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Towards carbon neutrality and China's 14th Five-Year Plan:

Green COVID-19 recovery, sustainable urban development and clean energy transition

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Policy insight

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1. Introduction

China's 14th Five-Year Plan, for the period 2021–25, presents a real opportunity for China to link its long-term climate goals with its short- to medium-term social and economic development plans. China's recent commitment to achieving carbon neutrality by 2060 has set a clear direction for its economy, but requires ratcheting up ambition on its near-term climate policy. Against this background, this paper extends the discussion on major action areas for China's 14th Five-Year Plan presented in a previous policy note (Stern and Xie, 2020), focusing on three aspects: the energy transition, a new type of sustainable urban development and investment priorities. First, we outline the current context – the COVID-19 pandemic and the international responses to date, and the importance of China's leadership.

The risks of a global depression and the critical need for a sustainable recovery

The COVID-19 pandemic has created an unprecedented threat to both public health and the global economy. At the time of writing, more than 2 million deaths from the disease worldwide have been recorded, and the world economy experienced a strong contraction in 2020. The World Economic Outlook of the International Monetary Fund (IMF) suggests that the ongoing economic shock could far exceed that which occurred during the 2008–10 financial crisis, and the worst recession since the 1930s (IMF, 2021a). Constrained investment could generate a permanent long-term hit to output by reducing capacity.

Coordinated action between countries is required to manage the risk and consequences of this unprecedented crisis. The response to COVID-19 will fall into three phases which overlap and interweave, but essentially involve different kinds of priorities: (i) rescue; (ii) recovery; and (iii) transformation to a new form of growth (Bhattacharya and Stern, 2020). After the rescue period,[1] the recovery from COVID-19 needs to be aligned with long-term development goals and focused on investment in zero- and low-carbon activities and sustainable infrastructure. Investments are required not just in physical capital, but also in natural, human and social capital. The stimulus in the recovery phase should avoid high-carbon and unsustainable investments or else the world faces increasing damage from global threats including climate change, biodiversity loss and infectious diseases – also there would be growing likelihoods of further pandemics as interactions between and among wild animals, domestic animals and humans continue to be transformed.

The pandemic has also underlined that the old economic model that is overly focused on physical capital was accompanied by many stresses through insecurity and inequity. We should protect and enhance natural and human capital to reduce the risks of climate change, biodiversity loss and infectious diseases, including pandemics. Investment in social and institutional capital is necessary to build trust and restore faith in effective institutions and replenish social cohesion. COVID-19 and the associated responses have highlighted the importance of cooperation and community spirit. We must be very clear about the necessity of not going back.

International policy responses to COVID-19

The 2020s will be a decade of fundamental importance for the world, especially for the climate, environment and biodiversity. Indeed, for many aspects of our future, this decade will be decisive. This will be a crucial test of internationalism for the world and for China.

We must be wary of opportunistic attempts to reinstate dirty industries for the stated purpose of economic recovery; such policies are routes to insecurity and decline. We need to design and implement stimulus packages in a way that ensures the recovery not only respects the environment but also leads to broad-based prosperity, better health and wellbeing, and social inclusion.

The European Commission presented the European Green Deal on 11 December 2019, before the outbreak of the COVID-19 pandemic, providing a roadmap with actions for making the EU's economy sustainable and reaching climate neutrality (net-zero emissions) by 2050. This ambitious plan remains the core EU economic and political project, even with a strong focus on the response to the pandemic. On 21 July

[1] See Ahmad et al. (2020) for a description of the priorities taken in the COVID-19 rescue period.

2020, the EU reached a deal on a recovery package and the European budget for 2021–2027, to counter the impact of the pandemic, and it will support investment in the green and digital transitions to ensure the EU builds back better and greener. This involves a €750 billion recovery instrument in the form of €390 billion in grants and €360 billion in loans, emphasising a "sustainable, even, inclusive and fair" recovery for all Member States, and recognising the importance of strengthening the role of development banks in unlocking investments and contributing to the EU's ambitions in fighting climate change and digitalising the EU's economy.

Some Member States were putting in place investments in a sustainable economy before the crisis. France has passed a total of €425 billion in fiscal measures, which will extend substantial support for environmentally relevant sectors (e.g. incentives to purchase greener vehicles and green investment support for the auto and aerospace sectors).

The German government's resolve to push for a sustainable recovery and transformation was illustrated by its determination to stand up to vested interests in the auto industry and not to slip back into supporting the production of diesel engines, in particular. Clarity and resolve of this kind will be necessary to implement effective policy and send the strong signals that can drive innovation and investment. Germany has announced a €130-billion fiscal package to strengthen broad consumption and incentivise private and public investment, particularly in green and digital technologies. These include a €50 billion investment package aimed at reducing Germany's carbon footprint, such as support for climate-friendly mobility; €7 billion funding for the national hydrogen strategy; and promotion of R&D especially on green and digital projects.

In July 2020, the UK announced a £3 billion green investment package as part of its COVID-19 recovery package, which includes a £1 billion plan for improving the energy efficiency of public buildings and a £2 billion Green Homes Grant scheme to pay for energy improvements such as insulation for more than 600,000 homes. (See IMF, 2021b for more details of these and other countries' responses.) In November 2020, an additional package of measures was announced by the UK Treasury, mainly to support households and SMEs during the health emergency. It also included measures that will impact on the UK's net-zero transition: £100 billion spending on infrastructure in 2021 includes investments earmarked for zero- and low-carbon sectors; and there are plans to launch a National Infrastructure Bank to fund new investment projects, 'level up' the economy and accelerate the transition towards net-zero emissions.

