17 Postface: China in the New Policies Scenario

Yongjun Gao, Yuliang Zhang, Jingbo Louise Liu, and Sajid Bashir

Contents

Author Contribution
G. Yongjun did all the internal data analyses from NEA, NRDC, and the five-year plans, including select figures; J. Liu translated some documents in English and completed the additional figures; and S. Bashir wrote the English draft and incorporated IEA, CAIT, non-China-based data sets. All authors reviewed the manuscript, which was submitted by J. Liu.

Y. Gao (✉) · Y. Zhang
Zhejiang Triangle Qing Energy Enterprise Management Co., Ltd., Hangzhou, People's Republic of China

Zhejiang Yangtze River Delta Clean Energy, Conservation and Environmental Protection Development Research Center, Hangzhou, People's Republic of China
e-mail: gyj@3ecube.cn

J. L. Liu
Department of Chemistry, Texas A&M University-Kingsville, Kingsville, TX, USA

Department of Chemistry, Texas A&M University (TAMU), College Station, TX, USA
e-mail: kfjll00@tamuk.edu

S. Bashir (✉)
Department of Chemistry, Texas A&M University-Kingsville, Kingsville, TX, USA
e-mail: br9@tamuk.edu

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Abstract

The rise of China since World War II has been centralized in the form of a series of five-year plans. These plans affected society at all levels and have now reached a zenith in terms of ecological, environmental, energy, and economic outcomes. A new power law was enacted to govern the Chinese Electricity sector. The central government intent is to decentralize energy generation, transmission, and storage through the formulation of policies which affect energy generation through tighter supervisory controls, through innovation and economic rebates and aid. These new provisions are targeted to slow down the rate of energy consumption and enable the transition of China to an electricity generator based on renewables including hydroelectric, biomass natural gas, and nuclear with a lesser reliance on coal-fired electricity generation. The policies are derived from earlier noticed in area of electricity generation, transmission, and environmental protection. The formulated policies using southern China as a test case migrated from general pronouncements to specific policy outcomes; the acceptance of which is based on the level of gain, fairness, and transparency. Heavy electricity users can buy directly from the power generator competitive rates; however, the social justice principle ensures that users who do not choose to participate in the electricity market are quoted prices that are not at far higher levels than high volume users. Also, there needs to be tighter integration between the supply and return of investment or rebates either at the government or province-level to ensure transparency and fairness to supply. To meet the ambitious targets of decarbonization and environmental goal's, the policymakers have allowed the local municipalities meet the projected targets using local knowledge, expertise, and resources; however, more research and development (R&D), technical assistance, and workforce training are required to meet the new policies scenario by 2040.

17.1 Introduction

Energy policymaking in the People's Republic of China (China) is coordinated by the State Council [1], but the practical implementations are decentralized through a number of entities in the form of a national action plan [2]. This plan lays out performance targets in the form of five-year plans which recently have included renewable energy with traditional energy portfolios, such as nuclear power, coal-fired power stations, methane, and methane hydrates [3]. The rise of China as an industrial power is aligned with its rise as an economic power like the United States or European Union political trading block of 28 countries (EU28) and is shown in Fig. 17.1 [4, 5, 6, 7].

The plot shows a positive correlation between carbon dioxide emissions and industrial production as measured in the gross domestic product, as well as a steady rise in atmospheric carbon dioxide levels. China is currently the world's largest electricity generator and energy consumer, as well as a carbon emitter [8].

Under the five-year master plan, China's electric power law coordinates energy services between state-owned enterprises and province or regional government entities that purchase using a decentralized approach [9]. The State Council formulates union which is delineated by the National People's Congress in the form of published articles. For example the 1995 National People's Congress (NPC) articles 35 and

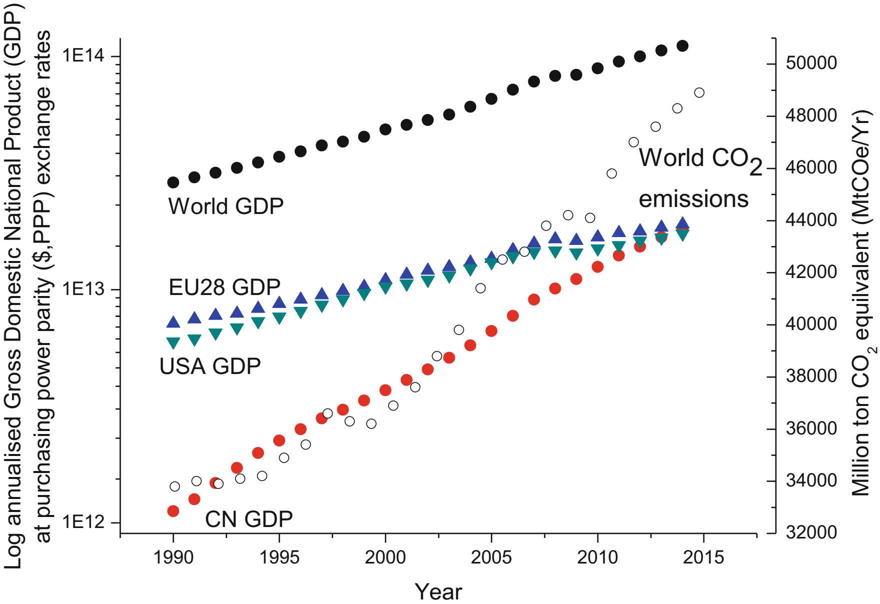

Fig. 17.1 Summary of the world, EU28, the United States, and China (CN) gross domestic product based on purchasing power parity (GDP, PPP) on the left axis superimposed with world carbon dioxide emissions (million-ton coal equivalent on the right axis). (Source: CAIT [7] and World Bank [6])

36 guarantee investment returns through price caps as a means of attracting "private sector" financing and meeting the energy demands set forth in the quinquennial five-year plan; the latest iteration is the 13th five-year plan (State Council [10–13]).

The early five-year plans emphasized a catch-up mentality to Japan, a regional competitor and a potential hostile foe, the United States as a Pacific dominant power, and Europe. These plans enable the Central Planner to meet the performance targets by enabling sectors such as manufacturing and heavy industries to have the power as required [14]. From the tenth to the current plan, a slight re-think was emphasized particularly during the Olympics held in Beijing to tackle grid inefficiencies, waste, greenhouses gas (GHG) emissions, and particulate matter which can cause serious health issues particularly to the millennials who are expected to carry the intellectual and practical burden into the next three decades [15–23].

In the early five-year plans, the purpose was to catch up after an internal civil war and a war against Japan to rebuild and rebuild fast using the Soviet planning model. To accomplish the energy requirements, a high investment in coal-fired generators was initiated from near 90% to around 70% to 40% around 2040 [24–26].

17.2 Evolution of Decentralized Energy Policy

It can be seen that the country's energy generation capacity and consumption are closely aligned, with an increase in consumption of 5.9%, the fastest since 2014 (Fig. 17.4). The new policy scenario envisages a transition to a more robust renewable portfolio by 2040 from the current 58% (coal-fired electricity generation) to 32% (Fig. 17.5) [27, 28]. A close look at electricity consumption over the last five-year plan is shown in Table 17.1. The per capita electricity consumption for 2017 is summarized in Table 17.2 by sector consumption. The total per capita usage was 4589 kW/h of which the domestic sector accounted for 628 kW/h with a corresponding increase of 268 kW/h from 2016. The total nationwide usage was 63,625 kW/h (Figs. 17.2 and 17.3).

