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A meso-level analysis of the evolution of the environmental policy mix to accelerate low-carbon energy transitions: policy sequencing in China from 1980 to 2020

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Abstract - Climate change is getting more acute, and energy transitions to low-carbon energy systems can lead to substantial reductions in greenhouse gas (GHG) emissions. As the largest GHG emitter, China's energy transition can help addressing climate change, and China's experiences can provide a blueprint for other developing countries that rely on high-polluting energy regimes. In this research, we perform a meso-level analysis of the environmental policy mix that facilitate the energy transition in China. We trace the evolutionary trajectory of this environmental policy mix over 1980-2020 in China, using a documentation analysis method. The results show that the policy mix has evolved from the adoption of a few authority-based instruments to a policy mix that has comprehensive coverage and diversity of instrument types. Three directions of the policy sequencing can be observed. (1) The government of China incrementally increased the intensity[1] of the policy instruments that combat emissions in conventional coal-based energy technologies. (2) The government incrementally reduced the intensity of the treasured-based policy instruments to encourage renewable energy technologies. (3) Carbon pricing was initially implemented through policy experiments and then upscaled to a national level scheme. This research contributes to the literature by providing empirical evidence on policy sequencing practices and has strong implications for the pathways to low-carbon transition in other developing countries.

Keywords: Policy sequencing; policy mix; policy instrument; energy transition; China

1 Introduction

Climate change, as a global environmental issue, is considered as a super wicked problem which exists in complex systems, lacks a central authority and becomes more acute with each passing year (Levin et al., 2012; Peters, 2017). Following decades of careful research, the scientific community has a consensus that anthropogenic emissions of greenhouse gases ("GHGs") are the major cause of global temperature increase (Anderegg et al., 2010; Carlton et al., 2015; IPCC, 2018, 2014). Of all the GHGs, CO_2 is considered the most potent due to its abundance (Huntingford and Mercado, 2016) and long atmospheric lifespan.

As of current, 184 Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have ratified the *Paris Agreement*, aiming to hold the global temperature rise under 2 Celsius (C°) over the 21st century above the pre-industrial levels (UNFCCC, 2019). Despite of the agreement, the global growth in fossil fuel consumption is outpacing the de-carbonisation efforts (Jackson et al., 2018). The global warming has reached 1.0 C° above the pre-industrial levels, and it is likely to reach 1.5 C° between 2030 and 2052 with the current rate of increase, causing risks of global sea level rise, extreme weather events and public health issues (IPCC, 2018; Silva et al., 2017).

The energy sector is a large contributor to global GHG emissions. In 2010, the energy sector contributed to 35% of global GHG emissions, with 25% indirect emissions from electricity and heat production sector and around 10% direct emissions from the energy sector which are not directly associated with electricity or heat supply, such as refining and processing (IPCC, 2014). Of all the energy sources, coal and oil currently dominate the global energy consumption (Figueres et al., 2018) and the associated GHG emissions are largely responsible for the growing emissions in the world (Quéré et al., 2018). The share of low-carbon energy technologies, including renewable energies and clean fossil fuel energies (such as natural gas), is picking up (Figueres et al., 2018), but more efforts can be made to decarbonize the energy systems. Some developing countries, such as China, still depend on coal to meet a large share of their energy demand (Urban, 2009). The transition of carbon-intensive energy systems to sustainable energy systems[2] is needed to mitigate climate change and to enhance environmental quality.

Despite the global need for sustainable transition of energy systems, there are barriers to the innovation and diffusion of low-carbon energy technologies. Unruh (2000) uses the term "carbon lock-in" to describe the situation in which a combination of systematic forces perpetuates fossil fuel-based energy systems in industrial economies and inhibit the diffusion of low-carbon technologies despite their positive environmental externalities. Transition to a sustainable and low-carbon energy system cannot happen automatically and public policies play an important role by informing, directing and accelerating the energy transitions (Jørgensen et al., 2017; Smith et al., 2010).

Energy transition needs a package/mix of policy instruments not only to break "carbon lock-in" of incumbent energy regimes but also to encourage diffusion and innovation of alternative energy technologies, such as renewable energy technologies, natural gas and clean coal technologies. Energy transition to a low-carbon energy system cannot take place overnight. Deliberately sequencing policy instruments to enable the energy transition is a new orientation in the climate policy field (Taeihagh et al. 2009, 2013; Meckling, Sterner, and Wagner 2017; Pahle et al. 2018). This study uses China's case to address the role of policy sequencing in low-carbon energy transitions, based on an in-depth investigation into the evolution of China's environmental policy mix from 1981 to 2020.