China's leadership in the global context

As one of the first G20 countries to have made the transition from rescue to recovery from the COVID-19 pandemic, China can show how to accelerate the transition towards the zero-carbon economy. China is already leading on the development of many new low-carbon technologies and will benefit from being at the forefront of the new global growth story, driven by the stimulus of higher investment in clean technologies and energy efficiency. The country has committed to environmental protection and conservation – or 'eco-civilisation' – at home, as emphasised by President Xi in April 2020 when he visited Shaanxi Province.[2]

The global importance of China, the world's second-largest economy, means that its immediate actions will have wide-ranging and lasting impacts on the world and its trajectory in the coming decades and over the entire century. This is due more than to the country's size – its influence also comes from its technologies, strategies and leadership in coming out of the COVID-19 crisis (Ahmad et al., 2020). China's consumption and investment demand could play an important role in the global recovery from COVID-19. And its actions in the coming months and years on climate change will influence other countries' commitments to reduce their emissions. If China heads back towards the old polluting and wasteful practices of the past, it would send a very backward-looking signal to other countries. Both China and the rest of the world would be deeply damaged for the foreseeable future.

[2] http://www.xinhuanet.com/english/2020-04/21/c_138995712.htm

This decade, 2021–2030, is of fundamental importance to human history. If we lock in dirty and high-carbon capital, we risk profound and irreversible damage to our climate. China's 14th and 15th Five-Year Plans will shape the future of the world.

The 14th Plan seeks to promote 'eco-civilisation', high-quality development, and strong, sustainable, resilient and inclusive growth. It is crucial that it tackles issues of public health, climate change, biodiversity and ecosystems, while also reinvigorating economic growth through technology, infrastructure, sustainable urban development, and fiscal sustainability. A clear sense of direction is required to guide both strong short-term actions for rescuing the economy and sound medium-term measures to promote the transformation to sustainable growth. The economic recovery must be sustained by confidence in the future strategy.

Structure of the paper

In Section 2 we put forward suggestions for key strategies for the 14th Five-Year Plan, among which energy transition, urbanisation and investment are particularly crucial. We address these in more detail in subsequent sections: Section 3 considers the energy transition and early peaking of CO_2 emissions; in Section 4 we examine a new type of urbanisation and its role in low-carbon economic growth; and Section 5 considers investment priorities across the four types of capital, in particular technological infrastructure. Section 6 concludes.

2. Key priorities for China's 14th Five-Year Plan after COVID-19

The transition to sustainable growth is the only credible economic strategy for China. It will involve the structural transformation of industry towards higher skills and technology, with less material input; new technologies, putting to work the extraordinary advances of recent times; re-designing energy and transport systems; much stronger investment in natural capital and infrastructure than in the past; investment in human capital, through both education and health; and strengthening community and social institutions. This transition can establish China's competitive leadership in the global economy and set an example to the world on sustainable recovery and transformational growth following the COVID-19 crisis.

The major priorities for action in the 14th Plan are described in the following sections.

Early peaking of emissions

China made historic commitments during 2020 on climate action. In September, President Xi pledged that China would reach carbon neutrality, or net-zero emissions, by 2060. In December, he further announced that China's carbon dioxide emissions would peak before 2030, rather than by 2030. This means that China's emissions will need to decline from a peak to net-zero in about 30 years, a hugely ambitious target given that many rich countries are seeking to achieve net-zero more than 40 years after their emissions peaked.

The 14th Plan will be a crucial period for China if it is to achieve the 2060 target. If China can peak its carbon dioxide emissions by the end of the 14th Plan period, at around 10 gigatonnes (Gt), it would be in a better position to reach the carbon neutrality target by 2060, not least because it would likely mean it seeks to reach net-zero from a lower peak and over a longer timescale. Early peaking could be achieved by accelerating many of the actions and investments that China will be making in order to make the transition to sustainable growth. This acceleration during the period of the 14th Plan would allow China to enjoy the economic benefits of these actions and investments earlier.

Clean energy transition

Cutting coal consumption and replacing it with cleaner energy sources have been important priorities in successive Plans since the 11th Five-Year Plan (2006–2010). President Xi has recently reiterated the importance of green development and the pressing need for a clean energy transition. China has also committed to a greening of its major multi-country infrastructure and development project, the Belt and Road Initiative. That should mean China will soon stop investing in coal-fired power plants domestically and in other countries.

If China accelerates the transition to cleaner energy, as part of a strategy for peaking greenhouse gas emissions during the 14th Plan (i.e. by 2025), it could change the world's commitment to the environment and could contribute greatly to the success of both the 15th session of the Conference of the Parties to the Convention on Biological Diversity (CBD COP15) and the 26th session of the Conference of Parties to the United Nations Framework Convention on Climate Change (COP26), both of which are due to take place in 2021.

Geographical rebalancing and the new urbanisation

In response to the slowdown of globalisation and the economic impacts of the COVID-19 pandemic, President Xi emphasised a so-called "dual circulation" strategy as a major shift away from the export-led growth of the last two decades. China now emphasises deepening the supply-side structural reform and innovative capabilities of the economy, and increasing the reliance on the domestic economy (including domestic supply chains, indigenous innovation and domestic demand) while maintaining close engagement with the global economy.

China's growth and wealth creation, which have been centred on large cities, must be adjusted to support people living in smaller towns and peripheral regions. Urbanisation – as a key driver of domestic

demand – will have to play a central role in the rebalancing towards greater reliance on the domestic economy. This rebalancing strategy can be enhanced through a shift from the export-oriented megacity 'hubs' to smaller, well-contained 'clean, compact and connected' (CCC) cities in the interior (Ahmad et al., 2020). By moving activities into the interior, China will generate employment and ensure a cleaner and healthier environment. The post-pandemic stimulus plans represent great opportunities to promote strong, dynamic and sustainable urban transitions.

Investment in technology infrastructure

China's blueprint for the so-called infrastructure development initiative could enable new drivers of economic growth. This initiative focuses on three aspects: information-based infrastructure; converged infrastructure for new digital technologies; and innovative R&D infrastructure. Some new technologies, such as hydrogen electrolysis, offer potentially huge export opportunities for China. The implementation of digital technologies across economic and social sectors can improve energy efficiency and promote a sustainable transition through systems innovations.

