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# Northeast China's Renewable Energy Transition: Drivers and Challenges

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## Abstract

Northeast China is undergoing a remarkable renewable energy transition. Driven by the challenges of resource depletion and climate change, fossil fuel production has declined significantly, and the production of renewable energy has climbed sharply. However, the transition is facing challenges in terms of wind and solar curtailment, burdening local economic growth, and rising dependency on energy imports. Technological innovation, infrastructure investment, and policy reforms are required to address these issues.

Keywords: renewable energy transition, drivers, challenges, Northeast China

## 1. INTRODUCTION

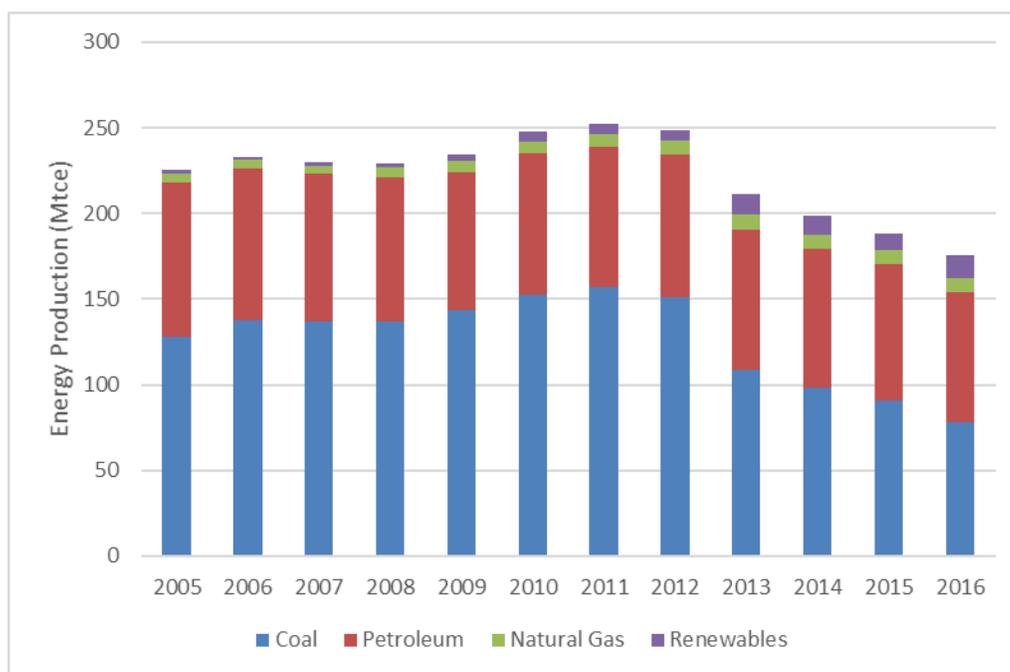
Northeast China (Figure 1), including Liaoning, Jilin, and Heilongjiang Provinces, is a region that is undergoing a remarkable renewable energy transition. During the Maoist era, Northeast China depended on its abundant natural resources and energy-intensive industries to achieve economic development [1]. To support the industries, the region became a significant production base for fossil fuels, especially coal and petroleum [1,2]. A large number of oil cities (e.g., Daqing) and coal cities (e.g., Fuxin) were established and prospered [3,4]. Recently, however, fossil fuel production has declined significantly, and the region is experiencing a bloom in renewable energy development, especially in wind and solar. As shown in Figure 2, the production of coal declined from a historic peak of 156.8 Mtce in 2011 to 75.6 Mtce in 2016, whereas the production of petroleum declined from 90.1 Mtce in 2005 to 75.6 Mtce in 2016. In contrast, the production of renewable energy increased over six-fold from 2.2 Mtce in 2005 to 13.3 Mtce in 2016. In a relatively short period of time, Northeast China has achieved considerable success in the renewable energy transition, which has important implications on climate mitigation in the northeast, as well as nationally. To better understand this remarkable transition, this paper first reviews the literature on renewable energy transition. It then examines the status of renewable energy development in the northeast and the driving forces. It argues that the transition is driven by both bottom-up problems of resource depletion and top-down national policies that are conducive to the transition. It concludes by identifying the challenges the renewable energy transition faces in the region.

