NCSC Working Paper:

Current Situation and Further Research Needs on China's 2050 Low Carbon Transition

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I. Introduction

As the biggest developing country, China's mitigation and development strategies have important implications for global efforts to hold warming to well below 2°C or even 1.5°C. China's development and mitigation pathways through 2050 – including interactions among sectors, scales, and development goals as well as robust actions and conditions – are of great importance.

Recent research has highlighted the importance of macroeconomic and structural assumptions for the understanding of Chinese emissions pathways (Grubb et al., 2015; Qi, Stern, Wu, Lu, & Green, 2016; Spencer et al, 2016). This is particularly important in the light of recent Chinese policy announcements regarding the ambition to restructure the economy away from investment, industry and exports, and towards consumption, services, and innovation. Emerging signs of transition, with growth slowing and the share of industry in GDP declining in recent years is appearing, which all fed into significant transition in the energy sector, with coal use and emissions falling somewhat in recent years, primary energy growth moderating, and the share of non-fossil fuel energy increasing significantly. Thus, there is still a need, however, for increasing the understanding of the implications of new era development for the energy and climate trajectory towards 2030 and 2050. There have been some attempts at ad hoc quantitative analysis of such pathways in the literature (Green & Stern, 2017; Grubb et al., 2015; Qi et al., 2016; Spencer et al., 2016). However, the literature still lacks deep analysis on the implication of new economic and development vision, implemented in a well-validated and detailed energy model. Energy models and integrated assessment models typically lack the requisite temporal and economic disaggregate to effectively explore the impacts of structural change on energy and emissions pathways.

In the meanwhile, recent studies also highlight the importance to considering non-CO2 climate forcers and non-energy related CO2 emissions in achieving relative stringent long-term targets, especially the well below 2-degree or 1.5-degree goals (Harmsen et al., 2017; Rogelj et al., 2014, 2015). In addition, assessing mitigation pathways in the context of SDGs or SD has also been more and more mainstreaming, an increasing number of modelling studies and literature show that sustainable development objectives and climate policy targets are interrelated, interact with each other and that synergies and trade-offs can be identified (Jakob and Steckel 2016; von Stechow et al. 2016; Epstein et al. 2017; Wüstemann et al. 2017).

Therefore, this paper attempts to rethinking the research agenda and modelling work of China's 2050 pathway study in a broader context, based on the review of current modelling studies.

II. Reviewing current modelling studies on China's future energy and emission trajectory

2.1 Reviewing the social economic trends

Trends in socio-economic development, including population and urbanization and energy service demands, will all influence China's emissions trajectory.

2.1.1 Review of trends in population and urbanization

Population has significant implications for energy consumption. Figure 2.1 compares the population assumptions of a range of studies. As can be seen, there is broad consensus on China's population trajectory with some minor differences. Across all scenarios, it is existing government policy will continue and that population growth will continue to increase gradually. The expected changes in population growth between 2005 and 2030 is small, ranging from 5–15%. This reflects a modest change over two decades largely due to the effectiveness of China's population policies. Projections suggest that China's population will peak by at approximately 1,450 million people by around 2030.

As noted, China is undergoing rapid urbanisation. This urbanization requires extensive material input and can consequently influence emissions levels. Based on historical experience internationally, the urbanisation process has three stages. First, there is the slow development stage which persists until an urbanisation level of approximately 30%. This is follow by the accelerated development stage, and then the modern development stage. The urbanization rate of developed countries is generally more than 70%. Some are higher, such as the US and the UK which are 81% and 90% respectively. Presently, China is in the accelerated development stage of urbanization. Table 2.1 sets out the assumptions on future urbanization across different modelling exercises. The models suggest that China's urbanization level will reach 56–63% by 2020, 64–70% by 2030, and 76–79% by 2050.

