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A critical review of China's rapidly developing renewable energy and energy efficiency policies

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A B S T R A C T

Renewable energy and energy efficiency (REEE) policies have far-reaching implications for energy security, climate change, economic competitiveness, pollution, and human livelihood. For these reasons, REEE has become a national priority for the Chinese government, particularly since 2005. This paper aims to critically review China's REEE policies in six sectors: electricity, industry, transportation, buildings, and local government. In addition to examining the progress China has made in the development and implementation of REEE policies, this review also identifies limitations and room for improvement. Finally, five policy recommendations are presented.

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1. Introduction

Renewable energy and energy efficiency (REEE) policies relate to five significant issues in China. First among these is energy security, defined as "unimpeded access or no planned interruptions to sources of energy" [1]. China's sustained economic development over the past three decades has accompanied a rapid rise in energy demand, which, at times, has contributed to widespread electricity shortages [2]. China's increasing dependence on oil imports is also a concern. China has changed from an oil exporting country in the early 1990s to one of the largest oil importing countries in the world, with an oil import dependency rate of more than 50% [3]. Oil imports are perceived as susceptible to interruption because most oil imported to China must pass through the Malacca Strait, a chokepoint wedged between Indonesia and Malaysia that is vulnerable to maritime blockage [4].

Climate change is the second issue affecting China's commitment to REEE policies. Despite its status as a developing country and its historically low emissions, China faces international pressure to control its carbon emissions, which has intensified since China surpassed the United States as the world's largest carbon polluter [5]. Domestic concerns about the impact of climate change also contribute to the urgency of climate mitigation [6]. Third, REEE policies affect economic competitiveness. The manufacturing of renewable energy products (e.g., wind turbines and photovoltaic cells) has been designated as a pillar industry by the government, which hopes that China will become a global leader and exporter of green technologies [7,8]. Therefore, REEE policies can be understood as both economic and environmental policies. Pollution is the fourth issue. The burning of fossil fuels is associated with air, water, and soil pollution, which have serious implications for health, water security, and food security. Finally, human livelihood is the fifth issue affecting China's adoption of REEE policies. Despite rapid development, many Chinese rural households still depend heavily on traditional biomass energy for heating and cooking [9]. Renewable energy, such as photovoltaic and solar water heating, can significantly improve the livelihood of people from underdeveloped areas in China.

Due to the salience of these issues, the Chinese government has expended considerable effort to develop and implement REEE policies, manifested in an array of major policy initiatives since 2005. However, as this critical review demonstrates, China's REEE policies are still far from comprehensive, and significant room for improvement exists. Chinese REEE policies are differ from those of the United States, where the federal government has been slow to act and instead relies on state-level policy experiments [10], and Europe, where a supranational body (the European Union) plays a significant role in REEE policymaking [11]. In China, the central government is the key policymaking body [12], and central-level policies are therefore the focus of this study. REEE policies span a wide spectrum and are very diverse. For example, policies designed to improve industrial energy efficiency differ significantly from policies aiming at improving energy efficiency in buildings or promoting the deployment of renewable energy. To ensure comprehensive coverage, this critical review is organized into five parts: electricity, industry, transport, buildings, and local government.

2. Electricity

The electricity sector in China is traditionally dominated by coal, but the Renewable Energy Law, which came into effect on January 1, 2006, sparked a dramatic rise of renewable energy, particularly wind and photovoltaic power [13]. In a few years, China will become the world leader in installed wind power capacity (75,324 MW at the end of 2012) [14] and one of the leading countries in installed photovoltaic capacity (8300 MW at the end of 2012) [15]. These achievements were made possible mainly by three policy measures: renewable portfolio standards, feed-in tariff, and direct subsidies.

2.1. Renewable portfolio standard

Renewable portfolio standard (RPS) is a popular policy instrument in the United States, where 37 states have implemented some form of RPS with different degrees of stringency [10]. The defining feature of RPS is that retail electricity suppliers are required to procure a certain quantity of renewable energy [16]. RPS can either be completely voluntary with no compliance requirements (weak RPS) or mandatory with financial penalties (strong RPS).

