

# China's Envisaged Renewable Energy Target

## *The Green Leap Forward*





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## *The Green Leap Forward*

### KEY MESSAGES

- 1 T The dominance of coal shadowed China's achievements in developing renewable energy (RE) during the last three decades. Small hydropower and later photovoltaic (PV) solar power were promoted by the government for electrification of rural counties and areas remote from the grid. After stalling during the 9th Five-Year Plan (FYP), 1996–2000, and the early years of the 10th FYP, 2001–05, wind and, to a lesser extent, biomass boomed after the effectiveness of the Renewable Energy Law in 2006. In 2009, installed RE capacity reached 55 gigawatts (GW) of small hydropower (the largest in the world), 22.68 GW of wind power (and rising), 4 GW for biomass, and 300 megawatts-peak (MWp) for PV.  
*These achievements are remarkable by any standard.*
- 2 The RE Medium- and Long-Term Development Plan, published in 2007, specified the country's commitment to increasing the share of RE to 15 percent of the 2020 primary energy supply. The government is envisaging increasing the targets of renewable electricity from 360 GW generating 1,490 terawatt-hours (TWh) to 500 GW generating 1,820 TWh (including large hydropower).
- 3 The envisaged government target (EGT), if confirmed, would constitute major progress in addressing local and global environmental issues. It would put the energy sector on track to achieve the goal of meeting 15 percent of the country's primary energy needs through RE. *The implicit local and/or global environmental externalities underlying the envisaged target indicate a tremendously increased focus on reducing local pollution and addressing climate change, as well as strong support to build a world-class RE industry.*
- 4 The impact of the RE programs on the cost of electricity generation could be significant in case of major scale-up, but it remains manageable.
- 5 The target could be achieved in a most-effective manner in the following ways:
  - **Developing hydropower faster:** Hydropower rehabilitation and more rapid and environmentally and socially sound development could achieve the target at a lower cost because hydropower is already competitive with coal. Developing hydropower more quickly would allow for increasing the RE target above the EGT without increasing the incremental cost of the program.

- ***Improving the performance of wind power rapidly:*** China's experience has been less than optimal in planning wind farms, operational integration and coordination between developers and grid operators. This considerably reduced the performance of the wind program. If not addressed adequately, the high level of inefficiencies could increase the cost to the nation of the envisaged wind program, which could become prohibitive.
- ***Promoting trade:*** With trade, provinces could achieve their mandated targets. RE transactions would amount to about 360 TWh, 42 percent of the total of the EGT. And more important, trade would reduce the discounted cost of the envisaged RE target by about 56–72 percent.
- ***Developing green electricity scheme(s):*** Green electricity has been well studied in China and piloted in Shanghai municipality. Deploying green electricity schemes at the national and/or regional levels should be considered among the options to pay for the incremental cost resulting from the development of RE.

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## Acronyms and Abbreviations

BG	Bright Green Case
BGOS	Bright Green Optimal Solution
CO <sub>2</sub>	Carbon dioxide
CGT	Current government target
DG	Dark Green Case
DGOS	Dark Green Optimal Solution
EGT	Envisaged government target
EU	European Union
FYP	Five-Year Plan
GDP	Gross domestic product
NO <sub>x</sub>	Nitrous oxide
O&M	Operating and maintenance
PV	Photovoltaic
RE	Renewable energy
SEPA	State Environmental Protection Administration
SO <sub>2</sub>	Sulfur dioxide
TSP	Total suspended particulates
VAT	Value added tax

**Currency Equivalents**

(exchange rate effective April 1, 2010)

Currency unit = yuan = 100 fen

Y 1.00 = US\$0.147

US\$1.00 = Y 6.82

Fiscal Year: July 1–June 30 of next year

**Units of Measure**

gce	Gram of coal equivalent
GW	Gigawatt
GWh	Gigawatt-hour
kWh	Kilowatt-hour
mtce	Million tons of coal equivalent
MWp	Megawatts-peak
tce	Ton of coal equivalent
tCO <sub>2e</sub>	Tons of carbon dioxide equivalent
TWh	Terawatt-hour

# Foreword

In 2004, China surprised the world during the Bonn Renewable Energy Conference by announcing its commitment to meet 10 percent of its primary energy needs with renewable energy resources by 2010. The announcement included a target of installing 20 GW of wind capacity by 2020. Skepticism abounded with good reason: the total installed wind power capacity in 2004 was only about 0.8 GW, and the country struggled during the ninth (1996–2000) and tenth (2001–05) Five Year Plans to develop a total of 1.2 GW.

The doubts quickly dissipated and China installed 22.68 GW of wind, 4 GW of biomass, 55 GW of small hydropower and 0.3 GW of photovoltaic capacity by the end of 2009. China is leading the world in its hydropower development, and ranks as number two in its wind power capacity.

This note is published by ESMAP to disseminate the rich experience of China's very successful journey in developing its renewable energy. Beginning with the enactment of the Renewable Energy Law in 2005, China has relied on a wide and diverse mix of policy instruments to achieve renewable energy growth. It has pragmatically combined (a) wind concessions; (b) feed-in prices for biomass and lately for wind; and (c) RE obligations imposed on power generators, provinces, and in the future, grid companies. Despite the problems and setbacks encountered along the way, China's achievements lead to the obvious conclusion that the country is gradually and pragmatically doing something right.

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A team from the Energy Research Institute (ERI) led by Hu Gao with the participation of Jingchun Fan, was the major contributor of the data and conducted the analysis for this publication. Ming Hu from Alberta Electric System Operator (AESO) compiled and improved the economic evaluation model. In addition, the activity benefited greatly from the feedback provided and discussions that took place during the consultation workshop on “Evaluation of China’s Renewable Energy Development Targets” held in Beijing in December 2009.

The World Bank team that prepared the report consists of Ximing Peng, Task Team Leader and Noureddine Berrah, Energy and Policy Advisor. The team would like to give special recognition to peer reviewers Susan Bogach, Senior Energy Economist, and Xiaodong Wang, Senior Energy Specialist, from the World Bank; and Dr. Fei Feng from the Development Research Center of the State Council. The team would also like to thank Defne Gencer, Energy Analyst at the World Bank, editor Rebecca Kary, editor Sherrie Brown, graphic designer Gemma Drohm, and designer Laura Johnson for their efforts for producing the final publication.

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# Introduction

The Chinese government embarked on the preparation of the 12th Five-Year Plan (FYP, 2011–15) and is envisaging increasing existing renewable energy (RE) targets substantially. Ongoing discussions focus mainly on the RE share in primary energy, technology choices, and the impact on electricity prices. This Policy Note first evaluates the existing and envisaged RE government targets against two optimal solutions determined based on the same economic and technical assumptions, but two contrasting values for environmental externalities. The environmental externality assumptions cover the wide range of estimates in recent studies. Second, the Policy Note assesses the existing policies and their adequacy to achieve RE scale-up and the government targets. Finally, the Policy Note provides high-level policy recommendations that could be considered during the revision of the targets.

The Policy Note is organized as follows: The next section, “In the Shadow of King Coal,” provides a brief history of the development of RE in China during the

last three decades, which were characterized by the dominance of coal. “Optimizing RE Targets” is dedicated to the calculation of the optimal RE solutions (share of primary energy consumption and technology mix). “China’s Envisaged RE Target: Aiming High” focuses on the evaluation of the existing and envisaged government RE targets based on the same economic, technical, and externality assumptions used for the optimization. “Two Birds with One Stone: Environmental Protection and Industrial Development” is dedicated to the comparison of the government targets and optimal solutions and the analysis of incremental costs associated with them. “The Policy Fundamentals on the Right Track” focuses on the impact of the development of RE programs on the costs of electricity generation and how to pay for it. “Someone Has to Pay!” provides high-level policy recommendations that could speed up the scale-up of RE and reduce incremental costs to society. The final section, “Toward a Greener Future,” provides recommendations based on the results of the study to achieve scale-up of RE at minimal cost.

# In the Shadow of King Coal

The dominance of coal in China's booming energy sector overshadowed the progress achieved in developing RE during the last three decades. RE progress made China the leader in small hydropower development and second only to the United States in installed wind power capacity.

## Momentous RE Growth...

### The 1980s and 1990s: The reign of small hydropower and emergence of photovoltaics

In the 1980s, the Ministry of Water Resources launched several rural electrification programs (such as the 100-county and 200-county programs) that led to the important development of small decentralized power grids that rely mainly on small hydropower.<sup>1</sup> By the end of 1980s, about 1,500 decentralized prefecture and county grids relied on small hydropower for more than 50 percent of their electricity needs. In 1990, the country's installed capacity of small hydropower reached 13.2 GW generating 39.3 TWh. Installed capacity continued to grow during the 1990s at an annual average rate of 6.6 (respectively, 7.4) percent bringing it to 24.9 GW (respectively, 80 TWh) in 2000, making China the second largest user of small hydropower after the United States.