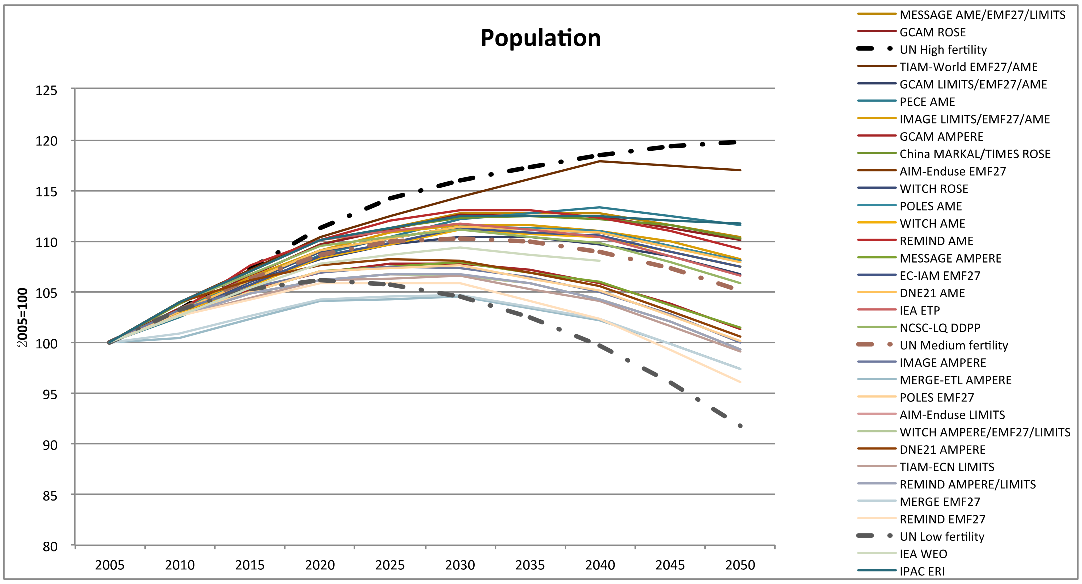

Figure 2.1 Trends in population among different scenarios[1]

[1] Note: Population changes are indexed to 2005. The 2005 population was 1,300–1,450 million, and an

Table 2.1 Urbanization ratio assumptions from different scenarios

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
China MARKAL	43%	49%	52%	56%	60%	64%	68%	71%	75%	78%
PECE	43%	50%	56%	62%	65%	68%	71%	73%	75%	76%
IEA	43%	49%	56%	61%	65%	69%	71%	74%		
IPAC	43%	49%	56%	63%	67%	70%	72%	74%	77%	79%
Medium	43%	49%	56%	62%	65%	69%	71%	74%	75%	78%

2.1.2 Review of trends in economic growth

Thus, China's economic structure, as well as the rate of economic growth, is one of the key variables determining its future emissions pathways. Industry has been the major driver of emissions growth over the period 2000–14. During the period of almost 40 years since reform and opening-up, China's GDP increased by around 9.4% on an average annual basis, and a rapid growth rate was maintained. Structural changes and growth in the Chinese economy will significantly influence energy demand and emissions. Table 2.2 and figure 2.2 contrasts the assumptions on the GDP growth rate across various studies. The assumptions in most studies are: 6.9–8.8% for 2010–20; 4.9–5.8% for 2020–30; 3.1–4.5% for 2030–40; and 2.1–3.3% for 2040–50. It is generally assumed that the relatively high rate of growth will continue and gradually drop due to restructuring of the economy towards the new normal, as well as demographic changes. However, if considering the latest two-stage target set out in the 19th national congress of CPC report, the annual growth rate of GDP till 2050 may need to be further increased.

estimated 1,308 million from the NBS.

Table 2.2 GDP growth rate assumptions among different scenarios

	2010–20	2020–30	2030–40	2040–50
AIM-Enduse	9.2%	5.8%	3.1%	2.1%
GCAM	6.9%	5.2%	4.1%	3.3%
IMAGE	8.8%	4.8%	3.9%	3.0%
MESSAGE	6.9%	5.1%	3.5%	2.9%
REMIND	9.2%	5.8%	3.1%	2.1%
TIAM-ECN	6.1%	4.4%	3.2%	3.2%
WITCH	8.8%	5.6%	3.0%	2.1%
IPAC-ERI	8.4%	7.1%	5.0%	3.6%
IEA-WEO	7.2%	5.3%	3.2%	
IEA-ETP	8.1%	4.9%	2.9%	2.9%
China MARKAL	7.4%	6.0%	4.5%	3.0%
PECE	7.4%	5.5%	4.5%	3.4%
NCSC (DDPP)	7.5%	5.5%	3.5%	2.5%
Among which:				
20th percentile	6.9%	4.9%	3.1%	2.1%
Median	7.5%	5.5%	3.5%	3.0%
80th percentile	8.8%	5.8%	4.5%	3.3%

