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# Sequencing policy instruments to accelerate low-carbon energy transitions: the case of China

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**T7P11.** POLICY MIX AND CAPACITY IN GOVERNANCE CONTEXTS: INTERACTIONS AND OUTCOMES

# Sequencing policy instruments to accelerate low-carbon energy transitions: the case of China

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**Abstract** - As the most significant GHG emitter, China can substantially contribute to global climate change mitigation efforts through decarbonising its coal-dominated energy system. This research is concerned with the policy pathway that guides the low-carbon energy transition in China, giving attention to policy instruments' timing and sequencing. Based on data collected from 1981 to 2020 from policy documents, we examined policy changes associated with China's energy transition and then use visual analytical tools to present the overall policy evolution trajectory and incremental institutional changes. This research demonstrates the temporal features of policy mixes and actor networks, and provides empirical evidence on policy sequencing practices. The findings show that China's government preceded air pollution mitigation policies and renewable energy policies prior to climate policies such as emission trading schemes, and integrating climate change into environment and energy policies rather than considering it as a standalone issue. China's policy development for the low-carbon energy transition is characterised by combinations of reactive and self-reinforced measures, and combinations of incremental and radical policy changes. Since China is moving towards further energy transition and decarbonisation,

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deliberation on policy sequencing would be critical to gradually relax or move future policy obstacles and enhance implementation effectiveness. This research extracted information from a large volume of textual data, and based on that, visualised temporal aspects of policy changes and actor networks, highlighting the importance of novel data visualisation tools for policy studies.

**Keywords:** policy design, policy sequencing, policy package, policy mix, energy transition, china, policy evolution, carbon dioxide emission, air pollutant abatement, renewable energy support

## 1 Introduction

Under the 2015 Paris Agreement, China's Nationally Determined Contribution (NDC) commitment is to reduce carbon dioxide ($CO_2$) emissions per unit of gross domestic product (GDP) (also known as $CO_2$ emission intensity) by 60%–65% in 2030 relative to the 2005 levels and increase the share of non-fossil fuel[1] consumption to 20% by 2030[2] (NDRC of China, 2015). An energy transition away from its current coal-dominated electricity production to a sustainable energy system is a major stride towards China's NDC commitment and contributes to improving domestic air quality.

There is a consensus in the literature on the need to move towards more sustainable energy systems, but the definition of the term energy transition may vary across studies (Child and Breyer, 2017). In this research, we consider energy transition as a process of decarbonising the energy sector. It is a long-term and large-scale social-technical transition

[1] Non-fossil fuels refer to energy resources other than coal, petroleum, and natural gas which cannot form in a short period. Exemplary non-fossil fuels include nuclear and renewable energies such as wind, solar and hydro.
[2] Data can also be found at the website of the United Nations Framework Convention on Climate Change, https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx.

process that needs a policy package to facilitate technology development and break incumbent systems. The future outcome of the energy transition is a sustainable energy system with low-level emissions (including $CO_2$ emissions and air pollution[3]) and a large share of renewable energy technologies in electricity generation.

Deliberate policy sequencing to enable the energy transition is a new orientation in the energy and climate policy fields (Li and Taeihagh, 2020; Meckling et al., 2017; Pahle et al., 2018; Rosenbloom et al., 2019; Taeihagh et al., 2013, 2009). Several studies have discussed utilising self-reinforcing feedback mechanisms and increasing returns to generate and stabilise support for ambitious decarbonisation policy interventions (Giest, 2014; Lockwood et al., 2017; Rietig and Laing, 2017; Rosenbloom et al., 2019). Levin et al. (2012) suggest that there should be intentional attempts to gradually build up the stickiness of climate policy interventions through entrenching support, expanding the populations being covered, and limiting reversibility.

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 policy sequences for China's energy transition from 1981 to 2020. This research takes a historical perspective and uses visualisation tools to demonstrate the timing and sequencing of policy measures taken by the Chinese government at different industrialisation stages to inform low-carbon policy sequencing in other developing countries with similar policy contexts.

[3] $CO_2$ emission is not considered as a type of air pollutants in China.

## 2 Policy changes and data visualisation

### *Policy change theories*

Incremental institutional change literature considers that institutional changes happen continuously and gradually over time (Béland, 2007; Streeck and Thelen, 2005; van der Heijden, 2011). Policies can be seen as institutions "to the extent that they constitute rules for actors other than for the policymakers themselves— rules that can and need to be implemented and that are legitimate in that they will if necessary be enforced by agents acting on behalf of the society as a whole" (Streeck and Thelen, 2005, p. 12). As representative scholars of incremental institutional change, Streeck and Thelen (2005, p.31) introduced such mechanisms as policy replacement, layering, drifting, conversion, and exhaustion. For instance, institutional changes are possible through layering new elements that do not directly undermine existing institutions but induce gradual transformation over time, despite increasing returns and lock-in effects of existing institutions (Schickler, 2001). Other institutional change scholars argue that increasing returns and positive feedback mechanisms impose constraints on policy innovation and sustain long-period stability, but periodical exogenous shocks may open opportunity for a radical change (e.g. civil wars, or financial crisis) (Baumgartner and Jones, 1993; Hall, 1993; Pierson, 2000a; van der Heijden, 2011).

Another critical topic of policy change is how the timing and sequencing of policy events or processes matter. Policy sequencing has an important implication that the sequential order of events or processes affects outcomes (Pierson, 2000b; Taeihagh et al., 2013, 2009). Increasing returns, also described as positive feedback or self-reinforcing processes or lock-in, is one mechanism for sequencing in policy development trajectories. The notion of increasing returns implies that "the probability of further steps along the same path increases with each move down that path" (Pierson 2000a, p.252). However, what has happened earlier in a sequence has an impact on outcomes, but it does not necessarily increase the probability of further steps in the same direction—it may provoke a reaction in a different direction (Pierson, 2000b). Negative feedback or reactive sequences are also common (Bardach, 2006). The reactive sequence describes a trajectory where each event along the trajectory is partially a reaction to antecedent events (Mahoney, 2000). Howlett (2009b) argues that reactive sequences seem more prevalent in the real world.