Electricity consumption in the whole country was 636.25 TW/h with an annual growth rate of 6.6% or a relative increase of 2.7% relative to 2016 [30–34]. These successive increases indicate that the expected industrial output due to the steel tariffs imposed by the Trump Administration either have not taken effect or have not slowed the economy significantly to affect energy consumption, with heavy industry contributing toward the largest increase in the share [35].

The five-year plans from 2005 have stressed self-sufficiency in energy, as well as manufacturing and a managed transition to renewables, and to lower greenhouse gas emissions and improve the air quality in large metropolitan cities of China [36–41]. This can only be accomplished if the reliance on coal-fired power stations is diminished (cf. Fig. 17.5).

The current mix is summarized in Table 17.3. This transition can be better managed by placing new environmental standards in the coal sector through policy reforms [42–44]. One is the modernization of older coal-power stations or early

Table 17.1 Summary of installed capacity and corresponding growth rate

Year	The installed capacity of power generation (kW × 10)	Growth rate (%)	The per capita installed capacity of power generation (1×10^3 adults, kW/h)	Growth rate (%)
2010	96,641	10.6	0.85	11.9
2011	106,253	9.9	0.79	9.3
2012	114,676	7.9	0.86	8.9
2013	125,768	9.7	0.93	8.1
2014	137,018	8.9	1.02	9.7
2015	152,527	10.6	1.10	7.8
2016	165,051	8.2	1.19	8.2
2017	177,708	7.7	1.28	7.6

Table 17.2 Summary of installed capacity and corresponding growth rate by the end user for 2017

	Electricity consumption ($\times 1 \times 10^9$, kW/h)	Growth rate (%)
Primary industry electricity	1175	7.5
Secondary industry electricity	44,922	5.5
Electric power in the tertiary industry	8825	10.7
Electricity consumption for urban and rural residents	8703	7.7

http://www.cec.org.cn/guihuayutongji/tongjxinxi/niandushuju/2019-01-22/188396.html

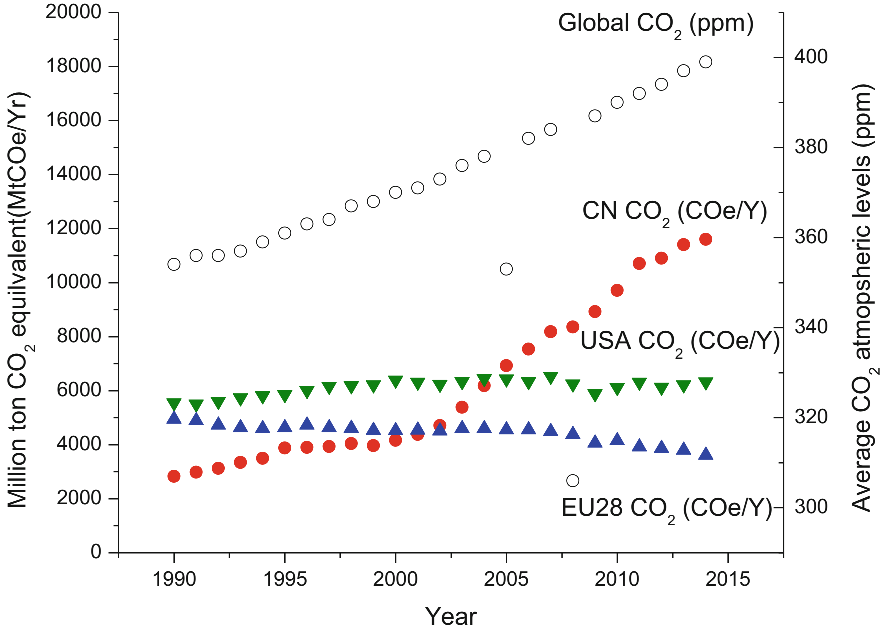

Fig. 17.2 Summary of annualized carbon dioxide emissions for EU28, the United States, and China (CN) in millions of tons of carbon dioxide equivalent per year on the left axis superimposed with world carbon dioxide atmospheric levels (in parts per million (ppm) on the right axis) (Source: World Bank [7] and NOAA [29])

retirements as solar, wind, and hydroelectric have increased their share. The second factor related to price and energy mix adjustment is related to the cancellation of projected commissions from the 12th five-year plan. Lastly, the third factor related to changes in energy policy is loosening of state controls in terms of pricing, to promote trade and competitiveness between power utilities and manufacturers as directed by the State Council in 2015 [25]. Collectively, these three factors are designed to increase efficiencies, enable fast transitions in use of the energy portfolio and minimize excess capacity.

The total installed capacity of non-fossil energy (non-thermal) power generation was 688.5 TW/h (37.8%), as renewables of the new policy scenario sustainable mix (wind power, solar energy) installed account for 16.5% [30].

This has enabled investment on renewables (excluding hydro, Eyre et al. [46]) to increase as their share of the total product portfolio increases. To promote efficiencies within the grid, the new price controls have resulted in reduced tariffs, saving regulatory costs and top-down supervision and enabling localities to better manage their production and demand. These State Council articles and local management have enabled China to be responsive at the local level while maintaining top-down control [47]. The policy makers within the State Council recognize that the cost of doing business should also factor in environmental and health costs associated with

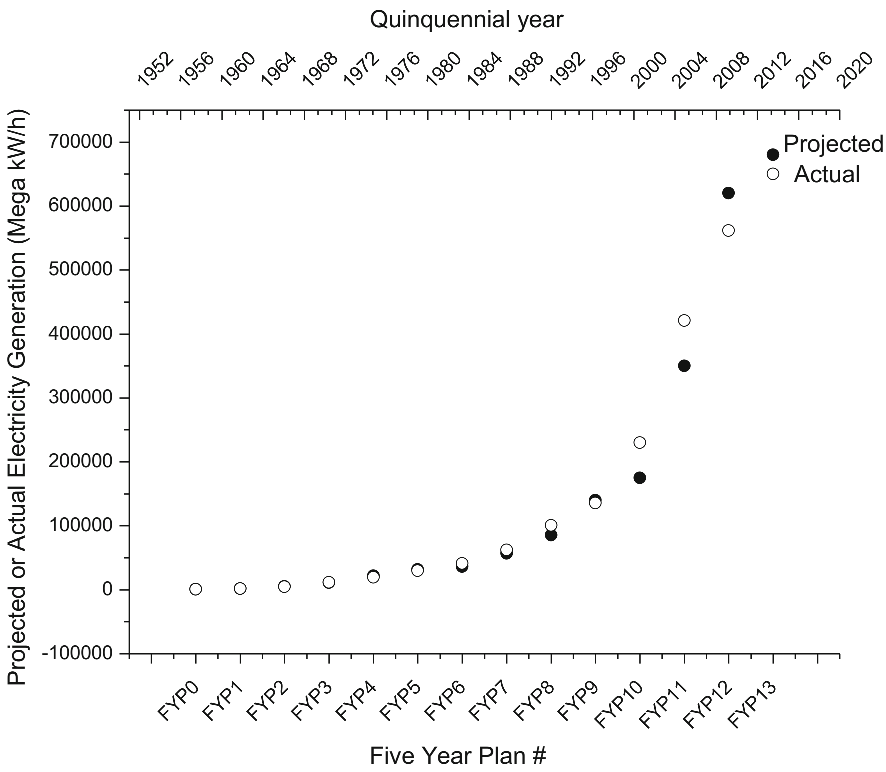

Fig. 17.3 Summary of annualized planned and actual electricity generation as outlined in the quinquennial five-year plans (bottom axis) and the corresponding years (to axis). (Source: IEA [30], USCC [16, 17], Sun et al. [45, 31, 32])

higher greenhouse gas emission and particulate matter. Since much of the electricity is dominated by coal-fired power stations, reform of the electricity system is logical as is the transition from a planned economy to a service economy, where the energy generators negotiate directly with the large energy consumers. The justification for this transition is based on the greater responsiveness and adaptability to changing circumstances from the bottom-up as opposed to the traditional top-down [48].