[2] The paper uses "sustainable energy systems" interchangeably with "low-carbon energy systems".

2 China's Ongoing Energy Transition

Due to its vast amount of GHG emissions, China faces international pressure to take mitigation measures. Since 2006, China has become the largest GHG emitter, surpassing the emission level of the US (Schreurs, 2016). The gap between GHG emission levels of the two countries has increased further since then[3]. Withdraw of the US from the 2015 *Paris Agreement* makes China's climate actions receive more global attention now (Liu et al., 2018). Under the *Paris Agreement*, China pledged to reduce its CO_2 emission per unit of Gross Domestic Product (also called CO_2 emission intensity; GDP-Gross Domestic Product) by 60%–65% in 2030 relative to the 2005 level and increase share of non-fossil fuel[4] consumption to 20% by 2030 (NDRC of China, 2015).

China depends on coal to meet about 64.6% of its primary energy consumption in 2016 and to produce more than half of its total electricity generation[5]. Coal burning is a major sauce of CO_2 emissions, accounting for about 72% of China's CO_2 emissions in 2014[6]. The transition from the coal-based energy system to a greater share of renewable energies is a big stride towards China's commitment to CO_2 emission reduction. Electricity sector accounts for about 45% of total coal consumption in China (Yuan et al., 2018). As such, low-carbon oriented changes in electricity generation are of significance to China's energy transition.

Coal combustion is also largely responsible for the severe air pollution in China. Coal consumption contributes to 90% of China's Sulphur Dioxide (SO_2) emissions, 67% of nitrogen oxides (NOx) emissions, 70% of particulate matter (PM) emissions, as well as about 70% of

[3] In 2012, the emission gap between the two countries was about 6.11 trillion tons CO_2e, as China's GHG emission level was about 12.45 trillion tons CO_2e and US's GHG emission level was 6.11 trillion tons CO_2e. Data can be found at the World Bank's database: https://data.worldbank.org.

[4] Non-fossil fuels refer to energy resources other than Coal, petroleum, and natural gas which cannot form in a short period of time. Exemplary non-fossil fuels include nuclear and renewable energies such as wind, solar and hydro.

[5] Data can be found at the data portal of the Energy Information Administration of US: https://www.eia.gov/beta/international/data/browser/.

[6] In 2014, China's total CO_2 emissions was about 7.43 trillion tons with about 10.29 trillion tons from coal consumption. Data can be found at the World Bank's database: https://data.worldbank.org.

the CO_2 emissions in 2010 (Chen and Xu, 2010). The severe air pollution has profound effects on the environment and causes high public health risks (Gao et al., 2017; Li et al., 2016; Tilt, 2019; Xie et al., 2018; Yang et al., 2018). Therefore, the energy transition is consistent with the domestic demand for better environmental quality in China.

China's concern about long-term energy security also drives domestic energy transition (Lo, 2014). China's overall self-sufficiency rate has decreased since the early 2000s, and was around 80% in 2016[7]. China has to turn to imported energy resources to meet its energy demand. In particular, China has a high dependence on imported oil, which makes China vulnerable to global oil supply and price fluctuations. Diversifying the energy resources can minimise the risks of energy insecurity related to resource concentrations.

Furthermore, China's GDP economic growth rate is slowing down, and the structure of its economy is changing from a high reliance on heavy industry to greater tertiary production, which leads to a slower growth rate of domestic energy demand (Green and Stern, 2017; Yuan et al., 2018). The lower pressure from energy demand provides a window of opportunity for China's energy transition (Liu et al., 2018).

China has implemented a mix of policy instruments to enable the energy transition. The share of coal in the primary energy consumption has increased from about 70.2% in 2001 to about 73.5% in 2006[8]. This may be related to China's participation in the World Trade Organization, rapid economic development, urbanization and rising economic demand (Dong et al., 2017). This rate decreased after the year 2006 when *Renewable Energy Law* came into effect, changing from about 73.5% in 2006 to 64.6% in 2016[9]. Similar to the trend observed in

[7] The rate was 101% in 2001, 98% in 2002, and 97% in 2003 and decreased to 80% in 2016. The data was compiled by International Energy Agency: http://energyatlas.iea.org/#!/tellmap/-297203538/1.
[8] Data can be found at the data portal of Energy Information Administration of US: https://www.eia.gov/beta/international/data/browser/.
[9] Data can be found at the data portal of Energy Information Administration of US: https://www.eia.gov/beta/international/data/browser/.

coal consumption, China's CO_2 emission intensity (kg per 2011 PPP$ GDP) increased from 0.69 in 2001 to 0.78 in 2006, but then decreased to 0.59 in 2014[10]. In 2016, coal was used for the production of about 58% of the electricity in China and the share of the renewable energy derived electricity (nuclear exclusive) in the electricity generation mix was around 35%, with 20% of hydroelectricity, 9% of wind electricity, 5% of solar PV electricity and about 1% of electricity generated from other renewables (e.g. biomass) (IEA and OECD, 2017, p.576). Yuan et al. (2018) projected that coal electricity would peak around 2020 at around 970GW, about 50.7% in the electricity generation mix, and then decrease to about 33.7% in electricity generation mix in 2030.