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**Figure 2:** Energy production of Northeast China (2005-2016) [5,7]

Avelino et al., Farla et al. and Geels analyzed the energy transition from multi-actors, including policy makers and public authorities, firms, civil society, experts and individual actors [11–13], and espoused the important role actor heterogeneity plays. There are many factors that can drive the energy transition, such as providing direction and leadership, being equipped with expert knowledge, and having an environmental consciousness [14,15]. Public awareness on the necessity for an energy transition pushes governments to make the necessary changes [16].

Networks provide the communication platform and allow knowledge exchange among actors and between stakeholders and the public, helping to find common regional interests as well as identify problems and define new fields of action [17]. Further, by instilling confidence in the public, decreasing uncertainty, and building consensus, networks can further drive the renewable energy transition [15], as supported by Geels who claimed that "perceptions and activities (of human actors) are coordinated (but not determined) by institutions and rules" [13].

### 2.1.2 Planning and process

Energy plans can provide guidance and guarantees in renewable energy development, so they, too, play an important role in energy transitions. As the studies have shown, the comprehensive and specific planning of renewable energy, built on place-based socio-spatial characteristics, will drive the development and deployment of renewable energy. For instance, as Coutard and Rutherford argue, comprehensive regional planning in which energy, emissions and climate are considered play a significant role in renewable energy transitions [18], while in the contrast, regional planning which specifically concentrate on the energy system show positively influence on energy transition [19,20]. Besides valid energy plans, the support from regional decision makers and long-term, stable legal and policy frameworks have been shown to have a positive influence in both developed countries and developing countries, such as Germany, Canada, India

and China [8,21–24].

During the energy transition process, measurable and specific targets and milestones not only facilitate beneficial coordination among various (private and governmental) actors, but can serve as incentives for efficient implementation of plans [19]. Also, the monitoring of goals plays an important role in transition management as an approach to mobilize the actors involved in the energy transition [25].

### **2.1.3 Economic circumstances**

There are many economic incentives driving the transition to renewable energy. One type of incentive concerns the producers of renewable energy, which include tax exemptions, direct subsidies, and access to attractive credit and guarantees. Another type of incentive is achieved by policies supporting the development of attractive markets for energy transition, e.g., carbon taxes and fixed feed-in tariffs for renewable energy electricity [26–28].

In addition, supportive funding is crucial in energy transitions. Funding structures are found to be quite heterogeneous, which means that projects usually rely on more than one funding source. In the UK, public funding from central government departments and agencies was, for instance, found to be insufficient, which required community energy initiatives to draw on further sources of financing, such as European, local authority, charity and private sector sources [29].

Besides, the positive influence of renewable energy on regional economies is a driver of energy transitions because discourses around the linkage between renewable energy and regional economic development can legitimize and support decision makers in upscaling the development of renewable energy [25,30].

## **2.2. Challenges**

### **2.2.1 Intermittency**

The development of renewable energy faces further constraints due to its intermittent nature. For hydro, the unpredictable change of stream flows increases the uncertainty of power generation and discourages investment [31]. Solar energy potential will be mainly affected by changes in cloud cover [32]. Wind energy potential will fall if temperature differentials between equatorial and polar regions continue to drop. The intermittent flow means that energy storage devices must be added, which raises the costs [31,33–35].

### **2.2.2 Technology readiness**

Immature technology of renewable energy makes it less competitive with traditional fossil fuels, which are well developed [22,23,36,37]. In addition, the nascent technology used in renewable energy has led to a mismatch between the domestic production of system components with imported ones, and the lack of technology to predict energy generation makes it difficult to understand the real potential of renewable energy, which deepens the lack of public trust in renewable energy [22,38,39].

### **2.2.3 Policy and politics**

Radical changes to planning and energy policies could generate uncertainty and further delay the development and deployment of renewable energy [15]. For example, in Canada, the unclear carbon pricing means the long-term benefits of renewables are unquantified, which results in a comparative disadvantage compared to traditional energy resources [23]. Under-valuing the

long-term benefits of large political and capital investments in environmental reform also keeps investors away from renewable energy [40]. The reduction of tax concessions and the withdrawal of subsidies reduce the benefits that investors can enjoy, resulting in less interest in investing in renewable energy development [22]. Besides, the lack of effective inter-institutional governance and commitment regulations has also led to poor communication among different actors and the regular maintenance of renewable energy equipment [23]. In addition, some power companies are required by law to produce electricity by the cheapest source, leading to the non-promotion of renewable energy systems [27].