China's economic recovery from COVID-19 should follow a different route compared with responses to past crises. It should avoid investments in traditional infrastructure, such as coal-fired power plants and roads, and instead should focus on the technologies of the 21st century. Tilting backwards would lead to stranded assets and stranded jobs.

Local public finances and sub-national own-source revenues

Local governments in China were facing a debt spiral before the pandemic. Strong fiscal measures and reforms are needed to ensure that the stimulus and investment packages in response to the pandemic can embody and incentivise sustainability in finances, and do not lock in existing and environmentally damaging production patterns.

The central government should clarify the key responsibilities of different levels of government, including innovation zones, metropolitan areas and clean, compact and connected cities. At the same time, appropriate own-tax handles (utilising the State Taxation Administration) are critical for accountability, together with better defined financing for central objectives. There should be an improvement in the flow of information about where money is spent and the outcomes of public spending and investment design. The Government should seize the current opportunity for fiscal reforms and lay the foundation for future growth and stability, as it did in the early 1990s.

Enhancing governance to deliver strong, sustainable and inclusive growth

Administrative reform, both regionally and across government, will be required to realise the new form of sustainable growth and development. As part of the necessary reform, clarity is needed on local spending assignments, as well as on financing mechanisms and the management of associated risks and liabilities.

High-quality strategies for sustainable and resilient investment and innovation must be coherently managed across the whole of government. That means there needs to be a special role for the National Development and Reform Commission (NDRC) and the Ministry of Finance, whose responsibilities cover the whole economy, to ensure the consistency of investment strategies with sustainable growth. If sustainability is embodied in all investments, it can really drive growth. It is a positive story and goes much further than simply objecting to damaging activities, however necessary that may be.

Encouraging positive behavioural changes after the COVID-19 pandemic

The COVID-19 crisis has generated creativity and the acceleration of change. Some of the positive behavioural changes should be encouraged, expanded and promoted after the pandemic. These include: better use of urban space; investments in public transport capacity to offer an attractive substitute for private cars, and to avoid sprawl and the hollowing out of cities; reclaiming streets for pedestrians and cyclists; and reducing local air pollution. Such improvements in the quality of city life can increase wellbeing and enhance future growth by creating an attractive environment for high-skill workers.

The pandemic has helped to create markets for new technologies and to spawn new business models, such as remote offices, online education, unmanned automated services, and fresh food e-commerce. Particular attention should be paid to strengthening connected technologies and virtualisation through:

high-speed broadband; technologies for virtual learning, healthcare and security; real-time supply chain management; and improved residential energy efficiency to decrease the costs of working from home. A permanent shift in business travel patterns should also be anticipated. And we should not forget the sense of community and neighbourliness that has emerged strongly.

3. Energy transition for ensuring sustainable development

Summary of action points for the energy transition

- Move away from coal while supporting affected coal workers and communities.
- Speed up the transition to renewable energy to ensure security of energy supply.
- Drive forward power sector reforms, including better grid management and market-oriented pricing to avoid irrational prioritisation of coal-fired sources.
- Support zero-emissions vehicles to build a sustainable future for transport.

Moving away from coal

China's 2060 carbon neutrality commitment will play an important role in accelerating its low-carbon energy transition, to rapidly reduce economy-wide emissions towards net-zero. Central to any pathway to achieve this goal must be that China begins to generate most of its electricity from non-fossil-fuel sources, and then quickly expand the use of this clean power wherever possible (Mallapaty, 2020).

Crucially, this means accelerating the transition to cleaner energy and a radical turn away from coal, replacing it with clean heating sources, reducing industrial coal consumption through restructuring and technological progress, and ending the construction of coal-fired plants while promoting renewable energy generation instead. A recent study by Tsinghua University suggests China would need to transform its energy mix dramatically by boosting its share of non-fossil fuel energy to 84 per cent, and completely phasing out coal-fired plants, by 2060 (Bloomberg, 2020). This calls into question the future of dozens of power plants currently under construction or planned, which either will lock in decades of pollution and high greenhouse gas emissions or will have to become stranded assets.

In many cases, the pressure to continue with coal mining comes from local governments that are dependent on royalties from mining operations. Tackling this dependency involves the joint determination of alternative tax assignments for local governments, and tax and pricing policies. These reforms should be undertaken in tandem with decisions to stop building more coal-fired plants, while promoting renewable energy generation.

There is also an urgent need to support affected coal communities and ensure a 'just transition' for workers. That should include transparent and comprehensive policies on compensation and medical support, as well as an occupational retraining programme to help affected coal workers build a future. Jobs in coal are jobs of the past and as such are insecure. Workers in China, as in countries across the world, would benefit from their government pursuing the employment opportunities of the 21st rather than the 20th century.

Dislocation within the labour market can and should be managed. There will be short-term and localised pain from the transition away from coal, with millions of workers laid off and the economy of coal-dependent provinces hit hard. However, in the longer run, the benefits to the whole economy will outweigh the harm, as China's investments in the low-carbon transition will create opportunities for green jobs, and will contribute to long-term economic growth through lowering the cost of clean energy. It will also lead to positive 'spillover' effects in other countries (Pollitt, 2020). Globally, solar PV costs fell by 83 per cent, and wind turbine costs by 35 per cent, over the period 2010–2018. The evolution of the renewable energy sector is just one example of the dynamic increase in returns associated with disruptive technological change during the zero-carbon transition. As the costs of new technologies become competitive with those of incumbents, investment increases, further accelerating deployment and cost reductions.

The same positive feedback mechanisms can already be seen with other technologies that will be central to the zero-carbon transition, such as batteries and electric vehicles. As these kinds of self-reinforcing

cycles gain momentum, investment in supporting infrastructure and institutions also increases. This generates positive network externalities and can lead to network effects on technology adoption: the net benefits to existing users of a technology rise with the number of others using it (Katz and Shapiro, 1986).

