White Paper

Major Green Technologies and Implementation Mechanisms in Chinese Cities

Prepared in support of Special Policy Study 3.2 for the China Council for International Cooperation on Environment and Development (CCICED)

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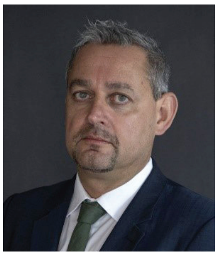

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The last decade was the first in history where more people lived in cities than in rural areas. The coming decades will see this trend continue and, by 2050, the UN predicts that more than two-thirds of the world's population will live in cities.[1] Cities are also economic powerhouses; they cover 2% of the world's surface, but drive 80% of its economic output.[2] Cities also consume the majority of global food production and, by 2050, will consume 80% of all food produced, meaning that a large percentage of rural economic activity is also connected to cities.[3]

The last decade was also the first where the majority of the Chinese population lived in cities. China has seen incredibly fast urbanization over the previous four decades with its urbanization rate rising from 17.92% to 60.6%. This trend is predicted to continue as China's urban population grows from 848.43 million at the end of 2019 to 1 billion, or 70% of the population, by 2035.[4,5]

As the world continues to urbanize over the coming decades, cities will face a number of challenges. Drastic action will have to be taken to avoid a global climate breakdown. Cities account for 64% of global primary energy use and produce 70% of the planet's carbon dioxide emissions, and will be on the front line of delivery of the Paris Agreement, SDGs and the building of an ecological civilization.[6] The cities network, C40, predicts that to avoid climate breakdown, emissions from global urban consumption must peak by 2020 and halve by as early as 2030.[7]

Cities are uniquely vulnerable to the effects of climate change: 15 of the world's 20 megacities are located in coastal zones threatened by sea-level rise and storm surges. An increase of extreme weather events from typhoons to heatwaves necessitates a strong focus on urban resilience.[8]

The devastating impact of COVID-19 has also reinforced the importance of health in cities, on which issues such as urban design, architecture and air pollution all have a strong effect. For example, cities that encourage walking and have lower air pollution levels can lower the rate of non-communicable diseases, which can cause underlying health conditions and put strain on medical systems.

Meanwhile, the continuing pace of technological change is faster than ever before. The Founder and Executive Chairman of the World Economic Forum, Klaus Schwab, has termed this technological change the "Fourth Industrial Revolution" and describes it as being "characterized by a range of new technologies that are fusing the physical, digital and biological world."[9]

As this report demonstrates, this rapid pace of technological innovation and deployment can help cities undertake the massive transformation required to become green cities. However, it needs to be harnessed in the right way. Policy-makers and other stakeholders need to work together to implement programmes and structures that will allow technology to serve the city for good rather than allowing urban development to be a servant of technology.

For example, in the case of automobile, the technology brought mobility to millions but resulted in the unintended consequence of urban sprawl and air pollution.[10] As we embrace technologies of the future, there is a need for a systemic view of the impact of new technologies so that they can be harnessed with intention and for the greater good of citizens.

Also shown in this report, the transformation of the city does not rely on one technology alone but on clusters of complementary technologies working together in a system. For example, on its own, solar power is an important technology. However, when it is combined with wind power to generate more power – in winter when winds are higher and there is less sun; long- and short-term energy storage to even out daily or seasonal variability in supply; ultra-high voltage energy transmission (UHV) to transfer power from high-generation areas to urban centres; and a smart grid that can balance supply and demand in the most effective way – it becomes a powerful system of technologies or an integrated green energy grid.

Consequentially, city leaders need to think about the urban technological transformation in terms of a system rather than a series of isolated issues or isolated technology solutions. Topics such as the circular economy, the Fourth Industrial Revolution, data governance and gender inclusion cut across all areas of urban technology development, either as a systematic approach or a vital enabler.

Most importantly, to achieve President Xi Jinping's vision for building an ecological civilization where "clear waters and green mountains are as valuable as mountains of gold and silver" requires Chinese cities to take actions immediately and for all stakeholders to work together to create an enabling environment for scaling-up green technologies.

Preface

This study is prepared by the World Economic Forum to support the China Council for International Cooperation on Environment and Development (CCICED) Special Policy Study 3.2 on Major Green Technology Innovation and Implementation Mechanisms. The study brought together a leading group of experts to select a series of technologies in the areas of energy, building, mobility, land use, food and water, which can have an impact on the greening of cities in China and throughout the world.

The study also worked with the same group to provide policy recommendations to China's State Council via the CCICED on the development and scaling-up of green technologies during the 14th Five-Year Plan. These recommendations and many of the findings of this report are reflected in the official SPS submission, authored jointly by the China Academy of Urban Planning and Design and the World Economic Forum and available on the CCICED website, which was submitted to China's State Council. This is not the final joint report submitted to CCICED on behalf of SPS and does not necessarily reflect the views of the CCICED.

This study follows a brief from the CCICED chief advisors to look for technologies that have the potential to scale within the time frame of the next Five-Year Plan, hence many of the technologies included have already reached some level of maturity. The report does not focus exclusively on particular technologies but also on groups of technologies that can work together in consort, or even standards and concepts that can support or are supported by technology; these could alternatively be conceived as urban innovations.

For each technology there is a description of the innovation in question; an overview of the context or challenges in China that the technology could help to alleviate; a description of the impact the technology could have; and the barriers that could stop it from scaling. This format allowed prioritization and practical recommendations on how to overcome key barriers, which, in turn, helped craft the policy recommendations for the State Council.

Section 1: Policy recommendations

The below recommendations are submitted to the China Council for International Cooperation on Environment and Development (CCICED) by the World Economic Forum on behalf of the international experts making up the membership of SPS 3.2.

In response to China's established vision of an ecological civilization as a basic strategy guiding its future development, these recommendations aim to support greater efforts to strengthen the people-centric development goals that promote eco-sustainability, resilience, equity and quality of life in Chinese cities; while also helping balance the Chinese economy towards high-quality growth, particularly through investment in new infrastructure and green technology.

1. **Create guidance for city- and building-level design**

Implement transit-oriented development in Chinese cities to accommodate for future urbanization. For new development, set and promote a standard for green buildings based on the best international practices.

1.1. **City level:** To cope with continued urbanization, cities should plan for the majority of new buildings to be built within clearly demarcated city boundaries, densifying urban areas along existing transport routes or redeveloping brownfield sites. When this is not possible, planners should allow the city to expand along transit corridors, planning for high-density, mixed-use neighbourhoods. The densification of cities should be human-centred, leaving green spaces intact. Pedestrian and bicycle routes should be improved and better connected in order to prioritize non-motorized transport.

1.2. **Building level:** Set and promote a standard for green, net-zero energy, healthy buildings in China that takes into account the various available standards (LEED, WELL, China Green Building Assessment Standard 2019 etc.) and different local climatic factors, and applies to residential and commercial buildings. Green buildings should incorporate several technologies, including passive architectural design that is adapted to the site and climate; optimal energy management of supply matching demand; and use of only renewable energy. There is a need to better train building managers to maintain building efficiency and in the future augment and assist their work through the use of artificial intelligence (AI).

2. **Invest in new (urban) infrastructure**

Continue with the New Infrastructure plan to help stimulate the economy post COVID-19. Add three key urban green technologies to the list of new infrastructure investments: building-integrated photovoltaic (BIPV), water treatment technology and energy storage, with ambitious targets for each. In order to build an integrated green energy grid (IGEG), double annual investment in wind, solar and energy storage.

In March 2020, the Politburo Standing Committee announced the acceleration of the construction of "New Infrastructure". This includes technologies mentioned in SPS 3.2 such as AI, 5G, new energy vehicle-charging infrastructure, internet of things (IoT)/big data, and urban transport. These technologies underpin technology-enabled green urbanization in Chinese cities and are rightly a core part of the post-COVID-19 stimulus and should be prioritized in the 14th Five-Year Plan.

In addition to the technologies, three other infrastructure technologies should be added to the plan: BIPV, water treatment technology and energy storage capacity:

2.1. **Building-integrated photovoltaic (BIPV):** China has a significant opportunity to become the global leader in this technology leveraging the existing PV industry and high rate of construction. The 14th Five-Year Plan could set ambitious targets for BIPV as well as implementing policies that help the growth of the PV industry such as subsidies, tax incentives and policies that would build the size of the domestic market by incentivizing greater adoption of BIPV in construction through building codes and targets or lower the initial cost of installation with innovative financial products.

There is also a need for active engagement with developers and architects to demonstrate the positive economics and aesthetics of modern BIPV. The 13th Five-Year Plan set a target for greening 50% of new buildings; it is recommended that, in the 14th Five-Year Plan, there should accordingly be a target of **the integration of BIPV in 50% of new urban construction with a particular focus on high-rise commercial and residential buildings.**

2.2. **Water treatment technology:** Recognize water as the most important recyclable resource in cities by increasing investment in wastewater treatment, including wastewater management, treatment and recycling. **Establish targets, standards and procedures for sludge treatment and disposal for the 14th Five-Year Plan, encouraging a circular economy approach** that maximizes the potential of wastewater as an important resource, by recycling the water and phosphorous; while harvesting energy from the sludge. Quality can be assured by smart technologies for water quality monitoring across piped and natural water systems.

2.3. **Energy storage capacity:** The most important action to green cities is the building of an Integrated green energy grid (IGEG). This is a cluster of technologies that include solar, wind, high voltage transmission and storage, supported by a smart grid or internet of energy. While solar and wind have reached maturity, the vital yet underdeveloped element of the IGEG is greater energy storage capacity, including lithium-ion (li-ion) batteries, which will facilitate all of the IGEG technologies. China is already a leader in li-ion technology but further investment at this critical stage of development could bring down costs significantly, allowing mass deployment of the technology in China and globally. It would also build a significant industry, which would be a pillar of the post COVID-19 economic recovery. It is recommended that, in the next **14th Five-Year Plan, China doubles its annual newly installed battery energy storage capacity as well as making it a significant focus of the New Infrastructure investment plan.**

In addition to adding these three new technologies to the list, it is suggested that China cements its lead as the world's largest investor in green power during the 14th Five-Year Plan and further develops the IGEG by setting a target to **double annual newly installed solar and wind capacity** (alongside energy storage capacity) to meet its demand for electricity without building any new unabated coal power plants. Reform in energy pricing will also help to spur the development of the IGEG.

3. **Continue to drive adoption of electric vehicles, starting with sharing fleets**

Create the infrastructure for the transition to shared, electric mobility technologies, with an initial focus on electrifying high-mileage commercial fleets and implementing transport demand management.

The New Infrastructure plan will see investments in charging infrastructure networks. These should consist of **slow, fast and rapid-charging stations.** These charging stations should form part of the IGEG and be powered by renewable energy. Electrification of vehicles should start with a phased-in electrification of **high-mileage commercial fleets**, including ride-hailing and taxi services. Shift to policy measurements that harness a transport demand management (TDM) approach by establishing zero-emission zones and road pricing at the city level.

4. **Innovation and digitalization along the food value chain**

Enable robust innovation ecosystems that can accelerate the use of digital innovation to connect the whole food value chain, improve traceability in food supply chains, and enable production and adoption of healthier, more nutritious and sustainable diets that include alternative proteins and food from indoor farming.