RPS were introduced in China in 2007 by the National Development and Reform Commission (NDRC) in the Mid- and Long-Term Development Plan for Renewable Energy [17], which is a long-term (up to 2020) strategic planning document for renewable energy. The NDRC is a powerful ministry in the central government that is responsible for planning the economic development of the country, and it has been assigned the responsibility for energy and climate change. China's RPS assigned renewable energy targets for grid companies (1% non-hydro renewable power by 2010, 3% by 2020) and generators (3% non-hydro renewable power by 2010, and 8% by 2020). However, many aspects of the policy are left undeveloped. In particular, the lack of monitoring and compliance requirements means that the RPS remains weak or voluntary. It has been reported that in 2010, none of the six largest generators met the 3% renewable energy target [13]. Furthermore, because the focus is on installed capacity rather than generation, many wind farms suffer from poor integration with the grid and the curtailment of wind-generated electricity by grid companies [13]. To address these problems, the NDRC began to develop an improvement plan in 2011. A draft that introduced a few changes and additional details to improve the RPS was released in May 2012 for public consultation [13]. First, individual targets were assigned to generators and grid companies, depending on their circumstances and capacities. This change made the RPS more practical and clarified the companies' obligations. Second, to address the problem of grid companies lacking incentives to purchase renewable electricity, their targets were significantly increased. For example State Grid, China's largest grid company, was expected to achieve a 4.8% non-hydro renewable energy share by 2015, although its previous target was 3% by 2020. Third, the National Energy Administration (NEA) was given the responsibility of monitoring compliance on a monthly basis. Renewable energy certificates would be used to track the fulfillment of targets, but the certificates had not been made tradable. Fourth, as a punishment for non-compliance, failure to meet the targets would negatively impact the managers' performance evaluations. All generators and grid companies regulated by the RPS are state-owned enterprises, and their managers are evaluated annually by the State-owned Assets Supervision and Administration Commission (SASAC). The state-owned enterprises have resisted this RSP update, and it is still under debate at the time of writing (June 2013). No a timetable for the release of the update has been announced.

Assuming the update comes into effect, China's RPS still has several problems. First, China's RPS does not distinguish between different types of renewable energy. Consequently, low-cost renewable energy, such as wind power, would likely dominate the market, crowding out emerging and more expensive renewable technologies such as photovoltaic power. This bias towards mature and inexpensive technologies in the long run may impede the development of renewable energy technologies. Second, the penalties for non-compliance are not clearly defined, even in the draft update. In particular, no financial penalties have been articulated for non-compliance, which has been demonstrated to be effective in international experience.

2.2. Feed-in tariff

Feed-in tariff (FIT) is a policy mechanism that guarantees renewable electricity generators a price that is above market value. Scholars debate the superiority of FIT versus RPS, but no theoretical barriers prevent the implementation of both measures. In fact, Dong [18] found that countries adopting both policy mechanisms are more effective in the development of renewable power. This dual-approach is followed by China.

FITs were implemented in China as early as 2003 in support of the deployment of wind power. At first, the tariff amount was determined on a case-by-case basis through bidding or negotiation. However, this arrangement created intense competition among large state-owned renewable power generators, which issued speculative bids that were often insufficient to actually implement the project [19]. This practice was considered harmful to the long-term sustainability of the wind power industry. In response, the NDRC set baseline prices for wind tariffs in August 2009. The minimum tariff ranged from 0.51 RMB/kWh to 0.61 RMB/kWh, depending on the location of the wind farm [20]. In 2011, the NDRC set national solar FIT at 1.00 RMB/kWh for projects started in 2011 or later [21]. To support the FITs, the NDRC established the renewable electricity surcharge in 2006, at 0.001 RMB/kWh [19]. The surcharge was increased to 0.004 RMB/kWh in 2009 and again to 0.008 RMB/kWh in 2011 to support the increasing demand for FIT following the rapid growth of renewable energy [20]. Despite the eight-fold rate hike, the surcharge remains low by international standards: with an average residential electricity price of 0.52 RMB/kWh [22], the surcharge is 1.5% of total electricity price. In comparison, Germany's renewable energy surcharge reached 0.053 €/kWh (0.43 RMB/kWh) in 2013, or 20% of total the electricity price. China's low renewable electricity surcharge is important to the sustainable development of renewable energy because it leaves sufficient room for future expansion of FITs.

China's FITs have a few problems. Most significantly, the FIT for photovoltaic energy was insufficient to provide incentives for generators. Table 1 compares China's FITs with similar programs around the world. For the purpose of comparison, tariffs are converted to RMB using the average exchange rate for 2012. The comparison reveals that China's wind FITs are similar to programs in other countries, but China's solar FIT is significantly lower than the international average. This is not because the cost of photovoltaic power is much lower in China. Rigter and Vidican [22] calculated that the average cost of residential and commercial photovoltaic electricity were 3.15 RMB/kWh and 2.33 RMB/kWh, respectively, in 2009—both significantly higher than the solar FIT. Second, China is a large country with a number of distinct climate zones. The singular solar FIT fails to accommodate the substantial geographical differences in solar output and, consequently, cost to produce electricity.

Table 1
Comparing China's wind power and solar power FITs internationally.
Sources: Germany and Canada (Ontario) [23], Spain [24], United Kingdom [25], Ukraine [26], Malaysia [27].