Energy security and renewable energy

National energy security, along with the ultimate emissions reduction target, is of utmost priority for China. China's Two Sessions ("*Lianghui*") took place in May 2020, putting energy security at the top of sector priorities, to be achieved primarily by developing production, supply, storage and sales of all energy sources including coal, renewables, oil, natural gas, and electricity. There was also a focus on the need to develop reserve systems – to respond to energy sector shocks and reduce reliance on imported energy – and for better regulation of energy company operations. However, the re-emphasis on energy security has led to concerns that energy industry lobbies may seek additional support in the name of 'promoting energy security', and creating a fundamental role for coal in ensuring future power supplies (Meidan, 2020).

Ever since China became a net importer of crude oil in the 1990s, its reliance on oil supplies has surged. China currently imports around 70 per cent if its oil, despite the Government's efforts to cap this at around 62 per cent of supply (Sullivan, 2019). This proportion is expected to grow above 80 per cent by 2030 (Wang et al., 2018). Oil insecurity in China has long been recognised, and is often associated with geopolitical challenges.

China has been a net importer of natural gas since 2007 and currently imports supply 45 per cent of consumption (Sullivan, 2019). As with oil, there has also been much debate over what level of overall dependence on natural gas imports is acceptable. Given that natural gas is a cleaner energy source than coal, it has been playing a growing role in China's energy mix in recent years under the coal-to-gas switching programme. This has exposed the supply-side shortage of gas, especially at times of peak demand in the winter months. As most natural gas supplies provide residential heating in China, shortages could lead to serious consequences – in winter 2017 residential homes in northern China were left in the cold due to gas supply shortages.

Underground natural gas storage is an effective way to achieve peak load regulation. However, China's underground gas storage development is still at a relatively early stage and there are far from enough gas storage facilities. In 2018, the capacity of working gas – defined as the amount of natural gas stored underground that can be withdrawn for use – only covered 3.4 per cent of annual natural gas consumption in China, far below the international average of 10–12 per cent (Mueller et al., 2019).

Investment in non-fossil fuel technologies is the key driver for China to transform its energy sector to zero-carbon. These will include lower cost solar PV and wind power to enable greater penetration, supported by commercialised energy storage technologies. An effective energy transition also means promoting the decarbonisation of the economy through greater electrification, for example switching from fossil-fuelled vehicles to electric ones.

Compared with fossil fuels, renewable energy offers much greater security for China. However, renewables are often discussed in China as an inherent part of the power system, with emphasis placed on their contribution to employment creation rather than to energy security. In fact, renewable energy is an important part of China's energy resource endowment and a feasible solution for ensuring energy supply security while also meeting its environmental and climate performance targets.

As noted previously, renewables, including solar PV and wind power, have become highly competitive economically. In addition, energy storage costs are falling, and network management is improving. These technical advances are likely to continue. A recent study by He et al. (2020) suggests that if the cost trends for renewables continue, 62 per cent of China's electricity could come from non-fossil sources by 2030, at a cost that is 11 per cent lower than would be achieved through the current business-as-usual approach.

Some may argue that China needs to build more new coal-fired plants to ensure power grid reliability and provide the necessary flexibility as renewables increase. This suggestion does not stand up to scrutiny, as the increasing penetration by renewable energy is technically and economically feasible with

a wide range of options other than using more coal (see below). There are lessons to be learned from the UK, where renewables accounted for 37 per cent of annual electricity generation in 2019 (Department for Business, Energy and Industrial Strategy, 2020). Energy storage capacity in the UK is undergoing massive growth, which contributes to the stability of the electricity system and ensures that power grids with high levels of renewables do not suffer from system balance problems. This potential has only begun to be tapped.

Power sector reforms

China's stimulus plan, launched in early 2010 in response to the 2008 financial crisis, led to a massive surplus of high-carbon capacity. This included a huge expansion in coal mining and coal-fired power generation, which was partly driven by the devolution of approval authority for new coal-fired power plants from the central government to local governments in November 2014. In 2016, China's NDRC and National Energy Administration (NEA) started to issue a series of restrictions on coal-fired power development. These were introduced due to concerns about coal power overcapacity and a decrease in the utilisation hours of existing coal-fired plants. A 'traffic light' risk rating system was launched in January 2017 to prevent provinces with overcapacity from permitting new projects (Global Energy Monitor Wiki, n.d.; Myllyvirta et al., 2020).

However, since then, China has lowered the risk ratings for coal-power overcapacity in many parts of the country. In February 2020 the NEA released the '2023 risk alert for coal power capacity planning and construction', which gave a red rating – indicating high risk of overcapacity in coal-fired power – to just three provinces (Shanxi, Gansu and Ningxia), and relaxed the criteria for local governments to approve new coal-fired power plants in 2021–23.[3] This move was made partly because of the potential for seasonal power shortages in some regions and concerns over ensuring energy supply security. It is worth noting that demand for electricity in China is still rising, especially from the service and residential sectors, which have more variable and unpredictable consumption compared with the industrial sector. For example, China's electricity consumption surged to 6.84 trillion kWh in 2018, up 8.5 per cent from the previous year. Demand from the service and residential sectors increased 12.7 per cent and 10.4 per cent, respectively (Yang, 2019). But this increase in demand does not necessitate the construction of more coal-fired plants.

In addition to new and cleaner power supply, storage and demand-side response measures – from participants including industrial users, private users and energy storage capacities – could offer a better solution for managing peaks in demand. This can help to create a balance between demand and supply and enable flexible utilisation of electricity, which can be used to provide extra capacity for peak periods, while reducing the need to curtail renewable energy in cases of local oversupply. The development of digital technologies allows technical support for realising the potential of demand-side responses, by offering greater control and optimisation of supply. Besides demand-side response, the existing coal-fired plants can play a role in providing flexibility, without the need to build new ones (explained further below).