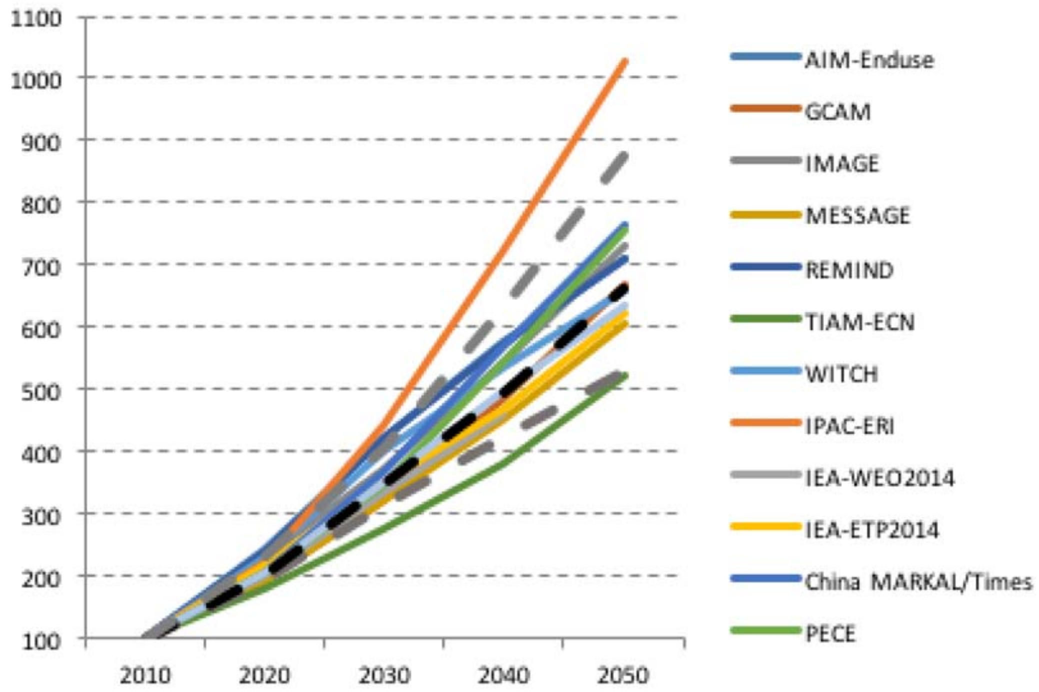

Figure 2.2 Trends in GDP growth among different scenarios[2]

2.1.3 Review of trends in energy service demand

The future demand for energy services will be a key driver in overall energy demand and CO2 emissions. The demand for energy services includes demand for high-energy-consuming products, transportation, and building space and construction. Tables 2.3, 2.4 and 2.5 compare the assumptions on the future energy service demand across the various scenarios reviewed. Several conclusions can be drawn from the tables. First, there is a wide range of projected drivers for energy service demand in the residential and transport sectors in China to 2050. Few models explicitly assess this parameter and those that do use a different base-year data. Second, activity levels for the analyzed sectors are projected to grow, by around a factor of 5 on average for passenger/freight kilometers, and 1.6 on

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[2] Note: GDP/ per capita changes are indexed to 2010. 2010 GDP per capita levels ranged from US$2,300 to $3,400 per capita (2005 price). The official NBS estimate was $2,900.

average for residential and commercial floor space. This is consistent with a transition from industrial to transport and residential energy demand. Controlling these emissions may be a major challenge for China in the future, and should be subject to more intensive scenario assessment.

Table 2.3 Comparison of energy service demand for residential and commercial floor space (billion m^2/year)

Model	**Scenario**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2040**	**2050**
China MARKAL	ROSE	38.6	46.7	56.6	62.9	68.3	73.7	84.0	93.2
GCAM	LIMITS-StrPol	53.1	56.2	59.6	62.9	65.9	68.7	73.6	77.0
POLES	AMPERE	15.4	18.4	23.2	28.0	32.3	36.7	41.7	44.5
PECE	AME	38.6	46.7	52.2	58.8	65.0	70.0	74.1	76.3
IEA	WEO	34.2	40.4	45.9	50.6	53.8	57.0	60.2	
Medium		38.6	46.7	52.2	58.8	65.0	68.7	73.6	76.7

Table 2.4 Comparison of energy service demand for freight transportation (billion tonne-km/year)

Model	**Scenario**	**2005**	**2010**	**2020**	**2030**	**2040**	**2050**
AIM-Enduse	EMF27-Base-FullTech	2,338.7	2,878.5	4,117.2	5,644.3	7,530.9	9,842.8
POLES		2,941.9	4,265.1	8,280.5	12,460.3	15,458.9	1,7885.7
GCAM		6,802.5	8,232.5	11,021.2	13,664.9	16,235.8	18,759.6
GCAM	AMPERE	6,802.5	8,322.4	12,331.7	15,721.6	17,873.2	19,639.0

