Discussion Draft

Pursuing an Innovative Development Pathway: Understanding China's INDC

Technical Summary

The Technical Summary draws out preliminary findings from the Report – "Pursuing an Innovative Development Pathway – Understanding China's INDC", supported by the World Bank's Partnership for Market Readiness (PMR). The full report is expected to be released in Spring 2016. The report is prepared by the following authors:

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On 30 June 2015, the Chinese government submitted its Intended Nationally Determined Contribution (INDC), detailing its commitment to climate change mitigation and adaptation for the post-2020 period.

Highlights of the INDC include specific goals such as:

- To achieve peak carbon dioxide emissions by approximately 2030, or sooner as best efforts allow;
- To lower carbon dioxide emissions per unit of GDP by 60% to 65% from 2005 levels;
- To increase the share of non-fossil fuels in the primary energy mix to approximately 20%; and
- To increase the volume of forest stock by approximately 4.5 billion cubic meters over 2005 levels, and;
- To continue to proactively adapt to climate change through: enhanced mechanism- and capacity-building; the effective management of climate change risks in sectors such as agriculture, forestry, and water resources, and in regions including urban, coastal, and ecologically vulnerable areas; improved early warning and emergency response systems and disaster prevention and mitigation mechanisms.

Key findings

1. **China is shifting to a 'new normal', powered by an 'innovative development pathway'.** After more than 30 years of rapid development, China has become a middle-income country and, in the process, lifted more than 600 million people out of poverty. Despite this impressive progress, much still needs to be done: around 40 million rural poor still live below the official Chinese poverty line. However, China's traditional input-heavy growth model is no longer sustainable. Constrained by limited resources and environmental pressures, China risks falling into the 'middle-income trap'. The country is therefore shifting to a 'new normal', focusing on the transformation of the industrial sector and reorientation towards domestic demand. This will be delivered by an innovative new path of development which shifts the drivers of growth from a focus on the quantity of inputs to their efficiency; reduces dependence on energy, resources, and environmental inputs; cultivates new growth points and competitive advantages; and allows the country to adopt a low-carbon, efficiency-focused path of development.

2. **China's INDC is a key vehicle in driving the shift onto the innovative development pathway and towards the 'new normal'**. By significantly accelerating the country's action on climate change, if successful, the INDC will:
    a. allow emissions to peak at a lower level per capita and at an earlier stage of economic development than any developed economy has achieved;
    b. facilitate the decoupling of economic growth from carbon emissions;
    c. lead to a fundamental restructuring in the country's energy sector.

3. **However, China faces tremendous uncertainty and challenge in achieving its INDC targets.** There is uncertainty about the future trajectory of GDP and population size; the extent to which technical progress can unlock further improvements in carbon and energy efficiency; and future developments in international energy markets. The country will also face challenges in securing sufficient natural resources to enable the transition; managing the political economy challenges associated with those sectors that will become relatively less significant; acquiring the necessary technological sophistication; and enhancing capacity across all key stakeholders. Intensive implementation effort will be required.

4. **To meet the global goal of restricting temperature increases to no more than 2°C, even more significant emission reductions will be required beyond 2030, by both China and its international partners**. As well as helping China make the difficult transition to the innovative development pathway, the INDC can also support progress towards the 2° goal. China's INDC will help it to foster the enabling conditions in the 2020s – especially around the scale-up of technology – that will be essential for further mitigation action beyond 2030.

5. **As the world's largest developing country, China's plans and actions can serve as a model for many other developing countries.** Its transition to an innovative development pathway sets an example that other developing countries might share: avoiding reliance on traditional, high-carbon modes of development and associated lock-in effects; and enabling them to embark on new development paths that are more efficient, innovative, and result in less pollution and lower emissions. In this way, China's own transition can support a global transition, contributing to better development worldwide.

Chapter 1 – The ‘new normal’ and China’s ‘innovative development pathway’

Summary

China’s impressive double-digit economic growth in recent decades has lifted more than 600 million people out of poverty.

However, the Chinese government recognizes that continued reliance on the existing growth model – export-led and reliant on resource-intensive activities – is unlikely to be as successful in the future. This growth model has also contributed to heightened inequality and presents risks to the environment.

China is therefore rebalancing towards a ‘new normal’ – focused on steady and better quality growth and an emphasis on a cleaner development trajectory, as embodied in the ‘innovative development pathway’.

The Chinese model, if successful, could prove a powerful example for other developing countries.

China’s unparalleled economic growth over the past three decades has elevated it to middle-income status and lifted hundreds of millions out of poverty. Since initiating market reforms in the late 1970s, China has achieved an average annual growth rate of 10%. By 2011 it had reached upper-middle-income status, with a per capita gross national income of almost USD 5,000. This rapid growth has enabled China to cut its poverty rate from 84% in 1981 to 13% in 2008, with more than 600 million people lifted out of poverty.

Despite significant progress, continued development remains essential. The number of Chinese living in poverty remains high – 173 million in 2008, measured against a standard of USD 1.25 per day and with around 40 million rural poor still living below the official Chinese poverty line (1,067 RMB per year). It remains a priority that China continues to focus on poverty alleviation and generally raising living standards.

However, achieving these objectives through China’s traditional input-heavy growth model is unsustainable. At present, China’s economic structure is geared towards exports and investment (47% of China’s GDP in 2014) and manufacturing (industry was 44% of GDP in 2013, Oxford Economics, 2015). The continued viability of this growth model is increasingly being questioned due to rising private debt, risks of financial instability, manufacturing overcapacity, and a large base of lower-value manufacturing which is at increasing risk of losing competitiveness due to rapidly rising labor costs (Fulin, 2015; IMF, 2014).

Resource constraints and environmental pressures compound this challenge. China recognizes that there are limits to national and global resources and that these are already affecting its economic prospects. High-carbon sources of energy are a prime example: China’s increasing dependence on energy imports brings energy security challenges and creates greater exposure to volatility in international prices. Linked to this, climate change implies that the limited global carbon budget is

becoming a scarce strategic resource that needs to be factored into future development. Likewise, the environmental and economic problems of air pollution are becoming increasingly obvious: coal-fired power stations and heavy industries are emitting large amounts of sulphur dioxide, nitrogen oxides, particulate matter and smoke dust, threatening public health and labor productivity.

The ‘new normal’ and the ‘innovative development pathway’

China is shifting to a ‘new normal’, focusing on higher-quality growth. The new normal captures a programme of reform and restructuring of the economy towards medium to high-speed growth (as opposed to high speed growth), improved and upgraded economic structures, greater reliance on domestic consumption, services and higher value-added manufacturing, and driven by innovation instead of input and investment. Domestic demand is expected to become one of the main pillars of the economy by 2030 as export demand is expected to weaken in relative terms due to rising labor costs. The manufacturing sector will also reorient towards more advanced, higher value-added industries including energy efficiency, environmental protection and low-carbon energy.

The innovative development pathway is an integral part of the new normal. The innovative development pathway aims to realize the growth that China requires with the lowest possible emissions, through a transition to a new economic growth model, substantial changes in energy production and consumption patterns, and new approaches to land use. In practice, this will involve a higher non-fossil fuel share in energy generation and consumption, increasing energy productivity, and reducing dependence on energy, resources and environmental inputs.

China is already integrating the innovative development pathway into its strategic planning. The innovative development pathway represents a fundamentally different model of development to that pursued by OECD countries. China is committed to creating the technological, financial, and other conditions necessary to achieve this. To this end, and as set out in more detail in the annex, China has already started the process of integrating the energy consumption, energy efficiency and environmental implications into its five-year planning process. This reflects the importance and urgency that the Chinese government attaches to avoiding being locked in to high-carbon pathways and increasing resource efficiency.