3 Method

3.1 Analytical Framework

A policy mix refers to a set of policy instruments chosen by decision makers to achieve one or multiple goals. The concept of the "policy package" is similar to the concept of the "policy mix". As defined by Givoni et al. (2013, p. 3), a policy package is "a combination of policy measures designed to address one or more policy objectives, created in order to improve the effectiveness of the individual policy measures, and implemented while minimising possible unintended effects, and/or facilitating interventions' legitimacy and feasibility in order to increase efficiency". We use "policy mix" and "policy package" as interchangeable nouns.

A policy mix consists of two elements: the policy strategy and the instrument mix. A policy strategy suggests a long-run strategic orientation, consisting of long-term objectives and

[10] Data can be found at World Bank Database: https://data.worldbank.org.

the principal plans to achieve them.[11] Policy instruments are more concrete tools that are combined into an instrument mix; each instrument contains a specific policy goal that contributes to the overarching policy objective (Grubb et al., 2017).

Figure 1 displays three policy strategies that are the focus of this study and exemplary policy instruments. The policy strategy of decarbonising traditional energy technologies is implemented by those instruments that directly target CO_2 emissions, such as CO_2 emission trading scheme (ETS). The policy strategy of reducing air pollutants in traditional energy technologies is implemented by those policy instruments that target air pollutants in fossil fuel-based energy technologies, for instance, SO_2 and NOx emissions from coal burning. In this study, the policy strategy of promoting renewable energy technologies uses policy instruments such as feed-in tariff (FIT) to encourage technologies such as wind energy, solar photovoltaic (PV) and hydroelectric technologies. The three policy strategies formulate the complex policy mix consisting of multiple policy strategies, multiple policy objectives and multiple policy instruments.

The policy strategy of reducing CO_2 emissions has profound implications on renewable energy deployment and local air pollution abatement. CO_2 emissions and air pollutants to a large extent originate from common emitters, as such policy instruments to reduce CO_2 emissions generate co-benefits of reducing air pollutants. Policy instruments to reduce CO_2 emissions discourage carbon-intensive technologies and in turn, boost the demand for renewable energy technologies, or other low-carbon technologies. On the other hand, policy instruments used to control air pollution can generate co-benefits for CO_2 emission reductions and policy instruments that encourage deployment of renewable energies, contribute to CO_2

[11] Policy objectives refer to the overall goal that the policy strategy attempts to achieve (Tuominen and Himanen, 2007). Principal plans outline the general pathways to attain the policy objectives. As an example, one of China's policy objectives by 2020 is to increase the share of non-fossil fuel consumption to 15%, while the 13th Five-Year Plan contains the principal plan to achieve the objective, outlining the development paths of various renewable resources (Gosens et al., 2017).

emission reductions through energy substitution. The three policy strategies constituting the policy mix closely interact with one another and conjointly facilitate the energy transition from a carbon-intensive and fossil fuel-based energy system to a low-carbon and sustainable energy system.