POLES	2-Base-FullTech	2,819.4	4,936.4	13,837.1	20,903.8	22,438.8	23,399.7
PECE	AME	9,394.0	14,454.0	27,686.0	42,337.0	61,398.0	75,660.0
China MARKAL	ROSE		1z3,964.1	23,003.1	38,347.6	56,253.3	75,691.7

Table 2.5 Comparison of energy service demand for passenger transportation (billion passenger-km/year)

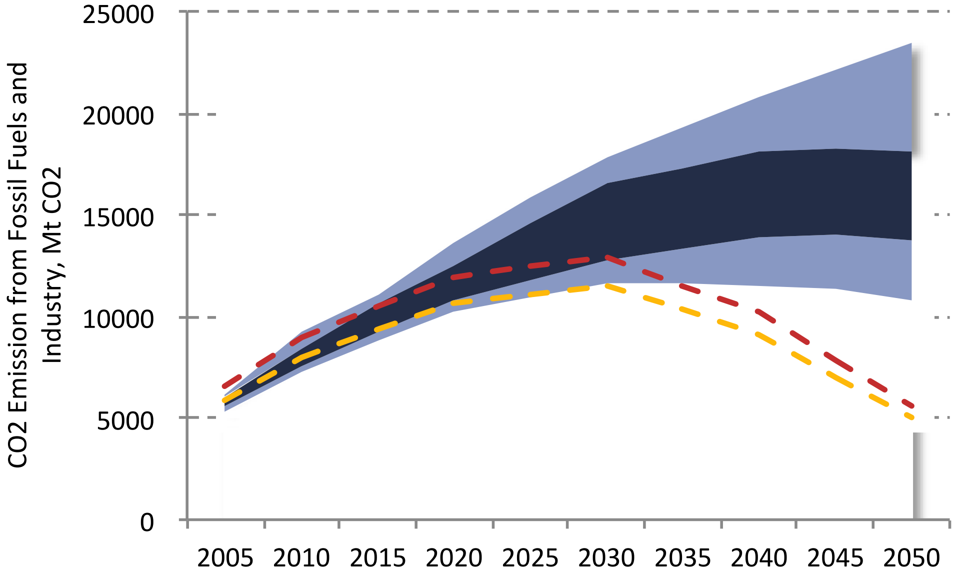
Model	**Scenario**	**2005**	**2010**	**2020**	**2030**	**2040**	**2050**
GCAM	AMPERE	1,504.0	2,148.3	4,069.4	5,862.6	6,994.0	7,787.5
GCAM	EMF27	1,504.0	2,128.7	3,521.5	4,977.4	6,435.4	7,798.7
GCAM	ROSE	1,504.0	2,131.2	4,006.1	5,836.7	7,111.5	8,064.1
DNE21	AMPERE	2,733.7	3,518.3	5,034.0	6,911.7	8,525.4	10,031.9
AIM-Enduse	EMF27	1,872.2	2,507.6	4,013.1	6,071.8	9,024.5	13,231.3
POLES	AMPERE	2,941.9	4,265.1	8,280.5	12,460.3	15,458.9	17,885.7
POLES	EMF27	2,819.4	4,936.4	13,684.0	20,617.0	22,198.8	23,096.5
PECE	AME	3,446.0	5,163.0	10,056.0	16,085.0	20,849.0	26,019.0
China MARKAL	ROSE		3,545.6	10,314.4	16,229.6	21,601.9	28,424.6

2.2 Reviewing the energy and CO2 emission trends

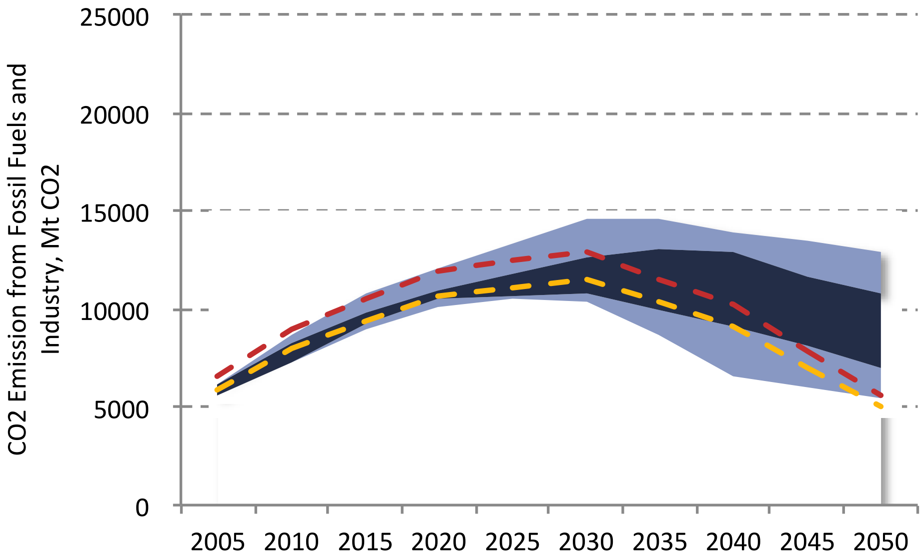
2.2.1 Review of trends in energy-related CO2 emissions