Addressing the different demands among the different profit-groups engaged in energy transitions poses a significant challenge for governments. For example, in Canada, different opinions on the development of renewable energy exist between NGOs and the energy corporations [23]. Also, the excessive power of fossil fuel actors gives them a dominant position in public policy formation related to energy development. This is to say, the particular interests of the fossil fuel sector actors have been regarded widely as being the same as that of the general public, manipulating governance structures, socio-technical systems and markets to work to their benefit. Another possible reason is governments' concern over energy security, which makes them reluctant to become heavily dependent on imported electricity, such as with Desertec [41]. This directly leads to ongoing fossil fuel dependency and hinders the transition to renewables [16].

#### 2.2.4 Society

Many researches have shown how discord within civil society challenges the renewable energy transition. The public may support the status quo, which makes it difficult to engineer the necessary investments to advance renewable options [42,43]. Lack of knowledge of renewable energy among the public and government officials has led to disagreement regarding the question of to what extent renewable energy should be developed [8,23].

The social impact of renewable power increases reluctance in the public and hampers the energy transition. Taking resettlement for example, hydroelectric dams have inundated forests, and, in some cases, entire cities have been relocated [35]. In addition, large-scale irrigation projects, with stagnant water, can lead to increases in water-borne diseases [44].

The impact of the use of renewable energy on the ecosystem has been a reason for local environmental opposition. Environmental side-effects, including local air, water and soil pollution, greenhouse gas emissions, and biodiversity loss are inevitably generated during the deployment of energy [31]. For instance, hydropower can have negative effects on aquatic and riparian ecosystems [44], and wind power stations are forbidden in many areas because of concern over bird and bat deaths [45].

### 3. RENEWABLE ENERGY DEVELOPMENT

Great progress has been made in renewable energy development in Northeast China in the last decade. According to official figures from the National Energy Agency [46], in 2015 the northeast utilized 42.1 billion kWh of renewable electricity, accounting for nearly 12% of total electricity consumption of the region. Table 1 outlines the installed capacity of the four main forms of renewable energy in 2014. It shows that wind energy and bioenergy are highly developed in the northeast, contributing to 15.2% and 11.1% of the national total, respectively. It also shows that there is significant variation, even within the region. Liaoning has attained a higher level of wind power development than Jilin and Heilongjiang, despite its poorer wind resources. Bioenergy development is mainly concentrated in Heilongjiang and Jilin where agricultural businesses are

more developed. The deployment of renewable energy in Northeast China is accompanied by the growth of related industries. In recent years, the northeast has emerged as a manufacturing hub for wind power equipment, drawing investment from large manufacturers like Sinovel Wind Group [47]. The cluster has been able to develop high-end products such as the 5 MW large wind turbine unit [48].

#### 4. BOTTOM-UP DRIVERS: RESOURCE DEPLETION

Table 2 shows the proven fossil fuel reserves of Northeast China and those of the whole country in 2016. The Songliao Basin and the Liaohe Plain in the northeast still have relatively abundant petroleum deposits, accounting for more than 20% of national reserves. The reserves of coal and natural gas in Northeast China are however much smaller, which accounts for around 4% of national reserves. After decades of exploitation, resource depletion has become an important issue in Northeast China. In the 13th Five-Year Development Plan for the Coal Industry, formulated by the National Energy Administration of the National Development and Reform Commission, Northeast China was regarded as a constrained development region, due to the continuous decline of coal production [50]. A large number of coal cities have been classified as resource-exhausted cities, including Liaoyuan, Panjin, Fuxin, Fushun, Qitaihe, and Hegang [51,52]. Even Daqing, the most productive petroleum city in the northeast, has gradually decreased its annual production of oil fields by approximately 1.5 to 2 million tons per year since 1999 to buy more time for the city to diversify its economic structure before traditional resources are exhausted [3]. Coupled with resource depletion is the increased difficulty in exploitation. In Northeast China, the resources left are mostly located deeply underground, which poses significant challenges to exploitation in both financial and technological terms [53].