In the mid-1990s, the government initiated several bilateral programs to provide electricity to isolated and arid areas using photovoltaic (PV) systems. The installed capacity of PV systems increased more than 10-fold—from 1.8 MWp in 1990 to 19.0 MWp in 2000. The government's national programs, mainly the Brightness Program initiated in 1997, accelerated the development of China's PV industry.

1. Small hydropower in China includes plants with capacity less than 50 MW. However, all decentralized grids relied mainly on small hydropower plants ranging from 1 to 10 MW.

By contrast, wind power stagnated during this period. Installed capacity reached 344 MW by the end of 2000, less than 35 percent of the country's 9th FYP target of 1,000 MW.

### The 2000s: The East Wind

In 2004, China surprised the world during the Bonn Renewable Energy Conference by announcing its commitment to developing RE to meet 10 percent of its primary energy needs by 2010. More surprisingly, it announced a target of 20 GW of wind capacity by 2020, although the country's total installed capacity was only about 800 MW, still 20 percent lower than the target in the 9th FYP. The 2020 wind power capacity target was increased to 30 GW during the Beijing Renewable Energy Conference in 2005.

The Renewable Energy Law, enacted in February 2005, and effective in January 2006, set the stage for RE scale-up to meet China's surging electricity demand and to achieve its objectives of energy security, pollution reduction, and poverty alleviation. The Renewable Energy Medium- and Long-Term Development Plan (Renewable Energy Plan), published in 2007, specified the country's commitment to increasing the share of RE to 15 percent of the 2020 primary energy supply.<sup>2</sup>

Established at the national level, the RE target eventually worked its way down to the provinces, through the 10th (2001–05) and 11th (2006–10) FYPs, and to individual energy-production entities, mainly through mandated RE shares.<sup>3</sup>

2. Many high-level Chinese officials have lately begun stating that the 15 percent includes non fossil fuel. If this new definition is officially adopted in upcoming plans, this would mean that the share of RE in 2020 would amount to 13.1 percent only if the nuclear capacity would be 70 GW by 2020. *This note is still based on the target of the 2007 Renewable Energy Plan.*

3. The Renewable Energy Plan mandated large power enterprises (with a total capacity  $\geq 5$  GW) to increase “non hydro”

The national target was ambitious for all technologies with special focus on wind and biomass:

- **Wind:** 5 GW installed and 12,300 GWh generated in 2010, and 30 GW installed and 73,800 GWh generated in 2020.<sup>4</sup>
- **Biomass:** 5.5 GW installed and 27,280 GWh generated in 2010, and 30 GW installed and 148,800 GWh generated in 2020.
- **Small hydropower:** 50 GW installed and 205,000 GWh generated in 2010, and 75 GW installed and 307,500 GWh generated in 2020.
- **Solar PV:** 0.3 GW installed and 474 GWh generated in 2010, and 1.8 GW installed and 2,844 GWh generated in 2020.

The policy's pragmatic approach mixes market instruments (for example, bidding on concessions and mandated market share) and government intervention (such as price controls and imposed technology targets). The accomplishments were beyond expectations for wind but mixed for biomass because of technical and fuel-supply problems. Photovoltaics progressed significantly, but remained marginal because of its high cost. Figure 1 illustrates the progress achieved, especially since 2000.

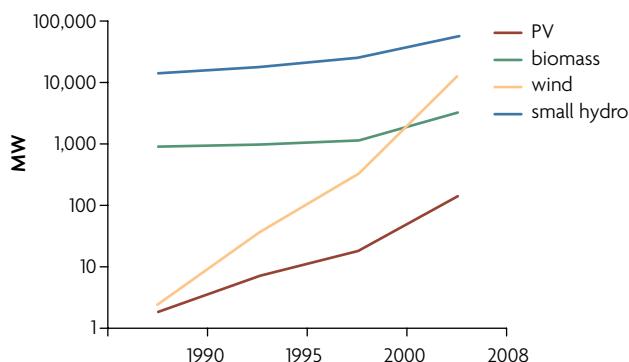
- Wind power capacity doubled in both 2006 and 2007, prompting the government to increase the Renewable Energy Plan wind capacity target for 2010 to 10 GW from 5 GW. The momentous wind development continued in 2008 and 2009; its installed capacity reached 22.68 GW at the end of 2009, 122 percent higher than the revised target for 2010.
- Construction of biomass-fired units boomed with the implementation of the subsidized tariff in 2006.<sup>5</sup> Total installed biomass-fired capacity

RE capacity in their generation mix to at least 3 percent by 2010 and 8 percent in 2020 (2007 Renewable Energy Plan, Section 8, p. 30).

4. The generation of each RE technology was calculated based on the estimated capacity factors provided in the annex.

5. A premium of Y 0.25/kWh over the 2005 coal-based regional generation costs was applied for biomass-fired projects. The government increased the premium by 10 fen/kWh for the biomass-fired projects commissioned in 2007 and 2008.

**Figure 1 Installed Capacity of RE in China, 1990–2008**



Source: Authors.

reached 3.1 GW at the end of 2008, including 0.6 GW of direct-burning straw-fired power plants. It is unlikely that the 2010 target will be reached.

- The total installed capacity of small hydropower reached 55 GW in 2009, exceeding the 2010 planned target. China became the world's leading country in hydropower development.
- With the development of the PV manufacturing industry and the initiation in 2002 of the government's Township Electrification Program, the installed capacity of PV surged from 19 MWp in 2000 to 300 MWp in 2009. Development of large-scale grid-connected PV stations began in the northwestern region in 2009.

### ...Despite Persisting Problems

Although these achievements have been impressive and unprecedented, especially for wind during the last four years, the journey has not been without difficulty.

#### All technologies still face technical problems

Small hydropower suffered at its early development stage from standardized design, low local technical expertise, substandard equipment, and rudimentary control systems. This led to less than optimal use of site potential. *Most of the capacity installed before and during the 1980s, and even in the 1990s, would benefit greatly from rehabilitation and modernization.*

Currently, small hydropower development in many provinces with great potential is constrained by

institutional barriers and, more than likely, psychological ones. Large developers and operators do not develop small hydropower projects because only “non-hydro RE” can be included in their mandated shares (see footnote 3). Furthermore, most developers would rather invest in more hyped technologies, such as wind. Although economically justified, small hydropower also suffers from very low locally regulated prices and a lack of policy incentives in provinces with great potential, *except Zhejiang where authorities established a feed-in price that triggered high levels of public and private investment in the sector.*

Several studies and a quick review of the generation subsidy-based payments to generators during 2007 and 2008 indicate that generation performance of the nascent Chinese wind power sector is lower than that of countries with similar wind resources. The studies point to the following reasons:

- A sizable share of the built capacity is not connected to the grid in a timely manner following commissioning because of the lack of coordination between developers and grid operators.<sup>6</sup>
- The capacity factors of Chinese wind farms are lower than comparable wind farms in developed countries because of the use of unproven turbines and the development of sites without confirmation of resources and proper micrositing studies, or development of sites with mediocre wind resources in some provinces to meet their mandated capacities.

Biomass development also encountered technical and fuel-supply problems during the early years. Defects in local feed-in and generation equipment slowed the development of the technology. *These problems stemmed from hurried deployment of local equipment before adequately addressing start-up and learning-curve problems.*

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6. “Survey of Wind Power Development in China,” State Electricity Regulatory Commission (July 2009).

### Prices are not yet quite right

China has made substantial progress in gradually freeing energy prices and relaxing controls. However, the approach to pricing reform has been piecemeal in that it addresses issues as they arise and not according to the comprehensive reform program clearly set out in State Council Document No. 5 (2002). *Prices still do not reflect the adverse environmental effects of production, transformation, and use of energy.* In addition, fuel taxation in China is low both in absolute terms and relative to other countries (especially energy importers), despite several years of discussion and consideration of an energy tax. However, it is recognized that “policy making has to serve and reconcile multiple objectives, not only health and environmental protection.”<sup>7</sup>

### Fiscal disincentives to trade

The fiscal system in China focuses on revenue collection at the generation level. Provinces, municipalities, and even government entities at a lower administrative level favor construction of generation units within their administrative boundaries to maximize their fiscal revenues and short-term benefits, to the detriment of national interests and optimal use of resources. This distorted behavior hampers interprovincial trade, unless mandated by the central government as in the case of the Three Gorges. *Although the issue is not limited to RE, this fiscal approach often leads to the development of high-cost resources and increases the burden on ratepayers and taxpayers.*

Given the envisaged rapid growth of the RE sector (especially wind and biomass), these technical problems and policy issues need to be addressed to ensure cost-effective use of resources. Otherwise, inefficiencies could lead to prohibitive costs and unacceptable impacts on ratepayers.

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7. “Energy Policy and Externalities: The Life-Cycle Analysis Approach,” OECD Nuclear Energy Agency, Paris, 2001, pp. 195–234.