Country	Wind power FIT (RMB/kWh)	Solar power FIT (RMB/kWh)
China	0.51–0.61	1.00
Canada (Ontario)	0.85–1.01	2.80–2.96
Germany	0.40–0.80	1.71
Spain	0.64	2.34
United Kingdom	0.42–2.17	0.69–1.55
Ukraine	0.54	1.97
Malaysia	0.47–0.72	2.57–3.59

2.3. Direct subsidies

The third policy mechanism to promote renewable energy is direct subsidies. In 2009, to address the Chinese photovoltaic industry's dependence on export amid mounting trade frictions with the European Union and the United States, China's Ministry of Finance (MOF) rolled out two photovoltaic power subsidy programs to boost domestic demand. The first is the Solar Roofs program, which supports distributed photovoltaic projects including rooftop systems and building integrated photovoltaic (BIPV) systems [28]. The program provides a subsidy of 50% of the bidding price for the supply of critical components. The subsidy amount has decreased substantially since the program's inception, reflecting declining cost of photovoltaic energy. In 2009, the subsidy amounted to 20 RMB/W for BIPV and 15 RMB/W for rooftop systems. By 2012, the subsidy amount declined to 9 RMB/W for BIPV and 7.5 RMB/W for rooftop systems [29]. The second subsidy program is the Golden Sun Demonstration project, which supports more types of photovoltaic energy projects than the Solar Roofs program, including BIPV systems, rural electrification projects, and large-scale photovoltaic power projects. The program provides 50% of the total cost for on-grid systems and 70% for off-grid systems in rural areas [30]. In 2012, on-grid systems received RMB 5.5/W, and off-grid systems received RMB 7.0/W [29].

3. Industry

The industry sector consumes between 60% and 70% of primary energy in China [31]. It is therefore an important sector for REEE, particularly regarding improvements to energy efficiency. To this end, China has developed four key strategies: forced closure, energy efficiency obligation, energy efficiency funds, and electricity pricing.

3.1. Forced closure

China has a large number of small, inefficient production facilities. Most of these facilities were constructed in the 1990s and, despite their inefficiency, survived well into the 2000s due to high demand for energy-intensive products [32,33]. To improve energy efficiency, the central government first began shutting down small coal-fired power plants in 1999, although progress was slow because of the high electricity demand from 2002 to 2005 [32]. In 2006, the MIIT and the NDRC renewed efforts and expanded the mandatory shut down to 12 other energy-intensive industries. To alleviate the negative economic and social impacts of the forced closures, funding was made available to local governments to support affected enterprises and workers. The policies generally have been effective, although local governments have frustrated the central government in some instances by sheltering local factories from closure because they contribute to revenues and employment [34]. In total, 72,000 MW of coal-fired power generators, 122 million tons of iron production capacity, 70 million tons of steel production capacity and 330 million tons of cement production capacity were retired during the 11th FYP period [35]. In 2011, the forced closure program was renewed and expanded to cover nineteen industries. In May 2011, an update was implemented to tighten the requirements for obtaining funding [36]. Enterprises that have not been in a normal state of production for the past three years are not allowed to receive compensation. Moreover, to prevent the misuse of funding by local governments, the policy stipulates that funding must be earmarked for worker placement, debt repayment and other expenses related to the phasing out program.

3.2. Energy efficiency obligation

Energy efficiency obligation (EEO) is a widely used regulatory REEE policy measure in Europe, although it is most commonly applied to the electricity sector and the buildings sector [37]. The key component of EEO is the assignment of energy-saving targets to enterprises. EEO was first used in China in 2006 by the NDRC after experimenting with voluntary agreement schemes for energy conservation in the industry sector [38]. Under China's EEO scheme, officially called the Thousand Enterprise Energy Conservation program based on the number of enterprises that are regulated, enterprises would be penalized for not meeting their assigned energy-saving targets [33]. The program targeted the 1008 largest enterprises in nine energy-intensive industries. Collectively, the enterprises accounted for 33% of China's total energy use in 2005 [39]. The program was significantly expanded in 2011 and renamed the Ten Thousand Enterprise Low Carbon and Energy Conservation program, reflecting the increased number of enterprises brought under the regulatory net. A total of 14,641 enterprises are now regulated under the program. Although only energy-intensive sectors were targeted in the 11th FYP period, the new program encompasses almost every type of industry, from breweries to water suppliers and drug manufacturers.