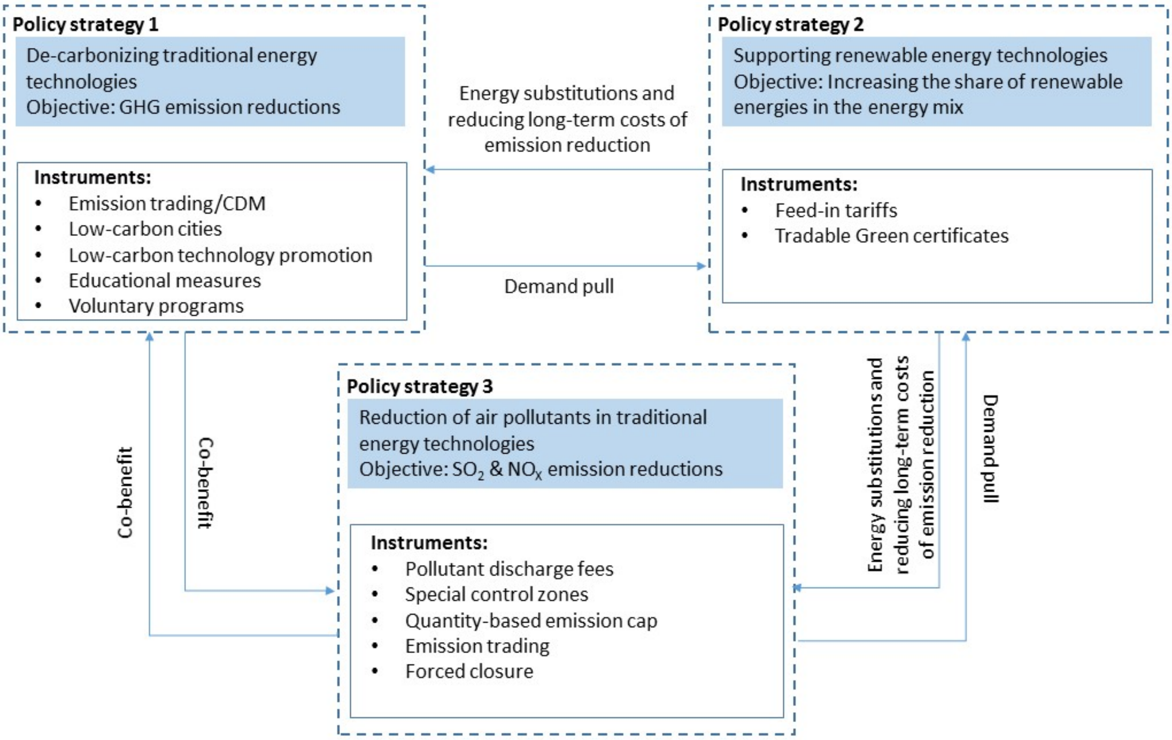

Figure 1. An exemplary environmental policy mix for the low-carbon energy transition

We use the framework illustrated above to identify the environmental policy mix for the low-carbon energy transition in China and examine how it evolved. We address the policy sequencing processes in the policy mix evolution. One assumption underlying the policy sequencing theory is that policy instruments and strategies interact with one another (Taeihagh, 2017; Taeihagh et al., 2014). In addition policy instruments themselves interact with each other, and a policy instrument can be a precondition strictly require for the successful implementation of another policy instrument, or facilitate the implementation of the other policy instrument for instance, and in a complex settings different policy packages formed from these policy instruments can have similar types of interactions (Taeihagh et al., 2013, 2009).

Also, we discuss changes in policy intensity and policy density over time. The concepts of policy intensity and policy density can be found in the policy change literature (Knill et al., 2011, 2012; Bauer and Knill, 2014). The density measures the number of the policy instruments. In the environmental policy field, an increase in the policy intensity refers to a higher cost of polluting behaviour, or a greater investment of resources, efforts, and activity. For a fee/tax imposed on emissions, a higher charging rate indicates a higher intensity. For a subsidy instrument, the level of the subsidy reflects the intensity.

3.2 Data Collection and Analysis Method

We traced the development of the environmental policy mixes in the electricity sector from 1981 to 2020 by five-year increments. First, China's Five-Year Plans (FYPs) for social and economic development were reviewed to identify the policy objectives and principal plans. Second, we searched for relevant Chinese policy documents to make a preliminary identification of the instrument mix serving each policy strategy. The policy documents were from the *pkulaw* database[12] also, we limited the search to the national policy documents in this study. We searched for policy documents with titles containing the following keywords: "wind power" (*feng dian* or *feng li fa dian*), or "solar PV" (*guang fu*), or "hydroelectricity" (*shui dian*), "renewable energy" (*ke zai sheng neng yuan*), or "sulfur dioxide" (*er yang hua liu*), or "carbon dioxide" (*er yang hua tan*), or "greenhouse gas" (*wen shi qi ti*), "low-carbon" (*di tan*), "carbon emissions" (*tan pai fang*) and "pollutant discharge fee" (*pai wu fei*). After removing duplicates and preliminary screening based on relevance, we downloaded the full texts of the 217 relevant policy documents (in Chinese). To establish a thorough analysis of the instrument mixes, we

[12]. The dataset can be found at http://www.pkulaw.cn.

reviewed the relevant literature to check if any other important policy documents and instruments had been missed in the initial policy document search. In the end, we reviewed 241 Chinese policy documents. After coding the policy documents, we present the policy sequencing processes in the evolution of China's environmental policy mix over time in Section 4. Section 5 and 6 present discussion and policy implications.