Figure 2.3 shows projections of total CO2 emissions from energy related fossil fuel use in China (ie excluding land use or industrial process emissions), from 2005 to 2050, according to the results of the 89 separate scenarios produced within the various different modelling platforms reviewed for this paper.

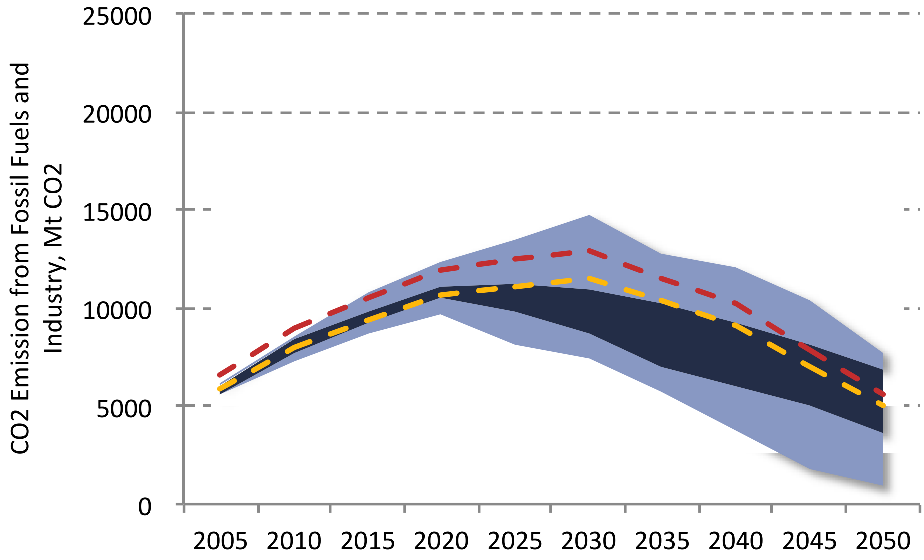
The scenarios have been grouped into three categories (as detailed in the figure 2.3(a), (b), (c)). Reference scenarios are shown in figure 2.3 (a) – these scenarios project emissions on the basis of current climate policies or no new additional climate policies from a single year. Enhanced Policy scenarios, shown in figure 2.3 (b), project emissions on the basis of some additional climate related policies being implemented. Realistic 450 or 500 ppm scenarios, shown in figure 2.3(c), represent projections on the basis of strong climate policies consistent with a global effort that would achieve stabilisation of atmospheric CO2 at 450-500 ppm in 2100, consistent with a roughly 50% or greater chance of keeping global temperature rise to within about 2 degrees centigrade above pre-industrial levels. Figures shows, the range of projections is large: Chinese emissions in 2030 span 7-18 GtCO2, and in 2050 span 8.7-23.5 Gt CO2 depending on the scenario considered.



（a） Reference scenarios



（b） Enhanced policy scenarios



（c）Realistic 2degree scenarios (450/500 ppm)

Figure 2.3 Total energy related CO2 emissions in all reviewed scenarios, 2005-2050[3]

2.2.2 Peaking year and level

According to figure 2.4, most reference scenarios imply that China will peak between 2030-2050, mostly will not peak before 2050. Under enhanced policy scenarios, with additional policy and measures, China will peak around 2030. For realistic 2-degree scenarios, China need to peak relatively earlier, between 2020-2030.

[3] Note: Red line: NDC Scenario by PECE model with data adjustment; Yellow line: NDC Scenario by PECE model without data adjustment; Light purple shadow: full range; Dark blue shadow: 20th-80th percentile.