Digital tools can accelerate efficiencies and information flow in the food system. Benefits include shortening of the chain between farmer and consumer, reducing costs; increasing efficiency; improving resiliency of food supply chains; minimizing food loss and waste by exposing vulnerabilities and losses; and increasing food safety through better visibility into the supply chain and consumer feedback. Furthermore, these tools can also support the consumer in their choices for sustainable and healthy diets through information and by supporting new behavioural norms for the Chinese urban population.

The basic requirement for the technology is rural connectivity, the **continued expansion of broadband and mobile connectivity for rural areas should be seen as a key pillar of New Infrastructure investment**. However, connectivity alone will not drive change. There is a need to build **capacity** of farmers to use digital tools to adopt sustainable agriculture practices and optimize inputs; and connect directly with consumers to understand their needs.

Alignment and coordination across government, the private sector, research institutes, innovators, civil society and others can harness the positive impact of digital technologies to create scalable solutions, governance frameworks and incentives that form a healthy innovation ecosystem. Further, **coordination** with clearer labelling standards, dietary guidelines and increasing **investment** in research on major areas are vital, such as changing purchasing decisions, data collection and aggregation, identifying bottlenecks, and promoting research and development.

Additionally, to reach the 2016 Chinese dietary guidelines target of a 50% reduction in meat consumption by 2030, **increase investment into innovation for alternative protein production and indoor farming** – supported by digital tools to drive new consumption norms – to ensure that meat consumption is replaced by sustainable as well as healthy alternatives.

5. **Implement a systematic approach to circular, carbon neutral communities**

Unite all stakeholders, including government departments and the private sector, around clear targets and a shared roadmap for carbon-neutral, circular communities.

The key to the successful construction of **circular** and **carbon neutral communities (CNC)** lies in coordinating the number of decision-makers and stakeholders in different areas.

Achieving CNC in China requires **collaboration on land use and planning, mobility, energy, water, food and solid waste, and between public and private actors**. To reach carbon neutrality, Chinese cities and provinces should create alignment on robust, long-term targets for clean energy transition and a transition to net-zero; and define pathways for achieving zero-emissions such as zero-emissions by 2050 and interim targets for the use of renewable energy.

Similarly, the implementation of the **circular economy** will underpin green development in many sectors. A circular approach is the only way to decarbonize the construction and materials sector due to the carbon emissions embedded in materials such as steel and concrete. An increase in EVs and energy storage will require systems to recycle li-ion batteries, and standards to facilitate the repurposing of used EV batteries for grid storage.

For water resources, it is necessary to build a system of reuse and recycling, which can also be combined with food-waste composting for energy or fertilizer production. **The 14th Five-Year Plan can promote the adoption of the circular economy by expanding the zero-waste pilot cities programme and creating city-level action plans as well as ambitious targets that go beyond waste management.** Given the significance of the circular economy in building a green economy and its application to many different sectors, it could become the subject of a special policy study.

6. **Delivery mechanisms**

Three strategies that will help to implement a green transition in Chinese cities include: Pilot cities and policy sandboxes; a cross-border alliance on green technology and engagement with the public.

6.1. **Pilot cities and policy sandboxes:** During the 14th Five-Year Plan, pilot cities should be selected that can pioneer the sets of technologies recommended in this report. Cities or even Special Economic Zones could also be used as policy sandboxes where new technologies and approaches can be piloted with the private sector to inform policy-making.

6.2. **Build a cross-border alliance on green technologies and innovations** to create a platform for a community of international and domestic companies, policy-makers and experts to facilitate ongoing communication and jointly solve the challenges in Chinese cities on an ongoing basis. Continue with programmes that link sub-national actors such as California and the Pearl River Delta.

6.3. **Engage the public** using social media, top-10 reports and public information campaigns to demonstrate the importance and potential of the adoption of green technologies, including how behavioural changes can lead to better green development.

Section 2: List of green technologies

To support the green transition in Chinese cities, the World Economic Forum worked with a group of global experts on urban development and technology. This group of experts selected the following list of technologies as the innovations that could have the greatest impact on greening Chinese cities in six pillars: energy, buildings, mobility, land use and planning, food and water.

Pillar 1: Energy

Officially, China targets to peak in CO_2 emissions by 2030. However, experts have said that this milestone could be reached as early as 2022.[11] China produced 9.2 billion tonnes of CO_2 in 2017 with 46% of this coming from the production of energy and heat. China has significantly reduced the CO_2 intensity of its economy, and CO_2 emissions per unit of GDP decreased from 2.5 in 1990 to 1.0 in 2017 and this trend is continuing.[12]

However, to keep in line with the Paris targets, there will need to be a large-scale decrease in carbon emissions led by the energy sector. China has invested large amounts in the development and deployment of renewable energy. However, in continuing to decarbonize the energy sector, there is an opportunity to scale up and complement this capacity with a systemic implementation of new energy technologies that can create a future-proof smart grid based on clean energy and supplemented by zero-emissions heating and cooling.

Tech 1: Integrated green energy grid

Description: An integrated green energy grid (IGEG) is a set of technologies, which when deployed together, can drastically reduce CO_2 emissions from the energy sector while maintaining a stable and affordable supply of electricity. The technologies are solar photovoltaic, onshore and offshore wind, energy storage, and UHV.

Using these technologies in conjunction takes advantage of seasonal changes, using abundant wind energy in the winter and solar in the summer to cover heating and cooling demand peaks, respectively, using short-term battery storage to account for variable supply and longer-term storage such as hydrogen, or pumped hydro for times of high supply and lower demand. Integration of UHV can transmit clean energy from areas of high renewable generation capacity, such as deserts, to areas of high demand, such as major cities.

Wind and solar power are considered mature technologies, as the costs of these technologies have declined rapidly in the recent years. In many parts of the world, these have become the most economic ways of meeting electricity demand.[13] Utility-scale battery storage systems will play a key role in facilitating the next stage of the energy transition by enabling greater shares of wind and solar generation; however, this technology has not yet reached the same scale of maturity and deployment as wind and solar.

Target problems: In 2017, 46% of China's carbon emissions came from the production of electricity and heat.[14] The only way to decarbonize this sector is through a transition towards an IGEG, which fully leverages energy sources such as solar and wind and avoids voltage fluctuations and supply shortages.[15]

Impact: In 2019, China generated 224.3 TWh[16] solar electricity, which is nine times that in 2014, avoiding 69 million tons of CO_2.[17] Meanwhile, wind power generation in China reached 405.7 TWh in 2019, avoiding 124 million tons of CO_2.[18, 19]

China's goal of significantly reducing and eventually completely retiring all its coal generation capacity can be reached by adding 50-70 GW/year of solar capacity, 14 GW/year of four-hour and six-hour battery storage capacity, 55-75 GW/year of onshore wind capacity and 9 GW/year of offshore wind capacity from 2020 to 2025; and 80-127 GW/year of solar capacity, 55-89 GW/year of four-hour and six-hour battery storage capacity, 47-80 GW/year of onshore wind capacity and 30-50 GW/year of offshore wind capacity from 2025 to 2040.[20]

Energy storage capacity can be seen as the missing link in the IGEG. It would reduce the amount of coal used to produce energy, in particular during peak demand days, increasing system reliability. In addition to that, energy storage adds flexibility to the grid, preventing energy wastage.[21] Often, surplus energy is lost because of the inability of grids to handle or properly store it.[22] In Alaska, an additional wind integration of 8 million kWh was secured through the installation of a 3 MW lead-acid battery storage system with a 4.5 MW wind power.[23]

Barriers: Both wind and solar technologies are proven, and near grid parity with coal power; and storage technologies, such as lithium-ion batteries, are expected to show at least a 50% decrease in costs due to mass manufacturing by 2030 as compared to 2016.[24] Other types of storage, such as hydrogen-based storage technologies, will require further investment to become commercially viable. Investments will also be required in smart electricity networks to integrate a high penetration of wind and solar (see Tech 2: Internet of energy).

As more wind, solar and storage technologies are deployed, new policies are needed to encourage increasing efficiency and flexibility of the overall system. Policies will also be required to develop a power market (and associated institutions), designed around low marginal cost generation, flexibility and ambitious carbon targets.[25]

Energy transition risk must be considered and can be represented by potential job and capital losses by owners of and workers in coal power plants. Such potentially large unemployment numbers could be mitigated by social welfare and retraining/up-skilling programmes managed at the local and national level. Investors may also be offered compensation to decommission polluting plants earlier than planned, as well as incentives to enter profit-making, environmentally friendlier projects.

Policies for the recycling and final disposal of batteries will be an important element that needs to be addressed to foster the deployment of chemical energy storage. Using a circular economy approach, used li-ion car batteries can be repurposed into use in the grid and then recycled after final use. The Chinese company GEM Recycling produces more than 3,000 tonnes of cobalt from recycled batteries per year. Currently, only 10% of batteries are collected by formal recyclers such as GEM. Increases in this rate and targets for the percentage of recycled materials in new batteries could aid the move to a circular economy for batteries.[26]

Other pillars: Buildings and mobility: Buildings and the construction sector represent 36%,[27] and transport represents about 28%[28] of final energy use, respectively. The accelerated electrification of buildings and transport can be powered by clean, renewable energy and storage.

Example: Policies to encourage the development of the IGEG

In 2018, the US Federal Energy Regulatory Commission (FERC) approved the FERC Order 481, a rule to encourage the development of energy storage. The FERC Order 841 enables energy storage resources to compete in wholesale power markets and removes barriers to participate in capacity, energy and ancillary services markets.[29]

In 2019, the EU Commission proposed a revised electricity market directive to set up a new market design providing technical and market conditions for energy storage, which included the introduction of smart grids and smart meters.[30] In addition to that, when planning for network development, transmission system operators must consider energy storage as an alternative to the expansion of the network.[31]

In early 2017, IKEA purchased its second wind farm in North America, reaching almost 400 MW of wind energy assets' direct ownership for self-generation.[32] An increasing number of Chinese and international companies operating in China are committing to sourcing up to 100% renewable energy for their operations. Cooperation with local government and grid operators could allow these companies to more easily directly purchase renewable energy from generators.

In Scotland, the $14.8 million Transition Training Fund was created to fund training programmes for workers affected by the downturn in the oil and gas sector. Trainees were prepared to work in industries focused on renewables and low-carbon technologies and, after the completion of the programme, were supported to secure employment. This way, the oil and gas workforce was provided the tools to target new roles in the wind energy sector.[33]

The European Green New Deal[34] calls for a 50% increase to the EU 2030 Climate target[35] and plans to make Europe the first climate-neutral continent by 2050. With the target "to leave no one behind", the European Green New Deal also proposes a Just Transition Mechanism to support the most vulnerable in different regions and sectors during the green transition, with a €7.5 billion ($8.4 billion) Just Transition Fund[36] under construction.

Example: Climate Change Act, United Kingdom[37]

Context: In 2008, UK institutions set goals to reduce greenhouse gas (GHG) emissions by 80% before 2050 (against a 1990 baseline) and to supply energy in an affordable and secure way. Battery storage benefited from the policies favouring renewable energy sources.