### *Data visualisation in policy studies*

In this work, we emphasise the usability of visual analytical tools for policy studies. This work applied visual analytical tools to clearly depict policy evolution trajectory and institutional changes associated with energy transition in China. Data visualisation is a powerful tool for summarising complex data and visualising the unimaginable information (Schneider and Nocke, 2014). In the environmental field, data visualisations contribute to shaping the understanding of environmental issues, concepts, and solutions, which can influence environmental policy-making (Morseletto, 2017; van Beek et al., 2020). With recent trends in big data, open data and data analytical methods, researchers have identified the potential of data visualisation tools to efficiently extract and effectively reveal themes expressed in large volumes of textual data (Hagen et al., 2019).

For policy studies, the application of visual analytical methods can help better understand policy networks and policy development. A policy network is "a subsystem of political actors that are bound by multiple relations relevant for the production of a given public policy" (Schneider, 2005). Analytical tools such as Gephi, Pajeck, IGraph and Networkx have been developed to identify and visualise policy networks, where the nodes consist of actors and edges consist of links between actors (Akhtar, 2014). For policy development, it involves a chain of policy events "in which problem-solving options are generated by the battle of interests between the participating actors in the respective time periods and policy phases" (Schneider, 2005). Scholars have developed and demonstrated the use of visualisations for policy sequencing (Boons et al., 2014; Boons and Spekkink, 2015; Spekkink and Boons, 2016; Taeihagh, 2017; Taeihagh et al., 2009). Taeihagh et al. (2009) applied policy sequencing to emission reduction strategies from the transport sector in UK and Boons and Spekkink (2015) applied the event sequence approach to visualise the policy event sequences in the Dutch environmental policy domain from 1989 onwards, revealing the policy trajectory towards the internalisation of environmental responsibility in the Dutch chemical industry.

## 3 Method and data

We identified policy sequences in the policy evolution for the low-carbon transition of China's electricity sector from 1981 to 2020. Following Li and Taeihagh (2020), the study covers three main policy strategies important for a low-carbon energy transition in China. The first policy strategy is to curb $CO_2$ emissions in traditional emission-intensive energy technologies using policy instruments that directly address $CO_2$ emissions, such as ETS. The policy strategy of reducing air pollutants in traditional energy technologies is implemented by those policy instruments that target air emissions in traditional emission-intensive energy technologies, for instance, sulphur dioxide ($SO_2$) and nitrogen oxide (NOx) emissions from coal-burning. The policy strategy of renewable energy promotion uses policy instruments such as feed-in tariff (FIT) to encourage wind energy, solar photovoltaic (PV) and hydroelectric technologies. The three policy strategies formulate a policy mix that is important for a sustainable energy transition because they help phase out traditional technologies by imposing costs on emissions and promoting the development of alternative technologies.

This study applies content analysis to understand the sequences in the evolution of China's policy mixes that facilitate a sustainable energy transition. We compiled 237 Chinese-language policy documents through searching the *pkulaw* database[4] and complementing the searching with a literature review. We extracted information from the collected policy documents and then translated them to English. Each policy document has an id, starting date, termination date, government agencies involved in publishing the policy document, previous policy documents mentioned as a reference, and policy instruments mentioned if there is any.

Following policy measure analysis and event sequence analysis methodology (Taeihagh et al., 2009, 2013, 2014; Boons and Spekkink, 2015; Mu and Spekkink, 2018; Spekkink, 2015; Taeihagh, 2017), we used the Gephi software (Bastian et al., 2009) and the Event Graph Layout module[5] to analyse and visualise policy event sequences in the evolution of China's environmental policy mix from 1981 to 2020. The evolution process contains a sequence of policy events. Taeihagh et al. 2014 and Taeihagh 2017 show deliberate sequencing processes that utilise reinforce or positive feedbacks to build policy packages and institutions for a policy goal. We consider publication of a policy document is considered as a policy event. A policy event may refer to previous events as its antecedent. A policy event may relate to the implementation of one or more policy instruments. The behaviour of publishing a policy document (i.e., a policy event) associated with the policy strategies is considered as a proxy to understand how a government agency acts. A policy event may

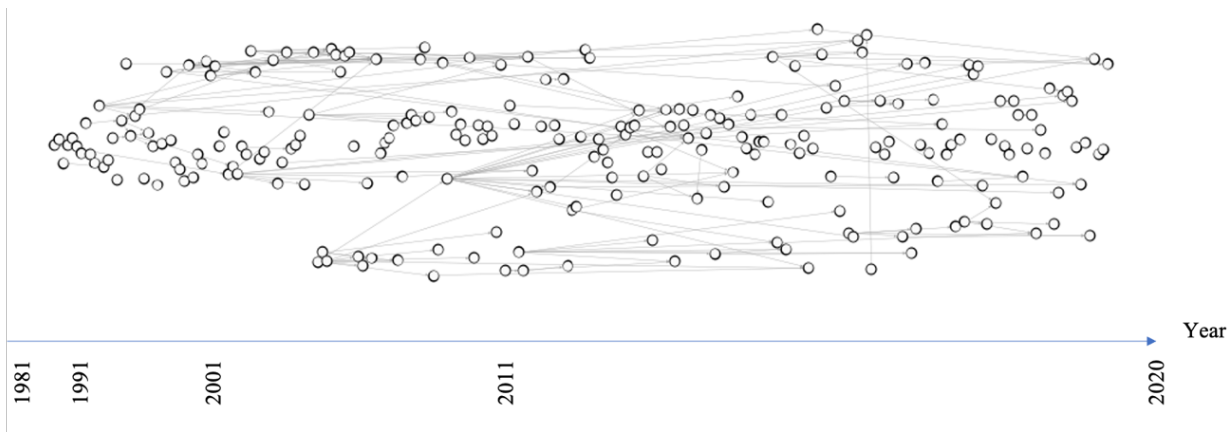
[4] The dataset can be found at http://www.pkulaw.cn.
[5] https://www.wouterspekkink.org/software/#event-graph-layout

involve two or more government agencies, indicating collaboration of the government agencies on the subject.