# Optimizing RE Targets

The World Bank teamed with China's Energy Research Institute of the National Development and Reform Commission to carry out quantity analyses and policy analyses. The goal of the quantity analyses was to update the optimal RE capacity and generation for 2020, taking into account technical, economic (for example, costs and discount rate), and local and global externality costs only. These optimal solutions were thereafter used as benchmarks for evaluating government RE targets. The goal of the policy analyses was to assess the adequacy of the policy instruments and their consistency with government targets. The analyses were carried out using a model developed during the preparation of the China Renewable Energy Scale-Up Program.

The approach to determining optimal RE shares in total electricity generation is based on the following:

- Developing provincial supply curves for electricity generation from RE and aggregating them into a national supply curve.
- Comparing levelized costs of electricity generation from RE sources and levelized costs of coal without

and with consideration of local and global environmental costs.

An abbreviated description of the methodology is provided in box 1.

The optimization was carried out for two base cases assuming the same technical, economic, and cost assumptions (summarized in the annex), and RE generation potential presented in table 1. The cases are differentiated by two contrasting assumptions related to local and global externality costs. They cover the wide range of estimates and uncertainty related to the economic impacts in recently published studies:

- In the first case, labeled the Dark Green Case (DG), local environmental costs are derived from a joint study by the State Environmental Protection Administration (SEPA) and the World Bank, as well as a global environmental cost of US\$15/tCO<sub>2e</sub>, based on the latest Clean Development Mechanism transactions in China. These externality costs are conservative and reflect low estimates of local pollution impacts on the economy. Other studies indicate that

**Table 1 RE Capacity Potential**

RE resources	Installed MW (2009)	Potential MW	Total MW
Wind	22,680	161,193	173,393
Small hydropower	55,000	76,775	128,045
Hydropower rehabilitation	—	5,243	5,243
Biomass	4,000	24,722	25,364
PV	300	22,670	22,670
<b>Total</b>	<b>81,980</b>	<b>290,653</b>	<b>354,715</b>

Source: Authors.

Note: — = Not available. The RE potential in the table is based on identified or extrapolated grid-connected electricity projects and does not reflect the full RE potential in China. Furthermore, it does not include the potential of direct use of biomass and projects that are not connected to the grid.

### Box 1 Optimizing RE Electricity Generation: An Abbreviated Description of the Methodology

The methodology used to determine the optimum share of RE in total electricity generation was developed during the preparation of the China Renewable Energy Scale-Up Program. The analytical framework consists of two parts.

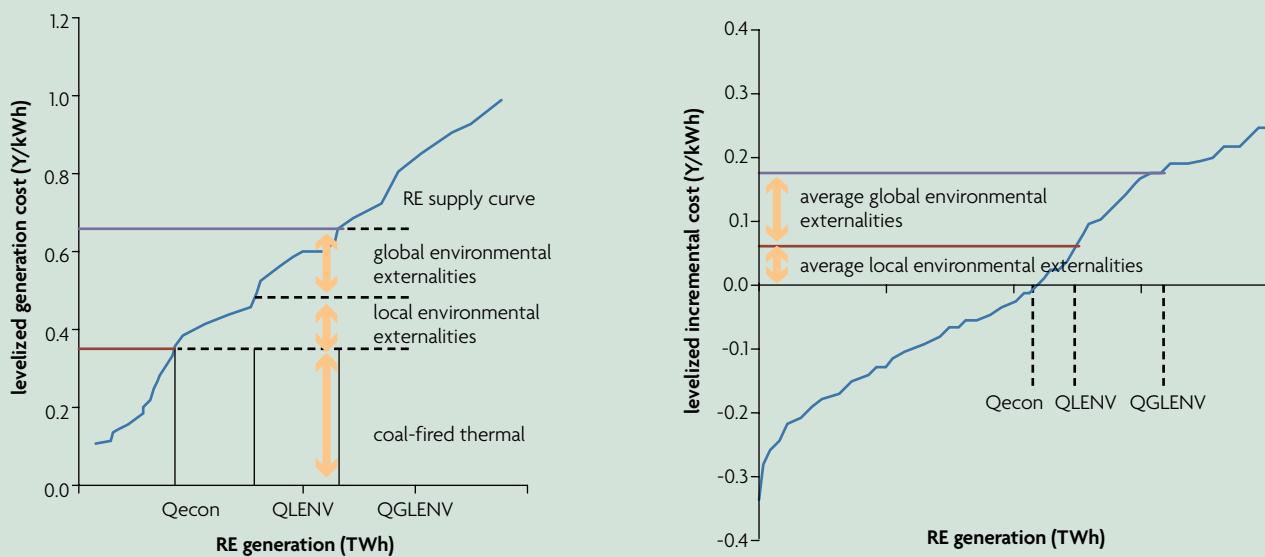
The first part, referred to as quantity analysis, estimates the optimum level of electricity from RE sources based on a set of assumptions relating to the costs of the dominant non-RE production options (coal-based generation in China); capital and operating and maintenance costs for RE technologies considered for electricity generation; and externality costs of local pollutants and greenhouse gases.

The second part, referred to as policy analysis, assesses the adequacy of policy instruments to reach the economic optimum quantity (or government-approved target) of power from RE sources and the financial impacts on the various stakeholders.

A simulation model is used in both the quantity and policy analyses to generate supply curves for potential RE projects, determine an optimum target quantity, and evaluate the economic and financial impacts of policy instruments designed to meet the target.

The quantity analysis begins at the provincial level by first computing the production cost of coal-based power generation and second by developing a database of all existing RE power generation projects at feasibility and prefeasibility stages, and possible projects derived by extrapolating project cost trends, taking into account general resource assessments. The model then constructs a provincial supply curve (left figure below) by plotting the leveled costs of kilowatt-hours generated by the database projects (including a capacity penalty for intermittent RE generation sources). Finally, the model subtracts the cost of coal generation and aggregates the incremental costs into a national supply curve (right figure below). The selection of the optimal RE generation shares are graphically shown in the illustrative figures below: (a) Qecon is the optimum share without consideration of environmental externalities, (b) QLENV is the optimum share considering local environmental externalities only, and (c) QGLENV is the optimum share considering local and global externalities.

The policy analysis focuses on determining the most efficient policy instruments or assessing the adequacy of existing country policies to achieve the optimum targets to meet, considering the distribution of benefits to various stakeholders.



**Table 2 Optimal Solutions**

Renewable electricity generation	Dark Green (SEPA externality + US\$15/tCO <sub>2e</sub> )		Bright Green (EU externality + US\$30/tCO <sub>2e</sub> )	
	GWh	%	GWh	%
Wind	60,729	9.5	386,386	35.8
Small hydropower	501,327	78.8	513,577	47.6
Small hydropower rehabilitation	21,837	3.4	21,837	2.0
Biomass	52,956	8.3	156,421	14.5
PV	—	—	830	0.1
<b>RE generation</b>	<b>636,849</b>	<b>100</b>	<b>1,079,050</b>	<b>100</b>
<b>% of 2020 generation</b>	<b>10.3</b>		<b>17.4</b>	
Installed RE capacity	MW	%	MW	%
Wind	22,269	13.9	154,618	49.3
Small hydropower	123,838	77.4	128,045	40.8
Small hydropower rehabilitation	5,243	3.3	5,243	1.7
Biomass	8,587	5.4	25,364	8.0
PV	—	—	520	0.2
<b>Installed RE capacity</b>	<b>159,936</b>	<b>100</b>	<b>313,790</b>	<b>100</b>
<b>% of 2020 installed capacity</b>	<b>11.4</b>		<b>22.4</b>	

Source: Authors.

Note: — = Not available.

the economic and financial impacts on the Chinese economy from pollution are higher than the externality costs adopted in this case.

- In the second case, labeled the Bright Green Case (BG), local environmental costs are quite high because they are derived from the European Union ExternE (External Costs of Energy) Study,<sup>8</sup> which is considered one of the most exhaustive local environmental studies published to date. The BG case uses a global environmental cost of US\$30/tCO<sub>2e</sub>, twice the price of the latest Clean Development Mechanism transactions in China.

The optimal (economically and environmentally justified considering the above assumptions) RE-based

electricity generation and capacity installed are presented in table 2. They are respectively referred to in the remainder of the Policy Note as the Dark Green Optimal Solution (DGOS) and the Bright Green Optimal Solution (BGOS).

As expected, the results show that the optimal solutions are highly dependent on externality costs:

- RE-based electricity generation is 70 percent higher in the BGOS than the DGOS. DGOS (respectively, BGOS) generation would amount to about 10 percent (respectively, 17 percent) of the total forecast electricity generation in 2020.<sup>9</sup>

8. “External Costs: Research Results on Socio-Environmental Damages Due to Electricity and Transport,” EUR 20198, Directorate General for Research, European Commission, 2003.

9. Forecasts considered for 2020: 6,200 TWh and 1,400 GW for electricity, and 4,772 million tce for total energy demand (“China’s Low Carbon Development Pathways by 2050,” prepared by Energy Research Institute, 2009).