Chapter 2 – China's INDC as a vehicle for achieving the innovative development pathway

Summary

China's INDC is a key vehicle for moving onto the innovative development pathway and supporting the new normal.

In particular, China's plans for emissions to peak by 2030 will imply lower and earlier peaking of emissions than in any developed economy.

Given continued significant economic growth, emissions peaking by 2030 will be achieved only by accelerating structural change, and reducing the energy and carbon intensity of the country.

A series of specific measures will be put in place to achieve this transformation, including measures for national and regional policy development, for supporting science and technology, and for developing economic incentives and behavioral responses.

Even with this ambitious agenda, there will be a need for even more pronounced emission reductions beyond 2030 to achieve the global goal to keep temperature increases below 2°C; China' INDC will help the country in establishing enabling conditions in the 2020s that will be essential for further mitigation action beyond 2030.

The INDC is a crucial vehicle in moving onto the innovative development pathway. The INDC sets out the emissions reduction and adaptation efforts China intends to take in the period to 2030. As such it represents the vehicle by which the aspirations of the innovative development pathway will be converted into practical policies and action. The discussion in this chapter is based on an analytical scenario that sets out a pathway towards achieving the INDC's mitigation targets. Some of the key assumptions and projections associated with this analytical scenario are provided in Table 2.1 below. The discussion explores:

- how the INDC will result in a fundamentally different development path to that seen in advanced industrialized countries;
- the structural changes that will be required in the Chinese economy to meet the targets embodied in the INDC;
- the policies and measures that the Chinese government has and will introduce to achieve these changes;
- how China's INDC relates to the global ambition to restrict temperature increases to 2°C.

Table 2.1: Key assumptions and projections in the INDC analytical scenario

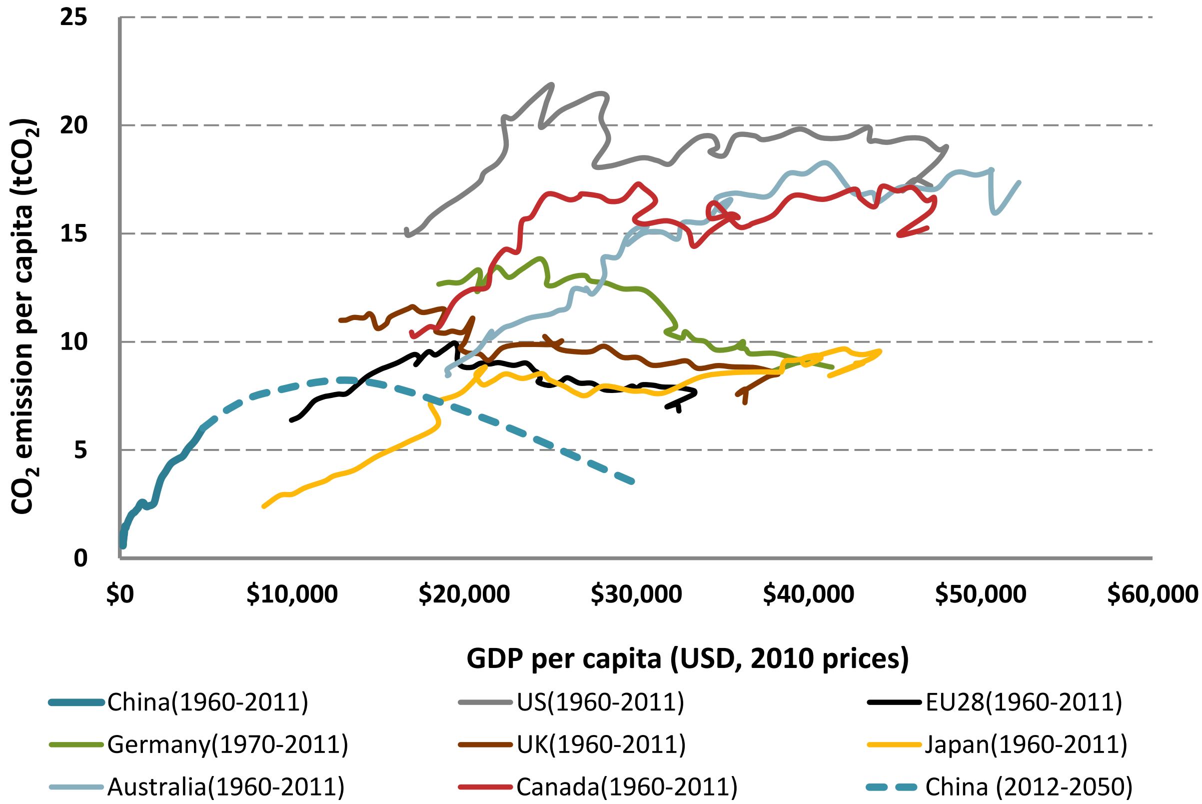
	2005	2010	2015	2020	2030	2040	2050
Population (million)	1,308	1,341	1,375	1,408	1,467	1,462	1,449
Urbanization rate	43%	48%	55%	60%	68%	74%	78%
GDP per capita, US$ (2010 prices)	2,708	4,503	6,429	8,639	14,026	21,245	29,938
GDP growth rate	–	11.3%	7.9%	6.6%	5.4%	4.2%	3.4%
Residential and commercial floor space (billion m^2)	38.6	46.7	52.2	58.8	70.0	74.1	76.3
Residential floor space per capita (m^2)	25.2	29.0	31.1	33.8	37.7	39.3	40.3
Freight transportation (billion tonne-km)	9,394	14,454	21,070	27,686	42,337	61,398	75,660
Passenger transportation (billion passenger-km)	3,446	5,163	7,610	10,056	16,085	20,849	26,019

China's INDC will drive progress onto an innovative development pathway that is different from that adopted by developed countries

The INDC target of peaking emissions by 2030 implies that China's innovative development pathway leads to a lower and earlier peaking of per capita emissions than achieved in advanced industrialized economies. In advanced developed countries (e.g. US, Canada, Australia), the relationship between economic growth and emissions per capita has typically taken an inverted U shape: emissions per capita first rise as GDP per capita increases, before falling after a certain level of development is achieved. This is commonly referred to as the environmental Kuznets curve. Figure 2.1 and Table 2.2 compare the trajectory of per capita GDP and emissions in China with advanced industrialized economies, combining both historical data and projections (based on INDC submissions). While the same general inverted-U trend will be replicated in China, the point of inflection at which emissions begin to fall will be at lower GDP and emissions levels. Peak emissions will occur at a GDP per capita of around 33% lower than in OECD countries, and at an emissions per capita level of around 30% lower than in OECD countries. More specifically:

- In the European Union and US, per capita fossil fuel related CO_2 emissions (CO_2 emissions in Figure 2.1 below) peaked when per capita GDP reached between USD 17,000-25,000 (in 2010 prices), while for Canada, Japan and Australia, per capita CO2 peaked with GDP per capita as high as USD 30,000-40,000 (in 2010 prices). The average for OECD countries was around USD 21,000. In contrast, projections based on China's INDC targets show that China's per capita emissions peak of will occur when per capita GDP is only around USD 14,000.
- The US, Canada and Australia saw peak emission values of 20 tonnes of CO_2 per capita, while the European Union and Japan had peak values around 10 tonnes per capita. The OECD average was around 11.5 tonnes per capita. China's expected peak emissions, by contrast, are expected to be markedly lower than this, at 8.2 tonnes per capita.