## 4 Analysis and visualisation of policy event sequences and networks

### *4.1 Overall policy event sequence*

Figure 1 displays the event sequence graph of the total dataset with 237 events from 1981 to 2020. The intensity of policy events increases across the years, from 11 events in 1981-1990 to 142 events in 2011-2020, implying the increasing policy efforts made by the government to curb emission-intensive energy technologies and expand renewable energy industries.



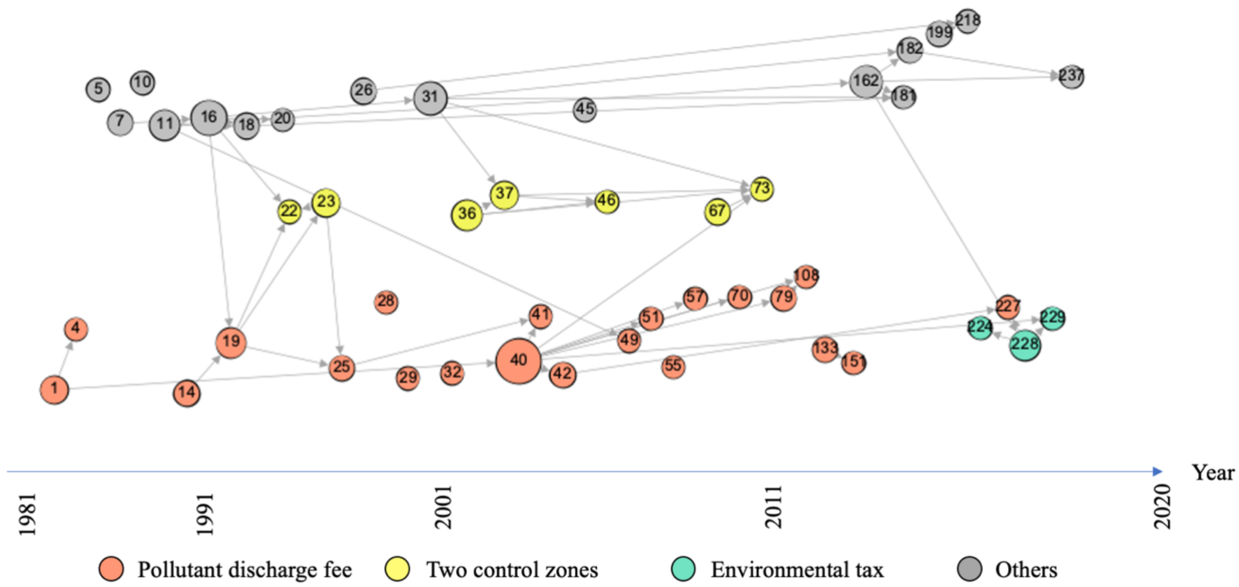

Notes:
1) Each node refers to a policy event- i.e., publication of a policy document.
2) Each edge denotes the fact that the later event explicitly refers to an earlier event.

Figure 1. Event sequence graph of the total dataset (237 events, 1981-2020)

### *4.2 Policy event sequence for air pollution*

Figure 2 displays the event sequence graph for air pollution abatement based on 47 policy events. Policy events concerning the policy strategy spread rather evenly from 1981 to 2000 (totalling 19 events), with an increase in the number of events in 2001-2020 (totalling 28 events), indicating more environmental policy efforts since the 10th Five Year Plan (2001-

2005). As shown in Figure 2, the pollutant discharge fee was an important pollution control instrument in China, having a long history from the early 1980s to 2018. The pollutant discharge fee was initially piloted in 1982, and then enforced in two control zones defined by the Chinese government, the acid rain and the $SO_2$ control zones. In 2003, the government promulgated the *Regulation on the Collection, Use and Management of Pollutant Discharge Fees* (i.e., policy event no.40 in Figure 2) to enforce the policy instrument nationwide, enhance the implementation measures, and reinforce the role of the pollution discharge fee as a primary pollution control policy instrument in China.




Notes:
1) Each node refers to a policy event- i.e. publication of a policy document.
2) Each edge is coded if a later policy document explicitly mentions an earlier policy document as its reference.
3) Node size is ranked based on its out-degree. A larger node size implies that this policy document is more likely to be referred to by other policy documents.