Actions taken to reach the goal:

- Feed-in tariff system (payments to households that produce their own electricity using renewable technologies) with fixed rates for plants with capacities below 5 MW
- A quota system for suppliers above 5 MW capacity that obliges them to supply a proportion of renewables from their total supply
- Taxation on fossil fuels for commercial and industrial users
- The Smart Network Storage project has £18.7 million ($23.43 million) in funding with the final goal of storing energy generated by renewable sources to help supply the distribution network at peak times
- Capacity subsidies through the Enhanced Frequency Response service, which has the goal of achieving 100% active power output after maximum one second from registering a deviation in frequency

As of today, research shows that, during the past decade, there has been a growth in UK energy storage projects.[38]

Tech 2: Internet of energy (IoE)

Description: The "internet of energy" is a broad category of technologies applying IoT technology and processes to the energy sector to balance electricity supply and demand in the most cost-effective way (including increasing efficiency and reduce waste). Examples include smart metering, remote control and automation systems, smart sensors, demand response systems, optimization and aggregation platforms, smart appliances and devices etc.

Target problems: The conventional electricity system structure was designed around a limited number of large-scale centralized generation assets connected to a grid that carried electricity in one direction, to customers, and divided the one-way flow of power into siloes of various roles across the value chain.

With distributed generation, distribution grids become active and see power flowing in both directions, with a higher number of active customers to manage. With more dynamic pricing information and two-way information flows, customer loads could also be modified to achieve better balance of supply and demand (demand-response programmes).

Impact: The electricity system is in the midst of a transformation, as technology and innovation disrupt traditional utility models from centralized grids to distributed micro-grids. Customers have the opportunity to be active elements of the system and this requires significant coordination. Digitalization enables more control, including automatic, real-time optimization of consumption and production and interaction with customers.

Research indicates that utilizing advanced flexibility measures such as demand-side responses and electricity storage could reduce the power system operational costs between 2-11% and the need for fossil generation capacity by up to 30%.[39] A smarter, more decentralized, yet more connected electricity system could increase reliability, security, environmental sustainability, asset utilization and open new opportunities for services and business.

Barriers:

Technical: The introduction of digital technologies has amplified the level of interconnectivity and introduced an additional dimension of risk that all organizations within the energy ecosystem need to manage together – cyber risk. Increased power network connectivity, the convergence of operational technology (OT) and information technology (IT), the proliferation of IoT devices and the digitalization of business models are expanding the cyberattack surface for malicious actors to exploit.[40]

Policy: Within existing power markets, a key enabler of the IoE would be the introduction of a more flexible pricing system for electricity which introduced real-time, location-sensitive price changes based on supply and demand, this could incentivize consumers to cut back on energy demand during peak times, with adjustments to energy use being made by the interaction between smart devices and integration of AI.[41]

Example: Cyber resilience in the grid

April 2019's European Commission recommendations underlined that the cybersecurity of the energy system, and in particular of the electricity grid, require a specific approach to overcome real-time requirements, advanced technologies and the cascading effects of disruption through the development of cybersecurity skills and regulation.[42]

The era of digitalization and technological innovation means that organizations are exposed to cyberattacks that are increasingly frequent and sophisticated. The organizational complexity of the Enel Group and the numerous environments it encompasses (data, people and the industrial world) expose the organization's assets to a wide range of cyberattacks.

To address this, the Enel Group adopted a cyber risk management model based on a "systemic" vision that integrates the traditional information technology sector, the operational technology field most closely linked to the industrial sector and IoT associated with the networking of smart objects.[43]

Example: Flexible pricing

In Gotland, Sweden, several hundred electricity customers participated in a programme that integrated price signals (e.g. lower prices at off-peak times) with a smartphone app that allowed them to choose between four pre-set levels.

At the start of the programme, 23% of total electricity consumption occurred during the five most expensive hours; this dropped to 19% and 20% in the first and second year of the programme, respectively.

Additionally, companies have begun to offer more advanced demand-response programmes. Opower's programme alerts customers about peak times through text or email messages. EnerNOC offers a turnkey demand-response programme to utilities and grid operators, as well as commercial and industrial companies.

Example: California Public Utilities Commission Demand Response programmes[44]

Context: California, one of the states that consume the most energy in the US, continues to set ever higher standards for its Demand Response programmes. Users from residential, industrial and agricultural sectors are incentivized to cut their energy usage at peak times. Customers are notified via text, email or phone and rewarded monetarily.

Actions taken to scale up the technology:

– Customers can receive discounts on their annual energy bill if they voluntarily allow the utility company to cycle their AC load (50% or 100% during selected hot days)
– Participants can receive up to $28.65/kW-month for providing demand response, depending on several factors, such as duration of the reduction, response time and calendar month
– Commercial and industrial customers can determine their firm service level (minimum load requirement) and receive a monthly capacity credit if they commit to reducing their energy consumption during events (specifically designated hours during which customers are usually asked, in advance, to modify their energy consumption pattern, e.g. in "selected hot days")
– Bill credit calculated based on load reduction between 14.00 and 18.00; the reduction is calculated based on the customer-specific reference level, defined as the average 14.00 to 18.00 usage for the highest three of five previous weekdays
– Customers are incentivized to allow demand response technology to be installed in their homes

In California, these approaches led to significant load reductions in the 2008-2018 period and an increased contribution of Demand Response for balancing energy supply and demand.

Tech 3: Net-zero emission cooling and heating

Description: Net-zero emission cooling and heating refers to all the measures, technologies and practices that can be adopted to reduce energy consumption, increase energy efficiency and provide renewable energy supply for cooling and heating systems, both for residential and industrial processes. These include solar PV and solar thermal systems for industrial and residential uses; co-generation and use of waste heat; ground source heat pumps; and better insulation and build quality, among others.

Target problems: China's fast urbanization, rising living standards and fast economic growth indicate enormous energy demands. Energy use on heating and cooling can be reflected in the following:

– **Residential:** Heating represented approximately 24% of the energy used in 2016 by buildings in the urban area of northern China.[45,46] Meanwhile, around 60% of the Chinese population now owns a cooling system, and the number could rise to 85% by 2030[47].

– This is particularly relevant in the summer period driving 40% of electricity consumption in peak demand and creating a need for excess installed capacity underutilized during other seasons. According to the Climate and Clean Air Coalition, hydrofluorocarbon emissions will increase about 10%-15% per year and will amount to about 9%-19% of total CO_2 emission by 2050 globally, especially in developing countries.[48]

– **Industrial:** China's rapid development of heavy industries, such as steel and cement (and their high temperature heat demands), has driven approximate 66% of overall heat demand growth over the past 25 years. That trend is now changing as low- and medium-temperature heat (industrial process that input heat less than 80°C and 200°C, respectively) covered 50%-70% of industrial energy consumption in 2018[49,50] and are expected to continue to grow.

– **Data centres:** Data centres are becoming an important source of energy demand. While demand for data centre services is increasing, continued efficiency improvements are offsetting this growth. This could, however, change with the end of Moore's Law. In 2018, global data centre electricity demand was almost 1% of global final demand for electricity and part of this demand was driven by cooling requirements, which soak up to 40% of the energy bill.[51]

Impact: A zero-emissions cooling and heating framework could lower to zero a significant portion of the emissions generated by the building and industrial sectors. A 2016 study by Tsinghua University calculated that 2 GT of CO_2 emissions in China came from the building sector while, according to the IEA, the Chinese industrial sector contributed 32% of all Chinese emissions (2.9 GT).[52,53,54]

Barriers:

Technical: The technologies needed to reach zero-emissions in cooling and heating for buildings are already available, such as the low-temperature heat pumps that are being tested in Northern China. Further research on technologies to supply high-temperature heat in industrial process is still needed.

Financial: High-efficiency cooling equipment typically has a higher upfront (purchase) cost, while saving energy costs over its useful lifetime. Consumer incentives for high-efficiency products as well as programmes that provide cooling as a service would help overcome this barrier.

Policy: Energy efficiency standards and labels are effective tools to promote high-efficiency cooling and heating appliances. While China has adopted such programmes since the late 1980s, the ambitions of these programmes need to be raised on a regular basis as technology advances. A long-term target for cooling efficiency (similar to the Top-Runner programme in Japan) could go a long way to overcome the inertia, and stimulate innovation by manufacturers to produce more-efficient products.[55]

Further, by requiring the rapid implementation of the Kigali Amendment of the Montreal Protocol, the impact of global warming will be further mitigated.

Behavioural: Less affluent population segments (especially in the countryside) cannot afford clean and high-efficiency heating and cooling technologies already employed in cities. Cities, often with more affluent (often urban) population segments, waste energy with behaviours such as not closing windows and doors, especially in office or commercial buildings, due to poor operational management. Therefore, a holistic approach that takes into consideration people's behaviour and awareness about wasting energy is also important. A McKinsey study in 2010 calculated that behavioural changes in US households could save up to one-fifth of US non-transport energy usage.[56]

Nudges could represent a useful tool when trying to modify people's energy consumption patterns. In Bangalore, the World Resource Institute India and the Technology Informatics Design Endeavor launched a joint initiative in 2015 to provide customized home energy saving reports to consumers. These reports pressured consumers by showing them a comparison of their household's electricity use against others' in their neighbourhood. Preliminary results showed that the initiative led to 17% savings from 45% of the participants.[57] A similar experiment, run in 2014 in Southern California, led to a reduction in demand that was equivalent to increasing the price of electricity by nearly 70% during peak load events.[58]

Other pillars: Net-zero heating and cooling will play a significant role in the systemic transformation of cities to a carbon-neutral future. The associated technologies will reduce emissions, energy consumption, water requirements and air pollution.

Example: Innovation in the cooling and heating sector

The Global Cooling Prize, launched by RMI, the Government of India and Mission Innovation in 2018, set out to mitigate the need for additional power-generation capacity driven by cooling. Innovators from across the globe were invited to submit their ideas for an affordable breakthrough cooling solution that had at least five-times less climate impact than the most commonly sold residential air conditioners on the Indian market.

Some of the solutions include:

- Smart hybrid technology to optimize efficiency and handle temperature and humidity separately
- Non- or low-GWP climate-friendly refrigerants
- Reusing system-generated waste heat and water
- Smart controls, sensors and automation to optimize hybrid operation based on outdoor and indoor conditions

Tech 4: Carbon capture, utilization and storage (CCUS)

Description: CCUS technologies describe a group of technologies that capture CO_2 emissions from sources – including fossil, biomass power generation, industrial, hard-to-decarbonize processes such as steel, cement, petrochemicals and the air – to be stored indefinitely without entering the atmosphere or utilized as an input to another process.

The technology has been in existence for 40 years. However, as of 2019, there are only 51 carbon capture and storage (CCS) facilities globally, 19 in operation, mostly linked to enhanced oil recovery operations, as well as two large-scale utilization facilities – one in the US and one in Canada. Globally, these facilities have the capacity to capture 32 million tonnes of CO_2 annually.[59,60]

CCUS has so far not proved to be a mature technology and is not a substitute for low-carbon alternatives, particularly in the power sector (i.e. building and IGEG, see above). However, there is an imperative to scale up the technology; the International Panel on Climate Change (IPCC) has reported that CCUS will play an important part in many pathways to keep global warming under 1.5°C or indeed 2.0°C. The IPCC particularly notes its importance for heavy industry, such as cement, iron and steel, which, unlike the power sector, do not yet have low-carbon alternatives.[61]

Some industries, including chemicals and oil and gas, have begun developing technologies that transform CO_2 from an emission (or waste material usually stored underground) to a raw material that could be used as an input to chemical processes or the food and drink industry, although the technology is still very immature and prices of materials such as plastics made from CO_2 will need to drop significantly to compete with virgin sources.