Figure 2.1: China's environmental Kuznets curve will peak at lower carbon emissions and GDP per capita than in developed countries



Note: Includes only energy-related CO_2 emissions.

Source: Historical CO_2 emissions data from 1960 to 2012 is from CDIAC. Population and GDP data is from the World Bank. Data after 2012 is calculated based on INDC targets.

Table 2.2: China's projected peak emissions per capita are considerably lower than those experienced by advanced industrialized economies

	GDP per capita at peaking year (2010 prices)	Fossil fuel related CO_2 emissions per capita – peaking level (tCO_2/person)
OECD	$21,075	11.50
Annex I Countries	$18,018	12.66
EU 28	$19,414	9.95
EU 15	$23,524	9.79
US	$25,085	21.88
Japan	$42,086	9.67
Australia	$41,108	18.25
Canada	$30,043	17.27
Germany	$24,301	13.82
UK	$17,030	11.62
France	$23,337	9.54
China	*$14,026*	*8.18*

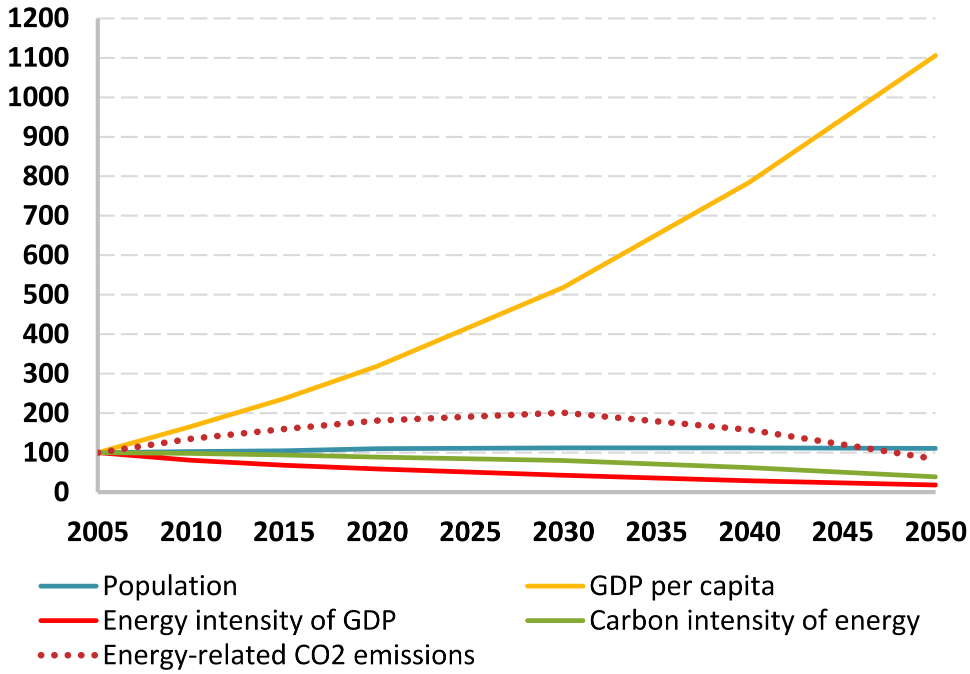
Source: CDIAC (2015) and World Bank database (2015); China's data from an INDC scenario from PECE model developed by NCSC and Renmin University of China.

Achieving the INDC targets

Given that China is set to achieve a markedly different development path from its advanced industrialized counterparts, it is important to understand how this will be achieved. This is explored below, using the standard Kaya decomposition which breaks down energy-related emissions into four drivers: population, GDP per capita, energy use per unit of GDP, and carbon intensity per unit of energy.

The crucial importance of further economic development means that economic growth will continue to be a significant driver of China's emissions. Economic growth projections indicate that China's GDP per capita will grow substantially, even if there is some variation over the precise values. The modelling conducted to support China's INDC suggests that by 2050, GDP per capita will have increased by over 1100% from 2005 levels (see Table 2.1 and Figure 2.2). Population will also be a driver of emissions, and is projected to increase to 2030 but then to remain stable to 2050.

Figure 2.2: Key drivers of China's emissions in INDC scenario modelling



	2005	2010	2015	2020	2030	2040	2050
Population	100	103	105	110	112	112	111
GDP per capita	100	166	237	319	518	785	1106
Energy intensity of GDP	100	81	68	59	43	29	18
Carbon intensity of energy	100	98	94	89	80	62	39
Energy-related CO_2 emissions	100	135	160	181	201	158	84

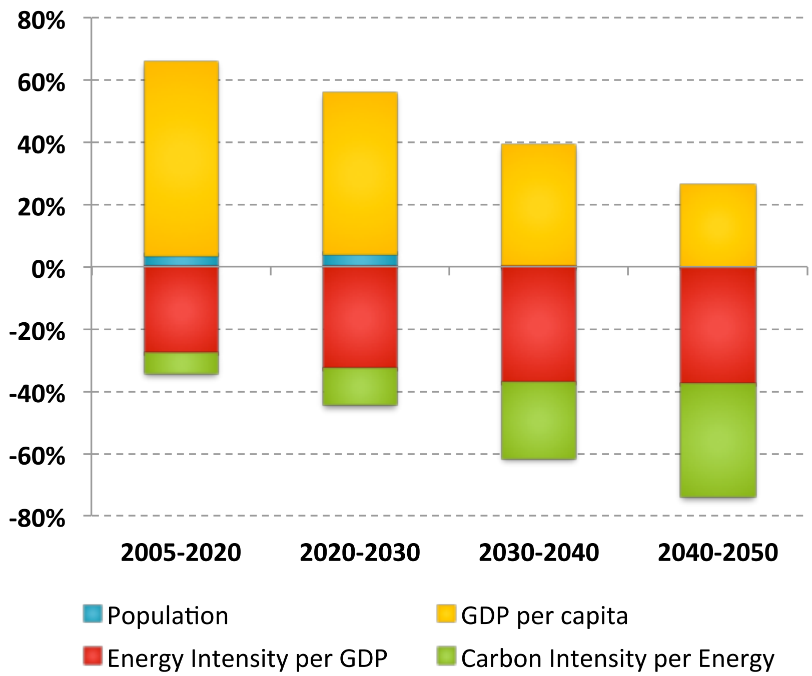
Note: Primary electricity is converted to energy based on coal equivalent approach.

Source: 2005 and 2010 data are from China Statistical Yearbook, China Energy Statistical Yearbook and China's official review of target completion.
Data after 2015 are from an INDC scenario from PECE model developed by NCSC and Renmin University of China.

Accommodating this economic growth while meeting the INDC targets implies that significant improvements in the energy intensity per unit of GDP and carbon intensity of energy consumption will be required. Figure 2.2 and its accompanying table demonstrate the decreases in the rates of energy and carbon intensity associated with the peaking of emissions in 2030, and significant emissions reduction by 2050. Reductions in the energy intensity of GDP will be central in limiting emissions growth to 2030 – energy intensity will need to fall to around 40% of 2005 levels by 2030. Post-2030, energy intensity will decrease further, reaching 20% of 2005 levels by 2050. Reductions in the carbon intensity of energy consumption will be relatively less important in limiting 2030 emissions (with 2030 levels at 80% of 2005 levels). However, beyond 2030, reductions in carbon intensity of energy become much more pronounced, with a proposed reduction to 40% of 2005 levels by 2050. The same pattern is also clear from Figure 2.3 which shows the relative contribution of different drivers to emissions. The energy

intensity effect is particularly important in delivering emission reductions during the period to 2030, while decarbonization of energy supply becomes a more important driver beyond 2030, and especially in the period 2040–2050. These patterns reflect the expected growth in the availability of low-carbon technologies in medium-to-long term.