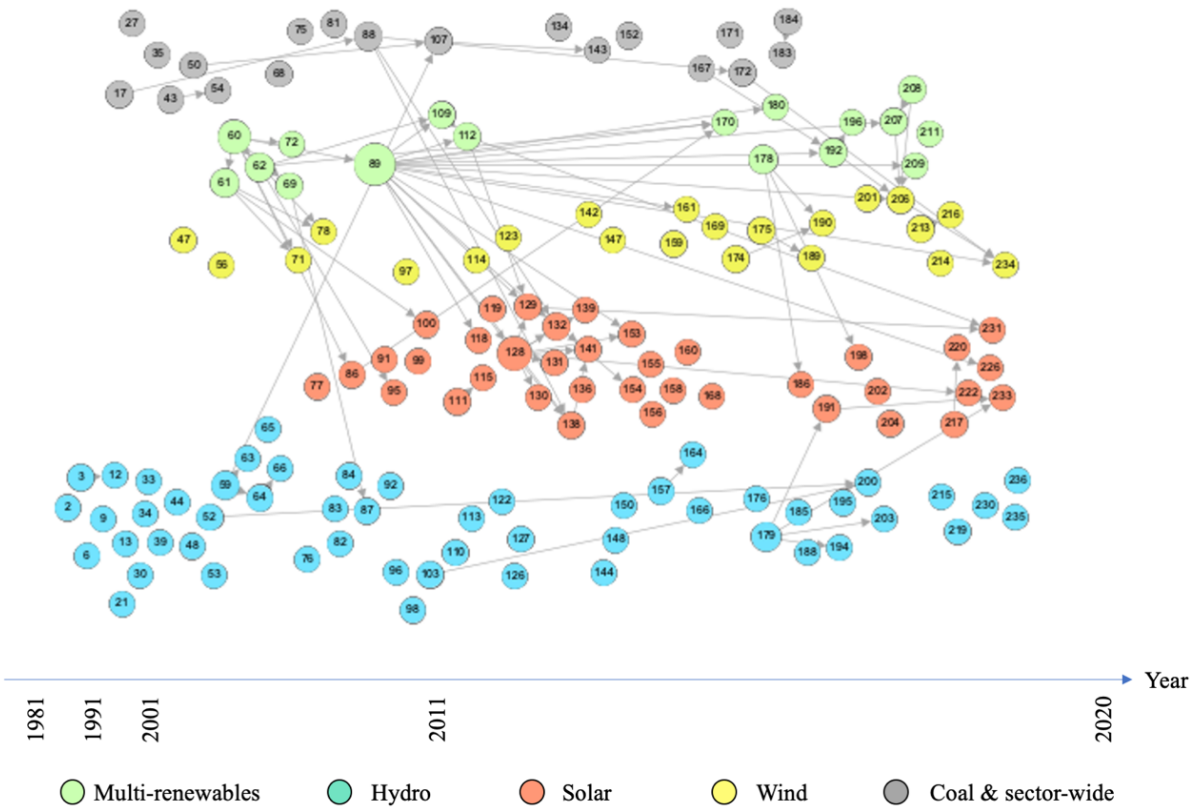
Figure 2. Event sequence graph for air pollution abatement (47 events, 1981-2020)

### *4.3 Policy event sequence for renewable energy development*

Figure 3 displays the policy event sequence for renewable energy development. It shows a general sequence of policy events concerning renewable energies: hydro energy got governmental support at first, followed by wind energy and solar energy. Between 1981 and

2000, China's renewable energy development was mainly about hydropower. In addition to developing large-scale state-owned hydroelectricity infrastructure, the Chinese government implemented a few programmes to encourage small-scale hydroelectricity projects in rural areas to serve the electricity demand of its large rural population (accounting for a larger part of the total population). Policy documents concerning wind and solar energy technologies had been mostly promulgated since the *Renewable Energy Law* was enacted in 2006. After that, China soon became a dominant manufacturer of solar PV modules in 2009 (Zou et al., 2017).

In Figure 3, policy events no. 60 and 89 exhibit larger node size, indicating their influence on China's renewable energy policies. They denote respectively the promulgation of i) *Renewable Energy Law* effective since 2006, and ii) the amended *Renewable Energy Law* effective since 2009. The *Renewable Energy Law* initiated the implementation of policy instruments such as FITs in China, leading to the rapid growth of wind and solar PV industries in China in the following years (Schuman and Lin, 2012; Sun et al., 2014). To deal with the imbalance between the increase in renewable electricity production and the smaller amount of actual on-grid renewable electricity, in 2009, the amended *Renewable Energy Law* came into place, asking grid companies to fully purchase renewable electricity, and launching the Special Fund for Renewable Energy Development to subsidise the on-grid price gap between the renewable electricity and the coal electricity.




Notes:
1) Each node refers to a policy event- i.e. publication of a policy document.
2) Each edge is coded if a later policy document explicitly mentions an earlier policy document as its reference.
3) Node size is ranked based on its out-degree. A larger node size implies that this policy document is more likely to be referred to by other policy documents.

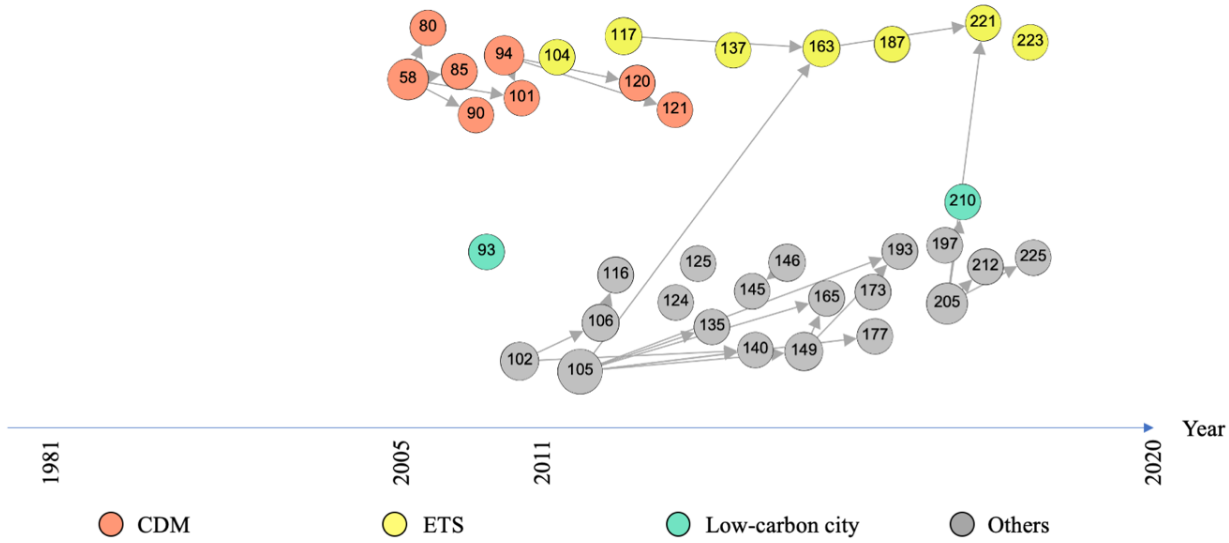
Figure 3. Event sequence graph for renewable energy support (146 events, 1981-2020)