In contrast to the depleting fossil fuel reserves, Northeast China is endowed with abundant renewable energy resources. Table 3 outlines the potential production capacity of wind, solar, hydropower, and bioenergy in the region. It shows that the northeast is well endowed with accessible wind (8.5% of the national total), especially in the central Northeast China Plain (Figure 3). As a highly developed agricultural and forestry area, the northeast is also very rich in biomass resources, accounting for 13.3%, 8.0%, and 11.4% of the national total for crop straw, firewood, and livestock manure, respectively. The western part of Northeast China is rich in solar resources. However, solar resources in this area account for only 2.3% of the overall national total in terms of accessible renewable energy potential due to fewer sunshine hours during the very long winter. Hydropower resources are not very abundant in the northeast, as many major rivers are located in plain areas or are along national borders. Overall, accessible hydropower potential accounts for only 1.9% of the overall national total.

#### 5. TOP-DOWN DRIVERS: NATIONAL POLICIES

National policies play an important role in driving the northeast's renewable energy transition. China faces mounting international pressure to curb emissions after becoming the largest CO<sub>2</sub> emitter [55,56]. The combustion of fossil fuels, especially coal, is a major source of CO<sub>2</sub> emissions for China. In 2011, China's coal consumption contributed 72% of the country's CO<sub>2</sub> emissions and 19% of global emissions [57]. Carbon intensity and per capita emissions in Northeast China far exceed the national average because of the concentration of heavy industries and coal-fired power plants [58]. Consequently, local governments in the northeast are under pressure from the central government to achieve quantitative energy and carbon targets [59,60]. To control carbon emissions, the central government has initiated many policies to curtail the consumption and production

**Table 1:** Renewable energy development in Northeast China (2014) [49]

	Wind energy (MW)		Solar energy (MWp)		Hydropower (MW)		Biomass resources (MW)	
	Approved capacity	Grid connected capacity	Approved capacity	Grid connected capacity	Installed capacity	Approved capacity	Approved capacity	Grid connected capacity
Liaoning	8026.5	6089.4	18	9.9	2930	132		83.5
Jilin	6689.8	4079.8	25	6	3770	833.8		415.9
Heilongjiang	6815.5	4615	22	1.15	970	872.1		555.9
NE China	21531.8	14784.2	65	17.05	7670	1837.9		1055.3
China	176858.4	97316.2	6837	2806.65	304860	14228.4		9477.1
Proportion (%)	12.2	15.2	1.0	0.6	2.5	12.9		11.1

**Table 2:** *Remaining fossil fuels reserves in Northeast China (2016) [54]*

	Coal	Petroleum	Natural gas
	Remaining reserves (Mt)	Remaining reserves (Bt)	Remaining reserves (TCM)
Northeast China	9872	745.2	0.2
China	249226	3501.2	5.4
Proportion (%)	4.0	21.3	4.0

of coal. These measures including the setting of a coal consumption cap [61], eliminating small and inefficient coal-fired units [62], the curtailment of new coal-fired power plants [63], and the coal capacity cut policy [64]. In particular, the coal capacity cut policy, introduced in 2016, has a strong and immediate impact on coal production in the northeast as local governments were given strict capacity reduction targets. National coal consumption data suggest that these measures have successfully stopped the growth in coal production and use [65].

Renewable energy development in Northeast China is also supported by the country's ambitious renewable energy policies [66–69]. In particular, feed-in tariffs and the full power purchase policy have played a significant role in driving explosive renewable energy capacity growth in the region.

## 6. CHALLENGES

The renewable energy transition in the northeast currently faces three challenges. The first challenge is the curtailment of renewable generation, which is among the highest of the country. According to the data released by the National Energy Administration, wind curtailment in Liaoning, Jilin, and Heilongjiang was 1.2 billion kWh, 2.7 billion kWh, and 1.9 billion kWh in 2015, respectively, accounting for 10%, 32%, and 21% of their generating capacity [46]. Because of the high curtailment rate, the National Energy Administration in 2016 declared that Heilongjiang and Jilin were put on restriction regarding their wind investments [70].