**Table 3 Share of RE in Total Energy Supply, 2020**

Sources	Unit of measure	DGOS	BGOS
RE generation	GWh	636,849	1,079,050
Large hydro generation	GWh	922,500	922,500
Other RE generation	GWh	37,358	37,358
Total RE supply of electricity	Million tce	510.9	652.5
Other RE supply	Million tce	137.7	137.7
Total RE supply	Million tce	648.7	790.2
RE share in total energy supply	%	13.6	16.6

Source: Authors.

Note: tce = ton of coal equivalent.

- Installed RE capacity is 96 percent higher in the BGOS than the DGOS. DGOS (respectively, BGOS) capacity would amount to 11 percent (respectively, 22 percent) of the total forecast installed capacity (respectively, generated electricity) in 2020.

Small hydropower (new and rehabilitated) dominates the RE mix in the DGOS with about 81 percent of the total installed capacity and 82 percent of the electricity generated in 2020. All the small hydropower rehabilitation potential and about 97 percent of the new potential are developed. Wind and biomass are moderately developed with, respectively, about 9 and 8 percent (respectively, 14 and 5 percent) of the RE-based electricity generation (respectively, capacity installed) in 2020. Photovoltaics is not included in the RE mix.

In the BGOS, the potential of both new and rehabilitation small hydropower is fully developed. Wind, therefore, becomes the most attractive RE source and is developed to reach about 50 percent (respectively, 36 percent) of the installed RE capacity (respectively, generated electricity). Biomass accounts for about 8 percent (respectively, 15 percent) of the installed RE capacity (respectively, generated electricity). PV is included in the RE mix, but remains marginal with 520 MW installed and 830 GWh generated.

Table 3 shows that if other RE resources,<sup>10</sup> especially large hydropower and decentralized (direct use and not connected to the grid) RE, are developed according to the Renewable Energy Plan issued in 2007, the 2020 RE share in the 2020 total primary energy supply could reach 13.6 percent in the DGOS and 16.6 percent in the BGOS.

Table 4 provides the avoided emissions of local pollutants and greenhouse gases forecast for 2020.

Table 5 provides (a) the cumulative avoided emissions during the study period (2009–20) and over the lifetime<sup>11</sup> of the projects implemented under the DGOS and BGOS programs; and (b) associated environmental benefits for the two optimal solutions assuming that the new capacity is installed linearly during the study period (2009–20).

10. Other RE resources include large and medium hydropower, solid biomass fuel, biogas, fuel ethanol, biodiesel, solar heating, and geothermal heating. The 2020 planned large and medium hydropower capacity is 225 GW; the planned biomass generation capacity includes 6 GW from bagasse, biogas, and solid waste; and other planned RE supply includes solar heating, biogas utilization, fuel ethanol, and biodiesel.

11. The economic life for wind, biomass, hydropower, and PV is assumed to be 15, 20, 30, and 15 years, respectively.

**Table 4 Avoided Emissions, 2020**

Pollutant	Unit of measure	DGOS	BGOS
TSP	Thousand tons	187	377
SO <sub>2</sub>	Thousand tons	393	787
NO <sub>x</sub>	Thousand tons	248	558
Carbon	Million tons	109	242
CO <sub>2e</sub>	Million tons	400	887

Source: Authors.

Note: TSP = Total suspended particulates; SO<sub>2</sub> = Sulfur dioxide; NO<sub>x</sub> = Nitrous oxide; CO<sub>2e</sub> = equivalent CO<sub>2</sub> credit.

**Table 5 Avoided Emissions, 2009–20 and Lifetime of Optimal Solutions**

Pollutants	Unit of measure	Avoided emissions (2009–20)		Avoided emissions (lifetime of program)	
		DGOS	BGOS	DGOS	BGOS
TSP	10 <sup>6</sup> tons	1.05	1.88	5.18	8.73
SO <sub>2</sub>	10 <sup>6</sup> tons	2.20	3.92	10.90	18.24
NO <sub>x</sub>	10 <sup>6</sup> tons	1.39	2.78	6.88	12.93
Carbon	10 <sup>9</sup> tons	0.61	1.21	3.03	5.61
CO <sub>2</sub>	10 <sup>9</sup> tons	2.24	4.42	11.10	50.56
Environmental benefits (SEPA+US\$15/tCO <sub>2e</sub> )	Billion Y	276	537	1,367	2,494
Environmental benefits (EU+US\$30/tCO <sub>2e</sub> )	Billion Y	2,346	4,519	11,613	21,000

Source: Authors.

# China's Envisaged RE Target: Aiming High

The government of China is envisaging a major revision to its RE target, based on lessons learned during the last two FYPs, to further scale up RE development and address rising concerns about climate change. Available information about the envisaged target indicates the following:

- Wind will gain momentum because of the success achieved during the last few years.
- PV will rise to address overcapacity in its manufacturing and will speed up cost reductions.

- Biomass might slightly retreat to give the technology and local manufacturing time to address the technical and fuel-supply issues they encounter.
- Small hydropower development would follow a business-as-usual trend.

Table 6 presents the current and envisaged government targets (CGT and EGT).

*If confirmed, the new target would aim very high. It would increase the 2020 installed RE capacity and*

**Table 6 Government Targets for 2020**

Renewable electricity generation	Government targets for renewable energy			
	CGT		EGT	
	GWh	%	GWh	%
Wind	73,800	13.8	369,000	43.0
Small hydropower	307,500	57.8	307,500	35.9
Small hydropower rehabilitation				
Biomass	148,800	27.9	148,800	17.4
PV	2,844	0.5	31,600	3.7
RE generation	532,914	100	856,900	100
% of 2020 generation	8.6		13.8	
Installed RE capacity	MW	%	MW	%
Wind	30,000	22.9	150,000	55.8
Small hydropower	75,000	57.3	75,000	27.9
Small hydropower rehabilitation				
Biomass*	24,000	18.4	24,000	8.9
PV	1,800	1.4	20,000	7.4
<b>Installed RE capacity</b>	<b>130,800</b>	<b>100</b>	<b>269,000</b>	<b>100</b>
<b>% of 2020 installed capacity</b>	<b>9.3</b>		<b>19.2</b>	

Source: Authors.

Note: Large and medium hydropower are not included in this table.

\*Only direct-burning biomass-fired thermal capacity was included. See footnote 10.

**Table 7 Share of RE in Primary Energy Supply, 2020**

Sources	Unit of measure	Targets	
		CGT	EGT
RE generation without large hydro	GWh	532,914	856,900
Large hydro	GWh	922,500	922,500
Other RE generation*	GWh	37,358	37,358
Total RE supply of electricity	Million tce	477.7	581.4
Other RE supply	Million tce	137.7	137.7
Total RE supply	Million tce	615.4	719.1
RE share in total energy supply	%	12.9	15.1

Source: Authors.

Note: \*See definition in footnote 10.

generated electricity targets by more than 100 percent and 61 percent, respectively. The share of installed renewable capacity in the 2020 forecast of capacity would increase to 19 percent from about 9 percent, and the share of RE-based generation in the 2020 forecast would increase to 14 percent from about 9 percent.

If other RE resources are developed according to the 2007 Renewable Energy Plan, RE would reach 12.9 percent (CGT) and 15.1 percent (EGT) of the 2020 primary energy supply. The EGT would therefore meet the 15 percent target announced in the 2007 Renewable Energy Plan. Details are shown in Table 7.

Table 8 shows that the EGT would reduce emissions of local and global pollutants substantially in comparison with the CGT: 115 percent for TSP, 116 percent for SO<sub>2</sub>, 140 percent for NO<sub>x</sub>, and 139 percent for Carbon and for CO<sub>2</sub> emissions.

Assuming that the new capacity is installed linearly during the study period (2009–20), Table 9 provides (a) the cumulative avoided emissions during the study period (2009–20) and over the lifetime of the projects implemented under the CGT and the EGT programs; and (b) associated environmental benefits if emissions are valued at the externality costs assumed in the optimization study.

**Table 8 Avoided Emissions, 2020**

Pollutant	Unit of measure	Targets		
		CGT	EGT	% increase
TSP	Thousand tons	133	286	115
SO <sub>2</sub>	Thousand tons	256	554	116
NO <sub>x</sub>	Thousand tons	177	424	140
Carbon	Million tons	76	182	139
CO <sub>2e</sub>	Million tons	279	667	139

Source: Authors.

**Table 9 Avoided Emissions 2009–20 and over Lifetime of Program**

Pollutants	Unit of measure	Avoided emissions (2009–20)		Avoided emissions (lifetime of program)	
		CGT	EGT	CGT	EGT
TSP	10 <sup>6</sup> tons	0.77	1.46	3.33	6.07
SO <sub>2</sub>	10 <sup>6</sup> tons	1.49	2.84	6.42	11.78
NO <sub>x</sub>	10 <sup>6</sup> tons	1.03	2.17	4.43	9.02
Carbon	10 <sup>9</sup> tons	0.44	0.93	1.90	3.87
CO <sub>2</sub>	10 <sup>9</sup> tons	1.62	3.42	6.98	14.20
Environmental benefits (SEPA+US\$15/tCO <sub>2e</sub> )	Billion Y	199	415	862	1,720
Environmental benefits (EU+US\$30/tCO <sub>2e</sub> )	Billion Y	1,690	3,483	7,304	14,452

Source: Authors.