Target problems: Despite China's standing as the world's leading country in electricity production from renewable energy sources, its primary sources of energy are coal and oil – which, combined, represent approximately 80% of primary energy. China's coal consumption reached 2813.7 Mtce in 2018. In 2019, GHG emissions from China's power sector represented 13%-15% of global energy-related CO_2 emissions. As already noted, industrial processes emit 2.9 GT of CO_2 annually and energy inputs can be difficult to substitute with renewable sources.[62]

Impact: The primary impact of CCUS would be the direct reduction of CO_2 emissions from power and industry. One study on decarbonizing industry in the European Union found that, in a stretch scenario, the EU could capture 232 MT of CO_2 per year by 2050 from industrial processes.[63]

Barriers:

Financial: Economic barriers include high capital requirements, lack of a business model in the absence of policy incentives, technical costs, long investment cycles and low short-term returns. In addition, concerns about CCUS long-term sustainability and the feasibility of technical advances have led to scepticism among private and public players, thus increasing the difficulty of obtaining financing.[64]

Technology and infrastructure: There is a need to develop significant infrastructure that can transport and store large amounts of CO_2 and can be used by industry as a whole. Moreover, to effectively use CCS in industrial processes such as steel production, significant process innovations will need to take place that can concentrate CO_2 into a signal source. In the cement sector, a challenge will be the distributed and small-scale nature of the industry.[65]

Policy: Political barriers include an imperfect policy system and financial mechanism, and the lack of policy guidance and incentive measures. A study by the Boston Consulting Group found that, in the past, governments around the world have largely failed to offer policies to support CCUS technologies, without which the technology is too costly to be commercially viable.[66]

The Chinese government could provide appropriate incentives to CCUS to lower costs, accelerate the learning and progress rates of the technology by larger participation, and further enhance its low-carbon competitiveness through carbon pricing. It could also promote the coordinated development of CCUS in the power generation and heavy industry sectors.

For example, the high concentration of CO_2 emissions from the chemicals industry has good potential for capture, which is conducive to the development of CCUS technology and the cultivation of the industry chain. Other policy measures exist and have been used in other CCUS projects, including grant support, tax credits and regulatory requirements.[67]

Example: CCUS cases in the United States and United Kingdom

In the United States, the Petra Nova project is the only large CCUS power generation facility. This project can remove 90% of the carbon in the waste gas of the generator sets through post-combustion capture, with an annual capture capacity of 1.4 million tonnes of CO_2.

Additionally, in 2018, the US announced its 45Q tax credit CCUS investment stimulus. It will provide up to $50 per tonne of CO_2 permanently stored and $35 per tonne of CO_2 used for enhanced oil recovery or other industrial uses, provided emissions reductions can be clearly demonstrated.[68]

In the United Kingdom, the Net-Zero Teesside project aims to develop the country's first decarbonized industrial cluster through the use of CCUS. A number of major UK energy-intensive industries are deployed in the project, which can create up to 5,500 direct jobs in the region and help many industries achieve low-carbon development.[69]

Pillar 2: Buildings

Energy consumption from the construction and management of buildings accounts for fully 40% of China's energy consumption (20% each).[70] When focusing on greening Chinese cities and greening the economy as a whole, the building sector is key. Buildings, like the cities in which they stand, are complex constructions, delivering heat, light, electricity and fresh air to their occupants as well as providing shelter and a place for social interactions, living or working. Therefore, the technologies highlighted here are not necessarily single technologies but innovations in standards and systems that allow multiple technologies to work together to create green and healthy buildings.

Tech 1: Net-zero energy buildings (NZEBs)

Description: NZEBs are an advanced form of nearly-zero energy buildings (NeZEBs). NZEBs are adaptable to climatic characteristics and site conditions, using appropriate passive building design to reduce the need for heating, air conditioning and lighting by taking advantage of natural conditions and the force of nature; and then supplementing them with active technical measures to maximize the efficiency of energy equipment and systems, while making full use of renewable energy to provide a comfortable indoor environment with minimal energy consumption.[71]

The indoor environmental parameters of NZEBs are the same as those of NeZEBs. NZEBs make full use of the buildings themselves and surrounding renewable energy resources, so the annual renewable energy production is greater than or equal to the annual energy consumption of the entire building.

Target problems: China is still witnessing a dramatic increase in building, resulting in tremendous increases in energy consumption and carbon emissions in the building sector. Annual building operational energy consumption accounts for 20% of the national energy consumption.[72]

By implementing NZEBs on a large scale, China could save a large amount of energy consumption and reduce CO_2 emissions.

Impact: In 2016, CO2 emissions in China amounted to 10 billion tonnes; more than 20% of this figure (>2 billion tonnes) came from building operations.[73,74] Assuming NZEB implementation can reduce emissions from the building sector by 10%, China could cut up to 200 million tonnes of CO_2 emissions (2% of total CO_2 country emissions).[75]

Still, in 2016, the annual building operational energy consumption was 986 Mtce[76] (megatonnes of coal equivalents), which is equivalent to 8.027 trillion kWh of electricity; at current residential prices, a 10% reduction in electricity use will amount to a savings of CNY 418 billion ($59.4 billion).[77] Real-world examples show that, by implementing NZEBs, energy consumption in buildings can be reduced by 60% and the remaining electricity can then be generated from renewable sources on site.

There were nearly 2 million m^2 of NeZEBs in China in 2017. It is estimated that at least 5,000 NZEBs will be built in China by 2020, and the industries related to NZEBs will reach $14.3 billion, thereby creating a significant amount of new employment opportunities.[78]

Barriers: China has five climatic regions where the meteorological conditions and the consequent building cooling and heating needs are very different. Thus, technology has to be adjusted to the five regions. In addition, the standards for building NZEBs are based on the ones used in Germany, where the climatic conditions are very different, and this makes implementation more difficult.[79] Moreover, international practices and techniques are more appropriate for low-rise buildings, while Chinese urban families live in high-rise apartment buildings.[80]

Measuring performance: once a NZEB is built, it is crucial to continue measuring its performance and monitoring how the building is operated, as efficiency can drastically drop over time. Currently, expansion is favoured by significant reductions in sensor prices, but performance assessment methods still need to be refined. For example, human perception of comfort is based on several factors, including air temperature, humidity, air velocity and radiant temperature: all of these could be measured by smart sensors, but currently only temperature is. Also, it is necessary to reskill and appropriately train all the personnel managing the buildings, as has been done in Singapore.[81]

This was put into practice in "The Edge", a building located in Amsterdam, Netherlands. Sensors that measure parameters like motion, light and temperature are perfectly integrated in the central dashboard of the building, which tracks consumption and user needs and then provides facility managers with real-time information.[82]

Artificial intelligence is not widely used due to lack of incentives for AI technology deployment in this sector, but there is definitely a large opportunity to expand its use in buildings by establishing market and regulatory incentives both to predict consumption and improve efficiency levels.

Other pillars: Energy: reduction of fossil and electrical energy consumption in public, commercial and urban residential buildings.

Tech 2: Building-integrated photovoltaics (BIPV)

Description: BIPV generally refers to the integration of PV modules in the building envelope. This could be "building-added" (building-added photovoltaics, or BAPV) such as PV cladding or shading devices; or "building-integrated" (BIPV in a narrower sense) such as PV curtain walls, skylights or semi-transparent windows.

Target problems: Apart from reducing CO_2 emissions, BIPV could be crucial to increase the areas available for solar PV development, particularly in fast-urbanizing cities. At the same time, BIPV will reduce the problem of competition for space, for example, on a rooftop, PV vs mechanical and electrical equipment or green roofs; in peri-urban areas, ground-mounted PV vs agriculture. It generates sustainable energy where it is needed, hence reducing transmission losses in electricity networks.

Impact: The Copenhagen International School has the largest BIPV façade system in the world, featuring 12,000 coloured solar panels that are integrated into the façade at slightly different tilt angles.[83] The system generates around 300 MWh per year, which is equivalent to ~50% of the school's electricity needs. Beyond that number is the Umweltarena in Switzerland, where a fully integrated BIPV envelope generates around 540,000 kWh of electricity per year, therefore guaranteeing the goal of a "plus energy house".[84]

The payback of BIPV systems generally depends on what conventional building materials the PV modules replace. For the case of a cladding or curtain walls, the payback against a typical cladding can be around eight years, even at low latitudes where less sun reaches the facades.[85] Taking into account the transmission line lost power, power delivery cost, the societal cost of carbon and material cost, research shows that the net present value of environmental and societal advantages in China could be $1.570 per watt.[86]

Barriers: Several surveys show that one of the most significant barriers to the implementation of BIPV systems is the biased perception of their economic feasibility, which has two components: the higher upfront cost, and the lower irradiation reaching the vertical part of the building (even in the absence of shading from the surroundings).[87] BIPV benefits from the substantial reduction in PV module cost over the past eight years (more than 85%), but the message of better economics has not reached planners and developers.

Another kind of biased perception is the lower flexibility in design and aesthetic considerations: sometimes architects find BIPV visually unattractive, and this affects their attitude when designing and projecting a building.[88] BIPV modules are available in almost every colour, including pure black and pure white (as extremes), and any design can be achieved by digital printing of the front glass that is used for BIPV. With sufficient economies of scale, this technology could follow the path set by solar PVs, the cost of which has dropped from $76 to $0.30 from 1977 to 2020 thanks to a combination of policies and incentives. [89]

Other Pillars: Energy: reduction of fossil energy utilization in the run towards renewable energy usage.

Tech 3: WELL-certified buildings

Description: The WELL Building Standard is a performance-based system for measuring, certifying and monitoring features of the built environment that impact human health and well-being through the air, water, nourishment, light, fitness, comfort and mind. WELL is grounded in a body of medical research that explores the connection between a building and the health and wellness of its occupants. WELL is managed and administered by the International WELL Building Institute (IWBI), a public benefit corporation whose mission is to improve human health and well-being through the built environment.[90]

Target problems: Research shows that people spend about 90% of their time in indoor environments. Issues like poor air quality and lighting, access to outdoor spaces, building interiors and water purity can affect not only people's health but also employees' productivity.[91] WELL-certified spaces can help create a built environment that improves nutrition, fitness, mood and sleep patterns.[92]

Impact: Since the WELL Building Standard is used especially for offices and work environments, the impact can be mainly observed in this kind of space. For instance, the investment company Landsec reported a 40% increase in satisfaction with air quality and a 25% increase in satisfaction with lighting, whereas Arup's Boston office reduced its energy costs by 12.6%.[93]

The certification also affects other aspects of employees' working life. For example, cybersecurity firm Symantec said that 30% of its employees felt more innovative, while the absenteeism score of the occupants of One Carter Lane in London improved by 19%, indicating that employees are working 16% more. [94,95] The WELL Building Standard was introduced in China in 2015.[96] In 2018, 220 out of 871 WELL-certified buildings in the world were located in China.[97]

Barriers: One of the challenges to scaling-up the adoption of for the WELL Building Standard is the lack of local certified professionals (WELL-accredited professionals) who are readily accessible to work with the growing demands of clients. Currently, most of the cases rely on overseas professionals, which is more costly, hence limiting scaling-up opportunities; Other barriers include the misconception of high initial investment cost to get a building certified, as people tend to jump straight to the top-level (Platinum) certification. In fact, depending on the type of building, nature of its operation etc., the certification level can be appropriately targeted (Silver, Gold, Platinum), depending on the design priorities and available budget. It's not a case of "all or nothing".