4 Evolution of China's Environmental Policy Mix From 1981 to 2020

4.1 Sequencing the Three Policy Strategies

Overall, there has been an increase in the density of the policy instruments, especially for the policy strategy to support renewable energy technologies. From the early days in 1980s the policy mix has evolved from a few authority-based instruments to a policy mix that has comprehensive coverage and diversity of instrument types nowadays in the 13 FYP.

China has a long history of combating air pollution with various policy instruments. In 1982, pollutant discharge fee was implemented as a policy instrument to control emissions of particulate matters (PM) from polluting industries. The policy instrument imposes a fee on emissions, indicating an additional cost to polluting firms. The policy instrument started to regulate SO_2 emissions in 1992 and NOx emissions in 2003. In total, pollutant discharge fee had served for air pollution abatement in China for almost 40 years until 2018 when it was converted to environmental protection tax. Meanwhile, the central government also implemented many other policy instruments to reduce air pollutions in coal-based energy technologies, such as emission limits, limiting Sulphur content of coal, reducing the on-grid price of coal electricity, and setting SO_2 emission caps for local governments. Authority-based policy instruments dominate the policy strategy to combating air pollutants, but there is an increase in use of nodality-based policy instruments. For instance, the revised *Environmental Protection Law* in 2014[13] stated that polluting firms should disclose environmental information.

In China, hydropower dominates renewable energy derived electricity generation due to abundance of hydropower resources and the low production costs of hydroelectricity. The government has been implementing programmes since 1983 to encourage the use of hydroelectricity for electrification in rural areas. Those programmes were significant for rural development after China's economic reform in 1978. Comparative to hydroelectricity, wind electricity and solar PV electricity generation were more costly and did not get much government support at the initial stage of China's economic reform. China started to subsidise some concession projects of wind electricity generation in 2003. After *Renewable Energy Law* came into effect in 2006, many treasure-based policy instruments, including FITs, were implemented to support wind and solar PV technologies. At the same time, policy instruments for hydroelectricity shifted the focus from increasing installed capacity to addressing river basin development and mitigating environmental impacts of hydro projects. To mitigate unintended effects from rapid diffusion of renewable energy technologies, the government used nodality-based instruments, such as distributing information of market conditions in different provinces, suggesting to investors not to invest in new installations in areas that have a curtailment risk.

Policy strategy to reduce CO_2 emissions in traditional energy technologies did not get serious attention until 2005 when the Kyoto Protocol became effective. Under Kyoto Protocol, the Clean Development Mechanism (CDM) allowed developed countries with GHG emission reduction commitments to buy certified emission reduction units (CERs) from emission reduction projects (e.g. renewable energy projects) in developing countries. Many CDM

[13] The revised Environmental Protection Law came into effect in January 2015.

projects were approved in China by National Development and Reform Commission (NDRC)[14] moreover, then sold CERs to developed countries. CDM projects contributed to renewable energy development in China on the one hand and introduced the idea of imposing a price on GHG emissions. From 2013 onwards China has started to build its own ETS market for CO_2 emission allowances. CO_2 ETS set the allowed level of CO_2 emissions in each jurisdiction and allowed the ETS-regulated firms in the region to emit up to emission allowances or trade allowances with each other. As such CO_2 emission allowances become a commodity with a price. Seven local ETS pilots were established one by one in 2013 and 2014, including Beijing ETS, Chongqing ETS, Guangdong ETS, Hubei ETS, Shanghai ETS, Shenzhen ETS and Tianjin ETS. Now the government is on the process of establishing a national CO_2 ETS, but it is uncertain when it will start to operate.

4.2 Sequencing Policy Instruments to Reduce Air Pollutants in Traditional Energy Technologies

Policy strategy to reduce air pollutants in traditional energy technologies exhibits an increasing policy intensity. As an example, the intensity of the pollutant discharge fee was enhanced gradually in multiple aspects, including the expansion of implementation area (geographically), coverage of more pollutants, and increase of the charging rates. Table 1 shows the changes in charging rates on SO_2 emissions and the policy implementation areas. The last row shows the tax rate when the pollutant discharge fee was converted to an environmental protection tax in 2018. Environmental protection tax is institutionalised by the *Environmental Protection Tax Law* (2018), and violators will be held liable under the Law. The pollution discharge fee was supported by an administrative regulation[15] issued by the State

[14] NDRC is a major macroeconomic management government agency under the State Council, while the State Council is the chief administrative authority of China.
[15] The Regulation on the Collection, Use and Management of Pollutant Discharge Fees (2003)