# Two Birds with One Stone: Environmental Protection and Industrial Development

As indicated earlier, decision makers have to serve and reconcile multiple objectives, not only health and environmental protection. The RE government targets are therefore justified on environmental and industrial grounds.

## Increased Willingness to Pay for Environmental Protection

Figure 2 assesses the government targets (CGT and EGT) in light of the optimal solutions (DGOS and BGOS).

Figure 2.a depicts the ranking of the RE quantities of the optimal solutions and government targets and their positions on the national supply curve.

Figure 2.b shows that the structures of the CGT and the DGOS capacity mixes are quite different. Wind and biomass are higher in the government target by about 36 percent and 280 percent, respectively, while hydropower capacity is 40 percent lower in the government target than in the DGOS. The figure also shows that the structures of the EGT and the BGOS are quite similar, except for solar PV, which is 20 times higher in the government target.

Figure 2.c depicts the implicit environmental costs that justify the government targets and the environmental costs assumed in the optimization analyses. The implicit externality cost of the EGT is 4.6 (respectively, 2.1) times higher than the CGT (respectively, DGOS), but 62 percent lower than the assumed externality cost of the BGOS. The figure also shows that the incremental costs are higher than the incremental costs of the equivalent optimal solutions (same installed capacity and generated electricity, but with optimal mix). *These costs reflect other government priorities or benefits not considered in the optimization.*

The current government 2020 RE generation (respectively, installed capacity) target is lower than the DGOS RE generation (respectively, installed capacity) by 16 percent (respectively, 18 percent), indicating that the implicit local and/or global externality costs are lower than those assumed in the DGOS. It must, however, be noted that the target was announced in 2005 when the price of coal was only about Y 435/tce (Qinhuangdao free on board price and VAT not included). The government target was at that time just 3 percent lower than the optimal RE generation based on the 2005 coal price with other assumptions unchanged. *The important increase in the price of coal during the last years warrants a higher target to at least the DGOS level of 637 TWh, even without increased externality values.*

The EGT, if confirmed, would constitute major progress in addressing local and global environmental issues. The 2020 RE generation (respectively, installed capacity) in the EGT would be higher than DGOS RE generation (respectively, installed capacity) by 35 (respectively, 68) percent, but lower than the BGOS RE generation (respectively, installed capacity) by 21 percent (respectively, 14 percent) *because the externality associated with the BGOS is clearly too high for China's current development conditions.* The increase of RE penetration from 15.1 to 16.6 percent almost doubles the incremental cost. *The willingness to pay for environmental benefits accounts for about two-thirds of the total incremental cost associated with the envisaged target* (see figure 2.c).

It must be noted that the considered RE technologies, except for small hydropower, are still quite far from being competitive with coal for electricity generation in China with consideration of environmental externality costs reflected in China's current environmental standards only. Sensitivity analyses were carried out

to determine the cost reductions that would warrant the government's CGT and EGT for each technology without consideration of environmental externalities. The results indicate that the cost per kilowatt installed for the considered RE technologies should be reduced by the following amounts:

- 35 percent (respectively, 46 percent) to justify the wind target in the CGT (respectively, EGT).
- 40 percent to justify the biomass target in the CGT and the EGT.
- 83 percent (respectively, 87 percent) to justify the PV target in the CGT (respectively, EGT).

### Strengthening Local Manufacturing: An Overriding Priority of Government Targets

Comparison of the government targets with the optimal solutions led to the following observations:

- If only technical costs and environmental externalities are considered, small hydropower should be developed almost to its full potential before wind and biomass are developed on a major scale, and solar PV should remain marginal under the assumptions considered in the study.
- Wind and biomass targets in the CGT indicate that the government gave high priority to the development of world-class local manufacturing industries

for both technologies. *In hindsight, the emergence of vibrant and competitive wind and PV industries and the expectation that the benefits to the country would outweigh the incremental costs incurred will likely justify these strategic choices.<sup>12</sup> However, the difficulties and constraints facing the development of biomass do not indicate yet that the benefits would outweigh the incremental costs incurred.*

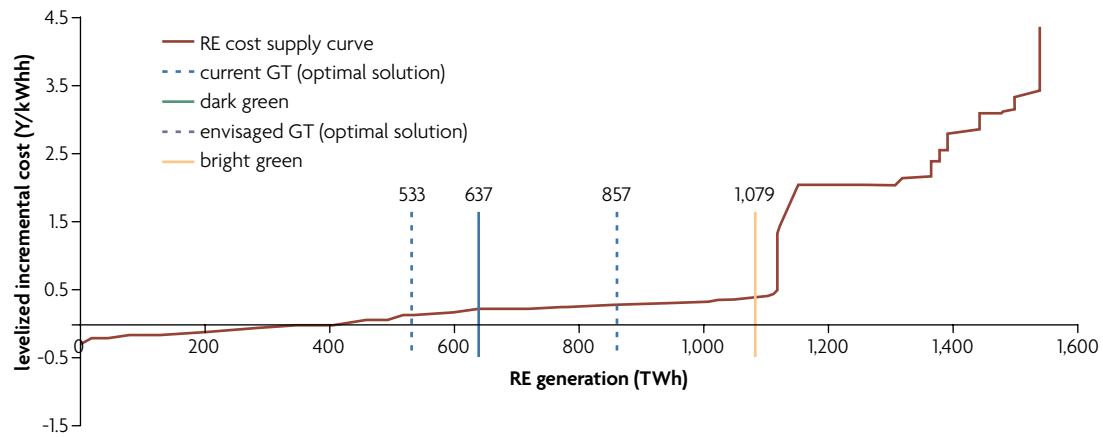
- The PV target is not justified unless the externality costs are significantly higher than the ones assumed in the study. *It is, however, recognized that the PV target is aimed at reducing the cost of the technology and helping the strong local industry survive the current slump in global demand. Given the past accomplishments of the Chinese PV industry, this stretched target may bring PV generation costs down, even if the bid prices of the first large PV concession are considered too low to ensure profitability of PV projects in the medium term.*

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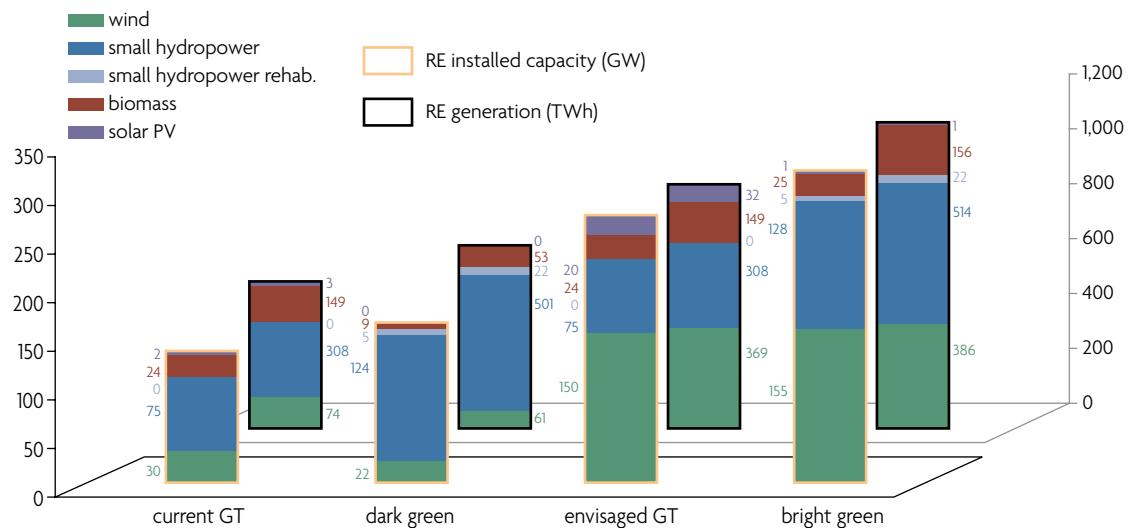
12. Numerous studies showed the benefits of developing the RE industry. For example, on November 2, 2009, the *Herald Tribune* reported that a 2004 study of the Renewable Energy Policy project by a research institute based in Washington estimated that about 4,300 jobs are created per 1,000 MW of installed wind capacity with about three-quarters generated at the manufacturing level and one-quarter generated at the operational level. A study on the economic impacts of the wind industry (and eventually biomass industry) in China is required to reach a significant conclusion on the subject.