Tech 4: Carbon-neutral communities (CNC)

Description: Communities that are able to reach net zero reduce their CO_2 and other GHG emissions to zero. Typically, carbon neutrality is achieved by using new energy sources and clean technologies and by balancing the processes that cause pollution with the ones that reduce its impact.[98]

Target problems: Carbon-neutral communities can be seen as a holistic framework to incorporate all the technologies mentioned above as well as many other addressing issues related to CO_2 and GHG emissions, energy consumption, people's health and quality of life.

Impact: Two of the most advanced carbon-neutral communities are located in Sweden (Hammarby Sjöstad) and Australia (Barangaroo South), respectively. While it is hard, now, to calculate their exact impact, it is worth mentioning their targets. Both of these projects brought down their emissions by embracing the circular economy. Barangaroo South aims at being water positive and diverting 97% of construction and 80% of operational waste from landfill, whereas Hammarby Sjöstad wants to reduce its water consumption by 50%, reduce noise levels under 40 dB, and increase the use of public transport.[99,100]

Barriers: The key success factor to establish a CNC is to coordinate many policy-makers and stakeholders usually operating in different silos. It is first and foremost a governance issue, as well as a communication and education issue for all the people involved, ranging from builders to policy-makers and residents, who have to respect more stringent standards and operate with transparency with each other. Therefore, the lack of training for workers and all stakeholders is a key barrier to improving the quality and effective operation of green buildings.

Example: Singapore's 3rd Green Building Masterplan[101]

Context: The Green Building Masterplan is aimed at making at least 80% of the buildings in Singapore green by 2030. The masterplan was designed to foster the construction of sustainable buildings, improve citizens' quality of life and make Singapore the global leader in green buildings. It proposes initiatives under three goals: continued leadership; wider collaboration and engagement; and proven sustainability performance.

Actions taken to enable the technology:

- Applying a holistic approach, a training framework has been developed to increase industries' capabilities in the design, maintenance and management of green buildings. Much of the construction sector workforce consisted of migrant labour from neighbouring countries who largely only possessed agricultural experience (in China, most of the construction sector workforce comes from villages and less-developed regions). Singapore implemented a mandatory training programme for workers entering the construction sector to provide the workforce with the skills needed to raise the overall build quality in the city.
- The government offers incentives to support the development and adoption of energy-efficient and cost-effective solutions and technologies.
- Photovoltaic panels have been installed in schools to achieve net-zero energy.
- Mandatory submission of building information and energy consumption data helps track buildings' consumption and consequently encourages users to adopt a sustainable energy consumption behaviour.

In 2017, "only" 30% of buildings in Singapore were green, and many builders and owners were not fully aware of the range of green products on the market. To reach the 80% goal by 2030, it will be crucial for the government to increase awareness of the importance of energy efficiency by facilitating the conversation in the industry.[102]

Example: ZEB technology in Shijiazhuang, Hebei province[103]

Context: Shijiazhuang government's requirements, core of implementation, supporting policy and safeguard measures enabled the development of passive ultra-low-energy buildings in 2018.

Actions taken to enable the technology:

- Goal setting: By 2020, at least 1 million m_2 of passive ultra-low-energy buildings should be under construction
- Requirements: For certain districts, at least 10% of the buildings should be passive ultra-low-energy buildings if the construction area is larger than 200,000 m2; otherwise the projects won't be approved
- Land support: Passive ultra-low-energy building projects are prioritized to acquire needed land
- Construction incentives: Nine percent of the building area is not included in the calculation of the floor area ratio, therefore costs generated on land and city and ancillary costs are reduced by 9%
- Process optimization: when applying for "Permit for Advanced Sale of Commodity Houses", passive ultra-low-energy building projects can go through a fast-tracked regulatory approval process
- Energy price reduction: Heating costs, made up of a flat fee and a differential fee, will be significantly lower for residents of passive ultra-low-energy buildings, due to an 80% cut of the differential part
- Financial subsidy: For passive ultra-low-energy building projects starting construction in 2018 or 2019, a subsidy of 200 RMB/m2 was given, and a single project could get a maximum of 3 million RMB; for passive ultra-low-energy building projects starting construction after 2020, a subsidy of 100 RMB/m2 is given, and a single project can get a maximum of 2 million RMB.
- Media promotion: Government will help to promote the passive ultra-low-energy projects on mainstream and social media.

As of September 2019, 67 ultra-low-energy buildings were built in Hebei province with a construction area of 3.162 million m^2.[104] This means that the region hit the target of 1 million m^2 ultra-low-energy buildings under construction.

The approach of choosing a pilot city or region to accelerate particular green technologies has proved very successful and has applications across all technologies in each of the pillars in this report. For example, a series of cities could be chosen to be pilot cities in each of the pillar areas.

Pillar 3: Mobility

Transport remains the major source of $PM_{2.5}$ in Chinese cities (responsible for 45% of Beijing's $PM_{2.5}$ emissions in 2019) and therefore has been a key part of the Chinese government's "war against pollution". The mobility sector has undergone a large transformation in the last 10 years, including restrictions on licence plates, massive investment in electric vehicles and a rapid move towards sharing and multimodal mobility.

Moreover, China has been the centre of a transformation to mobility on demand, with companies such as DiDi (ride hailing) and micro mobility companies such as Mobike (bike sharing). The technologies in this section are innovations or groups of innovations that can help to scale up these already significant shifts, either by accelerating existing trends (towards electrification or sharing, for example) or providing a platform that can allow citizens to easily access a multimodal, low-carbon mobility system.

Tech 1: Transport demand management (TDM)

Description: TDM comprises strategies and technologies focused on understanding how people make their transport decisions and helping them to efficiently use the infrastructure in place (for transit, ride-sharing, walking etc.) to travel. Alternatives to driving are encouraged through system design.[105] TDM technologies can be applied to reduce GHG emissions and air pollution caused by traditional forms of mobility; for example, by fitting road and curb use to actual demand rather than supply of services by time and type of use.[106]

Among the policy tools that demonstrate TDM is road pricing. Road pricing charges users a fee to enter a certain area with the aim of reducing traffic congestion, carbon emissions and air pollution, while increasing overall equity and economic productivity. Road pricing includes location-based approaches such as central district tolling (e.g. New York City), time or demand-based models such as congestion charging (e.g. London, Singapore, Stockholm, Milan), and emissions-based policies (e.g. London Ultra Low Emission Zone).

Other strategies include flexible curb management and digital parking solutions that use real-time data (extracted from fixed and mobile sources) to provide information about parking spaces to manage traffic flow efficiency, reduce the time spent driving and flexibly price parking, disincentivizing driving at peak times and consequently lowering emissions.

Target problems: At the end of 2019, China had about 348 million motor vehicles, 260 million of which were cars. During the past five years, the number of small-sized passenger cars grew by an average of 19.66 million per year.[107,108] The increasing rate of car ownership exacerbates their negative impact, such as GHG emissions, traffic congestion etc.

Impact: Road and emissions pricing disincentivize driving and incentivize the use of more sustainable alternatives and multimodality (active mobility, micro-mobility and public transport). Among the cities that have adopted road pricing technologies, London was able to cut CO_2 emissions by 20%, Stockholm has seen a 10%-14% drop and Singapore avoids emitting about 80 tonnes of CO_2 every day.[109]

Barriers: Most of the barriers to the implementation of TDM are institutional. Typically, governments react to the increasing demand for mobility by expanding transport networks. This can be counterproductive due to the phenomenon of induced demand, in which increased road capacity directly links to a higher volume of cars. For example, the expansion and improvement of the road network and poor public transport infrastructure in Mexico City resulted in a rapid increase in private car ownership; as a result, besides its air pollution, Mexico City was the most congested city globally in 2017.[110]

Governments should encourage and subsidize the use of multimodality (active, micro and public mobility) and TDM is fundamental to achieving that while ensuring schemes are revenue-neutral or even positive. In cases such as London, public opinion was not fully supportive at first but, over time, TDM has been broadly accepted. Success factors included communicating the benefits and increasing public transport options such as buses,[111] as well as proactive investments in transit upgrades, multimodality and mobility as a service (MaaS).

Other pillars: Land use: more efficient urban transport modes, design and integration could affect the way in which cities and their transport networks are designed.

Tech 2: New energy vehicles (NEVs) and smart charging systems

Description: The term refers to those vehicles totally or mostly powered by new clean-energy sources. These include plug-in hybrid electric vehicles (PHEVs, extended-range electric vehicles included), battery electric vehicles (BEVs) and fuel cell electric vehicles (FCVs).[112]

The range of electric vehicles has been increasing over the past two years. However, under current financial trends, high upfront costs, varying charging costs and unknown depreciation costs remain important barriers to EV adoption.[113]

China has led a successful piloting approach in technologies, business models and policies since 2009[114]. In 2018, 1.3 million NEVs were sold in China (4.6% of the overall market). This represented a 62% increase in sales compared to the previous year.[115] NEVs have received generous subsidies in China, which have been a major driver of sales.[116]

NEVs cannot be scaled up without the necessary charging infrastructure, and decarbonization cannot be guaranteed without the use of renewable energy for charging. New smart charging infrastructure leverages IoT, AI and the principles of energy demand management to better balance grid loads by limiting energy use if necessary. The next generation of smart battery design includes vehicle-to-grid (V2G), in which electric cars become part of the energy storage infrastructure providing energy to the rest of the grid when plugged in during peak periods.

Target problems: In all modern cities, air pollution, noise pollution and GHG emissions are causing a serious problem for citizens. A large-scale adoption of NEVs and smart charging systems based on renewable energy could significantly improve air quality, reduce CO_2 emissions and dependence on imported oil and, therefore, improve energy security.

NEVs can be used both for passenger transport and in heavy goods on-road shipping. In fact, the benefits associated with transitioning China's trucking fleet to NEV powertrains would be disproportionate to their numbers. Even if diesel trucks are just 7.8% of China's total vehicles, they produce about 57% of total nitrogen dioxide emissions.[117] One challenge for electric trucks is that they are hampered by shorter range resulting from battery capacity limitations, hence while there are a number of battery-powered trucks under development, there is also the possibility that hydrogen will prove a more suitable fuel type for heavy duty vehicles.[118]

Impact: In 2017, automobiles in China emitted around 436 million tonnes of pollutants.[119] According to a study conducted in Beijing, Shanghai and Guangzhou, during its lifetime an electric vehicle has emissions up to 43% lower than the ones of a comparable internal combustion engine vehicle, although this is highly dependent on the energy source used for charging. Electric vehicles alone could help reduce GHG emissions in the transport sector by up to 6.2% in 2030 with a 20% penetration rate.[120]

As for hydrogen, even when it is obtained from natural gas (one of the least sustainable sources) today's early hydrogen fuel cell vehicles can cut GHG emissions by over 30% compared to gasoline-powered cars and trucks.[121] A cleaner way to produce hydrogen is by using renewable energy at non-peak-demand times, such as solar energy not needed for heating and cooling in the spring, which may otherwise have been curtailed.