Council and had less legal authority. In that sense, the policy conversion from pollutant discharge fee to environmental protection tax indicates a further increase in policy intensity

Table 1. Fee/taxation on SO_2 emissions

Implementation time	Charging rate (yuan/kg SO_2 emissions)		Implementation area
	Upper bound	Lower Bound	
Sep-1992	0.2	-	Two provinces and nine cities
Jan-1998	0.2	-	Two control zones[16]
Apr-1998	-	0.2	Two control zones
Jul-2004	-	0.42	Nationwide
Jul-2005	-	0.63	Nationwide
Sep-2014	-	1.26	Nationwide
Jan-2018	12.63	1.26	Nationwide

Note: Some policy documents set upper bound, while some set lower bound. Local governments have the authority to calibrate the rate based on local contingencies. Pollutant discharge fee was under the responsibility of the environmental agency of the government, while environmental protection tax is under the responsibility of the State Tax Administration.

4.3 Sequencing Policy Instruments to Support Renewable Energy Technologies

Policy strategy to support renewable energy technologies has a lot to do with the production cost and governing resources. China implemented policy instruments to encourage hydroelectricity generation at first, and then implemented policy instruments to encourage wind-derived electricity, and finally implemented policy instruments to encourage solar PV electricity. Hydroelectricity has a good technology maturity and remains the lowest cost of electricity generated from renewable energy resources (Sternberg, 2010). Therefore, China started to develop hydroelectricity as early as the 1980s and began to subsidise wind and solar PV technologies in the 2000s.

[16] "Two control zones" refer to the acid rain control zone and the SO_2 emission control zone. State Council and the previous State Environmental Protection Administration defined the geographical scope of the two control zones in 1998 to use zoning policy instrument to reduce SO_2 emissions and the acid rain issue. Quantity-based SO_2 emission cap was imposed in the two control zones, which means that the total amount of SO_2 emissions in the two control zones cannot go beyond the allowed level.

Treasure-based policy instruments dominate the policy strategy to encourage renewable energy technologies. There is an incremental decrease in the intensity of treasure-based policy instruments. FITs, for instance, have decreasing tariff rates (see Table 2). At initial stages of the energy transition, renewable energy technologies such as wind and solar PV technologies cannot economically compete with established fossil fuel-based technologies. Policy instruments such as feed-in tariffs (FITs) can internalise the positive externality from innovation and deployment of those renewable technologies, which also help technologies travel down the cost curve and up the learning curve (Meckling et al., 2017). Renewable energy technologies emerge in market niches, but with technology maturation and diffusion over time, they can start to compete with the dominant regime (Kern and Smith, 2008).

Table 2. FITs of solar PV and onshore wind electricity in China

	Onshore wind	**Solar PV**
2006-2010	0.51-0.61 yuan/kWh, with a higher rate in regions with larger resource endowment	1.15-4.00 yuan/kWh, with a higher rate in regions with larger resource endowment
Jul-2011	-	1.11-1.15 yuan/kWh, with a higher rate in regions with larger resource endowment
Aug-2013	-	0.90, 0.95 and 1.00 yuan/kWh respectively for projects in category I, II, and III solar resource zones
Jan-2015	0.49, 0.52, 0.56 and 0.61 yuan/kWh respectively for projects in in category I, II, III and IV wind resource zones	-
Jan-2016	0.44, 0.47, 0.51 and 0.58 yuan/kWh respectively for projects in in category I, II, III and IV wind resource zones	0.80, 0.88 and 0.98 yuan/kWh respectively for projects in category I, II, and III solar resource zones
Jan-2017	0.40, 0.45, 0.49 and 0.57 yuan/kWh respectively for projects in in category I, II, III and IV wind resource zones	0.65, 0.75 and 0.85 yuan/kWh respectively for projects in category I, II, and III solar resource zones
Jan-2018	-	0.55, 0.65 and 0.75 yuan/kWh respectively for projects in category I, II, and III solar resource zones

Note: the tariff rate is higher in regions with a larger endowment of renewable energy resources.

4.4 Sequencing Policy Instruments to Reduce CO_2 Emissions in Traditional Energy Technologies

China's policy strategy to reduce CO_2 emissions in traditional energy technologies favours policy experimentation approach. For instance, the government implemented policy pilots of "Low-carbon Provinces and Cities" in 2010. This city/province branding policy instrument allows local governments to explore innovative policy measures to reduce CO_2 emissions. As another example, China's CO_2 ETS started from local experiments and then upgraded to the national level.