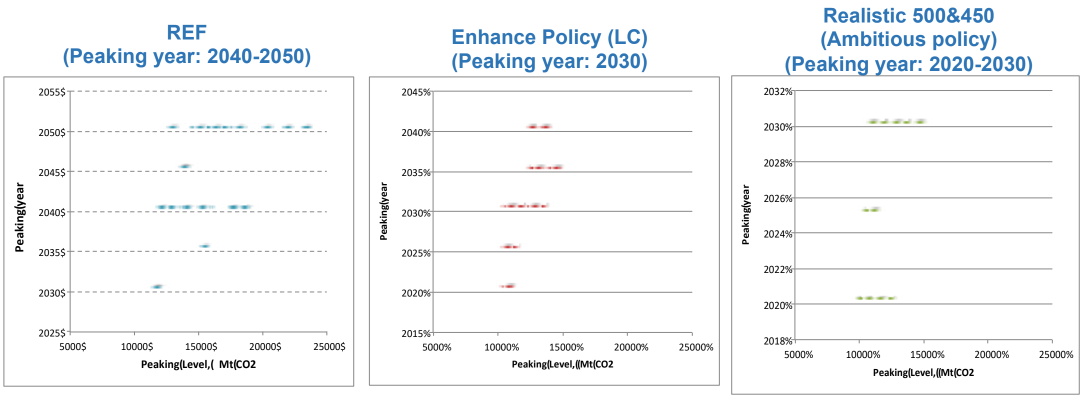
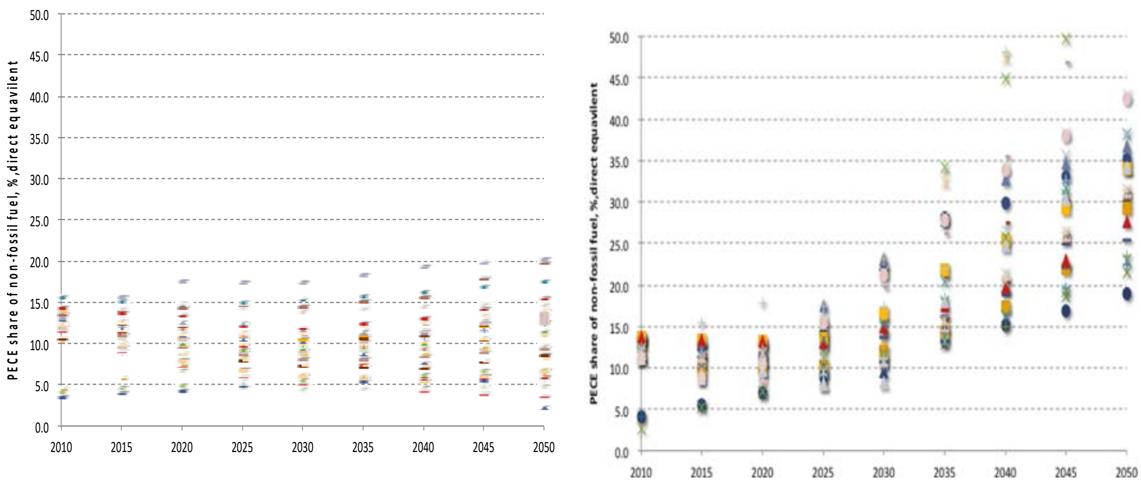


Figure 2.4 Peaking year and level

2.2.3 PE share of non-fossil fuel

Unlike China official energy data, the international modelling forum adopted direct equivalent while transforms primary electricity to primary energy. Same as other indicators, the results of different scenarios vary and results in wide range. The base year data varies because of different data sources, with or without traditional biomass, which will affect the outputs of scenarios in the future. According to China's INDC target on non-fossil fuel, the share of non-fossil fuel shall reach 11% in 2030 with direct equivalent method which within the range of Enhanced policy scenarios and 450-500 ppm scenarios.



（a） Reference scenarios　　（c）Realistic 2degree scenarios (450/500 ppm)

Figure 2.5 PE share of non-fossil fuel in all reviewed scenarios, 2005-2050

2.3 lessons learned from multi-modelling comparison study

Modelling analysis has proven to be an invaluable input to policymaking surrounding low emissions development. Modelling analysis has supported not only domestic decision making in China and around the world, it has also been a critical input to both multi-lateral and bilateral discussions and negotiations.

The comparison study in this section is very preliminary and far from calling multi-modelling analysis. Though, several observations could be drawn from the reviewing:

(1) Multi-modeling analysis is of great value. Comparison above show huge divergence in both inputs and outputs of modeling studies. Although there are existing studies examining China's development and mitigation pathways, as well as existing studies by Chinese researchers examining international development and mitigation pathways, these studies have been conducted independent from one another, with different assumptions, modelling structures, and scenarios. Lacking a systematic mechanism to compare different models and studies and to understand uncertainties and constraints, it is difficult for policy makers to effectively develop trust in the modelling results and to incorporate these results and associated insights into the policy making process.