According to a report by the World Economic Forum's Global Battery Alliance, smart charging of EVs and V2G applications could save 17 MT of CO_2 and generate $22 billion annually by 2030.[122]

Barriers: The lack of key technologies and cost competitiveness of efficient batteries and the absence of a system of supporting facilities – especially charging stations – are the major barriers to scaling up NEV numbers. If the number of NEVs increases, many supporting facilities would need to be developed quickly, thereby challenging cities in terms of capital investments, energy demand and land utilization.

With regards to FCVs, developing a well-functioning infrastructure that produces and transports hydrogen to stations would require years and billions of investments, but building it just for fuel cell vehicles would be inefficient. Ideally, vehicles should be integrated into a wider "hydrogen-based" economy, which uses the gas for other purposes, such as producing energy for homes.[123]

For smart charging and V2G, there is a need for industry standardization, including the large-scale development and deployment of bi-directional inverters within EVs and smart grid readiness (see Energy pillar), as well as incentives for fleet and vehicle owners to participate in V2G though financial incentives.

Other pillars: Energy: with the aim of finding cleaner solutions to produce the energy necessary for NEVs batteries, their spread could give a boost towards renewable energy. Moreover, hydrogen fuel cell vehicles would require energy plants to produce the hydrogen needed.

Land utilization: the system of supporting facilities such as charging or hydrogen stations would require large amounts of space within existing urban areas.

Tech 3: Shared rides and modes of mobility

Description: The term "shared rides and modes of mobility" refers to a wide range of transport solutions by which modes are shared (car-sharing, bike-sharing, scooter-sharing) and rides are shared (pooled rides, shared rides), i.e. vehicles are shared by users either simultaneously or one after another.

Target problems: According to research, cars are not used 95% of the time and when used, they generally carry just one person. Considering that, globally, there are about 1 billion vehicles, if cars could be used more efficiently, the room for improving environmental benefits such as GHG emissions reduction and economic benefits, such as cheaper mobility, would be huge.[124]

Globally, emissions from mobility are predicted double by 2050. Passenger vehicles account for 70% of these mobility GHG emissions and cause over 50% of urban air pollution. According to the Global New Mobility Coalition (GNMC),[125] by combining electrification efforts with encouragement of shared mobility and autonomous mobility solutions uptake, in an integrated manner, the number of vehicles can be reduced from the projected 2.1 billion to 0.5 billion and carbon emissions from 4,600 to less than 700 MT by 2050, while accounting for increasing mobility demand

and economic growth.[126] By developing and testing new and unique policies that integrate shared, electric and autonomous mobility (SEAM), 140 mobility experts curated by GNMC suggest that a cleaner city can be promoted, and carbon emissions can be reduced by 95% by 2050. SEAM can also improve mobility efficiency by 70% while decreasing commuting costs by 40%.

Impact: Shared rides and modes of mobility could provide cities with environmental and economic benefits. In 2017, a study carried out by MIT researchers argued that, in New York City, high-capacity carpooling options could satisfy 99% of the demand with a number of vehicles equal to 25% of the taxis on the roads of the city with an average waiting time less than three minutes.[127]

In an often-cited study, researchers modelled mobility use in Lisbon, Portugal. If all private cars were replaced by shared vehicles, based on using six-seater shared taxis, 90% of the traffic could be taken off the road.[128] AlphaBeta consultancy carried out research on Indonesia in 2017, modelling a scenario of widespread shared a pooled mobility in 2020, resulting in 159,000 MT of CO_2 emissions reduction, equivalent to saving 4,150 km^2 of land from deforestation, with an 8% reduction in air pollution, and a savings of 460 km^2 of land used as parking lots.[129]

Barriers: Lack of efficient matching platforms, culture, habits and potential losers are the main barriers for the implementation of shared and pooled mobility at scale, therefore a full shift to a transport-as-a-service mentality is needed. People may feel reticent to share a private vehicle with strangers and to adapt their schedules to shared mobility modes, typically less flexible and more time-consuming.[130]

The system can create losers, such as taxi drivers, if it doesn't treat mobility service providers with a level playing field. By digitalizing services and treating all shared rides and modes equally, successful business models can be enabled. Government may need to communicate benefits of shared and pooled mobility services to society to achieve greater penetration of low-carbon mobility by the general public. It can also invest in faster charging for high-occupancy shared rides, as opposed to single occupancy ones; not only will the electrification of fleets be encouraged, but there will also be higher utilization of every vehicle on the road.

Tech 4: Seamless integrated mobility system (SIMSystem) or mobility as a service (MAAS)

Description: A SIMSystem, also known as MAAS, is a "system of systems" that connects assets like cars and buses, bikes and pedestrian paths with technologies such as dynamic pricing and governance rules on the basis of which they operate in order to move people more efficiently.

The SIMSystem incorporates the information in a digital platform that provides a real-time picture of supply and demand for mobility as well as details about the ecosystem, such as weather or traffic conditions. A SIMSystem integrates different modes of transport so that people can efficiently use physical assets, and their supporting infrastructure plays an enabling role as the interface between consumers and mobility technologies.[131]

Target problems: Traffic is a worsening issue in many Chinese cities. For example, from 2010 to 2016, traffic congestion rose by 9% in Beijing.[132] The increasing population and the associated growing need for transport will likely exacerbate the situation, worsening noise and city air pollution, too. By providing an efficient connection between assets and infrastructure, a SIMSystem can promote a faster, cheaper and more sustainable mobility.[133]

Impact: Research suggests that SIMSystems mobility is cleaner and more efficient than traditional transport systems in terms of cost, traffic and time. A fully implemented SIMSystem could cut travel costs by 25%-35% per trip, accommodate up to 30% more traffic and reduce travel time by 10%.[134,135] Moreover, if all the vehicles used are automated and electric, a SIMSystem could reduce GHG emissions by up to 85%.[136]

Barriers: the implementation of a SIMSystem requires an exceptional level of coordination between public institutions, private actors and organizations that manage infrastructure. Moreover, it would be necessary to standardize and share data between the system stakeholders to create a transport marketplace with real-time price changes, i.e. higher tariffs for private ride-sharing may push more people to use public transport in peak periods, or free bus services in early morning hours may smooth commuting flows.[137]

Other pillars: Energy: a SIMSystem can have a higher impact on emissions reduction if most of the vehicles used are NEVs. Given the effective policy framework in place to scale up NEV adoption, SIMSystem advantages can be greatly enhanced.

Example: Incentives in Norway that promote the purchase of electric vehicles[138]

Context: In line with the European climate targets, Norway has set the goal of 35%-40% emissions reduction in the transport sector.[139] In 2017, 39% of new vehicles in Norway were electric, whereas in 2010 they accounted for just 0.3% of new cars. Policies promoting the spread of NEV were crucial for the reduction of CO_2 emissions.

Actions taken to scale up the technology:

- Norway undertook a number of policies to encourage NEV purchase over a sustained period of time:
  - Removal of purchase tax (1990)
  - No registration tax or annual circulation tax (which, in Norway, were among the highest in the world), or road tolls (1996-1997)
  - Free parking (1999)
  - Access to bus lanes (2003)[140]
- Similarly, to build out charging infrastructure, the government paid for the installation of 1,800 charging points as part of a 2008 stimulus package and later funded the roll-out of fast-charging networks (2010-2014); by 2017, much of the cost for the continued development of the fast-charging infrastructure was being borne by the private sector[141,142]
- Oslo recently built a city centre EV-only car park with fast-charging infrastructure[143]
- In cities, transport demand management, including a congestion charge on non-EVs, has been implemented
- Much of Norway's electricity is derived from hydropower, adding to the positive impact on the environment

The reason behind the success of the transition to EVs in Norway can be found not only in the incentives, but also in the improvement that this transition brings to air quality. Most of the electricity in the country comes from hydropower, meaning the increase of EVs had a particularly large impact.

Example: TRUE Initiative in London as a virtuous implementation of remote-sensing[144]

Context: From November 2017 to February 2018, the City of London started collaborating with The Real Urban Emissions (TRUE) Initiative. By using remote-sensing technologies attached to car tailpipes, the initiative had the goal of gathering vehicle-level information about GHG emissions produced by the vehicles present in the city and comparing it with previously collected data.

Key findings obtained thanks to remote-sensing:

- Euro 5 and earlier diesel cars produce more than 60% of nitrogen oxide (NO_x) emissions in London
- London diesel black taxis produce more NO_x emissions than diesel cars with the same emissions standard (e.g. Euro 5)
- Diesel cars emit six times more NO_x than petrol cars
- Carbon monoxide (CO) emissions are lower for newer passenger cars
- Buses and passenger cars emit less NO_x than five years ago

Remote sensing could offer the chance to gain significant insight into the emissions produced by vehicles. If governments could act on the data collected with the implementation of the appropriate technologies, it could have a massive environmental impact since the actions taken would be precisely targeted towards the most harmful pollutants.

Pillar 4: Land use

Land use and urban planning forms the backbone of the city. The shape and layout of a city has a significant impact on energy consumption, air pollution and GHG emissions particularly related to mobility. There is also a strong "lock-in effect", i.e. once a city has been planned and built, it is incredibly difficult to change and the effect can last centuries.

On the urban scale, the shape of the city matters (Tech 1a). On the scale of neighbourhoods, density and mixed land use can mean significant differences (Tech 1b). These technologies on various scales, combined with public transport infrastructure, reinforce each other under the concept of transit-oriented development, provided that a good design enables active modes of travel and mitigates side effects, such as noise nuisance, local congestion, urban heat island effects, lack of daylight and lack of green space.

Tech 1: Transit-oriented development (TOD)

Description: TOD is a planning approach that aims to create high-density and mixed-use business and residential centres clustered along transit stations and corridors.[145]

Target problems: By 2030, up to 70% of the Chinese population (around 1 billion) will be living in cities, which will lead to the expansion of existing cities and construction of new greenfield cities.[146] China has in recent years implemented a number of innovative urban planning strategies to mitigate pollution and emissions. However, some legacy issues still exist, including transport-adjacent rather than transit-oriented development. China's transport sector accounted for 55% of its oil consumption in 2015 and was related to around 900 million tons of the country's CO_2 emissions in 2016.[147]

Impact: Reduced energy use for transport, improved air quality, preservation of and access to open space are some of the benefits of TOD initiatives.[148] Others include improved safety for pedestrians and cyclists and congestion relief.[149]

TOD leverages mixed land use, which enables different uses, such as residential, commercial, institutional and recreational, to be located close together guaranteeing proximity to amenities at the neighbourhood, block and building level.[150,151]

Research shows that residents living near stations are five to six times more likely to commute via public transit than are other residents in a region, so the benefits deriving from TOD in terms of reduction of GHG emissions can be significant, e.g. in 2017, automobiles in China emitted around 436 million tonnes of pollutants.[152,153]

TOD with good design and planning will provide convenient transit and high-quality property supply for the general public, which will also result in increased property value and interest from the public and private sectors, therefore promoting TOD in a virtuous circle.