**Figure 2 Comparison of Government RE Targets and Optimal Solutions**

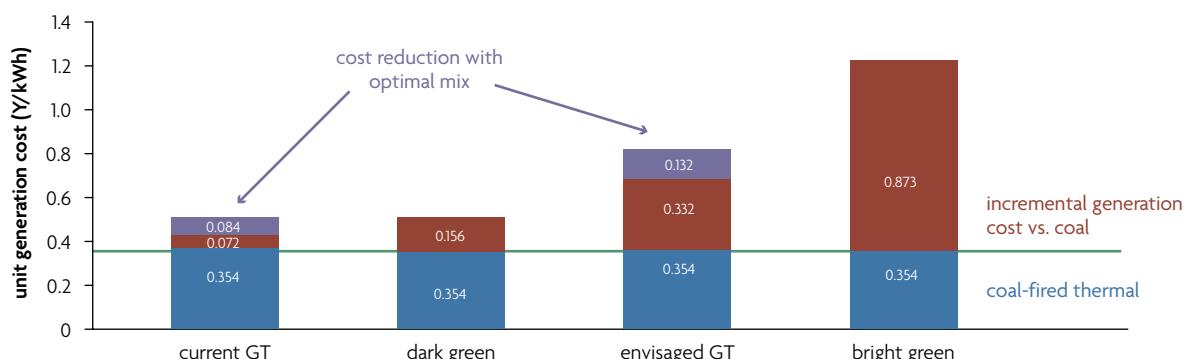
a. Cost supply curve of RE in China



b. Capacity structure



c. Implicit or assumed environmental cost



# The Policy Fundamentals on the Right Track

China relied on a wide and diverse mix of policy instruments, pragmatically combining (a) wind concessions, with a strict though unofficial price ceiling (however, developers benefited from compensatory subsidies per kilowatt-hour generated when bid prices failed to provide them with adequate returns); (b) feed-in prices for biomass and lately for wind; and (c) RE obligations on generators, provinces, and grid companies. This hybrid recipe, relying on both market and command-and-control policies, worked quite well during the years following the enactment of the Renewable Energy Law and led to a dramatic surge in wind and noticeable biomass development. However, with the multiplication of the projects at the national level and the different project approval standards applied at the local level, the hybrid and diversified approach became difficult to manage.

Lately, the government began to rely mostly on feed-in tariffs. Feed-in prices were defined at the national level with regional differentiation and an RE obligation on provinces (usually with reference to specific technologies) and on large energy operators. *This and fiscal disincentives made trading difficult, if not impossible, and led to inconsistencies and nonoptimal use of resources.*

## Feed-in Prices: Adequate Levels but Unequal Distribution

The RE pricing situation is evolving rapidly and, as of early November 2009, was as follows:

- The biomass feed-in price was instituted in January 2006. It was set at the regional grid prices of coal-based electricity generation in 2005, augmented by

a 25 fen/kWh premium. In 2007, the biomass premium was increased to 35 fen/kWh.

- The wind feed-in price was introduced in 2009. It is differentiated according to wind resources in four regions:

Region	Annual utilization (hours)	Feed-in price (fen/kWh)	
		With VAT	Without VAT
I	>2,500	0.510	0.470
II	2,301–2,500	0.540	0.498
III	2,101–2,300	0.580	0.535
IV	≤2,100	0.610	0.562

- A PV feed-in price policy is still under consideration.

The model was used to assess the consistency of the latest feed-in prices with the physical targets set by the government. The simulations showed the following to be true, without major changes under the prevailing cost and externality conditions:

- The original feed-in biomass price (with a premium of 25 fen/kWh) was too low to provide enough incentive to developers to meet the CGT biomass target. The price would have theoretically led to biomass-based generation of 47 TWh, compared with 149 TWh under the CGT, and installed capacity of less than 8 GW, compared with 24 GW under the CGT. The increase of the premium to 35 fen/kWh from 25 fen/kWh brought the feed-in price in line with the CGT biomass target and could, without a major drop in the price of coal, lead to biomass-based generation of about 156 TWh and installed capacity of about 25 GW, both slightly higher than the CGT. *Given that biomass-based*

*generation and installed capacity are not expected to change significantly in the EGT, the latest feed-in price would remain consistent with the government biomass objectives, if all other prevailing conditions remain the same.* However, it must be noted that the current biomass feed-in price favors the regions where electricity prices are higher, mostly the more-developed ones, to the detriment of poor inland provinces.

- The regional wind feed-in prices would lead to wind electricity generation of about 143 TWh and installed capacity of about 53 GW. The former is 94 percent higher than the CGT, but about 61 percent lower than the EGT. The latter is 77 percent higher than the CGT, but 65 percent lower than the EGT. *The wind feed-in prices would need to be increased if compensatory subsidies are removed, to meet the EGT for wind, unless the cost per installed kilowatt is reduced (or the performance of wind farms increased) by 17 percent in the near future.*
- There is still no feed-in price for solar PV. However, to achieve the EGT without reduction in the cost of solar PV, the feed-in price should be set at Y 3/kWh. *The feed-in price would be reduced to Y 2/kWh if the PV installation cost is reduced by 30 percent in the near future, and only Y 1/kWh if the PV installation cost is reduced by 80 percent. An 80 percent reduction is unrealistic in the near future.*

## Trade Would Benefit All

The analysis to assess the benefits of trade assumes that the national target is passed on equally to all provinces and that, *contrary to the optimal cases considered in this note*, each province would meet its share with its local resources. Therefore, in the nontrade option, provinces are allowed to buy neither physical RE quantities nor tradable green certificates from provinces with lower-cost resources to meet their targets.

The analysis shows the following to be true without major changes in the prevailing cost and externality conditions:

- *With trade*, provinces could achieve their mandated targets with RE transactions amounting to about 360 TWh, 42 percent of the EGT. The five top exporters would be Sichuan (74 TWh), Inner Mongolia (69 TWh), Yunnan (65 TWh), Xinjiang (40 TWh), and Tibet (24 TWh). The five top importers would be Jiangsu (64 TWh), Shandong (53 TWh), Guangdong (53 TWh), Shanxi (40 TWh), and Zhejiang (37 TWh). The discounted cost of achieving the EGT with trade over the life of the developed projects would amount to Y 1,193 billion.
- *Without trade*, 13 provinces would not be able to achieve the new mandated targets to meet the EGT with their resources identified to date. The shortfall would amount to 295 TWh, 34 percent of the EGT. The unmet quantities range from a low of 4,959 GWh for Beijing to a high of 50,780 GWh for Shandong province. To achieve mandated targets, equivalent to the EGT, these 13 provinces would have to develop more local, more-expensive resources, such as PV. Assuming that the cost of additional RE capacities would be 10 percent, 20 percent, and 30 percent (respectively, 20 percent, 40 percent, and 60 percent) higher than the marginal RE projects of the first, second, and third tier of the provincial potential, the discounted cost of achieving the EGT without trade over the life of the developed projects would amount to Y 2,696 billion (respectively, Y 2,978 billion). The cost of the *without-trade* option would be about 126–150 percent higher than the *with-trade* option. If all unmet RE quantities were met by PV, the discounted cost of achieving the EGT *without trade* would increase to Y 4,190 billion, about 250 percent higher than the *with-trade* case.

# Someone Has to Pay!

The impact of the development of RE on the cost of electricity generation in 2020 in real terms was estimated for the optimal solutions (DGOS and BGOS), the current and envisaged government targets (CGT and EGT), and the government targets with an optimal mix (CGT optimal and EGT optimal), *implicitly assuming that the national target would be achieved with trade among provinces*. Table 10 provides the results of the analysis for each of the technologies considered and for the whole RE program with and without small hydropower.

The results show the following:

- Development of small hydropower reduces the cost of generation by about 0.8 fen/kWh in all considered cases because it is cheaper than coal.<sup>13</sup>

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13. Although not considered in the current study, levelized cost calculations carried out for the envisaged hydropower plant show that medium and large hydropower is competitive with coal despite its remoteness. Accelerating the development of medium and large hydropower on sound environmental and social grounds could also contribute to achieving the target at a lower cost.

- Wind and biomass contribute significantly to the increase of the total generation cost.
- The increase of the generation cost from PV is negligible in most cases because of low penetration, but it would amount to about 1 fen/kWh (second-highest contribution after wind) in the case of the EGT.
- The increase in electricity generation costs in 2020 as a result of the implementation of the considered RE programs would vary from a low of 0.02 fen/kWh in the case of the CGT to about 2.5 fen/kWh in the case of the EGT. *For reference, average electricity tariffs in the regional grids vary from 20.1 fen/kWh to 42.4 fen/kWh (2009, VAT excluded).*

If the national target is to be achieved without trade, the impact on generation costs would be significantly higher and differentiated among provinces, for example, as follows:

- In Shaanxi, where RE resources fall short of its mandated share by about 9 percent, the impact of RE development without trade would increase generation costs in the province by about 2.0 fen/kWh.