### *4.4 Policy event sequence for CO2 emission mitigation*

Figure 4 shows the event sequence graph created based on 42 policy documents concerning $CO_2$ emission mitigation. The starting point of the policy event sequence was in 2005. Before that, $CO_2$ emission mitigation was not explicitly set as a policy objective in previous policy documents. In 2005, soon after Kyoto Protocol became effective, China's National Development and Reform Commission (NDRC), Ministry of Science and Technology (MOST), Ministry of Foreign Affairs (MFA), and Ministry of Finance (MF) collaboratively released the policy document *Measures for the Operation and Management of*

*Clean Development Mechanism (CDM) Projects* (i.e., policy event no.58), which guided Chinese CDM project development and helped China engage in the international carbon trading market. In 2011, NDRC published the policy document *Conducting Pilots of ETS for* $CO_2$ (i.e., policy event no.104) in 2011 to experiment with $CO_2$ ETS in China, initiating a sub-sequence of policy events concerning ETS.

Two other important policy documents, with larger node size in Figure 4 include the policy document *Work Plan for Greenhouse Gas (GHG) Emission Control during the 12th Five-Year Plan (FYP)* (i.e., policy event no.105) released in 2011 and the policy document *Work Plan for GHG Emission Control during the 13th FYP* released in 2016. The former laid out the GHG emission mitigation plan from 2011 to 2015, setting a few policy goals, including: 1) achieving a 17% reduction of the $CO_2$ emission intensity by 2015 in relative to the 2010 level, 2) establishing GHG accounting protocol, 3) experimenting ETS policy instrument, and 4) developing "low-carbon city" and "low-carbon province" in selected cities and provinces in China. Policy document no. 205 made the work plan for GHG emission control from 2016 to 2020, taking more ambitious climate actions, such as upscaling ETS policy pilots to a national scheme, enhancing the capacity of carbon sinks, encouraging a few cities/provinces to reach peak emissions by 2020, and emphasising policy coordination between $CO_2$ emission reduction and pollution control.




Note:
1) Each node refers to a policy event- i.e. publication of a policy document.
2) Each edge is coded if a later policy document explicitly mentions an earlier policy document as its reference.
3) Node size is ranked based on its out-degree. A larger node size implies that this policy document is more likely to be referred to by other policy documents.

Figure 4. Event sequence graph for air pollution abatement (42 events, 1981-2020)

### *4.5 Two-mode networks of government agencies and policy events*

Figure 5 exhibits the network of policy actors involved in China's low-carbon energy transition. The policy actors here are mainly formal organisations, i.e., governmental agencies, who play a dominant role in China's environmental and energy governance. Actors tend to shape policy decisions based on their interests, and their capacity to do so rely on their political influence, resources and structural positions in the policy area (Schneider, 2005). The analysis resulted in 31 policy actors who drafted and released policy documents relating to China's low-carbon energy transition (see Table 1).

In Figure 5, the actor-to-actor relation indicates that the two governmental agencies published at least one policy document together, suggesting their co-interest in a policy area. The thickness of a linkage is proportional to the intensity of the engagement between the two agencies in producing policy documents to guide societal changes (i.e., the more policy documents published between two agencies (nodes), the thicker the linkage).

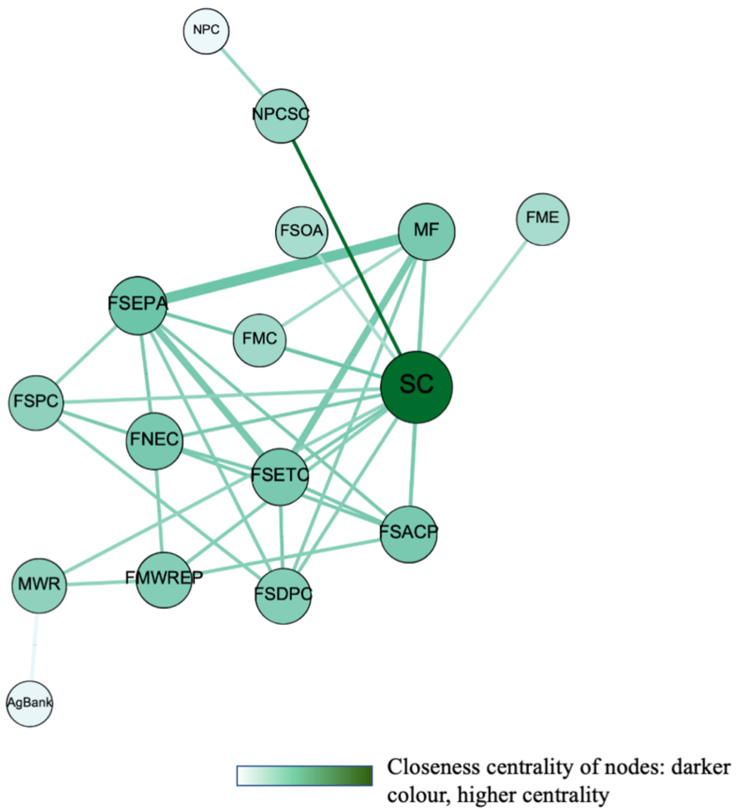
Node size and colour denote the centrality of a government agency in the network. The centrality is measured by closeness centrality, defined as "the ability of actors to reach any other actor in a small amount of steps" (Schneider and Leifeld, 2007). A larger node size and darker colour indicate that the government agency has a greater centrality. Accordingly, the State Council, NDRC, and MF have the highest centrality in the actor-network.