The goal of the current five-year plan to increase renewables (excluding hydro) to 15% by 2020 and to 20% by 2030 is designed to meet the environmental goals of all major 338 cities meeting the air quality standards. In 2016, only 84 major cities met the air quality standard [49, 50]. To lower both carbon and particulate emissions the dependence on central large thermal power stations needs to be better managed and aligned with local entities such that the power is transmitted from great distance to the desired location, and that better coordination is required over the use and

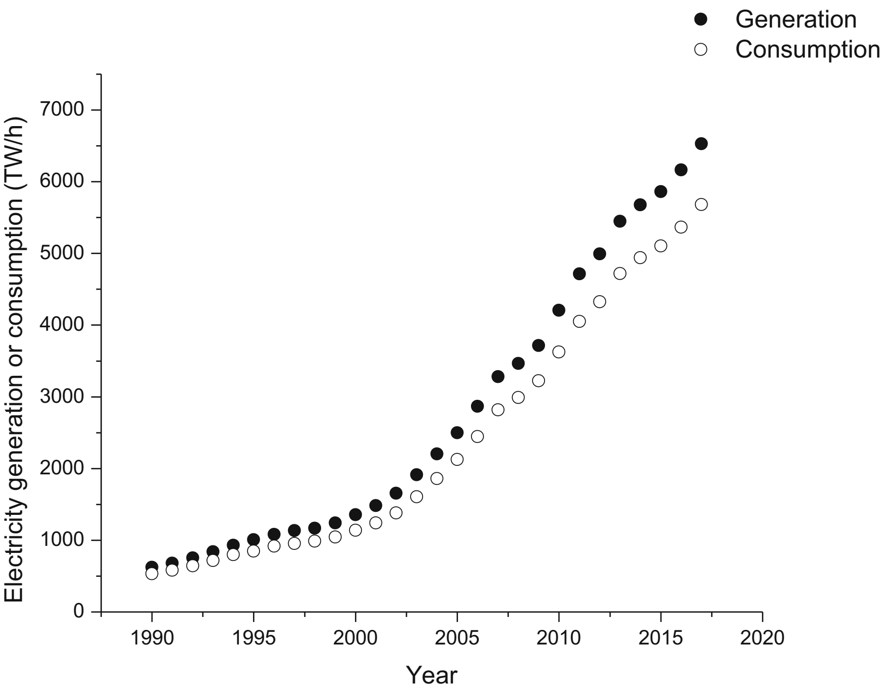

Fig. 17.4 Summary of annualized electricity generation and consumption (TW/h). (Source: yearbook.enerdata.net, 2017)

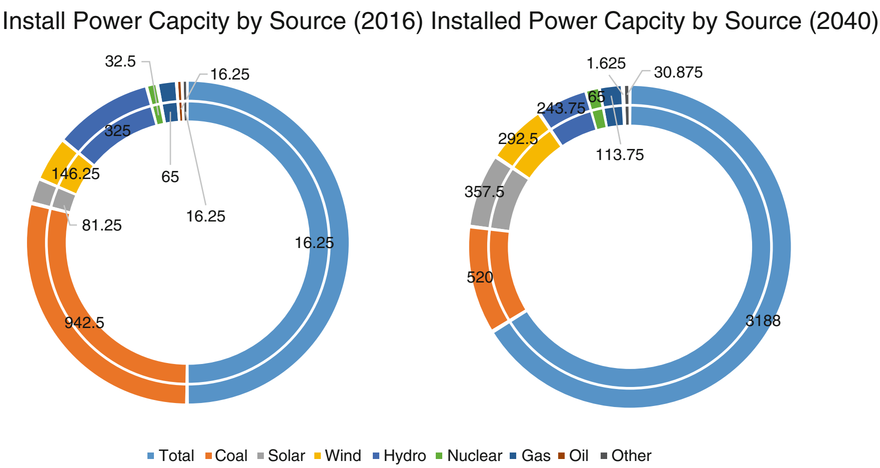

Fig. 17.5 Summary of the installed power capacity in China today (2016, left) and anticipated by 2040 (right) by energy source. (Source: IEA [30])

Table 17.3 Summary of energy from renewables and percent change from 2016 to 2017

Power generation installation structure	Percentage ratio (%)	
	2016	2017
Thermal (coal)	64.3	62.2
Hydropower	20.1	19.3
Wind power	8.9	9.2
Solar power generation	4.7	7.3
Nuclear power	2.0	2.0

http://www.cec.org.cn/d/file/guihuayutongji/tongjxinxi/niandushuju/2019-01-22/4fedb4c956f6059c5998913b10a6233a.pdf

Table 17.4 Summary of installed power capacity by energy type for 2017

	Installed capacity kW(×10)	Percentage ratio (%)
Coal-fired power generation	98,000	55.2
Gas power generation	7570	4.3
Yu Wen, residual pressure, residual gas power generation	2989	1.7
Biomass power generation	1651	0.9

http://www.cec.org.cn/d/file/guihuayutongji/tongjxinxi/niandushuju/2018-12-19/b386d97a65996f9e3520b9d63b4ba634.xls

management of the power grid, summarized in Table 17.4 [51]. In reference to Table 17.4, it can be seen that relative to 2016, the consumption of energy from large centralized thermal units or thermal power stations decreased by 2.2%, in spite of an overall increase of gas power station by 8% [52].

By the end of 2017, the national installed capacity of full-caliber power generation was 1.777 billion kilowatts, up from the previous year by 7.7%. In addition, by the end of 2017, the per capita installed was 1.28 kilowatts, an increase of 0.09 kilowatts over the previous year, an increase of 7.6%, Slightly above the world average (http://english.cec.org.cn/No.110.1481.htm).

In Fig. 17.6 and Table 17.5 it is clear that use of large thermal units and thermal power stations will remain a dominant mix of the energy portfolio for some substantial time, although transition to renewables (excluding hydroelectric) has resulted in a slight decrease of thermal consumption from 72% to 71% from a high consumption of 82.5% in 2010 [30, 53].

An example of the State Council (top-down) and local city planners (bottom-up) approach is how the City of Shenzhen (southern China) has managed its energy needs. According to the State Council article 9 [13, 25] and in coordination with the National Development and Reform Commission [54–56], a repricing of electricity and use of the transmission grid was initiated in 2015 [25].

