with time. The growth in residential energy demand is projected to slow with time, on average 0.1% per year to reach 7,911 ktoe in 2050 under the baseline

scenario, mainly due in part to declining population and using more efficient household appliances. Despite slow growth, residential energy demand accounts for more than one-fourth of total FED in 2050. At the end-use level, most of residential energy demand comes from space and water heating over the projected period, accounting for roughly three-fourth of total residential FED. The remaining one-fourth comes mainly from the use of electric appliances, cooking and lighting end-uses. Space heating, therefore, represents the largest opportunity to reduce residential energy demand by increasing energy efficiency of the heating equipment and by changing the energy-mix.

Both in absolute and percentage terms, industry is projected to be the largest final energy consuming sector, surpassing the residential sector from 2025 onwards in all three scenarios. Industrial energy demand is projected to grow more rapidly at 1.2% per year, reaching 10,536 ktoe in 2050 in the baseline scenario. At the end-use level, thermal (heat) energy use is projected to account for roughly two-thirds of all industrial FED, mainly due in part to strong growth in energy-intensive manufacturing industries. The remaining one-third comes from use of electric motor and electric appliances, and for motive and thermo-electric requirements. Within industry, manufacturing is by far the largest energy end-user, accounting for 86% of total industrial FED in 2050 in the baseline scenario. In particular, manufacturing industries such as iron and steel, chemical and petro-chemicals, and non-metallic minerals, dominate total thermal energy demand. Although the share of services in total FED is relatively small, services FED is projected to grow at much higher rate of 1.7% per year, doubling in absolute value in 2050 from the 2013 level. Over the projection period, almost half of total services energy demand comes mainly from space heating in office buildings, hotels, and wholesale and retail stores. Besides

using improved and efficient heating equipment, there is also great potential in reducing energy demand by renovating office buildings.

Currently, about one-fourth of total FED comes from transport sector. Energy demand in this sector steadily increases over 2013-2050, growing by 0.8% per year. In Romania, energy use in transport is heavily concentrated on road transport. Without any further policy measures, this trend is expected to remain the same over 2013-2050 period. In 2050, almost 90% of total transport energy demand comes from road transport in the baseline scenario. As for the travel demand in the country, road and railways are the main transport mode for passengers, while road, railway and inland waterways are the main transport modes for freight. Excluding air and maritime transport, the total passenger travel demand grows on average by 1.4% per year, reaching 167 Gpkm in 2050, while the total freight travel demand grows on average by 1.3%, reaching 94 Gtkm in 2050. Road transport dominates both passenger and freight projected travel demand during 2013-250. In particular, private passenger dominates road passenger travel demand, mainly due to rising incomes and increasing levels of private passenger vehicle ownership. Further, the lack of railway infrastructure coupled with declining population and growing number of vehicles during 2013-2050 period will most likely limit the increase of passengers travel by railways. Although reducing energy consumption in the transport sector is a particularly difficult challenge in the country, the Romanian government is encouraged to intensify its efforts to shift from private to public road and rail transport by promoting mass transit systems.

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