Pricing CO_2 emission is considered as a cost-effective policy instrument to internalise the externality of CO_2 emissions. China moved forward from being affected by the international CO_2 price under CDM projects, to develop its own policy pilots of CO_2 ETS, and ultimately towards operating a large national ETS market. The stakeholders involved in CDM projects are active in the seven local ETS markets and many CDM projects are converted to offset credits which can be traded in China's ETS markets (Ba et al., 2018). Implementation of the seven ETS policy pilots attract more actors to the low-carbon trading business in addition to those already involved in CDM projects, creating good support for the development of the national CO_2 ETS. CO_2 prices in those policy pilots have high volatilities (Li, 2018), and little is yet known about the design details of the national ETS (Stoerk et al., 2019).But the upscaling from local policy experiments to a national scheme indicates an increase in the policy intensity, adding an extra cost to nationwide emitters that are regulated by ETS.

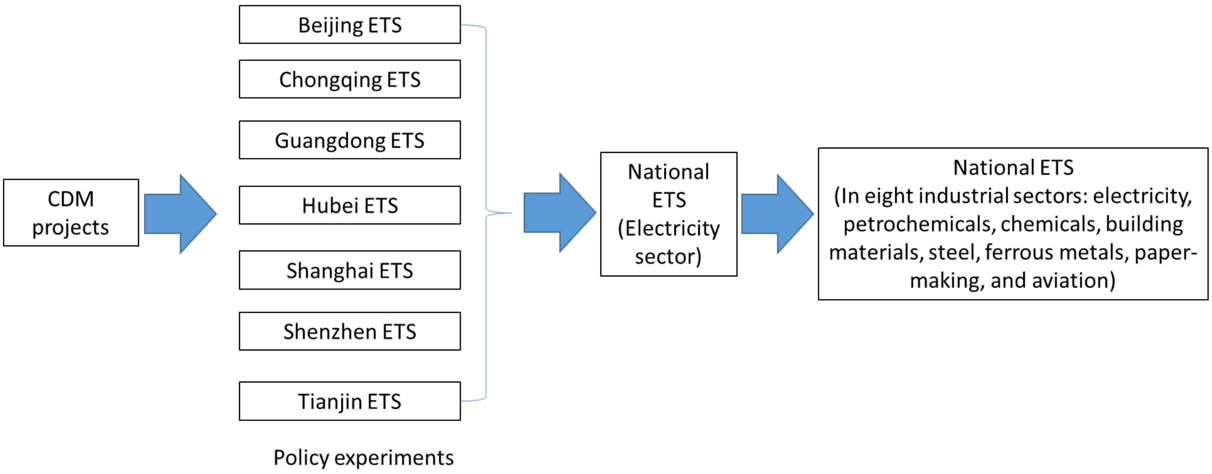

Figure 2. Evolution of carbon pricing in China

5 Discussion

In terms of overall policy sequencing, the policy strategy to reduce air pollutants in fossil fuel-based energy regimes predates policy strategy to encourage high-cost renewable energy technologies, which predates policy strategy to reduce CO_2 emissions in fossil fuel-based energy regimes by pricing CO_2 emissions. In the 1980s and 1990s, China implemented policy instruments to regulate environmental pollution from fossil fuel-based energy technologies, but the priority was to meet the growing electricity demand. Renewables, except hydropower, were not prevalently used for electricity generation until the 2000s. Since 2006, FIT and other financial incentives have been implemented to encourage wind and solar PV technologies now that the country has more governing treasures to do so and electricity supply is sufficient enough to meet the demand. Meanwhile, policy instruments to regulate pollution in traditional energy technologies have become more and more rigid since the 2000s (Feng and Liao, 2016) and the recent policy conversion from pollutant discharge fee to environmental protection tax indicates a further increase of policy intensity (Wang et al., 2019). Plus, the electricity market reform in 2002[17] increased competition in the market, creating an enabling market environment for multiple electricity generation technologies. The increasing technology maturity and decreasing production costs of electricity generation from renewable energy resources helped built up the interest groups for the introduction of CO_2 ETS. Because emission reduction credits from renewable energy projects can be sold to ETS-regulated firms to offset their CO_2 emissions. Shenzhen established the first ETS pilot in China in 2013. The city is relatively more advanced in use of clean energy technologies and does not have heavy industries. The resistance was expected to be low compared to cities with carbon-intensive industries. The implementation of pollutant discharge fee for air pollution control make industrial emitters become more accustomed to pricing instruments.