EEO proved to be effective in stimulating energy conservation practices and investments among the regulated enterprises in China. Of the 881 firms in the program at the end of 2010, 866 firms (98.3%) met their targets. Overall, the program conserved 165 Mtce of energy, which was 183% of the original target. It should be noted that the firms regulated from 2006 to 2010 were mostly large state-owned enterprises, which are naturally more sympathetic to the concerns of the central government. Moreover, the achievement of EEO targets is linked to performance evaluation for the state-owned enterprise managers. The NDRC has not yet announced the punishment for private enterprises that fail to comply. The lack of punishment may weaken the scheme's effectiveness.

Another concern for China's EEO is the uniformity in the allocation of EEO targets. Because industries and companies have different energy efficiency potentials, obtaining information regarding firms' energy efficiency potential during the target-setting exercise is a common practice internationally. For example, in the United Kingdom's Climate Change Agreement program, individual companies estimated their energy efficiency potential, which was summarized by their respective trade associations. The trade associations then negotiated with the government to set a target for the entire sector [40]. Because of the large number of enterprises participating in China's EEO scheme and the urgency of its implementation, the NDRC does not negotiate or solicit information about energy efficiency potential. Instead, EEO targets are pegged to the national energy intensity targets. China's EEO also suffers from a lack of flexibility, which may result in higher costs for compliance. Internationally, EEO is usually coupled with tradable white certificates (TWCs). Firms can decide whether to implement energy efficiency measures directly or to purchase TWCs, depending on their marginal costs of compliance. China currently has no plan to introduce TWCs.

3.3. Energy efficiency funds

Complementing the EEO scheme is the energy efficiency fund (EEF), which is a supportive policy to help industries improve energy efficiency performance. The MOF established the Energy-Saving Technological Improvement Fund in 2006 to support industrial energy efficiency improvement. Funding was limited to enterprises regulated by EEO. In 2011, funding mechanisms were modified in three ways to make it easier for enterprises to apply for subsidies. First, projects that conserve 5000 tce or more are eligible, which is a decrease from the previous threshold of 10,000 tce [41]. Second, the limitation on specific technologies has been removed. Third, funding has been increased from 200 RMB/tce to 240 RMB/tce for eastern provinces and from 250 RMB/tce to 300 RMB/tce for central and western provinces. Despite this relaxation of criteria, it is still far from easy for smaller businesses to obtain funding. Because the competition for limited funding is based on the amount of energy saving, a measure that clearly favors larger enterprises because of their greater energy-saving potentials.

3.4. Differentiated electricity pricing

In China, electricity pricing is controlled by the NDRC and can therefore be used as a policy tool to promote energy conservation among electricity-intensive industries. In 2004, the NDRC created a trial program in which energy-intensive enterprises with outdated production technologies and/or a poor environmental record were required to pay electricity surcharges [42]. According to the latest policy document released in June 2010 [43], enterprises in the category of “restricted” pay a surcharge of 0.1 RMB/kWh, whereas those in the category of “eliminated” pay a much higher surcharge of 0.3 RMB/kWh. The implementation of the policy is far from smooth because local governments refuse to implement the policy or counter it with preferential (reduced) electricity prices to protect local electricity-intensive industries [42,44]. This occurs because the regulation puts extra financial burden on the local government and because the policy often conflicts with the primary interest of the local government: growth in GDP. In response, the central government has vowed to conduct regular inspections and to punish local authorities who do not comply with central directives [45].

Several studies have analyzed the effects of the differential pricing policy. Lin and Liu [46] assessed the effects of the policy through on-site surveys of energy-intensive industries in Henan province. They noted that although the original intent of the policy was to restrict or eliminate energy-intensive industries by making them unprofitable, in practice, most enterprises affected by the policy were able to avoid closure through a combination of energy efficiency improvements and help from local governments. Using official statistics from the China Statistical Yearbook, Hu et al. [47] estimated that the policy reduced CO_2 emissions by 82.32 million tons from 2004 to 2009. However, the effects of the policy varied across different industries, with the largest impact on the non-ferrous metal smelting and rolling industry, followed by the chemical industry.

4. Transportation

In China, the transportation sector consumes a relatively low level of energy, but it consumes 97% and 55% of the national total gasoline and diesel consumption, respectively [48]. As oil security becomes an increasingly urgent issue [49,50], the stakes for conserving energy in the transportation sector also increase. Transportation is a complex sector with many stakeholders, and it is therefore common to observe a diverse set of policy instruments in this area [51]. For the sake of parsimony, this section focuses on the policies that relates to automobiles, which dominate the Chinese transportation sector [48]. There are four key policy mechanisms in this area: fuel economy standards and labeling, vehicle and fuel taxation, subsidies for energy-efficient vehicles and electric vehicles, and public transportation.

4.1. Fuel economy standards and labeling

Fuel economy standards (FES) are arguably the most important measure globally for improving automobile energy efficiency.

