An Energy Sector Roadmap to Carbon Neutrality in China

Executive summary

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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Executive summary

There is no plausible path to limiting the global temperature rise to 1.5 °C without China[1]. In September 2020, President Xi Jinping announced that China will "aim to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060". Announced 40 years after the country began its remarkable journey towards economic modernisation, this new vision for China's future comes amid growing convergence among the world's major economies on the need to reach net zero emissions globally by mid-century. But no pledge is as significant as China's: the country is the world's largest energy consumer and carbon emitter, accounting for one-third of global CO_2 emissions. The pace of China's emissions reductions over the coming decades will be important in determining whether the world succeeds in preventing global warming from exceeding 1.5 °C.

The energy sector is the source of almost 90% of China's greenhouse gas emissions, so energy policies must drive the transition to carbon neutrality. This Roadmap responds to the Chinese government's invitation to the IEA to co-operate on long-term strategies by setting out pathways for reaching carbon neutrality in China's energy sector. It also shows that achieving carbon neutrality fits with China's broader development goals, such as increasing prosperity, strengthening technology leadership and shifting towards innovation-driven growth. The first pathway in this Roadmap – the Announced Pledges Scenario (APS) – reflects China's enhanced targets that it declared in 2020 in which emissions of CO_2 reach a peak before 2030 and net zero by 2060. The Roadmap also explores the opportunities for an even faster transition and the socio-economic benefits it would bring to China beyond those associated with reducing the impact of climate change: the Accelerated Transition Scenario (ATS).

China can build on its current clean energy momentum

China's energy sector reflects decades of efforts to lift hundreds of millions of people out of poverty while pursuing other energy policy goals. Energy consumption has doubled since 2005, but the energy intensity of gross domestic product (GDP) has decreased significantly in the same period. Coal accounts for over 60% of power generation – and new coal power plants continue to be built – but solar photovoltaics (PV) capacity additions have outpaced those of any other country. China is the second largest oil consumer in the world, but also home to 70% of global manufacturing capacity for electric vehicle batteries, with Jiangsu province alone accounting for one-third of the country's capacity. China's

[1] The People's Republic of China (hereinafter, "China")

contributions to low-carbon technologies, particularly solar PV, were mostly driven by the government's increasingly ambitious five-year plans, leading to cost reductions that have changed the way the world thinks about the future of clean energy. If the world is to meet its climate goals, then similar clean energy progress is needed – but on a greater scale and in all sectors. For example, China produces more than half the world's steel and cement, with Hebei province alone accounting for 13% of global steel production in 2020. CO_2 emissions from the steel and cement sectors in China alone are higher than the European Union's total CO_2 emissions.

China's CO_2 emissions are rising, but a peak before 2030 is in sight. The sooner the emissions peak comes, the higher China's chance of reaching carbon neutrality on time. The leading sources of China's emissions are the power sector (48% of CO_2 emissions from energy and industrial processes), industry (36%), transport (8%) and buildings (5%). The specific targets made public so far from the latest Five-Year Plan include an 18% reduction in CO_2 intensity and a 13.5% reduction in energy intensity during the period 2021-2025. There is also a non-binding proposal to raise the non-fossil fuel share of total energy consumption to 20% by 2025 (from around 16% in 2020). If China achieves these short-term policy targets, the IEA projects that China's CO_2 emissions from fuel combustion will be on track to plateau in the mid-2020s and then enter a modest decline to 2030. We also note China's commitment at the United Nations General Assembly in September 2021 to discontinue building coal-fired power projects abroad and to step up support for clean energy. We also note China's commitment at the United Nations General Assembly in September 2021 to discontinue building coal-fired power projects abroad and to step up support for clean energy.

Carbon neutrality demands a rapid and profound transformation of the energy sector

Reaching a peak in China's CO_2 emissions before 2030 relies on progress in three key areas: energy efficiency, renewables and reducing coal use. In the APS, China's primary energy demand grows much more slowly through 2030 than the overall economy. This is mainly the result of efficiency gains and a shift away from heavy industry. A transforming energy sector leads to rapid improvements in air quality. Solar becomes the largest primary energy source by around 2045. Demand for coal drops by more than 80% by 2060, oil by around 60% and natural gas by more than 45%. By 2060, almost one-fifth of electricity is used to generate hydrogen.

The level of investment required for China to achieve its goals is well within its financial means. Energy sector investment climbs significantly in absolute terms, but falls as a share of overall economic activity. Total annual investment

reaches USD 640 billion (around CNY 4 trillion) in 2030 – and nearly USD 900 billion (CNY 6 trillion) in 2060, almost a 60% increase relative to recent years. Annual energy investment's share of GDP, which averaged 2.5% in 2016-2020, drops to just 1.1% by 2060.

Every sector has a viable path to deep cuts in emissions

A power sector dominated by renewables provides the foundation for China's clean energy transition. China's power sector achieves net zero CO_2 emissions before 2055 in the APS. Renewables-based generation, mainly wind and solar PV, increases seven-fold between 2020 and 2060, accounting for almost 80% of generation by then. By contrast, the share of coal drops from over 60% to just 5%, and unabated coal-based generation stops in 2050. Renewable capacity rises at least three-fold in all regions by 2060, with the largest growth in China's northwest and northern regions where solar and onshore wind take advantage of strong resource potential and good availability of land. However, investments in low-carbon flexibility sources to increase the reliability and resilience of electricity systems are highest in China's coastal provinces.