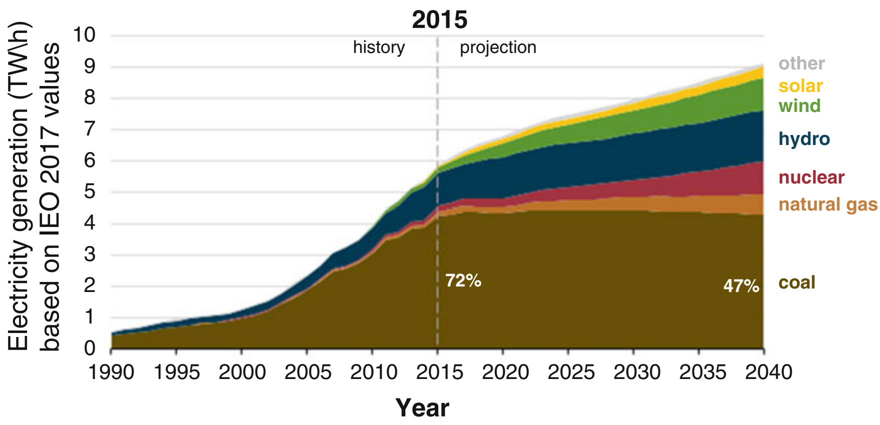

Fig. 17.6 Electricity generation (TW/h) based on IEO 2017 values for 2005–2040. (Source: EIA [32])

Table 17.5 Summary of installed percentage change of power capacity between 2016 and 2017

Generation	Percentage ratio (%)	
	2016	2017
Thermal (coal)	71.8	71.0
Hydropower	19.5	18.6
Wind power	4.0	4.7
Nuclear power	3.5	3.9
Solar power generation	1.1	1.8

17.3 Policy Implementation: Illustration from Southern China

The work plan for Shenzhen is shown in Fig. 17.6. Briefly, the State Council formulates the framework policy through assurances of articles [57, 58]. The provincial or municipalities formulate these articles at the local level based on need and available resources or access [59]. The aim of article six of the State Council circular is to improve efficiencies in energy production and transmission and is not focused on a single inflection point. The circular deals with several factors, which can be classed as either strengthening or improving supervision of energy production, technical improvements in the areas of energy generation or economic support to enable provinces to migrate to cleaner energies whilst meeting the energy targets. These include but are not limited to subsidies which yield tax discounts to manufacturers of solar cells who utilize the solar panels for light-harvesting and generation of electricity. A more common approach is to encourage the city planners to promote the purchase and use of local photovoltaic components, materials, and assemblies to provide energy at a local level. While the subsidies are modest at

Table 17.6 Summary of subsidies offered to entities in southern China business based on energy type per kW/h of generated electricity

Type	Cost (RMB)
Thermal	0.2~0.3
Hydropower	0.25~0.3
Onshore wind power	0.2~0.35
Photovoltaic power station	0.3~0.4
Nuclear power	0.45~0.5

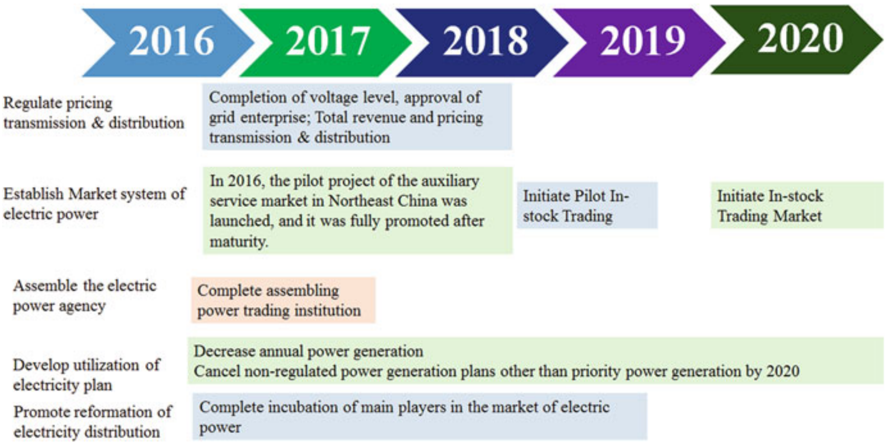

Fig. 17.7 Summary of the State Council policies driven at the local level using policy implementation and policy instruments at the City of Shenzhen as a test case

<0.3 yuan/kWh (cf. Table 17.6 for a range of tax credits), they promote local innovation and increase the non-renewable portfolio in line with the State Council articles [27, 43, 44, 60].

An analysis of approximately 32 major cities or administrative centers in southern China (such as Guangdong, Guangxi, or Hainan) shows an equal implementation of the three reforms (supervision, technical, or economic) [49, 61] (Fig. 17.7).

A common problem faced by policy planners is central versus decentral. Does the state consolidate and invest in a few but large energy producing or consuming entities, or does the state decentralize and have numerous but lower capacity generating or consuming entities [62]. In China, during the first few five-year plans, the earlier models were based on centralized management and quotas as developed by the Soviet System, that took less account of local needs, resources, and know-how. The current five-year plans have migrated towards more subsidiarity, enabling localities to develop solutions which impact the entire nation, such as the environment, economy, healthcare or energy. The five-year plans concerning energy have increased the sustainable mix and governance or implementation of directives via a more deregulated model. Deregulated energy thus relies on renewables at the local level, lowering transport costs and improving responsiveness to local energy needs and lowering the likelihood of blackouts or brownouts during peak emergencies as the grid is decentralized, including a stop on authorized construction projects [63, 64]. The first advantage of such a deregulated approach is fostering of adaptability to dynamic energy needs. Some of the older sustainable energies such as hydroelectric imply automation without heavy human involvement, while other newer sustainable energies such as PV and to a lesser degree wind suggest human involvement and capital costs providing near zero emitting carbon energy sources [55]. A number of policy instruments have been issued and adopted to promote deregulated energy to lower the barrier to market, promote market penetration, as well as lower carbon emissions and increase high technology products manufactured in China. These policies often have been contradictory and not consistently applied as the focus of successive five-year plans has not been the same, as macro-incentive policies have shifted depending on the specifically stated goal. Between November 2015 and July 2018, the NDRC issued a series of policies designed to reform the electricity generation and distribution in southern China [54, 56, 94]. At the end of 2016, the renewable portfolio accounted for 36% of the total electric installation with photovoltaic and wind energies contributing the highest kW/h in the world, although the relative ratio to the total energy demand in China is modest. Through the introduction of subsidies, preferential trading policies (cf. Fig. 17.8), and grants, the anticipation has been that uptake in renewables will increase [30].

The redistributed energy policy has three broad goals: the first is the reduction of electricity from coal-powered utilities, and the second is local planning, input, and implementation of central policy directives, based on local need and resources to provide clean, safe, reliable (high up-time), and sustainable energy to industry and local population centers [47].