The reasons behind such a high curtailment rate are complex and multiple, and both technical and institutional responses are required if the problem is to be addressed. First, weak electricity demand, which is primarily due to a pronounced economic slowdown and the structural shift from energy-intensive industries to less energy-intensive service industries and high-tech manufacturing industries [71], results in overcapacity. By the end of June 2014, installed capacity in the Northeast power grid amounted to more than 116 million kW, but the maximum electrical load was just 56.4 million kW [72]. Second, grid capacity is weak in the northeast. From Table 1, it can be seen that the grid connected capacities of wind, biomass, and solar power are all significantly lower than their approved capacities, showing that many renewable energy generators are left unconnected. Third, CHP (combined heat and power) plants are very common in the northeast and are given priority over renewable power in winters because of the importance in space heating, which is an essential service during the severely cold winters [73,74]. Fourth, the technical and institutional infrastructure for exporting electricity is inadequate in the northeast [75]. Before the renewable energy demand, the northeast was an electricity self-balancing region, so the region is not ready to export surplus power. In 2013, only a single 3 million kW power delivery channel existed in the region, which could not meet the demands of power export [76]. Meanwhile, institutional and market barriers to trade, such as price disagreements regarding inter-provincial power transactions and compensation for power losses during inter-provincial power delivery,

**Table 3:** Renewable energy resources of Northeast China [49]

	Wind energy (1000 MW)		Solar energy ( $10^{14}kWh$ )		Hydropower (Billion kWh)		Biomass resources (million ton)		
	Potential reserve	Technically exploitable capacity	Potential reserve	Exploitable capacity	Potential reserve	Technically exploitable capacity	Crop straw	Firewood	Livestock manure
Northeast China	292.2	219.2	10.6	0.93	145.5	46.5	31.8	12.4	107.0
China	3053.7	2565.9	147.2	40.18	6082.9	2474.0	239.8	154.8	941.3
Proportion (%)	9.6	8.5	7.2	2.3	2.4	1.9	13.3	8.0	11.4

**Table 4:** Production and consumption of fossil fuels in Northeast China (2016) [5-7,54]

	Coal		Petroleum		Natural gas	
	Production (Mtce)	Consumption (Mtce)	Production (Mtce)	Consumption (Mtce)	Production (Mtce)	Consumption (Mtce)
Liaoning	28	119	14.5	63.7	0.7	6.7
Jilin	9.7	54	8.9	14.4	2.6	2.9
Heilongjiang	40.5	85.5	52.2	27.1	5.1	5.1
NE China	78.2	258.5	75.7	105.2	8.4	14.7
China	2415.3	2712.0	283.8	844.1	183.4	314.3
Proportion (%)	3.3	9.5	26.7	12.5	4.6	4.7

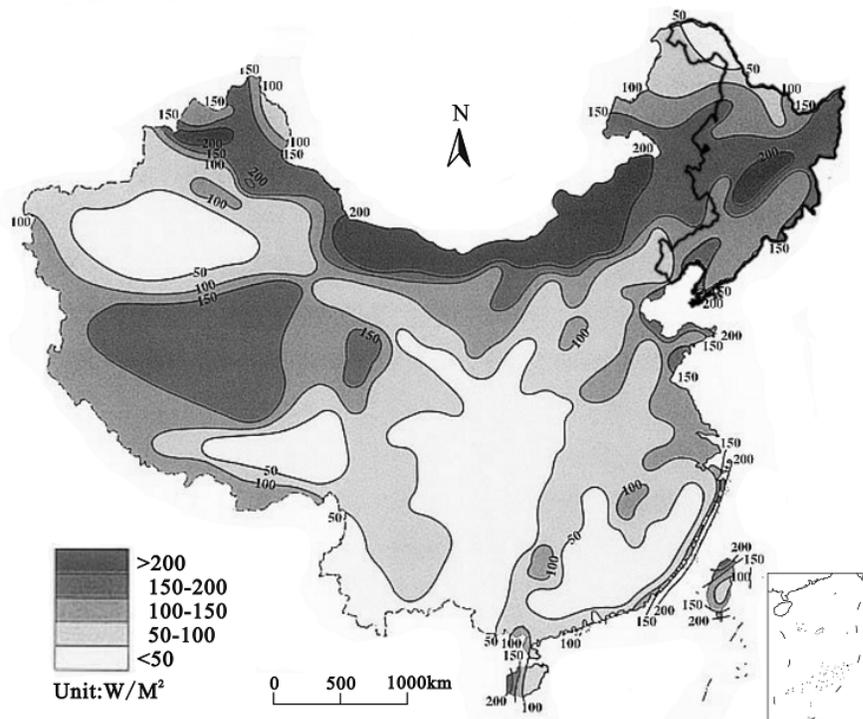


Figure 3: Wind resources in China [46]

also hinder inter-provincial power trade [77,78].