FES regulate fuel consumption or carbon emissions per distance traveled of new vehicles and thus require automakers to design more efficient products or shift sales towards more efficient models [52]. FES were introduced in China in July 2005 by the NDRC and the General Administration of Quality Supervision, Inspection and Quarantine (GAQSIA), which has the authority for creating and managing national standards [53]. Chinese FES were distinctive because they set standards for each vehicle, based on weight, rather than fleet average [54]. The fleet average approach was inapplicable in China because Chinese automobile market was highly fragmented, with more than a hundred manufacturers each producing a handful of models. The latest update to the standards, the Phase 3 Standards, is scheduled to be introduced in 2012 and will take full effect in 2015 [55]. The Phase 3 Standards aim to reduce the average fuel consumption rate of Chinese passenger vehicles to approximately 7 L/100 km. Furthermore, the fleet average system, differentiated by weight class, was introduced to offer enterprises more flexibility in achieving energy efficiency. Compared to other countries, China has less stringent FES than the European Union, which aims to reduce fuel economy of new vehicles to 5.6 L/100 km by 2015 and 4.1 L/100 km by 2020 [56], and the United States, which aims to reduce fuel economy of new vehicles to 4.3 L/100 km by 2025.

In January 2010, the Ministry of Industry and Information Technology (MIIT) introduced fuel economy labeling (FEL) to further promote energy conservation and raise consumer awareness of vehicle fuel efficiency [57]. The FEL standards require all new light-duty vehicles to be labeled with fuel consumption estimates for highway, city and overall average driving patterns, based on laboratory tests that use the European driving cycle [56]. A universal problem with FEL, which also affects FES, is the gap between laboratory and real-world fuel consumption. A recent survey found that Chinese labels underestimate fuel consumption by an average of 15.5% [57]. The results suggest that the laboratory estimates should be adjusted to better fit local driving conditions.

4.2. Vehicle and fuel taxation

FES and to a lesser extent FEL have helped improve fuel economy among new vehicles. However, these policy instruments have little effect on old vehicles and driving behavior. Therefore, vehicle and fuel taxation is considered more effective than FES in controlling fuel consumption in the transportation sector [52,58]. In China, vehicles are subjected to four taxes: a 17% value-added tax, a consumption tax, a vehicle acquisition tax, and a vehicle and vessel tax [59]. The consumption tax was reformed in 2008 to encourage the sales of vehicles with smaller engines. Vehicles with an engine capacity of 1 L or less are taxed at 1% of the vehicle value, whereas vehicles with a capacity of more than 4 L are taxed at 40%. The vehicle acquisition tax was a universal 10% of the vehicle value, but in 2009 the government reduced the tax to 5% (adjusted to 7.5% in 2010) for vehicles with an engine capacity of less than 1.6 L. Starting in 2012, the vehicle and vessel tax is also calculated based on engine capacity, with the tax rate increasing with engine size. The government obviously intends to use tax as a policy instrument to achieve energy efficiency objective in automobiles. However, the overall tax levels remain low due to the government's interest in protecting the domestic car industry.

In 2009, the government increased taxes on unleaded petrol by five times and on diesel by eight times [59]. Even with this increase, fuel taxation remains low compared to developed countries. Moreover, the increase in fuel tax is compensated with the abolition of various charges and road tolls, which further reduces the impact of the fuel tax in limiting vehicle ownership [59].

4.3. Subsidies to energy-efficient vehicles and electric vehicles

Recently, the government has actively promoted the adoption of three types of energy-efficiency vehicles and electric vehicles through subsidies. First, since June 2010, purchases of energy-efficient automobiles are subsidized 3000 RMB [60]. Energy-efficient automobiles are defined as automobiles with fuel consumption from 4.8 L/100 km to 6.9 L/100 km, depending on weight. Second, since 2010, the purchase of electric vehicles is subsidized [61]. The amount of subsidies depends on two factors: the capacity of the battery and the type of the vehicle. The rate was set at 3000 RMB/kWh, with a maximum subsidy of 50,000 RMB for plug-in hybrid electric vehicles and 60,000 RMB for pure electric vehicles [61]. Third, since 2009, hybrid and electric public vehicles, including buses, taxis, official vehicles, and municipal service vehicles (e.g., garbage trucks and mail trucks), are subsidized based on the length and type of vehicle, the fuel-saving potential, and the ratio of electric motor and battery type [62].

4.4. Public transportation

Governments can achieve energy efficiency objectives with modal shifts, typically by improving public transport [63]. The development of high-speed railways (HSR) in China is a good example. China's HSR network became the largest in the world in 2010, due to strong government support and consistent investment [64]. Since 1997, the Ministry of Railway (MOR) has initiated six rounds of "speed up" campaign to improve existing tracks. Large-scale railway development and planning began in approximately 2005 and accelerated massively in 2008 due to the stimulus package in response to the Global Financial Crisis [64]. The rapid development of HSR is also attributed to the success of a risk-sharing financing structure between the MOR, state-owned banks, and local governments [64].