The management of the grid is increasingly a major barrier to the large-scale penetration of renewables in China. The running of the current grid system implies there is a limit for the share of renewables that can be absorbed by the grid: when electricity generation from renewables increases, balancing mechanisms such as storage (e.g. batteries, pump storage or hydrogen) or generation from other sources, including coal-fired power, will also need to grow, to provide the necessary flexibility to respond to the intermittency of renewable supply. This is arguably why there has been an increase in generation capacity from coal-fired plants in parallel with growing supply from renewables, to meet rising electricity demand. However, the addition of more coal capacity is far from being the only way to manage the intermittency of renewables. As we note in the following sections, the dramatic increase in new energy vehicles (NEVs) could provide part of the solution by increasing the availability of batteries to provide storage that allows the management of the intermittency of renewables.

A modern, smarter grid system is urgently needed, not only through the upgrade of the grid infrastructure but also by providing the technical guidance and standards that determine how the grid

[3] http://www.nea.gov.cn/2020-02/26/c_138820419.htm

runs. At the end of 2019, China released a new standard and technical guidance, the 'Code on Security and Stability for Power System (GB38755-2019)'. It came into force in July 2020, replacing the old standard (DL755-2001), which the grid had been following for two decades.[4] Both national guidance and local implementation are greatly needed for the management of the grid, enabling more advanced technologies and eliminating the institutional barrier to large-scale integration of renewables into the electricity market.

The electricity market itself presents another barrier. Due to the incomplete forward electricity market, China's generation dispatch is primarily determined by the annual generation planning carried out by provincial governments. They set out long-term unit commitment plans specifying for each generation unit whether it serves as the base load generator or marginal generator. Generators of the same type (e.g. coal-fired, wind, solar) are usually allocated about the same annual utilisation hours in order to guarantee an equitable opportunity for cost recovery. However, this 'fair dispatch' rule is facing an increasing challenge with the fast rate of progress of low-cost renewable sources and rapid digital transformation accelerating change in power systems. The Chinese government should push ahead with market-based economic dispatch, in a way that the generation unit with the lowest costs has priority for meeting electricity demand. This would reduce the total costs of serving consumers, and improve renewable integration by taking advantage of the near-zero marginal cost of wind and solar generators.

Sound economic and practical measures to improve electricity generation include (i) better grid management to balance demand and supply in a smarter way and to avoid the irrational prioritisation of coal-fired sources; (ii) market-oriented pricing to increase efficiency and take advantage of the nearly-zero marginal generation cost from renewable sources; and (iii) other complementary measures such as innovative ancillary service market design to elicit investment in the operational capabilities needed for renewable integration.

Digitalisation is critical for the integration of intermittent renewables by enabling grids to better match energy demand at times when electricity supply from solar PV and wind is abundant, and to support demand response programmes in buildings, industry and transport. Investments in the development of digital transformation strategies will be important to promote the clean energy transition. Carbon taxation could play a role too, by creating appropriate incentives, overcoming the market failure from greenhouse gas emissions, and generating revenue that can be used to protect poorer households and finance measures to help dislocated workers.

New energy vehicles

In the aftermath of the COVID-19 pandemic, as the inhabitants of Chinese cities have returned to work, they have been reluctant to use public transport and there has been a major shift towards private car use (as revealed by satellite images). The resultant increase in congestion, higher air pollution and additional greenhouse gas emissions mean there is an urgent need to accelerate the switch from cars with traditional internal combustion engines (ICE) powered by fossil fuels to new energy vehicles (NEVs).[5]

Globally, more than 14 countries have either proposed banning the sale of ICE passenger vehicles or mandating 100 per cent sales of zero-emissions vehicles (IEA, 2020). A growing number of countries are setting out plans to speed up the phase-out of ICE vehicles. For example, in November 2020 the UK announced its plan to accelerate the shift to electric vehicles by bringing forward the ban on the sale of new petrol and diesel vehicles from 2040 to 2030.

The NEV industry in China has undergone rapid development in recent years, as part of the Government's strategy to address the challenges of energy security and emissions. Since 2010, the Government has introduced many incentives for NEVs, including fiscal subsidies, preferential tax rates and government procurement guidelines, to reduce their cost and increase their market competitiveness compared with conventional cars.

In 2018, 1.2 million NEVs were sold in China, accounting for 56 per cent of global NEV sales (Ou et al., 2019). China is also one of the leading countries in NEV battery technologies, with the highest number of

[4] http://www.xinhuanet.com/power/2020-01/08/c_1210429744.htm

[5] New energy vehicles (NEVs) in China refer to plug-in electric vehicles, including battery electric vehicles and plug-in hybrid electric vehicles (PHEVs) (Hao et al., 2019).

patents (Naumanen et al., 2019). China's NEV subsidy policies have played a major role in creating a NEV industry cluster (Aasness and Odeck, 2015).

However, when the Chinese government accelerated the phase-out of subsidies for NEVs in early 2019, it caused the market to shrink in the second half of the year. NEV sales in China fell for five consecutive months, to 88,000 in November 2019, a 37.7 per cent decline compared with the previous year, according to data from China's Association of Automobile Manufacturers (CAAM). In response, China committed to extend its subsidy scheme for promoting the use of NEVs until the end of 2022, and to ease the speed at which subsidies are subsequently phased out.

At this critical stage when the Chinese government is considering a total phase-out of subsidies on NEVs, special attention should be paid to setting a transparent schedule of reduction to ensure continuity and consistency in policies. Although fiscal subsidies for NEVs can encourage the adoption of these vehicles and spur market sales in the early stage of promotion, as use surges it is even more important to enhance the user experience to increase their attractiveness and convenience. Although the number of NEV charging piles in service exceeded 1 million by June 2019,[6] more than in any other country, China is still struggling to build the supporting facilities to recharge its electric fleet and some charging stations operate in an inefficient way (Li et al., 2016). Subsidies are particularly crucial to avoid limitations in charging infrastructure becoming a major obstacle to further NEV adoption.

As more and more NEVs are being used, there will be a huge capacity from car batteries and smart charging piles available to help create flexible balancing for electricity load variation. However, a direct consequence of the increase in NEVs is the growth in the number of retired batteries. China should seek better solutions for disposing of, reusing, repurposing or recycling these batteries. Establishing a second life market for retired batteries, which allows them to be used in other applications, such as in a stationary energy storage system, could be an attractive option and would have the potential to further improve NEV adoption rates.[7]

[6] Data from National Energy Administration's China Electric Vehicle Charging Infrastructure Promotion Alliance.