The second challenge regards the limited or even negative impact of the renewable energy transition on local economic revitalization. It has been suggested that most forms of renewable energy development, with the exception of hydropower, have negative impacts on local economic growth [79]. This is because, compared to coal-fired power plants, renewable power plants generate less tax and are dependent on government support through subsidies, feed-in tariffs, tax support, and industrial support policies. These measures place a burden on local fiscal budgets and restrict economic growth. Furthermore, renewable power increases result in a decreased share of coal-fired power generation. The share of coal-fired generation decreased from 94.2% in 2008 to 85.1% in 2014 [80]. This results in sub-optimal efficiency as existing power plants are often not run at their full capacity, and smaller plants are shutdown outright. However, as technological improvement and the economy of scale work to bring down the cost of renewable energy, the positive impact of renewable development is likely to strengthen in the future.

The third challenge is rising dependency on energy import. While the reduction in fossil fuel production has been dramatic, the demand for fossil fuels in the northeast has remained relatively stable (Figure 4), driven by factors such as increasing uptake of personal automobile [81], the demand for heating during winters [82], and the goal of industrialization as the region's main economic growth engine [2]. Consequently, the already significant gap between supply and demand of fossil fuels are growing. As shown in Table 4, the gap between production and consumption of coal, petroleum, and natural gas reached 180.3 Mtce, 29.6 Mtce, and 6.3 Mtce, respectively, in 2016. The gap is particularly significant in Liaoning and Jilin, but even Heilongjiang, the leading energy producer in the northeast, has become dependent on fossil fuel import to fulfill its energy demands.

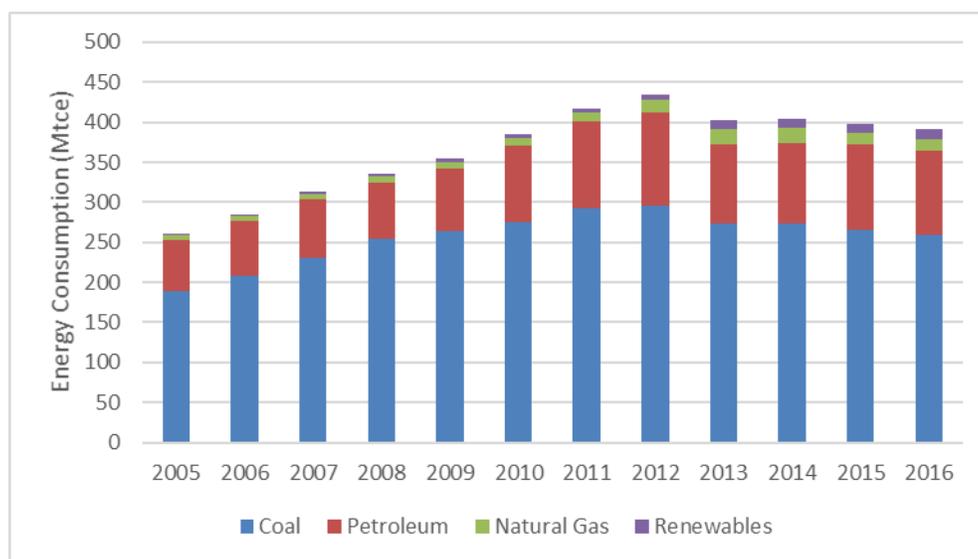


Figure 4: Energy consumption of Northeast China (2005-2016) [5-7]

## 7. CONCLUSION

As a region with rich renewable energy resources, especially wind and biomass, Northeast China has been a major site of renewable energy deployment during the past decade. While development has generated significant environmental benefits, its further development is difficult because of technical, economic, and institutional challenges. These challenges are manifested as problems regarding energy curtailment and the burden placed on local economies. Addressing these challenges is necessary and requires multiple solutions if long-term healthy growth of renewable energy is to be assured. Technological innovation is required to further reduce the cost of renewable energy production and transmission. Infrastructure investments in energy storage, ultra-high voltage transmission, and smart grid technology is required to promote the energy utilization rate. Institutional reform is also required, particularly replacing fiscal support with market-oriented policies such as the Renewable Energy Portfolio policy, which would reduce the fiscal burden and negative impacts on the local economy.

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