In China, the local government is responsible for urban transport. The role of central government in this area is limited. Nevertheless, following the State Council's call for local governments to prioritize public transit, Chinese cities have greatly expanded their public transit systems [65]. Most notable is the rapid development of metro rapid transit (MRT) projects in many cities [66]. The majority of these projects are funded by local government, sometimes with borrowed money, and are managed by large state-owned enterprises. Public–private partnerships are becoming increasingly common, however, because of the immense gap between limited public resources and rapidly growing urban infrastructure needs [67]. Table 2 indicates the development of MRT from 2006 to 2011, measured both in total distance (an increase of 174%) and in total passengers (an increase of 293%). The development of buses and trolleys has received less academic attention, but significant improvements have been made in distance (an increase of 316%) and in total passengers (an increase of 50%).

Table 2
Development of public transportation in China (2006–2011).
Source: [68].

Year	Total distance (km)		Total passengers (million trips)	
	MRT	Buses and trolleys	MRT	Buses and trolleys
2011	1699	521,253	7134	67,258
2010	1471	488,812	5568	63,107
2009	999	208,250	3658	64,018
2008	835	146,514	3374	66,926
2007	763	140,038	2206	53,259
2006	621	125,236	1816	44,776

5. Buildings

The buildings sector, including the operation of residential, commercial and public buildings, accounts for approximately 25% of the total energy consumption in China [69]. This proportion is likely to increase to 35% by 2020 because of rapid urbanization and increases in income [70]. The potential for energy conservation is considerable because many buildings in China have poor thermal energy performance, particularly in the northern region where winters are cold and long [71]. China has implemented five key measures to control energy consumption in buildings: energy codes for buildings, retrofits to existing buildings, appliance energy standards and labeling, subsidies for energy-efficient and renewable energy appliances, and increasing block tariffs.

5.1. Energy building codes

Most countries, including China, have implemented energy building codes (EBC) to prevent carbon lock-in because of the long-lasting nature of buildings. EBC were introduced by the Ministry of Construction (now the Ministry of Housing and Urban–Rural Development, MOHURD) in 1986 to regulate the energy design of residential buildings in the cold zone, where the heating season lasts for 3–6 months [72]. In 2000, EBC were extended to the hot summer and warm winter zones where energy is primarily consumed for cooling in summer [73]. These codes set national standards for the design and material choice of building envelopes as well as the heating and air-conditioning systems, although local governments are encouraged to set more specific local standards [73]. Another important EBC mandates that new buildings must achieve 50–65% reduction in energy consumption compared to buildings built in 1980 [74]. The enforcement of EBCs has been greatly improved since 2006. A compliance rate of 100% was reported in 2010 [74].

5.2. Existing building retrofits

Among the existing residential buildings in the northern regions that cover 5.45 billion m^2, 4.13 billion m^2 (76%) were reported to be energy inefficient with no or insufficient insulation [71]. With an average heating intensity of 25 kgce/m^2, the existing buildings consume 100–200% more energy than buildings in developed countries in the same latitude [75]. To address this problem, the MOF and the MOHURD jointly launched the Existing Building Retrofit and Heat Metering Reform program in December 2007. The program aimed to retrofit buildings of 0.15 billion m^2 [76]. Three types of retrofits were targeted: energy efficiency retrofits for building envelopes, such as using polystyrene insulation and double-glazed windows; retrofits for efficiency in heat generators and networks; and retrofits for heat metering and temperature regulation. The tasks were allocated to 15 northern provinces. To increase enthusiasm among local governments, monetary rewards (55 RMB/m^2 for severe cold regions and 45 RMB/m^2 for cold regions) were offered, with an additional bonus for speedy implementation [77]. By the end of 2010, existing buildings of 0.182 billion m^2 had been retrofitted, suggesting that the program performed better than planned [71].

The key problem with the retrofitting program is that there is no guarantee that energy saving will be achieved because of a lack of controllable heating. All northern cities in China are required by law to have district-heating systems, where residents make a lump sum payment to the heating supplier in return for a winter of heating. Residents generally lack incentives and means to alter the amount of heating they receive. Although programs to introduce individual heat metering are in place, progress has been slow [40]. One key implementation issue is that the heat metering system is unsuitable for apartments because users on the top floor or in corners of the buildings consume up to three times more heat energy; when an adjoining apartment is not heated, heating consumption increases by between 20% and 30% [78]. Thus, some apartment residents may see their heating bill increase substantially.