**Table 10 Impact of RE Development on Electricity Generation Cost (change in fen/kWh)**

RE source	DGOS	BGOS	CGT	CGT optimal	EGT	EGT optimal
Wind	0.181	1.789	0.192	0.130	1.594	0.605
Small hydro	-0.819	-0.771	-0.818	-0.823	-0.756	-0.814
Biomass	0.227	0.653	0.575	0.021	0.605	0.604
Solar PV	—	0.031	0.069	—	1.006	—
Total	-0.411	1.703	0.019	-0.673	2.449	0.395
Total (excluding small hydro)	0.409	2.473	0.836	0.150	3.205	1.209

Source: Authors.

Note: — = Not available.

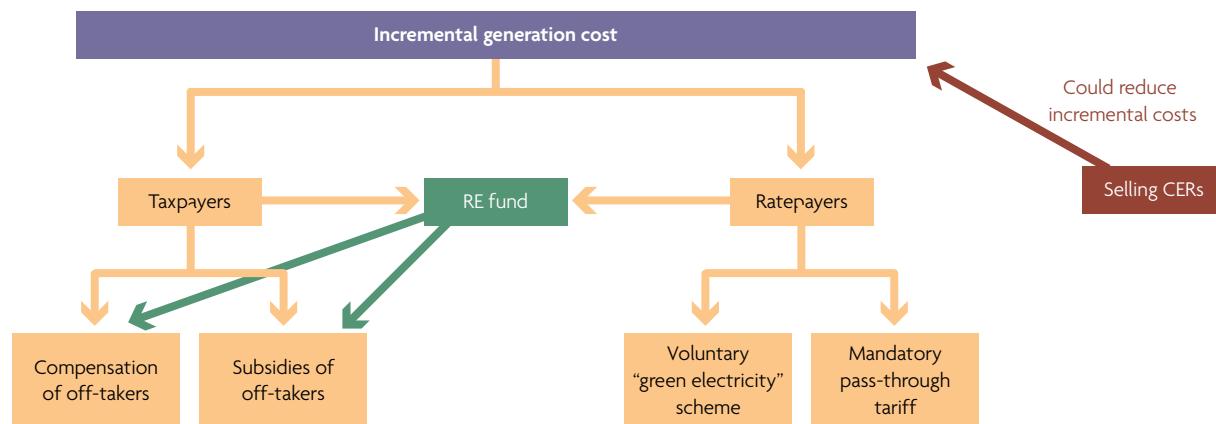
- In Beijing, Shanghai, and Tianjin, where RE resources fall short of the mandated shares by more than 95 percent, the impact of RE development without trade would increase generation costs in the municipalities between 4.9 fen/kWh and 23.1 fen/kWh.

Whatever the increase, someone has to pay the incremental generation cost. Figure 3 shows some of the options to pay for the incremental cost using either mandatory or voluntary pass-throughs to ratepayers to finance an RE Fund to compensate off-takers and/or developers. Selling certified emission reductions resulting from the development of the renewable program

could contribute to reducing the cost of incremental generation. However, it is expected that additionality and other issues related to the Clean Development Mechanism will limit the contribution of this option.

The recently revised Renewable Energy Law instituted a national RE Fund replenished by a fee on electricity consumption of 0.4 fen/kWh. The estimates of increases in electricity generation show that in 2020, the fee (or end-user tariff) on consumers should be increased to about 2.5 fen/kWh to compensate developers and/or off-takers for the incremental generation cost, in the absence of an RE cost reduction and/or coal cost increase.

**Figure 3 Someone Has to Pay the Incremental Cost**



Source: Authors.

# Toward a Greener Future

China achieved recognized and rapid progress in scaling up RE-based electricity using diverse technologies. It is envisaging a new target that would put it on the path of achieving its goal to meet 15 percent of the 2020 primary energy supply through RE. The following recommendations are provided for consideration during the revision of the target to further increase RE penetration at a minimum cost:

- Develop small hydropower more rapidly.
- Improve the performance of wind capacity.
- Promote trade.
- Develop green electricity schemes at the provincial or national level.

## Developing Hydropower More Rapidly

Small hydro rehabilitation *and more rapid development of hydropower* could achieve the target at a lower cost because hydropower is already competitive with coal. Based on the China Renewable Energy Scale-up Program experience in Zhejiang province, the rehabilitation of existing small hydropower could bring about increases of 38 percent in existing capacity and 50 percent in generated energy, on average, at an investment cost of only Y 2,870/kW. New capacity can be developed at a lower cost than coal in most cases and should be speeded up even without consideration of environmental costs. *Developing hydropower at a faster pace would allow increasing the RE target above the EGT and, at the same time, decreasing the incremental cost of the program* (see table 10).

Development of small hydropower could also trigger a technology revival in the manufacturing and service sectors and provide a strong stimulus to those sectors, such as through the development or improvement of bulb turbines for low head sites, efficiency

improvements in other types of turbines, computer-aided software to optimize design and take full advantage of the potential at each site, and technology improvements in control systems.

The success of Zhejiang province in developing its small hydropower resources shows how institutional barriers can be overcome and local private and public developers can be involved. Setting adequate and attractive feed-in prices, developing local engineering and construction services, and providing access to financing could lead to more rapid development of this cheap and abundant resource.

Although medium and large hydropower are not included in the study, complementary analyses carried out separately show that medium and large hydropower are competitive with coal-fired plant even without considering environmental benefits and taking into account the transfer of power from generation plants to load centers. Therefore, accelerating hydropower rehabilitation and development will contribute to achieving the RE target at a lower cost.

However, both small and large hydropower development should be carried out on sound environmental and social grounds and should involve concerned communities to ensure that they benefit from the development of indigenous resources.

## Improving the Performance of Wind Capacity

During recent years, the government has committed immense resources to the development of onshore wind. Teething problems, common to nascent industries, led to lower-than-expected performance. If these problems are not addressed rapidly and efficiently, the cost to the nation of the large envisaged wind program could become prohibitive.<sup>14</sup>

The government commitment to scaling up wind power development should be twinned with a clear objective to deliver electricity at minimum cost. Efficiency is contingent on ensuring that wind farms are built in places where critical requirements for success are present: the best resources, adequate project design, use of proven turbines, regulatory clarity, adequate incentives, and last but not least, appropriate operation and maintenance practices carried out by skilled staff.

Grid is the key! China's experience has been less than optimal in planning and coordinating the operational integration of wind farms between developers and grid operators. This considerably reduced the performance of the wind program. *If not addressed adequately and rapidly, grid connection and stability issues could jeopardize the future of the program. A high level of inefficiencies, especially in the gigawatt-level scale with no precedent anywhere in the world, could derail the wind program.* Comprehensive connection studies with special attention to the optimal connection size and connection circuit layout should be undertaken with the involvement of all stakeholders. Short-term operational forecasting studies and development of short-term wind forecasting methodologies are also necessary.

## Promoting Trade

Provinces with limited RE resources should not be mandated to achieve targets that require the development of very high cost resources. The cost to consumers and taxpayers could be very high and could reduce citizens' support of RE. The government should do one of the following:

- Mandate provinces to achieve RE targets adjusted to the provinces' levels of proven RE resources. If  $R_N$  is the national level of RE resources and  $R_{Pi}$  the

14. Some of the conclusions of this paragraph are based on key messages in the recent report titled “Strategic Guidance on Meeting the Challenges of Offshore and Large-Scale Wind Power Scale-Up in China,” prepared as part of a joint effort of the National Energy Administration/NDRC, the Australian Agency for International Development, the Asia Sustainable and Alternative Energy Program and the World Bank.

level of RE resources in province i, the target of province i ( $T_{Pi}$ ) could be

$$T_{Pi} = T_N (R_{Pi}/R_N),$$

where  $T_N$  is the national target.

Another method, such as targets proportional to the share of the provinces in the total gross domestic product (GDP), could also be considered.

Or better:

- Allow provinces with limited resources or higher-development-cost resources to buy from provinces rich in cheap-to-develop resources. The trade could involve physical transactions or tradable green certificates, or both. This would allow for better use of resources and development of RE in the low-income western provinces.

## Developing Green Electricity Schemes at the Provincial or National Level

Green electricity schemes have been widely studied in China. They offer nonpolluting renewable electricity at a premium price. Participation is voluntary and can cover total electricity consumption or a part of it. Participating consumers are guaranteed that for each kilowatt-hour of green electricity purchased, a corresponding amount of renewable electricity has been produced. *These schemes have been widely used to pay for the incremental cost of renewable electricity production.* Shanghai Municipality has been operating a green electricity scheme successfully since 2005. In 2008 and 2009, consumers participating in green electricity schemes worldwide were partly shielded from the significant electricity price increases because green electricity schemes acted as hedges against the volatility of hydrocarbon prices.

Chinese authorities should consider national or regional green electricity schemes to pass through part of the incremental generation cost to environmentally aware and willing-to-pay consumers.