Efficiency improvements and today's market-ready technologies can only take the industry sector part of the way to net zero. In the APS, industrial CO_2 emissions decline by nearly 95% and unabated coal use by around 90% by 2060, with the residual emissions being offset by negative emissions in the power and fuel transformation sectors. Energy efficiency improvements and electrification drive most of the industrial emissions reductions in the short term, while emerging innovative technologies, such as hydrogen and carbon capture, utilisation and storage (CCUS), take over post-2030.

Electrification is the key to decarbonising transport and buildings. New investments in metro, light-rail and electric buses in cities, and high-speed rail between cities, lower the energy intensity of passenger trips. Emissions reductions in road freight, shipping and aviation come from fuel efficiency gains and use of low-carbon fuels. Direct CO_2 emissions in the buildings sector drop by more than 95% by 2060 through electrification, clean district heating and energy efficiency.

Faster progress before 2030 is possible and beneficial

An early push reduces the emissions burden faced after 2030. The timing and level of the peak in emissions, as well as the pace of emissions reductions once the peak has been reached, are crucial for the achievement of China's longer-term goal of carbon neutrality. China has the technical capabilities, economic means and policy experience to accomplish a faster clean energy transition to 2030 than in the APS. Its recently launched emissions trading scheme and its power market

reforms are two clear examples. In the ATS, policy progress accelerates, resulting in a faster decline in coal use in power and industry, stronger deployment of existing low-carbon technologies, and more rapid efficiency gains. In 2030, energy sector CO_2 emissions are more than 2 Gt, or nearly 20%, lower in the ATS than their level today. Investment needs are not a major barrier: cumulative investments in the ATS are similar to those in the APS.

Accelerated progress before 2030 delivers socio-economic benefits beyond those linked to addressing climate change. They include bringing greater prosperity to regions that have not yet fully benefited from China's economic development, its central role in global clean energy technology value chains and its emerging leadership in clean energy innovation. Accelerated domestic action increases employment in China's clean energy supply by 3.6 million by 2030, compared with the 2.3 million jobs lost in fossil fuel supply and fossil fuel power plants. Net additional jobs in this faster transition are almost 1 million higher than in the announced pledges pathway. Employment could grow even more if China captures some of the raising demand for clean energy technologies driven by other countries' greater ambition.

Expanding the scope of China's neutrality target to cover all greenhouse gases would underscore the benefits of an early peak in CO_2 emissions. Such an ambition could require the energy sector to reach net zero CO_2 emissions well before 2060 to compensate for the non-energy sector emissions that are more difficult to eliminate. This would make accelerated progress in reducing CO_2 emissions through to 2030 essential. The longer-term transition challenge would be profound: for example, reaching net zero CO_2 emissions as soon as 2050 would imply that the installed capacity of solar PV and wind would be around 1 400 GW, or 20%, higher than it is in the APS in 2050.

Dealing with existing assets helps an orderly transition

Even without any further investment in new fossil fuel assets, China's energy-related emissions would still only decline very slowly. If the existing emissions-intensive infrastructure in China today continues to operate in the same way it has in the recent years, it could result in 175 Gt of CO_2 emissions between now and 2060. This is the equivalent of one-third of the remaining global emissions budget that could limit the global temperature rise to 1.5 °C.

The next cycle of heavy industry investment in China could result in a huge amount of additional emissions if cleaner alternatives are not ready in time. In the APS, about 40% of the Chinese energy sector's CO_2 emissions reductions in 2060 come from technologies that are still at the prototype or demonstration stage today. It is essential to have new and emerging low-carbon industrial technologies

available at the time of the planned phase-out of existing capacity so as to avoid the need for a further cycle of emissions-intensive capacity renewal. This alone could avoid emissions from heavy industry in China equivalent to almost 15% of the remaining estimated global carbon budget that is compatible with a 50% chance of limiting the average temperature increase to 1.5°C.

A faster clean energy transition between now and 2030 makes the process easier to navigate for existing assets and their stakeholders. The ATS avoids around 20 Gt of "locked-in" emissions to 2060 from long-lived assets in the power and industry sectors that are built in the period to 2030 in the APS. This early action means that the required average annual pace of emissions reductions to reach carbon neutrality by 2060 is nearly 20% lower over 2030-2060 than in the APS, leaving more time for markets to adjust and businesses and consumers to adapt.

Innovation is essential for the transition to succeed

Reaching carbon neutrality by 2060 hinges on a major acceleration in clean energy innovation. China is emerging as a world leader in clean energy innovation: public spending on low-carbon energy research and development (R&D) in China has risen by 70% since 2015. China accounts for nearly 10% of patenting activity in renewables and EVs. In recent years, its start-ups have attracted more than one-third of global early-stage energy venture capital.

But China's innovation system will need to be harnessed appropriately to stimulate the wide range of low-carbon energy technologies needed. The latest Five-Year Plan aims to shift the focus of innovation to low-carbon technologies and pursue new policy approaches. Current Chinese policy incentives are better suited to large-scale technologies like CCUS and biorefining than network infrastructure and consumer-facing products, which are China's current manufacturing strengths. Beyond direct R&D funding, policies can incentivise innovators through competitive niche markets, infrastructure investments and other regulatory measures to stimulate technology deployment.

A central actor in the world's energy and climate future

China's many strengths make it well-placed to successfully carry out its own transition to carbon neutrality while also demonstrating international leadership in technology and energy policy making. China is both the world's largest emitter and the largest manufacturer of key clean energy technologies such as solar panels and EV batteries. What happens in China will go a long way towards shaping the outcome of global efforts to reduce emissions in time to prevent the worst effects of climate change. For those efforts to succeed, international collaboration with China is essential.

For further information, please contact: timur.guel@iea.org

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