5.3. Appliance energy standards and labeling

Electric appliances consume a significant amount of energy. To eliminate inefficient appliances, the government introduced appliance energy standards in 1989 that mandated maximum allowable energy consumption for 30 types of equipment and appliances [33,44]. The standards have been regularly reviewed, usually resulting in a stringency increase of approximately 10% above the previous level [33]. Enforcement of the standards is challenging because the appliance sector is highly segmented with a large number of manufacturers and an even larger number of models. Moreover, insufficient resources and administrative capacity have hindered enforcement of the standards. Checks have been conducted in less than 1% of product models on the market [33]. Nonetheless, a 2007 study found that compliance rates for air-conditioners (91%), clothes washers (90%) and refrigerators (87%) were high and that the rate for freezers (71%) was acceptable [79].

Energy labeling encourages energy conservation by making appliance energy information easily accessible to consumers, and it has been successfully established in more than 40 countries and regions [80]. China introduced a voluntary energy labeling system in 1998 and a mandatory energy labeling system in 2005. The voluntary system covers 40 products and the mandatory system covers 23 products [80,81]. Officially called the China Energy Label, the mandatory labeling system has 5 categories of efficiency, ranked from 1 (internationally leading in efficiency) to 5 (barely meeting the energy standards), which is based on self-reported energy consumption data from the manufacturers.

5.4. Subsidies for energy-efficient and renewable energy appliances

Discounts, grants, subsidies and other related incentives can be effective in overcoming the cost barrier of adopting the use of energy-efficient and renewable energy appliances. In June 2009, the MOF and the NDRC initiated a subsidy program targeting air-conditioners and light bulbs [82]. The program proved popular. Before 2008, the market share of grade 1 and 2 air-conditioners was approximately 5%, whereas the market share of grade 5 was approximately 70%. By May 2010, the market share of grade 1 and 2 air-conditioners had increased to 80% [80]. In 2012, subsidies were introduced for five new types of appliances. A total of 25.5 billion RMB was allocated to support the program.

Another type of household appliances that received significant government subsidies is solar water heating. Adoption of solar water heaters accelerated without the governmental support. From 2000 to 2009, solar water heater installation increased from 26 million m^2 to 145 million m^2, with an annual growth rate of 21% [83]. In April 2009, the MOF launched a program to subsidize the purchase of solar water heaters in rural China. The program provided an allowance to rural consumers equal to 13% of the product price, with a ceiling of 5000 RMB per unit for solar water heaters. In June 2012, the MOF initiated another subsidy program for solar water heaters that included urban consumers, and offered up to 550 RMB per installation [84]. China has installed the most solar water heaters in the world, accounting for more than 60% of the worldwide solar water heaters [85].

5.5. Increasing block tariffs

In addition to subsidizing energy-efficient appliances, governments can also offer economic incentives for conservation by rewarding low electricity consumption or punishing overconsumption. Increasing block tariffs (IBTs) is a common pricing mechanism to structure household incentives towards electricity conservation. IBTs divide electricity consumption into several blocks for calculating the electricity price. The price of electricity is lowest for consumption up to a certain limit, and any consumption beyond this limit is charged at a higher price. In China, a proposal to shift from the single tariff system to an increasing block tariffs system was approved by the NDRC in 2010. However, the IBT system was not implemented nationally until July 2012 because the central government was cautious about the potential negative impacts of the change in price structure, such as the affordability of electricity and social stability [86]. However, the argument has also been made that the single tariff system disproportionally benefited the rich, with the top 27% of high-income qpeople receiving 45% of the subsidy, making it an unfair and regressive system [87].

China's IBT has a three-block structure. The price on the first block (0–240 kWh per month) is subsidized to ensure residents are able to afford basic electricity. The first block is expected to cover approximately 80% of electricity consumption [88]. The price on the second block (241–400 kWh) is set to recover full costs. Finally, the price on the third block (> 400 kWh) is punitive and considers resource scarcity and pollution externalities [89]. Low-income groups are allowed to consume a certain amount of electricity at no cost.

6. Local government

Although commonly described as a unitary authoritarian state, the political system in China has become more decentralized since reform, to the extent that scholars have argued that China's political system can be described as de-facto federalism [90]. The change is due to the belief that decentralization is compatible with economic development. This belief, and the refocus on economic development, resulted in an increase in powers, resources, and responsibilities at the local level and the rise of localism. Given that local interests may often be at odds with those of the center, the central government has relied on two policy mechanisms to ensure that local governments would implement REEE policies: the target responsibility system and pilot programs.