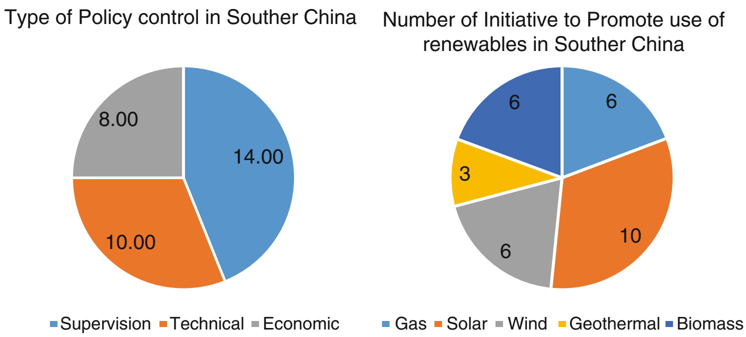

Fig. 17.8 Summary of policy types in southern China, such as enhancement of supervision and training, technical innovation and modernization or economic or infrastructure assistance (left) from the central government and number of policy subsidies or changes at the local level (southern China) to promote renewables (right)

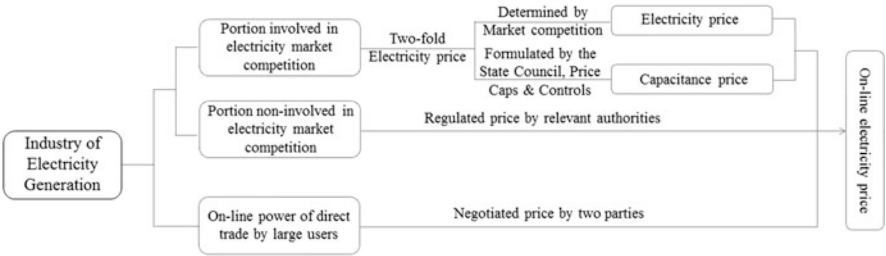

Fig. 17.9 Summary of classification of electricity price related to power generation enterprises

The second is to enable the local municipalities to have a greater say in which renewable energy portfolio is their focus based on financial strength, local resources, and need, such as photovoltaics (PV), wind, and hydroelectric. Lastly, is the minimization of long-distance or high-voltage transmission of energy from central thermal plants reducing cost, waste, loss, and cost of installation, maintenance management, training and safety upgrades. These initiatives are designed to lower power loss due to transmission but also increase the renewable energy mix portfolio [65].

In Shenzhen, the NDRC policy implementation has not resulted in price changes, but has enabled: (a) participation of high volume energy users in the power market to compete for feed-in electricity price adjustments from power generation enterprises; (b) increased participation of power generation enterprises to supply feed-in electricity at fixed prices, which were not competing before due to long-term fixed contracts with guaranteed price caps; and (c) the ability for direct negotiation between energy generator and user for more competitive rates, regardless of volume of energy usage. While these reforms have not altered the price category band, the new round of power system reform has altered how the market is managed and is summarized in Fig. 17.9 [66].

The new policy directives have four modalities “off-grid, on-grid, grid-connected without power injection, and grid connected with power injection.” In the off-grid modality, local energy services are provided without transmission from a central source; whereas on-grid, electrical power is supplied locally to the grid and then to a source with air-conditioning and steam supplied locally, with the grid supplying on-demand peak loads [67]. A series of reforms are tailored to enable renewable resources to be better managed and be price competitive with coal, where price caps, tariffs, and rebates have generated a pricing mechanism which generates a sales price band to ensure “fairness” and “equity” to both end users who enter the market to price competitive transactions and also for users who choose not to enter the market but rely on fixed price long-term contracts [1, 68, 95]. The charge caps within each price band take into account a form of social justice or “the protection of people’s livelihood” as well as being responsive to large combines who are major consumers of energy. This mechanism allows them to conduct strategic planning and budgeting, as the prices are fixed using long-term contracts for a definitive period, summarized in Fig. 17.10 [69, 70].

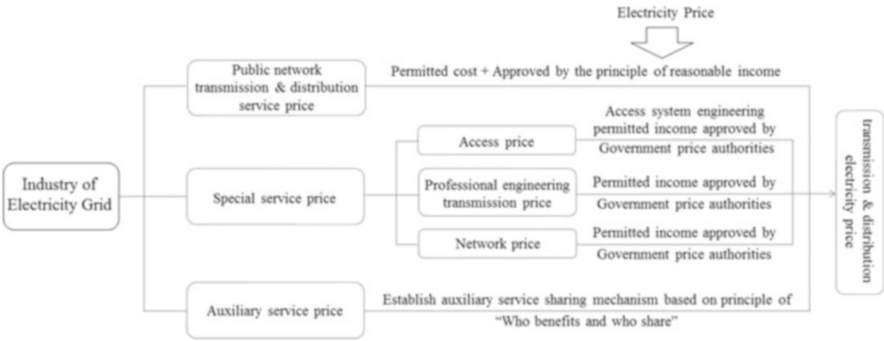

Fig. 17.10 Classification of electricity price related to related manufacturers or heavy energy consumers

The oil crisis focused policymakers on energy security, on the turn of the millennium, and environment dimension was added for minimizing climate change through a balanced energy approach of combining renewable energy, clean energy, and traditional fossil fuels [71]. The transition has also offered an opportunity for workforce training and new revenue lines. The State Council articles of 2016 [27, 60] are designed for stabilizing energy, reducing greenhouses gas emissions, and controlling air pollution. The reforms in the power sector incorporate elements of a regulated market in the decision making, a process in which the energy sector was opened to both domestic and foreign investments and capital and on/off-grid electricity tariffs, price caps, and subsidies [44]. The 2015 reforms [25] were build upon the 1985 reforms [57] with power generation sector using the concept of energy justice and social equity formulated in articles ["Chapter V Electricity Rates and Fees Article 35 The electricity rates herein refer to the rates charged to the power-generating enterprises for incorporation into the power network, the rates of mutual supply between different power networks and the sales rates of electricity supplied to consumers". "The rates of electricity shall be based on a centralized policy, fixed in accordance with a unified principle and administered at different levels. Article 36 Establishment of electricity rates shall be based on the principles of reasonable compensation of cost and reasonable determination of profits, legal incorporation of taxes, fairly shared burdens and promotion of electric power construction"] [13], which enshrine the concept of a guaranteed return on investment and also controlled inflation and capped the returns for investors. These early reforms enabled local and state entities to invest in the power generation sector to meet new growth targets. The relationship between electricity generation, consumption, and price controls is summarized in Figs. 17.10 and 17.11 [72].