Barriers: There are three main kinds of barriers to TOD: fiscal, political and organizational. Fiscal barriers include lack of financing, high costs of construction, development fees and all the risks associated with extra unpredictable expenses such as site clearance, environmental remediation and infrastructure upgrading.[154]

Political barriers may come from city inhabitants' reluctance about changes aimed at increasing density along linear axes. In fact, inhabitants often tend to believe that changes will result in increased traffic, longer lines at the grocery store, crowded schools etc.[155]

Organizational barriers are linked to the high number and diversity of stakeholders. Public sector, local governments and developers often have different interests that are not easy to coordinate.[156] Furthermore, land acquisition could become a barrier when transit agencies, redevelopment agencies or municipalities do not own enough land adjacent to existing or planned stations.[157,158]

Given the multitude of actors involved and the money required to effect changes of that size, to transition to sustainable TOD, there should be economic incentives and a predictable regulatory environment able to attract investments and guarantee commitment by different parties. In addition, higher levels of government should foster policies that promote city-level experimentation and provide stakeholders with the resources, space and flexibility required to properly operate. In this context, a constant bilateral city-national government interaction would help to exchange feedback and achieve policy goals.[159]

Tech 1a: City forms

Description: A compact city is the most well-known sustainable urbanization concept: Energy use is lower compared to dispersed cities and nature and rural areas are preserved. In particular, favouring shapes of cities that allow for high density along linear transit corridors such as star-shaped cities or Copenhagen's hand-shaped city, where a city centre in the "palm" of the hand has five high density transit corridors that branch out to the West. This type of city shape is more efficient for public transport than the usual circular shape of many cities, and shortens the distance to the rural and nature areas in the green or blue wedges between the "fingers".

Cities in Switzerland are known to often have good public transport links. This is partly aided by the fact that the country's valleys and lakes constrain city construction to narrow linear arrangements. These are well suited to high-density, linear public transport.

Another form is the polynuclear city. Almere, a new town near Amsterdam is an example of this shape. Instead of one continuous piece of urban fabric, Almere is planned as six nuclei separated from each other by green spaces and interconnected by dedicated bus lanes. By doing so, Almere allows for green spaces within everyone's vicinity while being well connected by public transport.

Research proves that, to reduce urban transport and GHG emissions, cities should be more compact.[160] However, compact cities may worsen the urban heat island (UHI) effect, with severe consequences for public health. The UHI effect increases as cities grow in size and density.[161] In 2013, Eastern China was hit by a severe heatwave, which in the coastal city of Ningbo alone caused 1,260 people to be hospitalized due to heat-related illness.[162,163] Hence, there is a trade-off between urban forms that reduce GHG emissions and those that reduce the UHI effect.[164] The same is true for air quality, which is worse in large and compact cities.

Target problems: Dense cities can be more attractive if there is access to green spaces. Circular "pancake shaped" cities have a relatively small amount of city fringe, making the nature and countryside less accessible. "Pancake" cities also lack the ability to let fresh air permeate neighbourhoods. Pancake cities do not follow the linear form of public transport infrastructure, so public transport is not optimized.

Impact: Cities organized along linear transport axes, in particular star-shaped cities, perform particularly well in addressing the problems caused by both CO_2 emissions and UHI, solving the trade-off between the two.[165] Well-thought-out and innovative city shapes facilitate the creation of high-density and mixed-use business and neighbourhoods clustered along transit stations and corridors, thus leading to several benefits for the environment, such as improved air quality and reduced environmental impact from mobility.[166,167]

Curitiba in Brazil is the city that has the highest number of cars per capita in the country.[168] However, since it was developed along high-density linear transport axes, it has the highest share of commuters using public transport and a fuel consumption 30% lower than in eight comparable Brazilian cities.[169]

Barriers: The main barrier related to city shapes is that, in the majority of the cases, their development cannot happen through the reshaping of existing cities but only through the planning of new ones or the significant expansion of small cities. China, with its considerable rate of urbanization, has an opportunity to expand existing cities or create new ones according to this principle.

In cases where it is possible to develop specific city shapes, a top-down approach that enables the rapid implementation of decisions and an easier alignment of government departments is essential. Importantly, the principles of the development plan should be maintained over a long period of time. This long-term approach is necessary to realize the vision of the original plan, as happened with the Copenhagen Finger Plan (over 60 years).

Other pillars: Transport: the application of the star-shaped city design could help to reduce the CO_2 emissions of transport. Food; Specific city shapes allow for shortened distances to food production.

Example: Copenhagen Finger Plan[170,171]

Context: The original plan was drawn up in 1947 and has been the governing development model for the city since then. It represents a model for urban development, which aims to organize the city based on overall regional structure.

Actions taken to reach that goal

- Urban development concentrated along city fingers linked to the railway system and radial road networks
- City fingers separated by greenery, which is exempted from urban development
- Urban development and new urban functions in the fingers are always located with consideration for existing and approved infrastructure and the opportunities to strengthen public transport
- The plan was popular among Copenhageners, especially those who moved out to the suburbs to enjoy greenery and fresh air as well as easy access to public transport
- In terms of endurance, the plan's main principles were maintained for over 60 years
- The Regional Planning Council (later Greater Copenhagen Council), with representatives of the municipalities involved, was set up to carry out regional planning for the Greater Copenhagen area
- Over the years, new demands and adjustments were made in a flexible manner, and based on deliberation between a broad range of public and private stakeholders

The plan has avoided urban sprawl and ensured easy access to recreational areas for the entire population, as well as access to central Copenhagen from the entire Greater Copenhagen area.

Tech 1b: High-density and mixed land use

Description: Higher building densities tend to go with shorter distances; as a result, the demand for mobility, on the whole, declines and active travel modes are more compatible options, compared to automobile use. Besides, higher densities offer a larger basis for mass transit, leading to a more developed public transport system that can compete with automobile use.

Car traffic is reduced even further when the distances to public transport nodes are short and if land uses (e.g. housing, jobs, amenities, leisure) are laid out in a mixed configuration.[172,173] This mixed use excludes heavy industry, which, due to noise and air pollution, should be kept separate.

Other ways to improve space utilization and circumvent challenges posed by building density are smart space allocation and multiple use in time. Smart space allocation refers to the deliberate choice of assigning parts of a building less suitable for some purposes (e.g. residential use in areas never directly exposed to sunlight) to other purposes that could benefit from such locations (restaurants, gyms, warehouses etc.).

Multiple use in time refers to certain buildings serving different purposes depending on the time of day, resulting in a reduced number of new buildings constructed. For example, sport accommodations can be used as community centre for the elderly in the morning or early afternoon, or schools can be used to hold events in the evenings or during the weekends. Buildings such as 1111 Lincoln Road, a multistorey carpark in Miami, Florida, was built to hold cars during the day but can be easily "reprogrammed" to host events such as theatre performances (enabled by triple height ceilings on one floor) and marketing events in the evening.[174]

Target problems: Low-density land use consumes more land than more-densely built areas, leaving less space for nature, recreation and agriculture. Besides, distances between addresses are, on average, longer in low-density areas, which leads to more car use, fewer options for mass transit and less use of active travel modes and, thus, more energy use for travel. Single-use of land leads to longer distances as well, compared to mixed-use.

In China, some urban areas are not well-suited for walking, for example, large, block-sized residential compounds often have only one or two entrances, increasing walking distances. Other cities have separated use neighbourhoods (residential, commercial) necessitating driving between the two; both of these factors encourage the use of automobiles.[175]

Impact: Mixed land use can benefit the environment in different ways. Tailpipe CO_2 emissions are lower for households that reside in mixed-land use neighbourhoods with good network connection. Shorter distances to destinations can increase walking and cycling while reducing vehicle travel.[176] Research suggests that mixed-use areas typically have 5%-15% less vehicle travel and that for each 1% increase in land use mix there is a 0.01%-0.17% decrease in vehicle miles travelled.[177,178,179] In the Netherlands, an increased degree of urbanization resulted in a decrease in the total distance travelled, which proved to be 14% lower in urbanized neighbourhoods compared to non-urban areas.[180]

Barriers: Starting from the first Industrial Revolution, residential and working areas have been separated from each other for the good reasons of hygiene, health and noise pollution. Urban areas have long been schemed for either housing, work or recreation. These functions are still reflected in the names of governmental departments in many cities; and each department has its own targets and budgets, making it hard to initiate mixed-use areas.

However, work is, in most cases, an increasingly less-industrial activity but is more related to office jobs, with very low noise pollution. This is evident with China's continuing move towards a more service-oriented economy. Moreover, COVID-19 will likely accelerate the trend of remote working lifestyles, decreasing further the need to separate work and housing. However, changing monofunctional areas in zoning plans to mixed-use areas can meet resistance and can, therefore go along with financial claims for planning compensation. The same challenge is true of densification of existing areas, where people may be concerned about the side effects for liveability and costs of living.

Other pillars: Mobility: The design of urban transport systems goes along with the design of mixed land use and high-density building. Higher densities provide better business cases for public transport as do mixed-use areas. Buildings: The building types are conditional for reaching certain densities and having mixed-use functions.

Example: Tianjin Eco-City[181]

Context: The Sino-Singapore Tianjin Eco-City is situated along the coast. It is the clear example of a new city that, from an urban planning perspective, has all the characteristics of a sustainable city: high-density transit-oriented development, mixed land use, renewable energy, water treatment etc. The project construction started in 2008, with ambitions in terms of duplicability and scalability.

Actions taken to reach that goal

- Wastewater naturally cleaned on a centrally located eco island
- Ecological corridor connecting the park area to the sea, with its branches cutting through the residential area
- Wind farm located nearby that provides electricity to the city
- Wide bicycle lanes and footpaths
- Light rail system with hybrid buses serving its remaining areas
- Five business parks within the Eco-City agglomeration, and some mixed-use development
- Buildings meet green building standards (good orientation towards the sun and daylight etc.)
- Provisions ensuring that environmentally sensitive or high-priority green areas remain under public control

Example: Roppongi 6-chome Redevelopment Project[182]

Context: The $2.47 billion Roppongi Hills project is the largest private-sector redevelopment ever completed in Japan, and it has become a model for urban development. As a result of this project, Roppongi Hills became one of the most influential mixed-use neighbourhoods in the world. Its key features are the presence of abundant greenery to make access more convenient and less congested; as well as convenient public transport, easier road access, restaurants and luxury brand retailers to attract consumers and office workers.

Actions taken to reach that goal

- Use of a non-recourse-based syndicated loan, which entitles the lender to repayment only from the profits generated by the project the loan is funding
- Prior to project planning, existing landowners and landlords founded an association to facilitate dialogue on redevelopment and to gain consensus among land-right holders (nearly 80% of them were individual households)
- The association handled inputs from more than 400 members, acting as the project leader. It solved land-right holders' issues such as the conversion of land rights to rights within the project

Roppongi Hills welcomes nearly 100,000 visitors on weekdays, around 20,000 employees in offices and commercial establishments, and has about 2,000 residents.