Figure 2.3: Reductions in China's energy-related CO_2 emissions will be driven by decreasing energy intensity of GDP up to 2040, followed by decreasing carbon intensity of GDP after 2040



Source: 2005 and 2010 data are from China Statistical Yearbook, China Energy Statistical Yearbook and China's official review of target completion.
Data after 2015 are from an INDC scenario from PECE model developed by NCSC and Renmin University of China.

These changes will necessitate fundamental shifts in the energy sector and the Chinese economy more generally. Overall, the energy intensity of the economy needs to fall by almost 50% by 2030 (from 2010 levels, as shown in Figure 2.2. This change will be driven by structural economic shifts and energy efficiency improvements. Economic activity is expected to shift to less energy-intensive parts of the economy, particularly towards higher-value services and industry, and away from primary industries and energy-intensive forms of manufacturing (as shown in Table 2.3 below). It will be further supported by energy efficiency improvements such as efficient industrial motors, insulation in homes and more efficient vehicles.

Table 2.3: China's economic activity is expected to shift from primary industries towards higher-value services and industry

	2005	2010	2015	2020	2030	2040	2050
Primary industry	11.7%	8.5%	7.2%	6.3%	5.6%	5.1%	4.7%
Secondary industry	46.9%	48.8%	48.8%	45.8%	42.3%	39.1%	37.3%
Tertiary industry	41.4%	42.7%	44.0%	47.9%	52.1%	55.8%	58.0%

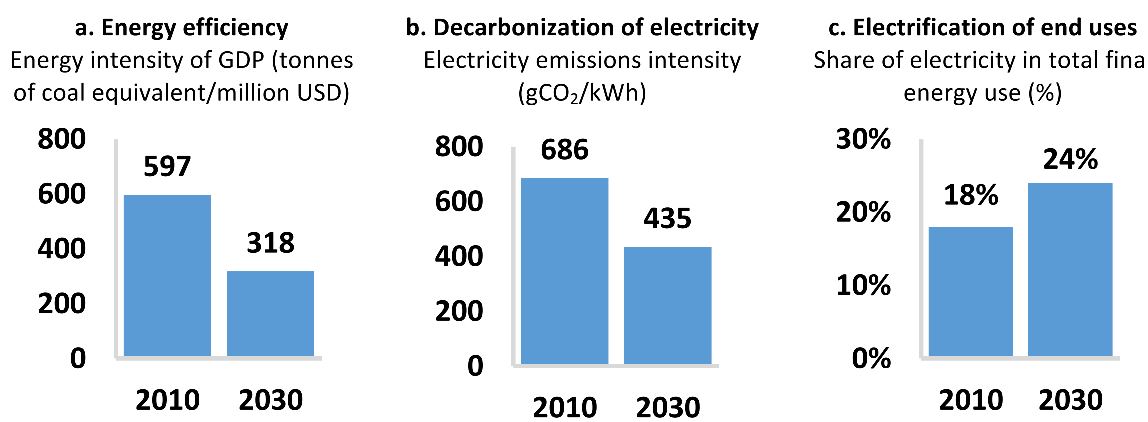
Note: Industry proportions calculated based on 2010 prices.

Source: 2005 and 2010 data are from China Statistical Yearbook.
Data after 2015 are from an INDC scenario from PECE model developed by NCSC and Renmin University of China.

Reducing the carbon intensity of energy will require a shift away from coal. Achieving the levels of decarbonization required under the new development pathway will require a shift away from coal in primary energy use towards gas and electricity, with electricity generated increasingly from renewable and nuclear sources. The share of coal in primary energy consumption might fall from 70% in 2010 to around 50% in 2030, while the share of non-fossil fuels and natural gas will need to almost treble over the same period. The share of electricity in total final energy consumption will have to grow to almost one quarter, driven by factors such as the increasing penetration of electric vehicles (Figure 2.4c).

The shift also requires significant decarbonization of electricity generation. The carbon intensity of the power sector will need to fall by nearly 40% by 2030 (Figure 2.4b). As noted above, this decrease will partly rely on large increases in the share of renewables and nuclear in power generation (to 30% and 12% of total power generation respectively) as well as the development of large-scale carbon capture and storage. By 2030, China's installed capacity of non-fossil power is expected to increase by over 900 gigawatts from 2014 levels, an increase roughly equivalent to the country's total installed thermal power capacity in 2014. As shown in Table 2.4, average annual installation of non-fossil capacity will increase from around 42 gigawatts per year in the period from 2005-2020 to 66 gigawatts during 2020-2030, and to potentially 87 gigawatts in the 2030-2050 period.

Figure 2.4: The change in energy and carbon intensity will have significant impacts on the energy sector to 2030



Source: 2010 data are from China Statistical Yearbook.
2030 data are from an INDC scenario from PECE model developed by NCSC and Renmin University of China.

Table 2.4: China will speed up the building and deployment of non-fossil energy

	2005-20	2020-30	2030-50
Annual average new installed capacity of non-fossil power generation (GW) (breakdown below)	41.8	65.6	87.1
Wind power (GW)	14.2	23.8	35.6
Solar power (GW)	7.0	25.0	36.4
Nuclear power (GW)	3.4	9.2	10.6

Source: From an INDC scenario from PECE model developed by NCSC and Renmin University of China.

Policies and measures to meet the targets

A wide range of policies and measures will be needed to help meet the INDC targets and drive China's transition towards the innovative development pathway. These include measures to address policy development challenges, energy system issues, support for climate science and low-carbon technology development, sector-specific plans, and mechanisms to alter economic incentives and behavior – see Table 2.5.

Table 2.5: China's INDC includes a range of policy measures to address climate change

Policy development	***Implementing proactive national strategies on climate change*, including strengthening laws and developing long-term strategies and roadmaps for low-carbon development**
	Improving regional strategies on climate change, including control of emissions and carbon intensity at the urban development zone level
	Innovating a low-carbon development growth pattern, such as through low-carbon pilots in provinces and cities
	Promoting international cooperation on climate change, such as by actively engaging in international cooperation and establishing a Fund for South-South Cooperation on Climate Change
Energy system changes	***Building a low-carbon energy system***, including the shift away from coal and the development of renewables and nuclear power
Support for science and technology	***Building an energy-efficient and low-carbon industrial system***, including the promotion of low-carbon industries, control of industrial emissions and the promotion of recycling systems
	Enhancing support for science and technology, including strengthening R&D on low-carbon technologies
	Improving statistical and accounting systems for greenhouse gas (GHG) emissions, including regular GHG inventories at national and provincial levels
Sectoral plans	***Controlling emissions from the building and transportation sectors***, through low-carbon urbanization planning and optimized green transportation systems
	Increasing carbon sinks in forests, wetlands and grasslands
	Enhancing overall climate resilience, through infrastructure development and improved assessment and risk management of climate change
Incentives and behavior	***Increasing financial and policy support***, such as funds, financing mechanisms, preferential taxation policies, green government procurement systems and green credit mechanisms
	Promoting carbon emissions trading markets, building on emissions-trading pilots
	Promoting a low-carbon way of life, by supporting low-carbon choices in daily life
	Increasing broad participation of stakeholders, in order to increase public- and private-sector awareness of low-carbon development