(2) Harmonizing base year data and key assumptions is needed to reduce noise in projection. Though it is less important for comparison of scenarios simulated with the same model, is a significant factor for differences in results in multi-model studies.

(3) Development of new scenarios to reflect the new development vision. Bearing in mind the new development agenda set out in the 19^{th} national congress of CPC report, New-era Development Pathways (NDPs) could be developed and used to guide the scenario analysis on the feedbacks between Climate Change, socioeconomic factors and other SDGs. Each scenario provides a brief narrative of the main characteristics of the future development path of an NDP. Internally consistent assumptions on key elements such as demographics, economics, technology and other development indicators will be shared within each NDP to improve the consistency and harmonization of most important boundary conditions in national models.

(4) Improvement of existing modelling tools to fit the new research requirements. Existing modeling tools mainly are the linear extension of current situation, no radical changes have been considered. We are now in a world with rapid change, emerging technologies such as AI, Automatic drive car, internet+, big data, block chain, 3D print, energy storage together with new consumption mode such as sharing economy may have huge impact on future energy and emission trajectory, thus, new type of models or improvement of existing models would be needed. In addition, existing modeling tools mainly focusing on the energy system, extension of model coverage and cooperate with other professional modeling tools are also needed.

(5) Establishment of on-line planform to enhance transparency. Absolute transparency of models is important goal to achieve and would help to enhance the trust on modeling study. An on-line data sharing platform could be established to minimize the uncertainty, improve transparency, and validate the data and estimates.

III. Thinking on China's 2050 pathway study

Achieving development and GHG emission reduction goal by 2050 will entail balancing many challenges. As discussed above, recent scientific studies and the new IPCC process reveal that it is of great importance to promote integrated thinking from different dimensions, e.g. the coherence between sub-national, national and global objectives and actions, the interlinkage between short and median term actions with long term goals, the harmony between development and other sustainable development goals, etc. It is also recommended to enhance the policy relevance, feasibility and transparency of the quantitative scenario studies, such as the better integration of existing policies, highlight of consumption-side measures, development of new generation of scenarios (SSPs), involvement of non-IAM models. China's 2050 pathway study shall of course fulfil the above requirements.

As shown in figure 3.1, China's 2050 pathway study shall aim to depicting a harmonious and beautiful long-term low-carbon development blueprint for China, considering socio-economic development, energy, climate change, environment and other important development dimensions, combined with the domestic development needs of construction of ecological civilization, green Low-carbon sustainable development and build beautiful China, in conjunction with the international needs in promoting the building of a community with a shared future for mankind, led by the development strategy put forward in the 19th national congress, and in line with Chinese characteristics of the new era of development.

Specifically, several key strategic issues including new development vision and philosophy of New Era, Trends in population and urbanization, New engine, format and tendency for economy, Change and implications of consumption and production pattern, Trends and influence of technology innovation, Trends and influence of infrastructure investment, International political, economic and climate situation and China's positioning, etc. will need to be accessed. Five strategic areas, e.g. Social-economic, Energy and energy related CO_2 emission, Non-CO_2 and AFOLU, Link with other sustainable development goals will be covered.

Finally, integrated analysis framework need to be established to make integrated strategy suggestions, to provide a high-level overview of the vision for China's 2050 pathway, describing the characteristics of development and mitigation pathways under new era towards 2050, important interactions among sectors, scales, and development goals, as well as robust actions and conditions needed to get from here to there.