# Annex:

## Basic Assumptions of the Study

The technical, economic, and cost assumptions of this study are summarized in this annex. The assumptions relate to (a) the social discount rate; (b) the technical and economic characteristics of coal-fired thermal plants, including capital and operating and maintenance (O&M) costs, efficiency, and price of coal; (c) environmental externality costs; and (d) RE resources.

### Social Discount Rate

A social discount rate of 8 percent was adopted in this study. This rate is recommended by both the National Development and Reform Commission and the Ministry of Construction in *Economic Evaluation Methods and Parameters for the Investment Projects (Third Edition)*.

### Technical and Economic Characteristics of Coal-Fired Thermal Plants

#### Investment cost

Actual investment costs for the same type of coal-fired thermal power plants vary slightly by province. The investment cost adopted in the study is Y 3,643/kW. It is recommended by the China Power Engineering Consulting Corporation in its reference handbook<sup>15</sup> and is based on a 2 x 600 MW supercritical power plant.

#### Generation efficiency

The average generation efficiency of existing capacity in each province was adopted as the reference. The gross coal consumption rates ranged from 293 gce/kWh

(in Beijing) to 411 gce/kWh (in Xinjiang) with an average of 332 gce/kWh in 2007.

#### Coal price

The market coal price in past years was reviewed. In 2009, the price of coal was stable at about Y 640/tce (without VAT, Qinhuangdao free on board price). This price was adopted as the reference coal price in the study. The coal price in each province was calculated to reflect transportation costs, ranging from Y 255/tce (in Xinjiang) to Y 830/tce (in Jiangsu).

### Environmental Externality Costs

Environmental externality costs were derived from two separate studies to reflect the minimum and maximum valuation of local pollution impacts on the economy and the population. The costs considered in the study are provided in table A.1. The economic development level and population density of each province were taken into account to convert the national averages to provincial externality costs.

### RE Resources Database

The RE database was established from data collected by the Energy Research Institute on existing, under-construction, and planned RE projects from the central and provincial governments. Some extrapolation was made to define possible RE projects that would be needed to develop the full potential of identified resources. The investment cost and capacity factor of each RE project are based on the Energy Research Institute's estimates. Table A.2 summarizes the RE database used in this study.

15. *Quota of the Capital Cost for the Design of Thermal Power Projects*, CPECC, 2007.

**Table A.1 Environmental Externality Cost in China—National Average**

Pollutants	Unit of measure	SEPA study	EU study
TSP	US\$/ton	5,801	62,214
SO <sub>2</sub>	US\$/ton	379	11,373
NO <sub>x</sub>	US\$/ton	269	7,660

Source: Authors.

**Table A.2 Summary of the RE Database**

RE technology	RE resources (MW)	Investment (Y/kW)	Fuel cost (Y/ton)	Capacity factor (%)
Wind	173,393	8,700–10,800	—	21–37
Small hydropower	128,045	3,548–9,965	—	13–50
Hydropower rehabilitation	5,243	Avg. 2,870	—	13–50
Biomass	25,364	9,500	260–350	80
PV	22,670	24,000	—	10–25
<b>Total</b>	<b>354,715</b>	—	—	—

Source: Authors.

Note: — = Not available.

# Glossary

The glossary provides the definitions of the terms and indicators used in this Policy Note.

**Levelized cost (LC).** Because the economic life of different generation technologies (including both RE technology and coal-fired thermal) varies, the levelized cost per kilowatt-hour is adopted to compare them. An equivalent annual cost is calculated by dividing the net present value of a project's costs, including the investment cost, fuel cost, and O&M cost, by the present value of an annuity factor. LC is then calculated by dividing the equivalent annual cost by annual electricity sales, which is annual electricity generation less auxiliary consumption.

**Incremental cost (IC).** The incremental cost is defined as the cost difference between RE technology and a coal-fired plant. In this study, the LC of RE technologies was adjusted by applying a capacity penalty when justified. (See *Capacity penalty*.)

**Capacity penalty (CP).** The capacity of some RE technologies, such as run-of-river hydropower, wind, and PV, is nondispatchable because of their intermittent generation, which decreases their capacity value to meet the system peak load. The capacity penalty (cost) is applied to these types of RE to make up for this difference in capacity value. Normally, a system analysis could be done to calculate the avoided or replaced firm capacity by the RE addition, and the capacity penalty could be calculated as “1 – replaced firm capacity / RE capacity.” In this study, the capacity credit is roughly proportional to the respective annual load factors. For example, the capacity credit for a wind project with a 35 percent annual capacity factor that displaces a coal plant with a 75 percent annual capacity factor may be taken as 46.7 percent ( $= 35\% / 75\%$ ). Therefore, the capacity penalty to be subtracted from the levelized capacity cost of this particular RE project is 100%

$- 46.6\% = 53.4\%$ . The formula to calculate the capacity penalty of RE project  $j$  is as follows:

$$CPj^* = CCj (1 - \alpha)$$

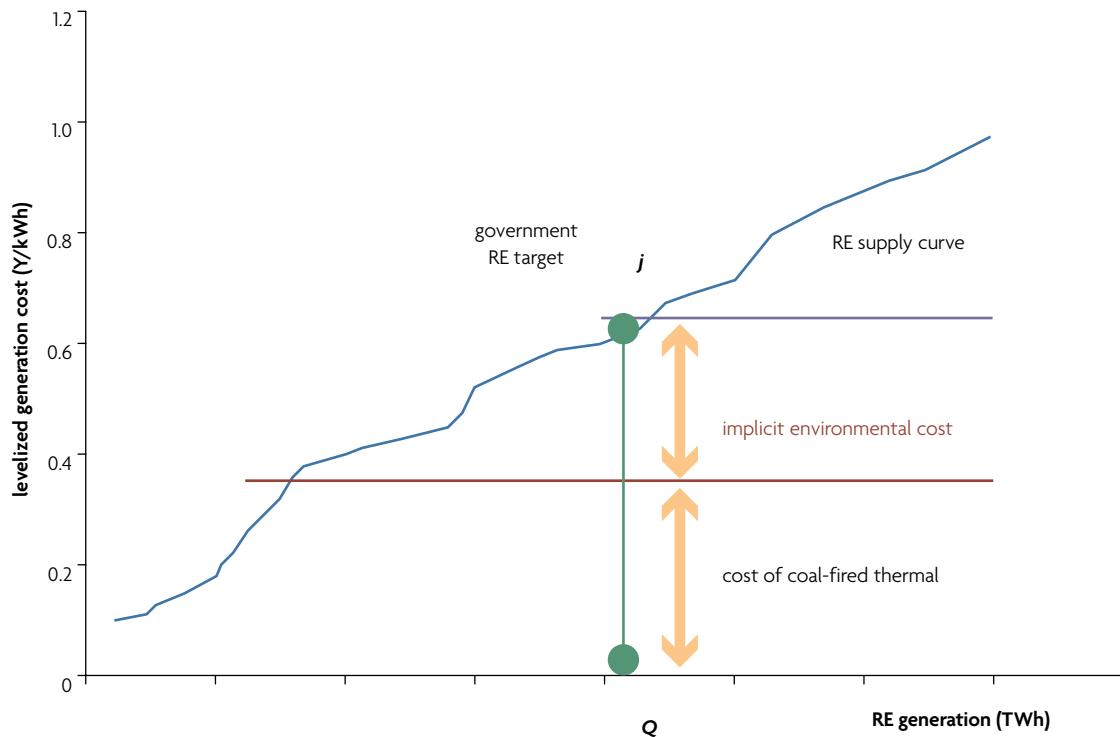
Where  $CPj^*$  = capacity penalty applicable to the  $j$ th RE project,

$CCj$  = capacity cost of coal generation in the  $j$ th project location, and

$\alpha$  = capacity adjustment factor (such as for wind and run-of-river hydropower, the ratio of annual capacity factors).

**Environmental externality cost.** The term environmental externality cost refers to the negative environmental impacts of coal-fired thermal generation resulting from its emission of pollutants. These negative impacts are not reflected in market transactions. Internationally, many researchers have obtained different quantities for the environmental externality cost of coal-fired thermal. This Policy Note uses the results of two studies to cover the full range of externality costs: one is a joint study by the SEPA and the World Bank, which was completed in 2008; the other is the European Union ExternE (External Costs of Energy) Study, which has much higher figures.

**Implicit environmental cost.** The implicit environmental cost is defined as the equivalent incremental cost of the marginal RE project to meet a specific government's RE target. As shown in figure A.1, when the government establishes an RE target  $Q$ , all RE projects between 0 and  $Q$  should be developed to meet this target. The full cost of the marginal project  $j$  should be covered. It implies the government values the incremental cost of project  $j$  as the benefit that was brought about by RE development.

**Figure A.1 Optimizing RE Electricity Generation**

Source: Authors.



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Energy Sector Management Assistance Program

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance trust fund program administered by the World Bank and assists low- and middle-income countries to increase know-how and institutional capability to achieve environmentally sustainable energy solutions for poverty reduction and economic growth.