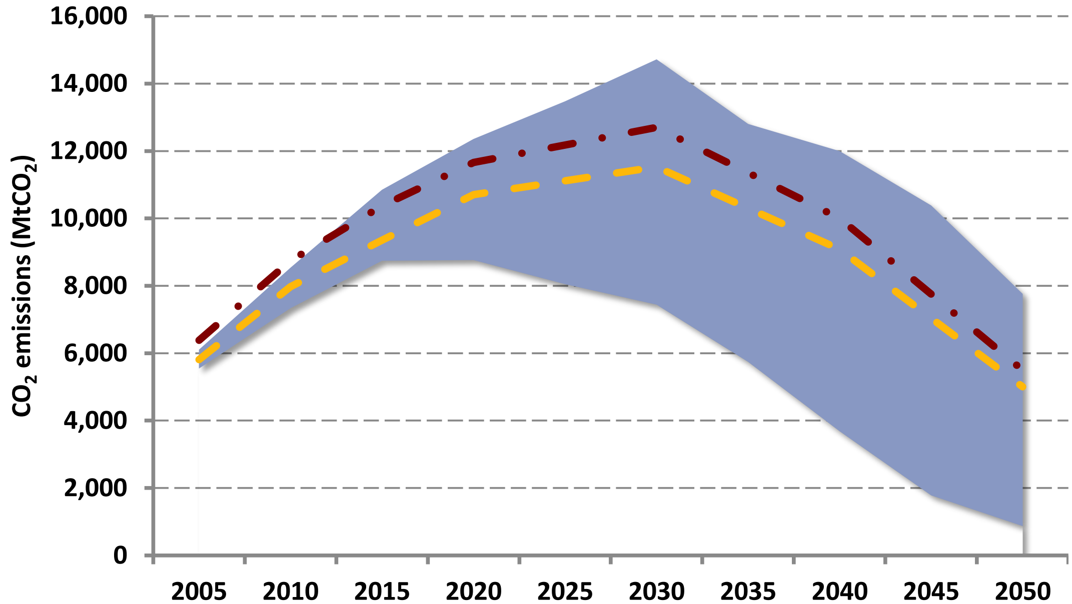
Progress towards the 2° goal

Progress towards and attainment of the 2030 INDC targets will lay a strong foundation for China to further accelerate emissions reductions in the period beyond 2030. Successful implementation of the INDC would enable China to improve its approach to development, consolidate public support, further refine its policies and institutions, build technological and innovative reserves, and develop comprehensive and specialized capabilities to respond to climate change. Progress in these areas will establish a solid foundation for an accelerated transition in the post-2030 period – in particular the development of low-carbon technologies and CCS.

In this way, China's INDC provides an important foundation for supporting the global goal to keep temperature increases below 2°C, although intensive efforts will be required by both China and its international partners. If the build-up of technical expertise in the period to 2030 described above is successful then, beyond 2030, China will be in a strong position to significantly reduce its emissions. The scenarios developed for this analytical work suggest that emissions could fall by around 50–60% on their

2030 levels by 2050, returning emissions to roughly the same level as in 2005, despite a more than 1000% growth in GDP per capita. These changes, in conjunction with action by the international community, would contribute to keeping global average temperature increases below 2°. Figure 2.5 shows pathways for China's emissions in which INDC commitments are included to 2030, with strong reductions thereafter (dotted lines), compared with the ranges of IPCC AR5 scenarios for emissions in China in which the 2° goal is achieved.

Figure 2.5: China's projected emissions under INDC commitments are consistent with IPCC '2 degree future' scenarios



Note: The purple area represents IPCC AR5 emissions scenarios for China with more than 50% probability of achieving the 2° goal given China's current status.
Red and yellow lines indicate China's emissions trends after implementing INDC targets (with and without energy data adjustment following latest economic census).
To ensure comparability with global data, the CO_2 emissions here include energy-related CO_2 emissions plus CO_2 emissions from cement production.

Source: IPCC AR5, PECE model developed by NCSC and Renmin University of China

Chapter 3 – Challenges and opportunities of the low-carbon transition

Summary

Various uncertainties and challenges may impede the shift to the innovative development pathway, including uncertainty as to when new technologies will be available, financing challenges and difficulties in accessing natural resources.

With adequate planning and intensive effort, many of these challenges can be managed and reduced.

There is also a set of opportunities associated with climate action, both domestically and internationally. Opportunities include a reduction in air pollution; an increase in green jobs; developing a comparative advantage in international trade of low-carbon technologies; and providing an example and reference for other developing countries.

Challenges, uncertainties and managing the transition

There are a number of uncertainties and challenges related to the attainment of the INDC targets. These challenges and uncertainties are both domestic (such as underlying rates of growth in GDP, population growth and urbanization) and international (such as possible global energy supply and demand shocks or the speed at which new technologies are developed globally). These uncertainties must be effectively and carefully managed to avoid challenges or setbacks to reaching the innovative development pathway. This section explores a small selection of the challenges China must manage in its transition.

Achieving the innovative development path relies on the availability of new technologies at manageable cost, which is currently highly uncertain. Some key low-carbon technologies are not currently widely available and cost projections are highly uncertain. For example, the availability of CCS at scale is of primary importance for decarbonizing both the power and industry sectors beyond 2030 – however, at present, this technology remains costly and is not widely deployed. In addition, China needs to provide low-carbon electricity via renewables whilst maintaining reliability of supply for the electricity grid – although technologies associated with the integration of high penetrations of renewables have not yet been demonstrated at the scale being considered by China. To illustrate the scale of the technical challenge China faces, Table 3.1 presents a technology roadmap, highlighting the wide range of technological advancements likely to be needed at different stages in order to achieve the targets set out in China's INDC and beyond.

China's mitigation actions will involve high initial upfront costs and financing challenges. For example, renewable electricity generation technologies tend to have a higher share of capital cost as a proportion of total cost compared with traditional fossil fuel technologies (where the fuel costs are also significant). This is also the case for the infrastructure required to integrate these technologies into the grid (e.g. transmission and distribution systems). The continued availability of different forms of capital, at appropriate cost, will be essential for financing these investments.

Table 3.1: China's INDC technology roadmap shows that rapid advances in low-carbon technology are required

	Immediate term (2010–2020)	Medium term (2020–2030)	Long term (2030–2050)
Power	Ultra-supercritical Large-scale onshore wind power generation Efficient natural gas-based power generation Third-generation large-scale pressurized water reactors Ultra-high-voltage power transmission technology Advanced hydropower technology	Integrated Gasification Combined Cycle Large-scale offshore wind power generation Advanced geothermal power generation Solar photovoltaic Second-generation biomass energy	Low-cost CCS Fourth-generation nuclear power Concentrating solar power Solar nanotechnology photovoltaic Large-scale electricity storage systems for intermittent power supply Low-cost hydrogen fuel cells Smart grids
Steel	Coke dry quenching Pulverized coal-injection technology Negative energy-based steelmaking Residual heat and pressure recovery Energy management center Coal moisture control Combined-cycle power plant	SCOPE21 coking technology Smelting reduction technologies Advanced electric arc furnaces Hydrogen production from coke oven gas Waste plastic technology Ultra-thin Castrip Itmk3 iron-making technology	Low-cost CCS technology
Transportation	Engine, transmission and vehicle technologies for better fuel economy in automobiles Advanced diesel vehicles Electrified railway Urban rail transport	Hybrid vehicles Information-based and intelligent transportation system High-speed railway	Fuel cell vehicles Efficient pure electric vehicles
Cement	Large-scale new suspension preheater kilns Efficient grinding Pure low-temperature waste heat power generation	Eco-cement Fuel substitution	Low-cost CCS technology
Chemicals	Large-scale synthetic ammonia plants Large-scale ethylene plants Ethylene feedstock substitution	Fuel and feedstock substitution	Low-cost CCS technology
Buildings	Light-emitting diode New building envelope materials and parts Energy-efficient appliances Combined heat and power cogeneration Solar water heater	Distributed energy systems Heat pump technology Combined cooling, heating and power systems Advanced ventilation and air-conditioning systems Low-cost and efficient solar PV buildings	Efficient energy storage technology Zero-energy buildings
General technologies	Frequency control technology Advanced electric motors	Frequency control technology Advanced electric motors	