In practical terms, direct trading between major energy users to buy electricity at competitive prices has expanded. While the pricing mechanism to determine the unit purchase price of heavy users has not been substantially been changed, the policy tweak has enabled the voice of small to intermediate energy users to be factored into the overall pricing model, along with the choice of renewable energy mix into long term strategic planning [73]. Through this reform, market bid to transactions of energy units has

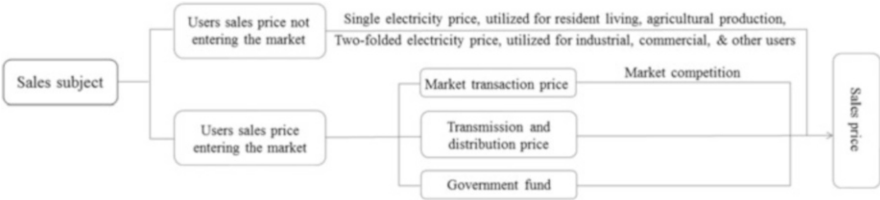

Fig. 17.11 Classification of electricity price related to electricity sales companies

increased, while maintaining price structure similar to pre-reform approach, for end-users who did not enter the price competitive bidding process. The purpose of these market-based reforms is to make the electricity generation to market process more responsive to local needs across different regions of South China, whilst maintaining the concept of 'social justice' [74]. The rollout of reforms is not consistent or uniform across the region; some cities are able to implement the reform policy quicker, while there is a lag in adoption in other municipalities. The pre-reform trading includes large users who directly buy [66–110 kW/h] electricity or greater users such as heavy industrial and commercial manufacturers and power generation enterprises who trade directly with local commercial consumers [75]. Power generation enterprises will sell electricity to the power grid to sell to end users and a third to heavy users who bid directly to the power generating entity. The price band is designed to provide an equitable settlement, with the power grid enterprises ensuring a guaranteed power supply services and also minimum length contracts to stop end users from shopping for a power supplier too frequently [45, 76].

17.4 New Policy Scenario

This triad approach is designed to simultaneously increase the power supply from renewables, by fostering local actors to build local power generation capacity from domestic and foreign investors, who are guaranteed higher on-grid tariffs to entice their investment and allow a maximum return on investment [77]. The role of foreign investment or higher returns may not be politically beneficial at the State Council level, but by deferring to local municipalities, the political penalty is by-passed as a greater foreign share of power generation in China is decentralized, limiting the probability of one foreign actor dominating the China power-generating market [73, 78]. The electric power law has pivoted China to consolidate the infrastructure phase and maintain annual growth of 1% in contrast to an annualized growth of 4.5% over the last two five-year plans. The stabilization of growth is equivalent to an improvement of 3.4% gain in energy on a per capita basis which is expected to increase until 2040 [30, 33]. The growth model also predicts that China will overtake the EU28 by 2035 in per capita energy consumption [79]. The energy law promotes "newenergy" through the generation of electricity from renewable resources such as natural gas, and nuclear, and hydropower while lessening the reliance on coal. This

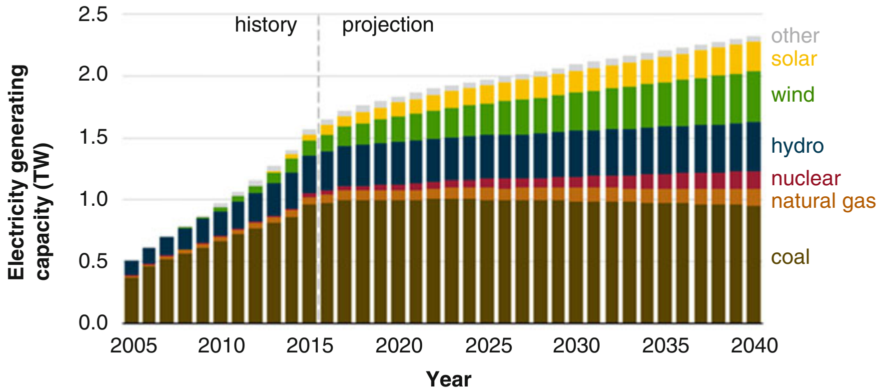

Fig. 17.12 Electricity generating capacity (2005–2040) using IEO2017 as a reference (Source EIA [32])

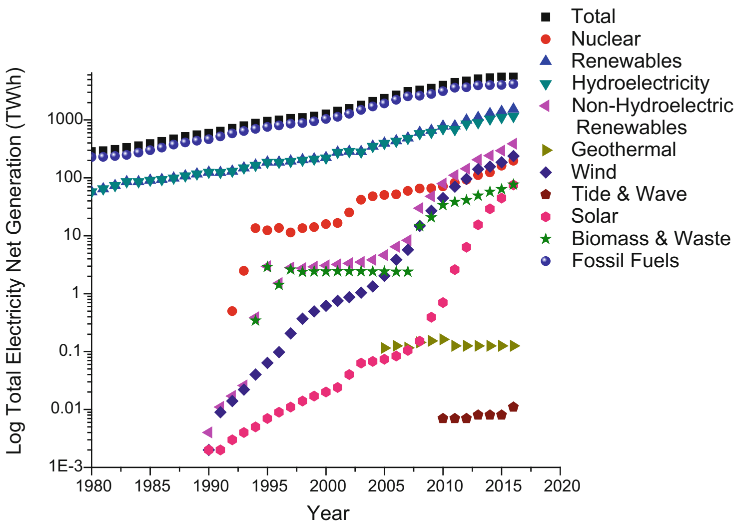

Fig. 17.13 Net electricity generating capacity by type. (Source: EIA [31, 32])

diversification in the energy mix is expected to continue for at least the next 3–4 five-year plans (cf. Fig. 17.12; [30, 80]). The renewable portfolio is also used for energy storage related to heating and transport. If the current trend is continued, electricity as an energy carrier will be the dominant form of energy consumption rather than natural gas or petroleum or coal [81]. The cross over is expected to occur around 2025–2030 for both coal and oil as photovoltaics, biomass, and wind provide energy for domestic, light energy, and battery/and hydrogen for transport (cf. Fig. 17.13). A total of 150 GW of new coal capacity has been postponed until 2020, in addition to the retirement of 20 GW of older coal-fired plants and technological upgraded to 1 TW of current coal-fired power stations and is expected with natural gas and petroleum to be significant until 2040 [30, 33].

17.5 Photovoltaics as a Model of Deregulated and Redistributed Energy

New Power Law of China is designed to formulate a distributed energy system through administrative controls [52]. These controls consist of the top-down State Council policies which apply to all state and private agencies, the Ministry of Industry and Information Technology for industrial entities, and other area-specific ministries such as the Ministry of Science and Technology. These State Control entities also offer directly or through the province assistance to promote and use renewable energy resources in the form of tariffs, feed-in tariffs, power generation, or installation subsidies, in addition to state grants, tax rebates, preferential loans, on-grid tariffs, and guaranteed minimum returns in the form of articles, notices, or interim measures as the communication instrument [82]. At the top level, the National Energy Administration (NEA) supervises the province or special administrative unit power generation capacity. The province dictates the scale and scope of implementations of the power capacity scale, requiring state-owned enterprises or other actors to buy power generation rights from large thermal power stations [83].

To encourage and lower the cost of business, financial loans, subsidies, and heavy rebates were implemented; however, this rate of investment cannot continue and is likely to be tapered off, as some businesses generate less income than anticipated, while others are unable to meet the current financial obligations (as subsidies are lowered). Return back to the province may not be accounted for until 2–5 years after the initial construction phase was completed; lastly, the quality of the electricity generation and feed into the grid varies with load [83]. Photovoltaics (PV) and wind is intermittent, and some power generation units are not appropriately grounded or produce a lower voltage with a broad frequency distribution which can affect the quality of the grid voltage [84]. The device storage capacity, grounding, voltage level steady output, connections, type of inverters, and frequency/voltage filters are important factors in addition to power generation prior to grid injection [85].