The State Council is the parent organisation of many government agencies involved in China's environmental, energy and climate policies, including the NDRC, the MF, the Ministry of Ecology and Environment (MEE), the Ministry of Water Resources (MWR), and the Ministry of Science and Technology (MOST). MEE was established in 2018 to replace the former Ministry of Environmental Protection (FMEP), which was known as the former State Environmental Protection Administration (FSEPA) prior to 2008. MEE is the leading governmental agency responsible for environmental protection in China, covering air, water and land pollution prevention and control, climate change mitigation and adaptation, nuclear safety, and environmental protection[6]. NDRC is a major agency affiliated with the State Council, formulating and administering social and economic development policies and coordinating energy saving and environmental protection in China[7]. NDRC coordinated with other government agencies to adopt policy measures for air pollution control, $CO_2$ emission mitigation and renewable energy technology development. Under the NDRC, the National Energy Administration (NEA) formulates and carries out energy development policies and plans, administers energies including coal, oil, natural gas, electricity, and renewable

[6] Information can be found at: https://www.mee.gov.cn/zjhb/jgzn/
[7] Information can be found at: https://www.ndrc.gov.cn/fzggw/bnpz/

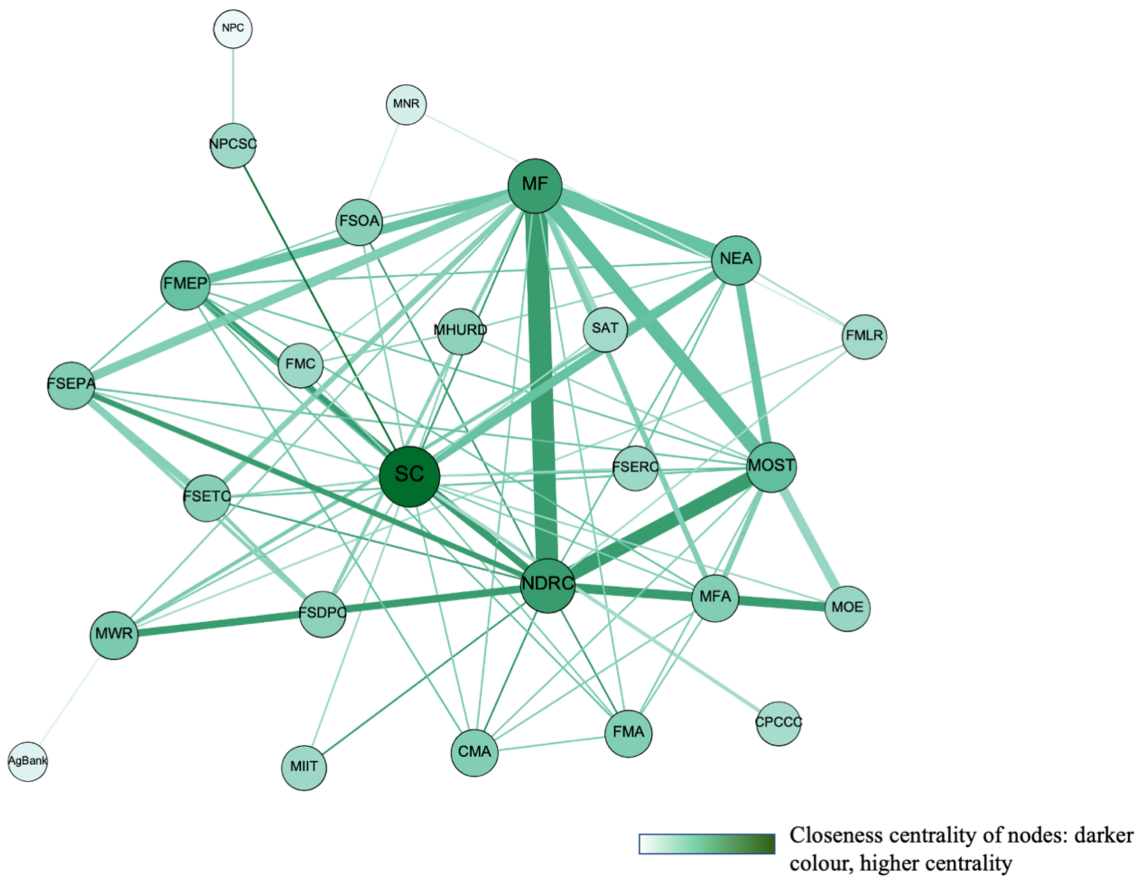
energies, and guides energy technology development, and oversees energy conservation and resource utilisation in China.

Figure 5 shows that MF and MOST closely worked with NDRC and the State Council. MF provided financial resources for many policy instruments to be effective, including budgeting and monitoring subsidy schemes for renewable energy projects (Shen and Luo, 2015). MOST manages technology research and development, selects priority areas of technological development and raises policy measures for promoting technology innovation (Zhao, 2001)[8]. NDRC and NEA are the main actors involved in formulating policies relating to renewable energy development and mitigation in China. For pollution control purpose, MEE and its previous forms, FSEPA and FMEP, worked closely with MF and NDRC. For hydroelectricity development, MWR closely worked with NDRC.




a) 1981-2000

[8] Information can also be found at the website of MOST: http://www.most.gov.cn/zzjg/kjbzn/201907/t20190709_147572.htm




b) 2001-2020

Notes:
1) Each node denotes a government agency that wrote at least one of the policy documents in our dataset.
2) Each edge indicates that the two government agencies wrote at least one policy document together. The thickness of an edge shows the degree of this type of interactions between government agencies.
3) The colour and size of nodes are ranked based on a government agency's closeness centrality in the network. Larger node and darker colour indicate higher centrality.