China's stage of development and economic structure may make it more challenging to achieve the INDC targets. As China is still in the process of industrialization and urbanization, heavy industry sectors such as steel, petrochemicals, construction materials, and equipment manufacturing continue to make up a large proportion of the economy. This creates the risk of path dependencies that are likely to persist, at least in the medium term. Limited access to the natural resources required for low-carbon power generation, such as natural gas, further constrains possibilities. As a rising proportion of the Chinese population enters the middle class, increasing emissions from transportation and buildings are likely to surpass emissions from manufacturing over the medium-to-long term, making widespread behavior change a crucial driver in the success of reducing emissions. There are further significant challenges in ensuring that China's institutions have the capacity and awareness required to tackle climate change through effective policies and legislation.

Managing these challenges and risks requires, among other things, development of effective policy measures. These include policies such as energy efficiency standards or carbon taxes that could result in rising consumer prices, but can be designed so as to minimize adverse impacts. The potential regressive impacts of low-carbon policies, e.g. structural unemployment, etc., will need to be addressed, including through compensatory subsidies for low-income groups, trainings for the reemployment of laid-off workers and campaigns to raise awareness among low-income groups on the health benefits of a low-carbon society.

The necessary technological change will require the creation of a sound and mature national innovation system. This includes introducing a policy framework for energy R&D and environmental policies to incentivize low-carbon innovation, such as the recently adopted stringent air pollution standards. A major component of meeting this challenge will be to enhance engagement in international innovation networks, harnessing their power to collaboratively transform domestic and global energy systems.

Opportunities associated with the innovative development pathway

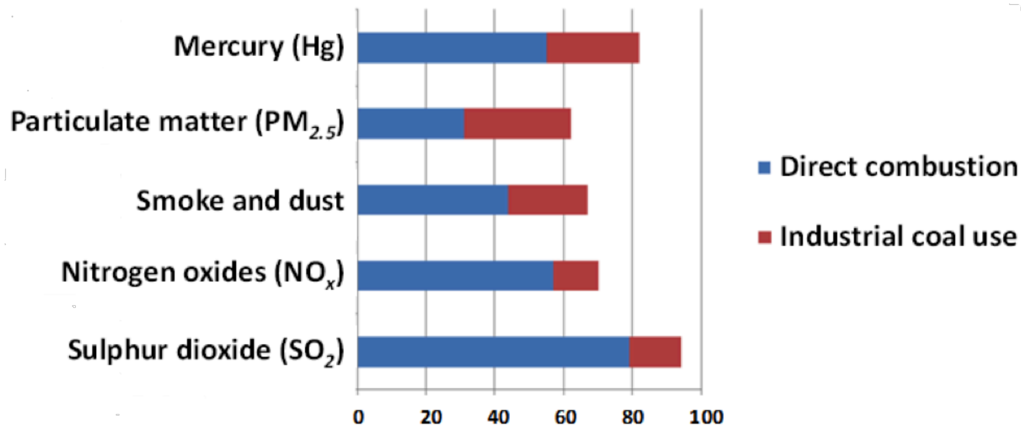
Despite the challenges, a successful transition to the innovative development pathway offers China multiple opportunities, in addition to supporting global efforts to reduce emissions. Some of the most important of these include: reduced air pollution; increased employment; the creation of new sources of comparative advantage; and the opportunity to foster South-South collaboration.

A key benefit of a low-carbon development pathway would be a reduction in air pollution, with significant benefits for human health and ecosystems. The main sources of air pollution are coal-fired power plants and industrial processes. As Figure 3.1 shows, around two thirds of emissions of major pollutants – including sulphur dioxide, nitrogen oxides, particulate matter, smoke and dust, and mercury – are a direct result of coal combustion and industries closely related to coal.

Public health benefits from reduced air pollution alone may be sufficient to turn net mitigation costs into net mitigation benefits. The adoption of low-carbon technology that reduces coal use will impact public health both directly and indirectly:

- Direct health effects include improvements in health of workers who are engaged in coal-related occupations, including through a reduction in pneumoconiosis, occupational poisoning and accidents.
- Indirect health effects relate to health improvements of the general public due to reduced pollutants emitted as a result of combustion and processing of coal.

Figure 3.1: Coal combustion for power generation and industry coal use are the main drivers of air pollution in China



Source: The Contribution of Coal use to China's air pollution, China Coal Consumption Cap Plan and Policy Research Project, available at: http://www.nrdc.cn/coalcap/

Low-carbon policies are projected to have a net positive impact on employment. New low-carbon jobs are expected to emerge, especially in renewable energy, transport and construction. While this will be offset by some loss in employment in carbon-intensive power generation and related industries, recent studies (Cai Wenjia, et al, 2014) suggest that the net impact of low-carbon policies on employment is expected to be positive.

China can create new global comparative advantages in low-carbon technology and avoid lock-in. The innovative development pathway can give rise to new capabilities that have the potential to create comparative advantages in international trade. If China can bolster its capabilities, some of the most attractive opportunities are likely to be in energy conservation, environmental protection, new energy, and energy-efficient vehicles. Policies to support these emerging industries have the potential to create new path dependencies that redirect R&D efforts towards these new technologies, creating a virtuous circle between deployment and R&D. This can help the country avoid the lock-in of carbon-intensive infrastructure.

China's experiences can serve as a demonstration and reference point for other developing countries. China's rapid growth already serves as a model for many other developing countries. In its transition to the innovative development pathway, China has the opportunity to demonstrate a sustainable framework for development to these countries, supported by active South-South cooperation. By sharing China's experiences, other developing countries can avoid reliance on traditional high-carbon growth models and pursue more efficient and innovative paths that result in less pollution and lower emissions. China's move to the innovative development pathway could therefore promote a global transition to low-carbon development models.

References

AMPERE Consortium. (2014). AMPERE Scenario database. International Institute for Applied Systems Analysis (IIASA), available at http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy /AMPERE_Scenario_database.html.

Cai, W., Mu, Y., Wang, C. & Chen, J. (2014). "Distributional employment impacts of renewable and new energy–A case study of China". Renewable and Sustainable Energy Reviews, 39, C, 1,155–1,163.

Carbon Dioxide Information Analysis Center (CDIAC). (2015). CO2 emissions from fuel combustion. US Department of Energy, Oak Ridge National Laboratory.

Communist Party of China Central Committee and State Council. (2015) Opinions on Accelerating the Building of Ecological Civilisation.

EMF27 project consortium. (2014). EMF27 Scenario database. International Institute for Applied Systems Analysis (IIASA), available at http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/EMF27DB.html.

Fulin, C. (2015). *China in 2020: Transformation and Reform for Marching towards a Big Service Economy*. Address to China-EU Reform Agendas conference, 29 Feburary 2015, CEPS Ideas Lab, Brussels. Retreived from http://www.chinareform.org/newsevents/news/201503/t20150313_220474.htm.