[7] For more evidence on the potential profit for using second life batteries from NEVs to serve as energy storage systems, see Wu et al. (2020).

4. New urbanisation as a major driver of low-carbon economic growth

Summary of action points for new urbanisation

- Accelerate a 'rebalancing' that shifts activities from coastal megacities to clean, compact and connected (CCC) cities in the interior.
- Design clean and efficient buildings and infrastructure in CCC cities and adopt digital technologies to promote improvements in energy efficiency.
- Ensure health and education services are more evenly distributed, including sufficient availability within CCC cities, to enhance the attractiveness of China's interior.
- Transform already developed areas, e.g. limiting congestion by improving cycling and pedestrian facilities, retrofitting buildings, and creating high-tech innovation zones.

Old drivers of urbanisation are no longer sustainable

In parallel with industrialisation, urbanisation has been the central driver of China's rapid economic growth in recent decades. China's phenomenal export-led growth performance has been based on the development of coastal 'hubs', leading to a transformation of the whole country from a traditional agrarian society into one that is modern and urban (Stern and Qi, 2020). Urbanisation has brought new jobs, enhanced livelihoods, and enabled the modernisation of education and healthcare for most of the population.

But cities are now facing great challenges, including environmental pollution due to a concentration of industrial production; income and wealth inequality within and between different regions; traffic congestion; and shortcomings in education, healthcare and social support, as more people are moving to cities and the population ages. This is partly a result of China's prior emphasis on developing the coastal megacities, and there is an urgent need to transform its established urban areas and steer urbanisation towards sustainable hubs in its interior, which have yet to benefit from the degree of wealth creation experienced in urban regions along the coast (Ahmad and Colenbrander, 2020).

The old drivers of urbanisation are losing momentum, as the industrialisation model of polluting, energy-intensive and high-carbon growth can no longer meet the requirements for building a strong, sustainable and resilient economy (Qi et al., 2020). In the past, access to raw materials or ports was important but in a maturing economy skilled workers are likely to matter more for a city's prosperity (Glaeser and Gottlieb, 2008).

The growth benefits experienced by Chinese cities have resulted from agglomeration economies where the clustering of people generates higher productivity and higher wages (Stern and Zenghelis, 2018). A mix of specialisation and diversity drives a fertile environment for innovation in ideas, technologies and processes, while also generating pools of skilled labour and infrastructure for more efficient use of resources (Glaeser and Gottlieb, 2009). But COVID-19 and the threat of other pandemics could undermine these gains by encouraging policies to limit direct social and economic interaction.

The COVID-19 pandemic has also raised questions around modern urban design. High-rise and densely populated buildings may induce conditions favourable for disease transmission through air-conditioning and ventilation systems, sewage systems, high-use common spaces, and, especially, lifts/elevators. However, this does not necessarily mean that the transmission and impacts of COVID-19 are worse in densely-populated metropolitan areas, as these areas may offer better access to healthcare facilities and allow for more effective implementation of social distancing practices than less densely populated areas (Hamidi et al., 2020). Most importantly, proper urban planning and management are needed to ensure

densely-populated areas are well located and coordinated with services.[8] The use of mass public transport systems, including metros and bus rapid transit (BRT) systems, may also play a role in the spread of respiratory infectious diseases, although their impact on the progression of the COVID-19 pandemic is still under debate.

There are significant policy and investment challenges in combining the many advantages of high-density living and working in functioning, efficient and attractive cities, with the successful management of the risks of infectious diseases.

New urbanisation and clean, compact and connected cities

While China has taken serious action in recent years to address environmental and climate challenges, the rapid development of new technologies and the lessons from the pandemic add fresh urgency to the need to adopt sustainable urban development. This involves accelerating structural measures for a 'rebalancing' that shifts activities from coastal metropolitan areas to clean, compact and connected (CCC) cities in the interior, while also transforming already developed areas (Ahmad et al., 2020). This rebalancing strategy, in line with the new 'Go West' development plan announced during the 2020 National People's Congress (NPC) (Tang, 2020), can facilitate a transition from exports to domestic consumption, along with a higher-tech, more service-orientated and cleaner economy to accelerate the realisation of an 'eco-civilisation'.

CCC cities can play a central role in generating investment and employment opportunities in both the short and longer terms, including for migrant workers stranded in the interior of the country. They can also help create a cleaner and healthier environment through a sustainable urban transformation embodied by this structural change.

It is easier to design clean and efficient buildings and infrastructure in more manageable county-sized sub-jurisdictions and CCC cities than in the large conurbations. Better urban design and development also means reducing fossil-fuel use, water use and waste production through greater adoption of renewables, recycling and efficiency in public infrastructure. Congestion can be cut in cities and regional integration can be increased by investments in green mobility systems (e.g. electric vehicles), public transport and improvements in links between cities. Functionally and socially mixed neighbourhoods with accessible green spaces, comfortable, affordable, climate-smart housing for all, and efficient public transport networks, could both protect natural capital and provide a basis for higher quality, stronger and more sustainable economic growth.

Urban areas consume 80 per cent of energy worldwide, with buildings accounting for almost half the total (Qi et al., 2020). This means it is important to implement best practice in energy and resource conservation in new buildings. The careful planning of compact, connected and coordinated use of land in cities can unlock the power of urban areas to deliver clean economic development and avoid sprawl and the hollowing out of city centres. With many existing buildings in China's cities likely to be operational for decades to come, a priority area for investment therefore should be retrofits to improve energy efficiency in both electricity and heating.

Investment in urban trees and woodland promotes outdoor recreation, with positive effects on physical and mental health, reducing burdens on health systems and cutting the number of working days missed, while increasing the returns to residential investment. Trees also help to absorb harmful particulate pollution and to lower carbon emissions, increase water retention, and provide cooling and shading services. COVID-19 has highlighted the urgent need to strengthen the quality and resilience of natural assets in cities and beyond.