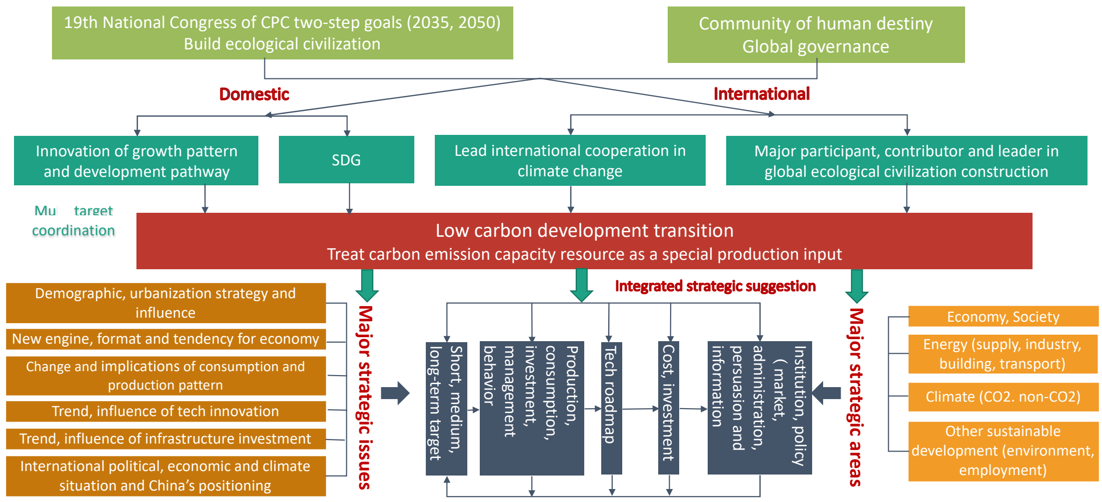


Figure 3.1 Storyline of China's 2050 pathway study

Meanwhile, an integrated modeling analysis framework as shown in figure 3.2 is also necessary. For social economic models, both Partial/General Equilibrium Economic Model could be adopted to analysis on trends on future economic development (Amount, Growth rate, Structure, Investment, Consumption, Export, etc.). Agent-based Model would be focusing on behavior change analysis. Urbanization Model could be adopted for analysis on geographical and spatial distribution, mode of urbanization, etc. 4E CGE model able to assess the impact of climate policies, especially the social economic feedbacks (new development engine, GDP, employment, etc.). For Energy service demand model, dynamic energy system optimization model which searching for Least cost solution is the key to project energy/ emission scenarios (Pathway, mitigation potential, technology roadmap, incremental investment/cost, etc.). Sector specific models are used for analysis on sectoral trends, feasibility, technology options, demand side measures, etc. Regional/city level model will be focusing on typical region/city/ metropolitan area analysis. In addition, specific technology model may be needed for analysis on technological trends, learning rate of specific technologies. Agriculture, non-CO2 or air pollutant model such as CARPI, Globiom and Gants, could be used for analysis on Land use mode, food security, biomass supply, co-benefits and trade off with climate mitigation, etc. Finally, global model will be needed to provide for the global context, such the international assumptions, requirements of global long-term goals and conduct analysis on the global impact of China's strategy and policies, such as BRI, etc.

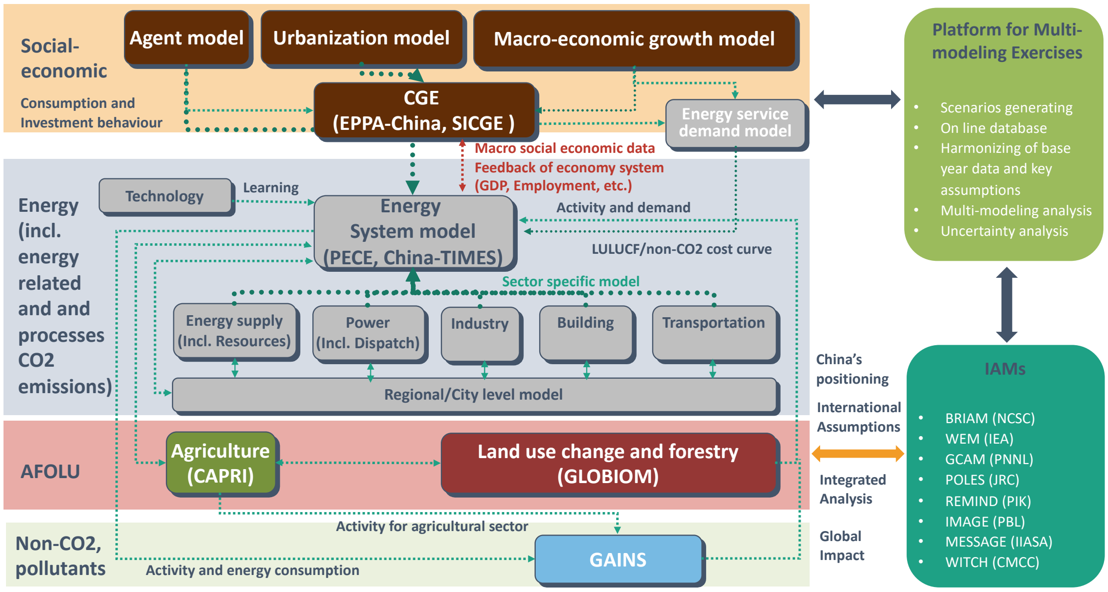


Figure 3.2 Modelling package of China's 2050 pathway study