6.1. Target responsibility system

Target responsibility systems (TRS) are commonly employed in China to improve implementation. They are in essence rules governing job assignment, performance appraisal, and remuneration [91]. The energy conservation TRS, which imposes mandatory energy efficiency targets and other related requirements on provincial governments, was first introduced in 2007. The system was comprised of a target allocation system, a monitoring system, and an evaluation system. Evaluation results are fed into the annual evaluation process of the provincial cadres. Furthermore, major investment approval is withheld to punish provinces that fail to achieve the targets. As such, the system creates powerful incentives for local officials to improve energy efficiency within their jurisdiction. The system was slightly modified in 2011 such that the provincial energy intensity targets are more sensitive to local conditions [12].

The key limitation with the energy conservation TRS is the use of energy intensity, defined as the energy required to produce a unit of GDP, as the sole assessment criteria. In other words, the system does not impose a ceiling on local energy consumption. Local governments can greatly increase the energy consumption within their jurisdiction, but still achieve the energy conservation target as long as the GDP increased more rapidly. The energy conservation TRS also does not provide incentives for local government to go beyond minimal compliance. To fix these problems, the central government aims to introduce energy consumption targets and renewable energy consumption targets. However, the work is still in progress.

6.2. Pilot programs

The NDRC initiated the Low-Carbon Province and City pilot program in 2010 as a key climate change response. Participating local governments are encouraged to go beyond mere compliance with existing REEE policies. The specific obligations and commitments include developing a long-term low-carbon development plan; exploring institutional reform and effective policy instruments to lower carbon emissions; developing low-carbon industries, buildings and transportation; developing carbon emissions accounting and management systems; and promoting low-carbon lifestyles and consumption. Participation in the pilot program is voluntary, and its policy coverage is therefore limited; five cities and eight provinces participated in the first phase of the program. However, it should be noted that the voluntary pilot program is used to complement rather than replace the energy conservation TRS. Compared to TRS, the advantages of pilot programs are twofold. First, pilot programs are easier and quicker to implement because of their voluntary nature, whereas TRS may generate dissatisfaction and resistance from local governments. Second, TRS do not provide incentives for local governments to exceed mere compliance. Conversely, pilot programs can deliver additional results and stimulate novel and innovative local actions. Therefore, pilot programs are best used in conjunction with TRS.

7. Conclusions

This critical review of China's REEE policies has highlighted an array of major policy developments since 2005, although significant improvements are still needed. First, although REEE policies have been effective in stimulating the growth of renewable electricity, it is unclear whether they are sufficient to meet China's long-term renewable energy goal, which is to increase renewable energy share to 15% by 2020. The update to the existing RPS should be expedited, and the rate for solar FIT should be increased. The FIT increase would require an increase in renewable electricity surcharge. Given the current low level of surcharge, this increase should not put too much pressure on the cost of living. Second, the government must continue to increase funding for REEE, particularly in helping smaller businesses to improve their energy efficiency. Fortunately, unlike many other national governments, the Chinese central government is blessed with a sound financial position, which allows significant investment in REEE. In 2012, spending on energy conservation and environmental protection totaled 200 billion RMB [92]. This large sum only amounts to 3.1% of the total central government expenditure. There is certainly room for increased investment in REEE.

Third, the government can further support smaller businesses by promoting the use of energy service companies (ESCOs) and energy performance contracting. ESCOs provide comprehensive solutions for energy conservation by helping clients overcome financial and technical constraints to investing in energy efficiency [93]. In return, ESCOs receive a percentage of the savings from energy efficiency improvement. To support the energy services industry, in June 2010, the MOF and the NDRC introduced a subsidy for energy conservation projects run by ESCOs at a rate of 300 RMB/tce of energy saved [94]. However, ESCOs were unable to realize their full potential in China because of market, institutional, financial barriers, and a lack of trustworthy relationships between ESCOs and potential clients [95,96]. Additional policy support is needed to help ESCOs overcome existing barriers. Support may include information campaigns to build trust, better regulations of ESCOs, and increases in subsidies to make ESCO projects more attractive.

Fourth, improvement to the EEO scheme is essential because it is a central part of China's REEE policy. As discussed previously, the greatest problem with the EEO is that the government does not consider energy efficiency potential at the industry or firm level during the target allocation process. The government should incorporate information collection and/or negotiation for the next phase of implementation (2016–2020). Another option is to introduce flexible mechanisms, such as tradable white certificates.

Fifth and finally, the energy conservation TRS, which governs local government behaviors regarding REEE, needs a major update because it currently does not offer sufficient incentives to local governments. The key problem is the reliance on energy intensity as the sole assessment criteria. The government should introduce energy consumption targets and renewable energy targets, which would force local governments to dedicate more resources to REEE and diversify the economy away from energy-intensive industries.

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