Technological innovation should be a major driver for both creating sustainable growth and tackling climate change. Digital technologies should be incorporated more rapidly into buildings. For example, upgrading existing electricity meters to smart displays can help optimise energy utilisation patterns and promote energy saving. Use of digital technologies connected with related IT infrastructure, including 5G stations, big data centres, AI and the Industrial Internet of Things, can effectively promote massive

[8] For more context on the ongoing debate around whether density contributes to the current pandemic transmission, see, for example, Fang and Wahba (2020) and (Hsu, 2020).

energy efficiency improvements in all the major sectors of manufacturing and services. Integrated technological systems, including high speed trains, inter-city transit, and energy-efficient buildings combined with renewable energy sources, electric vehicles, charging stations and smart grids, can help put China on a sustainable growth path, while accelerating the transition towards a low-carbon economy.

Moderating or reversing the current migratory trends towards the existing coastal megacities requires investment to enhance the attractiveness of remaining in the interior regions. This investment should not only be in physical capital, but also in human and social capital and services, particularly to ensure that health and education are more evenly distributed within CCC cities and across the country. The tremendous technological advances made by China through e-commerce, information technology and big data could also benefit the evolution of interior CCC cities, persuading private firms to relocate closer to population centres and to bring supply chains nearer to where demand is generated. The provision of basic services to attract workers and households will be critical.

A focus on CCCs could also facilitate a more radical sustainable urban transformation of the existing megacities too. This would include measures to limit congestion by improving facilities for cycling and pedestrians, retrofitting buildings to make them more energy-efficient and climate-resilient, and upgrading fossil-fuel-based infrastructure to become low-carbon. It would also mean fiscal transformation, and improved governance with monitoring and accountability at its core, to enable these changes in megacities. The transformation of the existing megacities can also be promoted by the creation of high-tech innovation zones, with the development of IT infrastructure, high-skill research centres and top universities and financial sectors, in the drive to sustainable and strong growth (for example, the Yangtze River Delta and Greater Bay Area programmes).

China needs to continue to invest in urban infrastructure as part of its rebalancing towards interior CCC cities, as well as the transformation of the megacities in light of COVID-19. The choices made in transport, infrastructure, buildings and industry, in cities today as they continue to grow, will determine, via the technology and way of life they engender, whether humankind can both manage climate change and capture the benefits of low-carbon growth over the coming decades. This investment in a new type of urbanisation could be a major driver of, and requirement for, sustainable, resilient and inclusive economic growth.

5. Investment for ensuring a post-pandemic recovery

Summary of action points for well-planned investment

- Invest in the four types of capital (i.e. physical, human, natural and social capital) to promote a strong, sustainable, inclusive and resilient recovery.
- Invest in infrastructure and technologies that promote energy transition and new urbanisation.
- Bring forward the peak in China's greenhouse gas emissions to no later than 2025, and within the 14th Five-Year Plan period, to ensure the carbon neutrality target of 2060 can be achieved and influence other countries to increase their commitments.

The shock of COVID-19

Compared with the global financial crisis of 2008–10, the COVID-19 pandemic has already had both deeper and broader economic impacts, alongside the tragic direct health consequences. Due to the nationwide lockdown and closure of businesses and premises when COVID-19 first emerged, China's economy shrunk by 6.8 per cent in the first quarter of 2020, marking the first contraction since the end of the Cultural Revolution in 1976. It then bounced back to growth in the next three quarters as the lockdown was lifted. The annual growth rate for 2020 was 2.3 per cent, still far below its previous assumed trend (National Bureau of Statistics of China, 2021).

Moreover, this is a truly global crisis, with worldwide collapses in both output and demand. At the time of writing – January 2021 – most countries are still responding to the health emergency and protecting the vulnerable, while implementing measures for rescue and recovery of the economy. Only China among the G20 nations is expected to have experienced annual growth of the economy in 2020 (IMF, 2021a). As China continues to lead the world out of the recession, it is in a position to lead the vision and strategy for investments and policies to drive a strong and sustainable recovery. While the rescue phase has been focused on protecting as many jobs as possible, policymaking for the recovery should seize this opportunity to 'build back better' by creating strong, inclusive and resilient growth that offers high-quality employment opportunities and the jobs of the future. This would enable China's workers to competitively participate and thrive in the new economy, offering much more security than would result from focusing on the preservation of the jobs of the past.

Investment in the four types of capital

Hepburn and Stern (2018) have set out a new sustainable growth strategy for China in broad terms. Within the context of that growth strategy, Stern, Xie and Zenghelis (2020) have examined the complementary nature of the four types of capital – physical, human, natural and social – and their role in China's new phase of development. Although the pandemic has changed the situation in many important ways, inside and outside China, the fundamentals of the medium- to long-term analyses of these papers have not changed: i.e. that the relevance of the old economic model with a narrow focus on physical capital has come to an end and a new, high-quality growth model driven by innovations and investment in the four types of capital is the only path to long-term prosperity. However, the short term is very different due to the health, economic and social effects caused by COVID-19, and it will be important to integrate, both in China and the world, the recovery from the pandemic with the transformation of the economy in the medium to long term. This means the transition to a low- and zero-carbon world and a revolution in digital technologies.

China's recent commitment to a net-zero emissions trajectory will also be critical to its economic and environmental wellbeing in the coming years, including not only sustainable growth but also clean cities where citizens can move and breathe and ecosystems that are robust and fruitful. While physical capital has been central to China's economy over the past few decades, recently there has been a deepening of

the understanding that low-quality and polluting physical capital can damage other types of capital, leading to a form of economic development that is unsustainable.