Figure 5. Interactions between government agencies

Table 1. List of government agencies releasing the collected policy documents

| Abbr. | Description | Abbr. | Description |
|---|---|---|---|
| NPC | National People's Congress | MF | Ministry of Finance |
| NPCSC | Standing Committee of the National People's Congress | MFA | Ministry of Foreign Affairs |
| CPCCC | CPC (Communist Party of China) Central Committee | MHURD | Ministry of Housing and Urban-Rural Development |
| SC | State Council | FMC | Former Ministry of Construction |
| NDRC | National Development and Reform Commission | MIIT | Ministry of Industry and Information Technology |
| FSDPC | Former State Development and Planning Commission | MNR | Ministry of Natural Resources |
| FSETC | Former State economic and trade Commission | FMLR | Former Ministry of Land and Resources |
| FSPC | Former State Planning Commission | FSOA | Former State Oceanic Administration |
| FNEC | Former National Economic Council | MOE | Ministry of Education |
| NEA | National Energy Administration | MOST | Ministry of Science and Technology |

| | | | |
|---|---|---|---|
| FSERC | Former State Electricity Regulatory Commission | SAT | State Administration of Taxation |
| FME | Former Ministry of Energy | CMA | China Meteorological Administration |
| FMEP | Former Ministry of Environmental Protection | FMA | Former Ministry of Agriculture |
| FSEPA | Former State Environmental Protection Administration | FSACP | Former State Administration of Commodity Prices |
| MWR | Ministry of Water Resources | AgBank [3)] | Agricultural Bank of China |
| FMWREP | Former Ministry of Water Resource and Electric Power | | |

Notes:
[1)] It denotes when a government agency is dismantled, merged with another agency, or reorganised and renamed. If none of those happened, "Present" indicates that a government agency is operating at present.
[2)] If a government agency is dismantled, or merged with another agency, or reorganised and renamed, "Current form" denotes the agency that currently takes over its role.
[3)] Agricultural Bank of China is one of the four biggest state-owned commercial banks in China.

# 5 Discussion

## *5.1 Overall policy sequence discussion*

Overall, China has a long history of combating air pollution dating back to the 1980s, followed by strong policy support for renewable energy technologies (especially wind and solar energy) since the mid-2000s, direct carbon pricing, and low-carbon city development since the 2010s.

As early as 1978, environmental concerns were incorporated into the Chinese constitution; meanwhile, the Reform and Opening-Up Policy was launched. In 1982, pollutant discharge fee was implemented as one of the first concrete policy instruments 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. In 1988, the FSEPA was established to enforce environmental policies and report directly to the State Council. From then on, the FSEPA went through a number of institutional reforms, and many more policy instruments were introduced to combat environmental pollution (Li and Taeihagh, 2020).

The Chinese government has implemented programmes to encourage hydroelectricity development since the 1980s but started to give strong policy support for solar and wind energies only in the mid-2000s. Similar to countries such as the United States and Japan, in China, hydropower dominates renewable energy derived electricity generation (IEA and OECD, 2017). To some extent, this can be attributed to the abundance of hydropower resources and the low production costs of hydroelectricity. In the early 1980s, China faced significant energy shortage problems (Tsang and Kolk, 2010). The Chinese government launched some hydroelectricity programmes around 1983 to develop small-scale hydroelectricity infrastructure to achieve electrification in rural areas.

Comparing to hydroelectricity, wind and solar PV electricity generation were more costly and did not get much government support at the initial stage of China's economic reform. In 2003, China experienced severe energy shortages and blackout across provinces (ibid). Thereafter, policy makers intensified efforts to curb energy-intensive industries to reduce energy demand. In 2003, China started to subsidise some concession projects for wind electricity generation. Against the background, the promulgation of the *Renewable Energy Law* in 2006 was a milestone, introducing a package of policy measures to support renewable energies, contributing to the prosperity of the renewable energy industries in China.

Policy strategy to directly target $CO_2$ emissions did not get serious attention until the 2010s. Before that, China took some domestic institutional measures and largely equated climate change with energy conservation (Tsang and Kolk, 2010). In 2002, China ratified Kyoto Protocol[9], and in 2003, the State Council built the National Coordination Committee on Climate Change (NCCCC) under the direct leadership of the NDRC (ibid). NCCCC was a coordination group with limited policy-making power, composing of vice ministers from 13

[9] http://www.china.org.cn/english/China/41661.htm

ministries. In June 2007, the State Council established the National Leading Group on Climate Change (NLGCC) to replace the NCCCC. NLGCC was initially led by ex-premier Wen Jiabao[10] and comprised 27 ministries and agencies, including the former MEP, NDRC, and MWR[11]. NLGCC is responsible for designing national climate change strategies, coordinating climate actions, and researching international cooperation and negotiation issues. The NLGCC has another identity, which is the State Council Energy Conservation and Emission Reduction Leading Group, suggesting that the same group of government officials guide climate change and energy conservation.

Under the Kyoto Protocol, although China did not take mandatory emission reduction targets, it participated in the CDM, which 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. As of 2012, China hosted almost half of all CDM projects and then sold CERs to developed countries (Edwards, 2012). CDM projects introduced the idea of imposing a price on GHG emissions and contributed to China's renewable energy development. From 2013 onwards, China has started to build its own ETS market for $CO_2$ emission allowances. Seven local ETS pilots were established one by one in 2013 and 2014. Now the government is establishing a national $CO_2$ ETS, but it is uncertain when it will start to operate.