Both wind and solar have significantly increased their share over the last 3 years with a relative rate increase of 20% in 2017 from 2016 in terms of installed capacity. In 2017 an additional 103 GWh was installed a capacity increase of 29.4% year, a record high [30, 33]. The photovoltaic (PV) surge is occurring in China, the United States, Japan, and India as the ‘big four players’ in the PV market, who account for more than 80% of the available capacity, the installed capacity of 53.06 GW, 10.6 GW, 331 9.63 GW, and 7.2 G W, respectively. As the world’s largest photovoltaic market, China has installed more than half of the world’s capacity in 2017, and the Chinese market has largely swayed global market trends in the past 2 years, with newly installed increments in the Chinese market in the 2016 and 2017 accounting for 70% and 82% of the global market increase [33].

China's photovoltaic new grid capacity in the first three quarters of 2018 was 34.5 GW, a decline of 19.6% relative to the same period in 2017. A starting capacity of 19.6%, at 17.4 GW from the province's power generating entities, to 10.92 GW over the previous year, which was a decline of 37% in generating PV capacity. This slowdown may be a reflection of the implementation of the new policy scenario rebalancing. The off-grid capacity in the province of southern China was 17.1 GW, an increase of 12% from the previous year with 13% in off-grid usage [30]. The overall decline in state-owned enterprise capacity is balanced by an increase in installation, and usage by new businesses and heavy energy users and also installation in provinces previously identified as being below the poverty line are consistent with State Policy regarding "social justice" and "equity" and opening up of markets to new players particularly in financially depressed regions or provinces [13]. The current photovoltaic construction and installation in southern China are expected to be capped at 30–40 GW, although private non-subsidized projects are likely to increase leading to grid injection and lower output from coal-powered power utilities. The combined subsidized and non-subsidized PV installed capacity is expected to reach 45–50 GW by the end of 2019. One reason for the increased participation of smaller companies in the PV market without subsidies is the lowering of market entry as the cost of PV has continued to decline. While power generation from PV is less than 2% of the global total energy (~333 vs. 16,894 TW/h or 1.97%, [34]), it is likely to increase as the cost of PV continues to fall and the environmental costs of coal-based electricity generation are expected to rise, not in the generation of electricity but in environment-related cleanup costs, related to acid rain and greenhouse gas emissions. In southern China, the cost of photovoltaic electricity is about 31% higher than that of coal, without subsidies. With increased marketization, the cost of photovoltaic power generation is expected to be lower than coal by 2021 years, and continue to decrease or taper off. It is expected that the share of photovoltaic power generation will gradually rise to 10% by 2040, while photovoltaic and wind energy will account for 37% of the total installed capacity of electricity generation in southern China by 2040, which will be a fourfold increase (cf. Fig. 17.14 and insert). "Solar photovoltaic (PV) module prices (measured in 2016 US$ per watt-peak) versus cumulative installed capacity (measured in megawatts-peak, MWp). This represents the 'learning curve' for solar PV and approximates a 22% reduction in price for every doubling of cumulative capacity" (Our Word in Data and Fig. 17.15 including insert).

17.6 From Yesterday to Today to Tomorrow: Lessons Learned, What to Expect Next?

The early five-year plans emphasized self-sufficiency and today's plan are no different in ensuring that there is energy security in China. The consumption of energy outstripped capacity, resulting in the fifth five-year plan promoting an increase in coal-fired power stations to meet and exceed demand. This trend has continued until the ninth five-year plan. The economy in the 1990s focused on

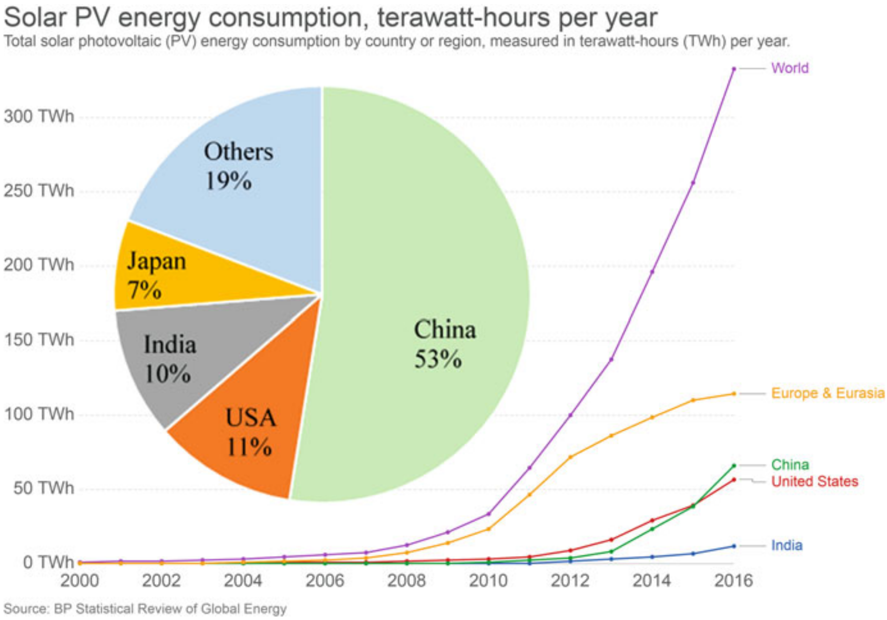

Fig. 17.14 Solar PV consumption by country. (Source: Our World in Data)

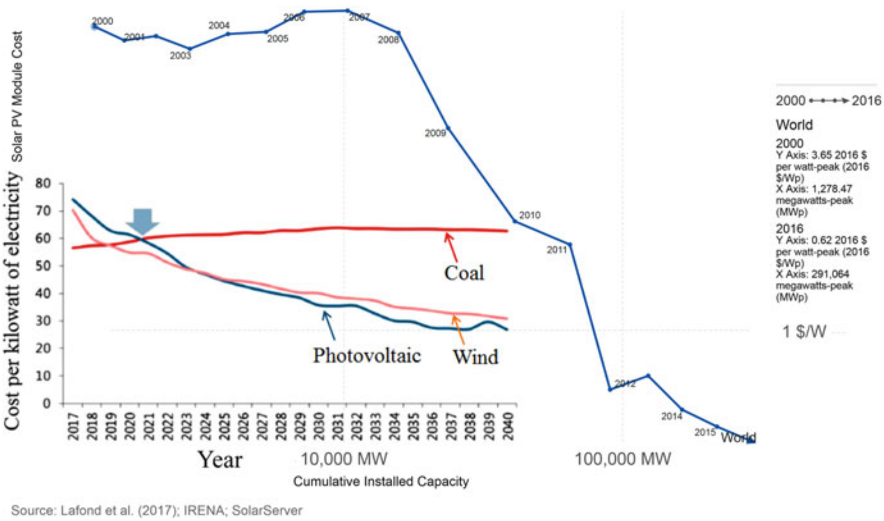

Fig. 17.15 Solar PV module price versus cumulative capacity, 2000 to 2016. (Source: Our World in Data)