The Chinese government has made clear that investing in natural capital and social capital is an important part of its strategy in the next phase of development. China has already recognised how essential natural capital is through an emphasis on the framework of 'eco-civilisation'. It has started to take action to conserve biodiversity and ecosystem services, and to fight against air, water and land pollution. Examples include: (i) the near-term clean air targets delineated in the *Three-Year Action Plan to Win the Blue-Sky Defense War* and long-term clean air targets that are in line with the WHO air quality standard in its major cities (UNEP, 2019); (ii) the launch of the 'Sponge City Program' (SCP) in 2015, which aims to manage urban storm water and is seen as a breakthrough of planning in urban water resilience and sustainability (Ma et al., 2020); and (iii) China's soil pollution action plan initiated in 2016, which aims to bring 90 per cent of polluted land safely into reuse by 2020 and to continue to improve soil quality with 95 per cent of contaminated land being available for reuse by 2030 (Li et al., 2019). China has also introduced ambitious reforestation programmes, such as the 'Great Green Wall', to fight desertification and increase its forest cover. And, of course, it is moving to curb carbon dioxide emissions and become carbon-neutral by 2060.

China recognises the importance of social capital and a cohesive society, tackling inequality and taking action to promote good governance. China has long invested, through health and education, in the human capital of its people, although there is a need for further investment, especially in rural areas.

Following through with these policies and investments would offer returns that could be very large for China. There is convincing evidence that stimulus plans can deliver both economic and climate goals. Projects that cut greenhouse gas emissions as well as stimulating economic growth can deliver higher returns from government spending, in the short and long term, than more conventional stimulus spending (Hepburn et al., 2020). Many sustainable projects and programmes can be implemented quickly, are labour-intensive and create strong economic multipliers. This can foster a transition from a strong recovery from COVID-19 into sustainable, resilient and inclusive economic growth. It can also crowd in long-term capacity by stimulating investment in complementary productive assets (Zenghelis et al., 2020).

Investment in infrastructure and technologies that promote the energy transition and new urbanisation

Tong et al. (2019) estimated that, as of 2018, the world's existing CO_2-emitting energy infrastructure has grown to US$22 trillion in economic value. By the time of its retirement, this infrastructure will have been responsible for cumulative emissions of 658 Gt of CO_2 – that is 19 times the global CO_2 emissions of 2019 – with more than half coming from the power sector. That amount could rise to 846 Gt CO_2 if all proposed power plants around the world are built. Although it accounts for less than 25 per cent of the estimated economic value (roughly US$5 trillion), power and industry infrastructure represent more than 75 per cent of total committed emissions (519 Gt). Tong et al. also concluded that the power and industry sectors in China represent especially prime targets for unlocking future emissions – Chinese infrastructure is associated with 46 per cent of these sectors' global committed emissions.

This highlights the urgent need for China to stop building more coal-fired plants. Instead it should redirect investment into low-carbon and resilient infrastructure and technologies to promote an energy transition towards more renewables, and build more productive, more attractive and healthier cities.

The investment in greening the power sector is of great significance to China and to the world. It needs to include energy saving through increasing the efficiency of electricity generation, and switching to cleaner sources, including from coal to gas but also to non-fossil fuels, to reduce emissions per unit of electricity generated. It should also invest in carbon removal technologies (e.g. carbon capture and storage [CCS]) and nature-based solutions to increase carbon sinks. As discussed in Section 4, investment in digital technologies and related IT infrastructure is critical for promoting massive energy efficiency improvements across all major sectors.

Investment in clean technologies is undoubtedly the key driver for China's shift to a strong low-carbon transition pathway. The share of non-fossil fuels in China's national energy mix rose to 15.3 per cent in

2019, achieving its target ahead of schedule. According to the NEA, China had 204.7 GW in installed solar photovoltaic (PV) power generation capacity at the end of 2019, a significant increase on the 0.02 GW 10 years earlier; similarly, the total installed capacity of wind power generation increased from 16.1 GW in 2009 to 210.1 GW in 2019. Robust future growth in renewables is anticipated; China has become the world's largest producers of solar cells, surpassing Europe and Japan (Shuai et al., 2018). China should continue its investment in developing stronger solar PV and wind power industries, and encourage more technological innovation to further enhance the international competitiveness of its products. The job creation rate of these industries is between 1.5 and three times that of traditional energy industries, according to Varro and Fengquan (2020).

As discussed in previous sections, investment in an improved kind of urbanisation can deliver great benefits in terms of sustainability and resilience. It can also result in more attractive cities with functionally and socially mixed neighbourhoods, strong public services and efficient public transport networks (Stern and Zenghelis, 2018). Sustainable urban development would offer China a much more attractive future than the urban sprawl that is developing in many cities (see also Coalition for Urban Transitions, 2019). Investment in integrated technological systems can boost sustainable growth by creating new kinds of jobs, while accelerating the transition towards carbon neutrality. For example, investments in the creation of a flexible electricity supply to residential and office buildings, based on a direct current (DC) distribution network, can enable their effective combination with renewable power generation, electric vehicles, charging stations and smart grids, and promote cross-sector decarbonisation.

6. Closing remarks

To limit the human and economic impacts of the COVID-19 pandemic, governments must take visionary and decisive action to turn the crisis into an opportunity for transformation. A strategic long-term vision that supports the commitment of 'building back better' is needed to avoid reverting towards the old dirty technologies of the 20th century. Hesitation and inaction on sustainability could push the world towards catastrophic climate change.

Due to its size and growth momentum, China's role in world demand is fundamental. During the financial crisis of 2008–10, China's soaring demand boosted growth worldwide and drove a global economic recovery. Now, in contrast to recovery from previous crises, China will likely increase demand through a balanced combination of consumption and investment rather than a strong and narrow focus on infrastructure. China's leadership in the COVID-19 recovery phase is crucial for the country and for the world.

There is a critical need for a path out of the current global economic crisis that is focused on investment in the sustainable products, technologies and activities of the future. China's future development, wellbeing and quality of life will depend critically on the four complementary types of capital. China is creating its 14th Five-Year Plan, for the years 2021–25, in the aftermath of the pandemic – the actions it commits to are critical to how the world moves forward and can establish China as the global leader for the 21st century.

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