Incrementally tightening of policy instruments to control air pollution relates to changes in policy contexts such as problem severity, environmental awareness, institutions, monitoring and enforcement. The incremental increase in the intensity of policy instruments to control air pollution relates to severity of pollution issues and growing public concern about environmental quality and sudden pollution incidents (Xie et al., 2018) (Zhang, 2007). Second, the increase in the intensity of policy instruments used for controlling air pollution can be partially attributed to the growing authority of the government agency who oversaw administrating environmental policy measures, which used to be the State Environmental Protection Administration (SEPA), a vice-ministerial level government administration. In 1998 SEPA was upgraded to the ministerial level and in 2008 further upgraded to the cabinet-level Ministry of Environmental Protection working under the State Council. In 2018, as a part of institutional reform of State Council, the Ministry of Ecology and Environment (MEE) was established, taking over environmental protection responsibilities scattered across other

[17] In 2002 reform, the State Power Corporation, which monopolized the electricity industry at that time, was dismantled into five state-owned electricity generation firms and two state-owned grid firms. The 2002 reform also differentiated on-grid electricity price, transmission price, distribution price and retail price.

government agencies to enhance policy coordination. For instance, MEE took over the responsibility of tackling climate change-related issues from NDRC, in addition to its role of controlling environmental pollution, with the aim of better coordinating CO_2 mitigation instruments with air pollution abatement instruments. Third, effective pollution monitoring and information disclosure reduce the implementation barriers of pollution control policies. For instance, 362 cities of China have established real-time pollution monitoring systems, which are essential for policy instruments such as pollutant discharge fee or environmental protection tax (Tambo et al., 2016). Fourth, the intensity increase of policy instruments to control air pollution also relates to the fact that environmental quality has become one of the top priorities in China. Since 1996, the State Council has requested governments at all levels to be responsible for environmental protection affairs in their jurisdictions and environmental quality has become one of the performance indicators to evaluate government officials (Lo and Tang, 2006), and government officials are enforcing environmental policy instruments better since then (Gao et al., 2009).

In a sustainable energy transition resulting in lower levels of emissions and higher share of renewable energy technologies, the initial phase is characterized by the development of niches and demonstration projects of new technologies with policy instruments creating favorable conditions for them (Markard, 2018). For instance, when implementing FITs, it is important to impose high tariff rates at the beginning. But it is essential to create a tariff decreasing mechanism to account for cost decrease with maturation and diffusion of renewable energy technologies. Nowadays China is going into a second phase of energy transition when policy instruments to support renewable energy technologies can be downscaled and policy focus could shift to wider socio-technical changes, such as demand side management with energy efficiency and conservation policy options, coping with unintended curtailment issues resulting from rapid transition, enhancing transmission and distribution infrastructure.

Additional focus should be given to phasing out coal-based energy technologies by further integrating concerns about environmental quality and climate risks into the energy sector decision making. At instrument level, China has started to try out more flexible policy instruments such as TGC for increasing share of renewable energy technologies.

The precondition to the implementation of ETS policy instrument includes legacies from CDM projects, the growing concern of emissions from coal-based energy systems, and declining costs of alternative energy technologies. Progressive tightening of policy instruments to regulate air pollutants, implementation of policy instruments to support renewable energy technologies and implementation of ETS policy experiments has nurtured a powerful constituency for the introduction of a national CO_2 ETS.

6 Policy implications

Packaging and sequencing policy instruments are critical to decarbonising energy systems. China's experiences provide policy implications for other developing countries on deliberate packaging and sequencing policy instruments to guide and accelerate energy transitions to low-carbon energy systems. This study found certain policy sequencing processes in China's ongoing energy transition: (1) an increasing intensity of policy instruments to regulate air pollutants in traditional fossil fuel-based energy technologies; (2) a decreasing intensity of treasure-based policy instruments to support renewable energy technologies; (3) an upscaling of CO_2 ETS policy experiments to a national level scheme.

Energy transition to a sustainable energy system can be facilitated by packaging policy instruments for phasing out carbon-intensive energy technologies with policy instruments for encouraging alternative energy technologies. Policy instruments used for CO_2 emission reduction and air pollution abatement can play a vital role in break the carbon lock-in of the incumbent energy regimes. This experience is valuable for fast-growing developing countries that pursue energy transitions. From among the three policy strategies adopted it is evident that China had a long history (more than 30 years) of air pollution control before it embarked on regulating CO_2 emissions and while China had a ten-year history of supporting wind and solar PV technologies before CO_2 ETS implementation started. For other developing countries that may deliberately sequence these policy strategies, the time gap between the policy strategies have to be much shorter. Climate change is becoming more acute with each passing year, and a mix of the three policy strategies can together guide energy transitions towards low-carbon energy systems.

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