Hu Jintao. (2007). *Report to the Seventeenth National Congress of the Communist Party of China on Oct. 15, 2007.*

Hu Jintao. (2011). *Report to the Eighteenth National Congress of the Communist Party of China on November 8, 2012.*

International Monetary Fund (IMF). (2014). People's Republic of China 2014 Article IV Consultation – Staff Report; Press Release; and Statement by the Executive Director for the People's Republic of China. IMF Country Report No. 14/235, retrieved from https://www.imf.org/external/pubs/ft/scr/2014/cr14235.pdf.

LIMITS Consortium. (2014).LIMITS Scenario database. International Institute for Applied Systems Analysis (IIASA), available at http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/LIMITs_Scenario_Database.html.

National Resources Defense Council. (2014). *The Contribution of Coal use to China's air pollution*. Output from China Coal Consumption Cap Plan and Policy Research Project, available at http://www.nrdc.cn/coalcap/

National Development and Reform Commission. (2014). *National Plan on Climate Change (2014-2020).*

National Development and Reform Commission. (2015). *Enhanced Actions on Climate Change – China's Intended Nationally Determined Contribution.*

National People's Congress. (2006). *Eleventh Five-Year Plan (2006-2011).*

National People's Congress. (2010). *Twelfth Five-Year Plan (2011-2015).*

Oxford Economics. (2015). *Oxford Economics [Online]*. Available through Thomson Reuters Datastream, https://www.thomsonone.com.

State Council. (2011). *Work Plan for Greenhouse Gas Emission Control during the Twelfth Five-Year Plan Period.*

World Bank. (2015). *World Development Indicators 2015*. Washington DC: World Bank. Retrieved from http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators 2015.

Annex: China's pre-INDC emissions reduction efforts

Summary

Since the mid-2000s, China has made significant efforts to address climate change.

It has recognized the importance of responding to climate change at a national level, and has incorporated this into its national strategic planning, including its five-year plans (FYP).

China has made notable progress to date, and by 2014 was approaching or had already exceeded its key 2015 targets. It has also established robust targets for 2020.

National and local institutions have been established to lead and coordinate the response to climate change, and climate change has been incorporated across sectoral plans and frameworks.

A range of legislative, executive, economic and market-based tools have been put in place to implement the response. China is also expanding its international cooperation on energy and climate issues to support international progress in addressing climate change.

Progress to date

China has accelerated the incorporation of sustainable development and climate change into its national strategic planning over the last decade. Former President Hu Jintao's speech to the G8+5 in 2005 stressed that climate change and environmental policies are a central pillar of development planning. China has already put this into practice in a number of ways:

- The 2006 *Eleventh FYP* set mandatory energy-saving and emissions-reduction targets for the first time.
- The 2007 *Report to the 17th National Congress of the Communist Party of China (CPC)* clearly elaborated the need to promote environmental conservation and energy and resource efficiency as a requirement for economic development.
- The 2010 *Twelfth FYP* prioritized an active response to climate change, including the promotion of green development and low-carbon development.
- The 2011 *Report of the 18th National Congress of the CPC* recommended incorporating climate change and sustainability into all aspects of economic, political, cultural and social planning.
- The 2015 *Opinions on Accelerating the Building of Ecological Civilisation*, published by the Politburo of the CPC Central Committee, established that China should prioritize energy savings and environmental conservation and regeneration as core development policies. It also noted that ecological progress and innovation is an imperative pillar of development and the advancement of an 'ecological civilization'.

China's commitment to a low-carbon 'ecological civilization' future is also evident its adoption of near-term climate change targets.

The importance of sustainable development and climate change is reflected in detailed short-term targets for 2015 and 2020 for reducing energy consumption, increasing energy efficiency and rolling out renewable energy electricity generation. The 2010 *Twelfth FYP* was the first planning document to impose mandatory targets for the energy and carbon intensity of economic activity, and also included targets for the share of fossil fuels in energy consumption and for total energy consumption. These objectives have been further developed by the *Energy Development Strategy Action Plan (2014–2020)*, which includes targets to cap annual primary energy consumption and annual growth rates of primary energy consumption, alongside fuel mix and generation targets.

China is making good progress towards meeting its targets – and in some cases has already exceeded them. By 2014 the energy intensity of GDP had fallen by 13.5% against a 2010 baseline, while the installed capacity of renewable energy had increased by more than 70% from 2010 levels. In 2014, both the share of renewables in installed capacity and power output from renewable energy had already exceeded the 2015 targets. Table A.1 lists China's progress in meeting key 2015 climate change targets.

Table A.1: China has made good progress towards meeting key 2015 targets

Outcome	2015 target	Progress to 2014
Energy consumption reduction per unit of GDP relative to the 2010 level	16%	13.5%
CO_2 emissions reduction per unit of GDP relative to the 2010 level	17%	16.2%
Share of non-fossil fuels in primary energy consumption	11.4%	11.2%
Share of renewable energy installed capacity	30%	31%
Share of renewable power output	20%	22%
Hydropower installed capacity	260 million kW	300 million kW
Connected-grid wind power installed capacity	100 million kW	96 million kW
Nuclear power installed capacity	40 million kW	20 million kW
Connected-grid solar power installed capacity	21 million kW	26.5 million kW

Programs and policies to 2020

China has already established a detailed policy framework to structure its response to climate change up to 2020. The 2014 *National Plan on Climate Change (2014–2020)* identifies guiding principles, main goals and targets, a roadmap, and policy directions for addressing climate change to 2020. Key objectives include adjusting China's industrial structure; improving energy conservation and efficiency; optimizing the structure of the energy sector; controlling emissions from non-energy activities; and increasing carbon sinks. The *National Plan* also outlines continued low-carbon and emissions-trading pilot programs, and sets out plans for building capacity, scientific understanding, and data to support climate change policy-making.

The key target for 2020 is to reduce the carbon intensity of economic activity by 40–45% compared with 2010. Table A.2 presents China's other key energy-related 2020 targets. These are in addition to a target to cap total primary energy consumption over the entire thirteenth FYP period at 4.8 billion tonnes of coal equivalent (tce). To help achieve these economy-wide targets, China has also established sectoral targets to increase energy and carbon efficiency in the industrial, construction and transport sectors; to shift the structure of the economy towards a less energy-intensive mix of activities; and to increase forest coverage, as shown in Table A.3.

Table A.2: China has established a range of energy-related targets for 2020

Outcome	2020 target
CO_2 emissions reduction per unit of GDP based on the 2010 level	40–45%
Share of non-fossil fuels in primary energy consumption	15%
Hydropower installed capacity	350 million kW
Connected-grid wind power installed capacity	200 million kW
Nuclear power installed capacity	58 million kW
Connected-grid solar power installed capacity	100 million kW
Coal consumption	4.2 billion tce
Maximum share of coal in total primary energy consumption	62%
Minimum share of natural gas in total primary energy consumption	10%

Table A.3: China has established sectoral climate change targets for industry, buildings, transport and forestry for 2020

Sector	Outcome	2020 target
Industry	Emissions reduction per unit of industrial added value	Around 50%
	Added value of emerging industries of strategic importance in GDP	Around 15%
	Added value of service industry in GDP	52%
Buildings	Urban green buildings in new buildings	50%
Transport	Public transport share in large and medium-sized cities	30%
	CO_2 emissions reduction per road revenue passenger kilometer (RPK)	5%
	CO_2 emissions reduction per road freight tonne kilometer	13%
	CO_2 emissions reduction per unit of railway traffic volume	15%
	CO_2 emissions reduction per unit of waterway traffic volume	13%
	CO_2 emissions reduction per unit of civil aviation traffic volume	11%
Forestry	Forest area increase (ha)	40 million
	Forest reserves increase (m^3)	1.3