Although climate change is on the policy agenda of the Chinese government, it has never been a standalone issue. It is managed with energy policy and primary air pollutants (e.g., $SO_2$, NOx, $PM_{10}$ and $PM_{2.5}$). ETS is one distinct policy measure to address CO2

[10] NLGCC is currently led by premier Li Keqiang. See http://www.gov.cn/zhengce/content/2019-10/12/content_5438830.htm.
[11] https://unfccc.int/sites/default/files/resource/China%202BUR_English.pdf

emissions in China directly. Now climate change mitigation is under the duties of MEE, aiming to enhance coordination of managing $CO_2$ emissions and primary pollutants.

### *5.2 Combination of incremental and radical policy changes*

The policy sequence analysis reveals that a combination of incremental and radical policy changes characterises China's policy development. In 2006, the promulgation of the Renewable Energy Law implied radical policy changes, leading to the introduction of a mix of policy measures in following years and resulting in the rapid growth of renewables in China (Li and Taeihagh, 2020; Schuman and Lin, 2012). The radical policy changes were followed by a long period of incremental policy changes. For example, the FITs were introduced for the first time by the *Renewable Energy Law* in 2006 and started at a rate of 1.15-4.00 yuan/kWh for solar energy and a rate of 0.51-0.61 yuan/kWh for onshore wind electricity. With technology maturation and diffusion over time, production costs of renewable electricity decreased (Kern and Smith, 2008). Therefore, the tariff rates have been incrementally reduced since 2011, eventually reduced to a rate of 0.55-0.75 yuan/kWh for solar electricity and 0.40-0.57 yuan/kWh for wind electricity. In 2010, as a radical climate action, China introduced the national low-carbon pilot program for the first time after NDRC announced the "*Notice on Launching Pilot Work in Low-carbon Provinces and Low-carbon Cities*". The central government selected eight cities located in five provinces as policy pilots. As the low-carbon city pilots tried out innovative solutions towards a low-carbon development and some other cities showed enthusiasm to become low-carbon cities [12,13], China chose another 28 cities and one province as the second batch of policy pilots in 2013,

[12] http://www.ncsc.org.cn/SY/dtsdysf/202003/t20200319_769716.shtml
[13] http://www.gov.cn/xinwen/2017-01/24/content_5162933.htm

and 45 cities as the third batch in 2017 (Ma et al., 2021). Through these policy changes, China gradually developed 81 low-carbon cities and one low-carbon province.

### *5.3 Combination of self-reinforced feedback and reactive feedback*

A combination of self-reinforced feedback and reactive feedback can also be observed from China's policy development related to a low-carbon energy transition. Reactive feedbacks can be exemplified by some subsidy programs for renewable energy promotion. A few subsidy programs, such as the Golden Sun program, offering high subsidies to support renewable energy projects, were soon implemented after the *Renewable Energy Law* amended in 2009. The Golden Sun program provided high subsidy rates. For instance, the Golden Sun program provided up to 50-70% upfront subsidies to cover the total costs of solar PV power projects (Lo, 2014). Between 2010 and 2012, due to the decrease in production costs, the subsidies were gradually reduced. However, the problems of these high subsidy programs soon appeared, including the construction of low-quality solar PV projects, subsidy cheating cases, and placing a financial burden on the government (Wang et al., 2017). As a reactive feedback, the government terminated the program in 2013.

The policy changes of the pollution discharge fee to mitigate air pollution in China exhibited self-reinforced and reactive feedback. Polluters generate negative environmental externalities, and the "polluter pays" principle is a commonly accepted principle that asks the polluters to bear the expenses of reducing pollution[14]. This "polluter pays" principle injects the idea of price signals into environmental policies[15], supporting the utilisation of policy measures such as emission tax, emission charges/fees, and emission trading to increase the costs for polluters[16]. In China, the pollution discharge fee, as a form of emission charges/fees,

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[14] https://www.lse.ac.uk/granthaminstitute/explainers/what-is-the-polluter-pays-principle/
[15] https://www.oecd.org/dev/1919252.pdf
[16] https://www.oecd.org/dev/1919252.pdf

was initially applied to PM in the 1980s, and then used for managing both PM and $SO_2$ emissions since 1992, and extended to NOx in 2003. The government also tried out ETS as an alternative policy measure to manage $SO_2$ emissions in a few pilots between 2000 and 2010 (Chang and Wang, 2010). These $SO_2$ ETS pilots were not successfully operationalised, whereas the government gradually reinforced the pollution discharge fee as a primary policy measure for air pollution control. In 2018, the environmental protection tax, supported by the *Environmental Protection Tax Law*, was implemented to replace the pollution discharge fee as a reactive feedback to deteriorated environmental quality and China's ambitious environmental protection policy agenda in the 13th Five Year Plan (2015-2020) [17].

## 6 Conclusion

This study comprehensively examined the policy sequences in the long-term policy development from 1981 to 2020 related to China's low-carbon energy transition. It used innovative visual techniques to depict the policy changes and analysed both policy and institutional changes. This study provides insights into China's transition towards a low-carbon energy system, which is featured by preceding air pollution mitigation policies and renewable energy policies prior to emission trading policy and low-carbon city development and integrating climate change into environment and energy policies rather than considering it as a standalone issue. It contributes to policy change studies by utilising China's case to show that policy developments, in the long run, are characterised by combinations of reactive and self-reinforced measures, and combinations of incremental and radical policy changes. The research also shows that visualisation tools are helpful to illustrate and compare characteristics of policy changes.

[17] https://www.china-briefing.com/news/china-environmental-protection-tax/

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