expectation and actuality in the tenth five-year plan which slowed the construction of new coal plants. To meet this "shortfall," the planners at the province level continued to build plants or look at renewables. Also, the early market reforms of 2002 decoupled generation and transmission with a state-owned enterprise quintopoly to compete with each other and other private sector actors in the power generation sector [58]. These reforms were supplemented in 2004 by "generation rights" whereby construction of thermal plants (heat and power from coal) required prior approval from the national development and reform commission [64], due to decoupling between central planning and performance targets for the 11th and 12th five-year plans, resulting in a divergence between projected and actual growth or generation of electricity. As China was developing, little attention was paid to tangential issues regarding workflow training, safety, and environmental impact, but the emphasis shifted in the 13th five-year plan to incorporate societal and environmental goals into industrial output and energy targets. For example, the plan placed a 5 billion metric tons of coal cap [12] as a means to lower carbon emission to 15–18% [27, 60] in addition to particulate matter. These new requirements resulted in older coal power stations being retired equating 20 GW [27], as well as newer and cleaner manufacturing techniques [43, 54]. The current plan emphasizes on three aspects: supervision, technical innovation, and economic aid. It is likely the latter aspect will taper off as newer generating capacity including non-hydro renewables become more prominent, to meet China's ecological and environmental goals. The proportion of non-fossil energy installed capacity in China will exceed 40% by 2020 and will continue to surpass that of the European Union and the United States over the next 20 years [30]. This is both clean [coal, natural gas, and nuclear] and [wind, solar, wave, geothermal] renewable energy. The downward trend in carbon and greenhouses gas is related to market reform and stricter [NDRC] control of the scale of coal power development and the quick elimination of "dirty" production capacity forming the supervisory arm [44, 55, 56]. The development of new wind, PV, and thermal storage including batteries has enabled smaller firms to participate directly in the electricity market as purchases of electricity or as buy-to-sell entities, which has been implemented with varying degrees of vigor within southern China, promoting grid flexibility. Lastly, economic aid to clean up or replace coal-based electricity generation and/or utilization of clean electricity has resulted in an increased rate of renewables. Technical innovations and deployment of intelligent power systems improvements in load-leveling have contributed to increasing efficiencies in available electricity and decreased the requirement for transmission over large distances from large thermal units. Unrelated directly to the generation of electricity, but tangentially involved in the incorporation of elements from information technology to provide technical support for the intelligent development of the power system [86].Other allied areas of incorporation are the use of cloud computing, big data, Internet of the Things, mobile Internet, and deep integration between the smart grid and appliances. Specific applications include communication between electric vehicles, wireless charging, and other fields of rapid technological breakthroughs that rely on electricity [87]. These have promoted distributed energy using an intelligent supply system to increase responsiveness to load changes at high efficacy and low transmission loss. Third, the internationalization of electric power development, particularly at the province level, is an important component in attracting outside (foreign or out of province) investment, both as importers and exporters related to "Belt and Road" initiatives. This implies that Chinese business related to energy will be exported to nearest neighbor countries as well as attracting outside investment and research and development. These R&D efforts are based both within China and also at "technology hubs" in select cities in the United States, Canada, Europe, Australia, Africa, and the Middle East. This research includes both devices, software, and artificial intelligence tools; thus China can export and promote both products [solar panels] and solutions [intelligence, cell phone-based apps, smart algorithms] to improve its economy, aid its workforce in high technology, and open up new markets in Africa, Asia, Eurasia, and Latin America [88]. The internal marketization within China will continue in the form of institutional mechanisms. : A new round of power system reform, from power generation, transmission, distribution, to electricity sales, and user's service. These reforms include provisions from the State Council circular which are promulgated in the form of articles, notices, and interim measures, reflecting varying degrees of 'implementation urgency'. The application of State circulars conforms to the multi-mode pilot level of multi-level integration reflecting both human ('vertical') and capital/technical ('horizontal') resources type of amalgamation. The above reform involves comprehensive promotion across local, provincial and national areas of administration to make stakeholder aware and to enable planners to implement the provisions uniformly across the energy mix portfolio. The steel and good tariffs imposed on China by the Trump Administration resulted in a focused attention on the internal market, which was often obscured by the drive "to go outside" [89]. Heavy energy users can directly buy electricity within their province or cross-provincial bidding, promoting the province-to-province retail transactions which are beginning to increase in the proportion of total market share. With the gradual maturation of this business model, both light and heavy industries can take advantage of competitive pricing, driving innovation and leading the development of the power industry in a new direction and fostering potential new revenue streams as export products and solutions [90].

The five-year plan is a blueprint which is not implemented consistently or uniformly as drivers are different from province to province. The Electric Power Law has attempted to unify both social justice, equity, and energy security to maintain the high electricity generating capacity to meet the high energy needs. This has been accomplished using both administrative supervision changes, technical innovation, and economic aid. The end result is for China to continue to be a world leader in electricity consumption, but to generate electricity from renewables including hydro and nuclear. This is expected to keep prices low (controlling inflation) and lower the carbon emission as cleaner coal stations are brought on-line and renewables take up a greater share of the total energy mix [91].

In southern China (Guangzhou Province), the electricity generation sector played an important role in delivering the state policy outcomes from upper administration, although the actual implementation was varied based on local needs and resources. The decarbonization process of the sector was accomplished through increased photovoltaic, wind, and biomass usage, as well as pricing deregulation to manage the local sector [92]. This has resulted in improved efficiencies and savings, gives each heavy energy user a stake, and is more transparent as end users are aware of the price structure and how they can contribute and gain financially through grid-injection or off-line consumption [93]. In general five approaches have been observed which contributed toward the decarbonization process: (a) Policy deregulation enabling each municipality to manage its energy needs has allowed heavy energy users to buy directly from local energy generators and has each user to strategically plan on how best to manage their resources, using a market price mechanism [95]. (b) Diversity in the energy mix: Allowing each municipality to generate electricity using local resources, as diversified energy generation. While solar and PV are the more dominant forms of renewables, others include biomass, thermal storage, as well as clean coal for heating and cooling, to lower the carbon footprint, restricting unauthorized electricity from coal [94]; (c) the use of targeted subsidies to enable high-cost items such as construction of energy plants to progress on-time and on-budget. Subsidies, tax rebates, and in-feed pricing should promote renewables through issuance of green electricity certificates [68], which are seen as a price competitive advantage relative to energy from large thermal units [96] (d) technical innovation in construction and energy production is important in driving costs down due to incorporation of new technology, improvement of current technologies, and availability of expertise from the "research hubs" to promote local businesses to become more energy efficient [97]; and fifthly, (e) the decoupling of generation and transmission. The last 'structural' change requires constant monitoring and adjustment to avoid excess capacity or brown-outs. The promotion of local generation and off-grid storage is tailored towards a smart grid approach using sensors and artificial intelligence that self-manage load and energy balance in real-time by making the appropriate electric power adjustments at each node as an energy device injects or feeds electricity The five-year plan has a provision for a smart grid development plan to distribute medium and low voltages and is expected to be deployable around 2020 [98].

In summary, China is today a world leader in power generation and power consumption and will be a world leader if calculated on a per-capita basis by 2040. To continue with its "social justice" program, the policymakers need to examine their approach to decentralize and distribute energy to incorporate an element of subsidiarity and diversity. Subsidiarity is enabling local municipalities to manage how the target goals are met and when they are met over the five-year plan projected targets. Diversity is using different energy mixes, from solar, hydro, nuclear, wind, tidal, biomass, or thermal storage. The policy instruments should continue with adaptable supervision, technical innovation, and economic incentives and tighter integration between on-grid injection and payback of subsidies.

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