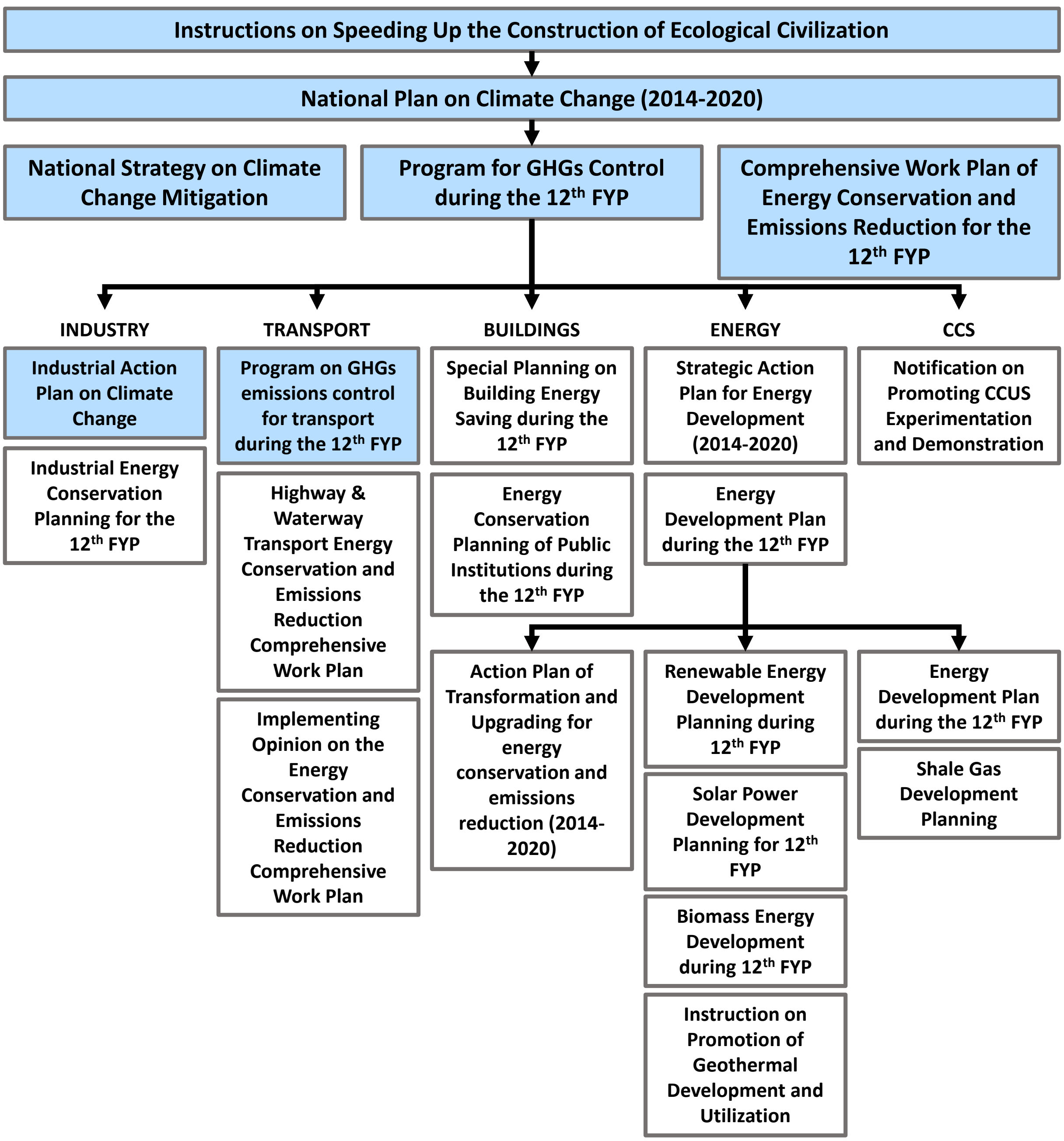
Note: All proportional reduction/increase targets are based on a 2010 baseline except for the forest reserve increase target, which is based on a 2005 baseline.

A range of institutions have been established to assess impacts, coordinate responses, and implement policies at different levels. The National Leading Group on Climate Change and Energy Saving was established as a forum for national-level deliberation and coordination, consisting of leaders from more than 20 ministries, the Premier and Vice-Premier. This is supported by the Department of Climate Change, which conducts technical analysis and formulates national climate change strategies, plans and policies. The National Center for Climate Change Strategy and International Cooperation (NCSC) leads national-level research and consulting on climate change. These national institutions are complemented by regional agencies (individual departments or divisions of local Development and Reform Commissions) and local research institutes in the 31 provincial administrative regions.

China has also incorporated climate change into sectoral planning frameworks to ensure appropriate action across the economy. In the context of the 2014 *National Plan on Climate Change*, China has developed a *Work Plan for Greenhouse Gas Emission Control During the Twelfth FYP Period*. This was then incorporated into sectoral development plans, climate change plans and/or energy conservation

and efficiency plans in the industry, transport, construction and energy sectors, and into a plan for promoting CCS experimentation and demonstration, as shown in Figure A.1. These plans include sector-specific measures, such as subsidies, mandatory indexes, to accomplish national-level targets from the *National Plan*.

Figure A.1: Climate change has been incorporated into China's national and sectoral planning frameworks



Note: Blue boxes indicate special planning to address climate change.

A range of legislative, executive, economic and market-based tools have been put in place. Some of the most important of these include:

- *Legislation and regulations.* More than 30 national laws and 90 administrative regulations relating to low-carbon development have been passed, including energy conservation and renewable energy laws. Various local governments have also introduced sub-national climate change regulations in line with national legislation.
- *Executive orders.* This is the most common climate change policy tool in China. One of the key focal areas of executive orders has been to bring about mandatory energy savings and emissions reductions across government, enterprises and society. These orders include compulsory standards and/or required actions relating to industrial processes, transport, buildings and government procurement.
- *Economic incentives.* These include pricing systems and fiscal support. Pricing systems include differentiated power pricing in high-energy-consuming industries and punitive pricing on products exceeding energy-consumption standards. Fiscal support includes investment subsidies, preferential loans and funding for areas such as renewable energy development.
- *Market mechanisms.* Emission-trading schemes currently operate in seven pilot regions, including Beijing and Shanghai. They were launched in 2013 and 2014, with total trading volumes of 15 million tonnes of CO_2 by the end of 2014. The government is also formulating an overall plan to implement a carbon-trading system which is expected to launch in 2016.
- *Low-carbon development pilot programs.* These have been deployed in six provinces and 36 cities, covering 57% of national GDP and 42% of national population (in 2010), and covering a range of geographies, levels of economic development, and industrialization. The pilots include area-specific development plans for establishing low-carbon industrial, construction and transportation systems, as well as the establishment of systems for GHG emission controls.

China is also expanding its international cooperation on energy and climate issues to support international progress in addressing climate change. This includes support for the international transfer of low-carbon manufacturing and production and the strengthening of international energy cooperation. China is also promoting international cooperation on science and technology, including on R&D, as well as manufacturing techniques and the development of standards. Finally, China is working to strengthen relationships with international organizations to increase capacity-building and training.

The institutional set-up and structural actions over the last decade, as well as the plans in place to 2020, already constitute an important response to the climate change challenge and provide an important base for the implementation of the INDC targets.