Tech 2: Connected street networks

Description: Connected street networks are designed to be walkable; walkability is aided by a dense network of paths with manageable block sizes.[183]

Target problems: The challenge posed by increasing GHG emissions from the transport sector could be partially tackled by fast and frequent transport systems and connected street networks, which are proven to lead to less vehicle travel at a given income level, energy use and CO_2 emissions.[184,185] However, street connectivity has been decreasing since 1975 in 90% of the 134 most populous countries.[186] Poor street connectivity is related to an increase in traffic congestion as the street pattern does not provide alternative paths to travellers.[187]

Roads in Chinese cities tend to have fewer intersections and longer distances between them compared to European cities such as Turin, Barcelona and Paris.[188] As a result, the street connectivity of a Chinese neighbourhood made of superblocks is 5%-20% lower than that of Manhattan or Rome.[189]

Impact: Increased street connectivity could partially contribute to the reduction of the transport sector's emissions in China, which reached 900 million tons of CO_2 in 2016.[190]

In fact, research shows that connected street networks lead to manifold benefits, such as improved distribution of traffic flow, increased network capacities and reduced use of motorized traffic modes.[191] An analysis performed as part of the Utah Street Connectivity Study showed that the implementation of street connectivity alternatives led to a significant reduction in network travel times, delays and vehicle-miles travelled. Improved connected street networks were also compared to street widening, outperforming them in most cases.[192]

Barriers: According to experts, street networks are by nature connected to many other assets in the city that depend on them, such as houses, offices, bridges etc. For this reason, they are hard to change from a cost and feasibility perspective. A rapid policy response, including regulation and pricing tools, is a prerequisite to avoid the construction of more unconnected networks during the final phase of the urbanization process. Besides guidance for city planners on road-network planning, other measures could include the addition of environmental taxes to incentivize developers to build more connected street networks or the prohibition of gated communities, or a minimum number of entrances for residential facilities.[193]

Other Pillars: Mobility: the road network is directly related to transport issues.

Example: Houten, Utrecht[194]

Context: Houten is a new town in the Netherlands that represents the perfect example of an entire city designed and built from the 1970s onward to prioritize cyclists and pedestrians.

Actions taken to reach that goal

- Filtered permeability (an urban planning and design technique that allows pedestrians and cyclists to travel through an area more directly than motorists); Street networks are connected for active transport modes and public transport and disconnected for motorized vehicles
- Mixed land use policies favour the co-presence of cyclists and pedestrians
- Provision of public bikes and car-sharing
- Provision of bike parking
- Application of employer contributions and educational programmes to promote cycling

These factors combined have resulted in good transit access, reduced motorized transport, improved cyclist and pedestrian safety and increased activity levels of residents.

Pillar 5: Food

By 2050, cities will consume 80% of all food produced, meaning that much of the world's rural activity is tied to urban areas.[195] The food system has been found to be responsible, producing up to 30% of global emissions and considered one of the major drivers of biodiversity loss.[196,197] This, coupled with health issues such as poor nutrition and obesity, led the landmark Eat-Lancet Commission report to state that "Food is the single strongest lever to optimize human health and environmental sustainability on Earth."[198]

Technologies implemented in cities will play a significant role in moving this lever to a more sustainable and healthy future. Digital and Fourth Industrial Revolution technologies have the potential to accelerate food systems transformation by shaping demand, promoting value-chain linkages and creating efficient production systems.

Tech 1: Alternative proteins

Description: Alternative proteins are food products that seek to substitute for animal-based protein (meat, dairy, eggs, fish) in terms of taste, texture, appearance and nutritional content, and that do not contain meat originating from live animals.[199] They are intended to act as substitutes for traditional animal-based foods. There are various types of alternative proteins – from traditional fruits and vegetables (such as pulses and nuts) to processed plant-based substitutes (such as tofu, which has been part of the Chinese diet historically, to the more recently developed soy- or pea-based products such as the Impossible Burger[200] or OmniPork[201]) to novel and very early-stage alternatives such as cultured meat (grown in a lab).[202]

Target problems: An average Chinese citizen consumes more than 60.59 kg of meat per year, much less than Americans (around 124.1 kg) and Western Europeans (60-100 kg), but that figure is growing and total meat consumption in China is significant.[203] However, recent research from the EAT-Lancet Commission[204] puts these figures in a new light: it indicates that a much reduced intake of 14g/day or 5.1kg/year for red meat and 29g/day or 10.6kg/year for poultry are ideal for both good health outcomes in populations, and for the protection of planetary resources.

In 2016, Chinese dietary guidelines promoted eating less meat, with a target of a 50% reduction by 2030.[205] While this recommendation comes from the dietary health perspective, its implications have the potential to address several challenges China may face.

First, animals produced for food generally have much higher feed conversion ratios – the measure of the efficiency of converting feed to food compared to plant-based proteins (with much variance between protein sources with chicken, salmon, pork and beef yielding a 1:1.7; 1:1.2; 1:3.9; and 1:8 conversion rate, respectively[206]) – high utilization of water and huge dependencies on feedstock, which often comes at the cost of land and forest conversion. Globally, livestock production is responsible for approximately 15% of global anthropogenic GHG emissions.[207,208]

Second, the volume of the world's supply of animal food and feed needed to feed China's population creates significant dependency on imports. This is further exacerbated by recent diseases directly impacting the Chinese supply of pork and chicken – notably the African swine fever and avian influenza.[209]

Impact: Both plant-based and lab-grown meat has the potential to significantly decrease the environmental impact of traditional meat production techniques by lowering the level of GHG emissions, reducing the amount of land needed for conversion to ranching and feed, and reducing additional natural resource use, such as water. Substituting a single 200-kcal portion of beef each day for a plant-based protein could result in up to a 26% reduction in emissions[210]. Furthermore, plant-based protein production, for instance, could cause median savings of 95.5% water use and 93% land use,[211] whereas cultured meat requires 99% less land and 82%-96% less water than animal meat.[212] Life cycle assessment of this alternative is still in progress and will be highly dependent on using renewable energy models for growth.[213]

Barriers: Meat has an important social function in many societies, where meat consumption signals status or hospitality. In addition, distribution, accessible pricing and consumer adoption/preferences present barriers for the uptake of plant-based alternative proteins.

The distribution and accessible pricing of plant-based alternatives could be supported by government investments and policies, and regulatory frameworks reformed to provide positive incentives for the producers to accelerate the development and access of alternative proteins – particularly those which deliver both environmental and health factors. Cultured meat is not yet commercially available; significant government investment and subsidies, attuned to the scope of investments by countries in renewables, could help to bring these products to the commercial state.

For consumer adoption of alternative proteins, studies following the avian influenza and African swine fever outbreaks indicate that many consumers look more favourably towards alternative proteins.[214]

Several options exist for the government:

- Promote research to gain more data on the full health and environmental benefits associated with such food, e.g. with grants and/or facilitating contacts between the private sector and investors

- Launch communication programmes directed at both investors and consumers

- Evolve dietary guidelines to support the diversification of protein sources by individuals

- Increase government procurement of these products for government-supported meals and banquets

- Provide fiscal and policy interventions, such as repurposed public investment, supporting the production of food types with fewer externalities and removing perverse incentives that favour production of high externality foods, or labelling requirements that highlight differences among products[215]

Tech 2: Digital and Fourth Industrial Revolution Technologies for the food value chain

Tech 2a: A digital platform for food

Description: A digital platform that connects all stages of the supply chain, from producers to consumers, to link consumers directly to producers and ensure convenient supplies of fresh produce. All operations such as ordering food and payment are performed online, taking advantage of existing services such as WeChat or Alipay. The direct contact between producers (supply) and consumers (demand) ensures a high level of trust and an efficient allocation of resources. Digital platforms that include everything from B2B procurement for agricultural and food products to platforms that enable farmers to easily sell products to consumers or restaurant suppliers are increasingly gaining traction.

Before COVID-19, online food delivery was a $65 billion market in China; during the COVID-19 quarantine, Meituan, a leading Chinese website for locally found food and delivery service, spiked 400% in online grocery sales,[216] while JD's Fresh Food sales increased 215%.[217]

Target problems: According to the International Food Policy Research Institute, globally, the level of food waste in the value chain from production to consumption is around 30%, although there is significant uncertainty and regional variance to this figure.[218] Guaranteeing food freshness and waste reduction is difficult when there are many intermediaries between producers and consumers, and often stores accumulate surplus products that end up wasted.[219]

Impact: If well implemented, a digitalized food supply chain could reduce food loss by 50%. Considering that annually 835 million tonnes of corn, rice, vegetables, sugar cane and wheat are produced in China, food loss reduction could result in up to 125 million tonnes of these products saved.[220] Moreover, high-value agriculture such as fruits and vegetables, dairy and meat, are more susceptible to food loss and waste along the supply chain, meaning the financial benefits will be proportionally larger.

Digital platforms can provide technical support to farmers and give them advice on how to produce food more efficiently as well as communicate demand needs, especially during times of supply chain disruption. By directly linking consumers with farmers and providing a highly efficient system, these platforms would build a high level of trust between producers and consumers.

Little Donkey Farm was the first farm to apply this model in China. To give people access to fresh and healthy food, the organization connects customers and producers through social networks; it also offers consultancy advice to farmers who want to adopt the model and use more sustainable technologies. As of November 2017, more than 500 farms in China had implemented the model proposed by Little Donkey Farm.[221]

AI helps agricultural professionals to rationally plan production by analysing data, such as ambient temperature, rainfall and soil salinity, to ultimately improve crop output. Tencent is actively engaged in "AI + Agriculture" and has made preliminary progress. Driven by policies like "Internet + agriculture" and "Internet targeted poverty alleviation", Shenzhen Wugu Network Technology launched an online platform to help farmers to solve problems, such as a single-sales channel for traditional agricultural materials and lack of knowledge on agricultural technologies. Meicai, a digital platform for food that helps farmers to sell products to restaurants, raised $450 million in the largest farmtech deal of the year.

Barriers: Farmers' inadequate access to digital tools and the lack of knowledge of applications is one of the main barriers to the large-scale implementation of this technology. Governments should invest resources to provide the infrastructure and build capacity to improve the uptake of relevant knowledge and information through modern technologies.

In addition, equitable access to data and information must be ensured to guarantee not only a competitive market, but also the survival of smaller platforms. It is critical that digital platforms enable enhanced collaboration between diverse stakeholders throughout the food system to strengthen inclusivity and empower small-scale producers and distributors across the supply chain.

Tech 2b: Technologies to enable traceability and transparency

Description: Technology-enabled traceability helps make much of what is currently "invisible" within our food systems visible and, in doing so, enables more transparency in food systems by allowing the comprehensive tracking of the environmental, economic, health and social consequences of food production, distribution and consumption.

In particular, traceability technologies can:

- Enhance the ability to identify, respond to and even prevent food safety issues by enabling food companies and governments more efficiently to "identify, isolate and address the source of a food safety issue"

- Meet consumer demand for more transparency to inform their purchase decisions and reduce the risk of buying illegal, unethical or counterfeit products

- "Support supply-chain optimization and reduce food loss by enabling effective identification of vulnerabilities in the supply chain"

- "Validate and verify sourcing claims" to validate sustainability claims, hold companies and governments accountable to their commitments and more accurately measure the social and environmental footprint of production, in real time and at lower cost.[222]

Technology innovations can improve traceability in food value chains. IoT can allow for consistent and comprehensive data collection, in real time. Blockchain can effectively track, aggregate and share data from supply chains, and food-sensing technologies have the identity information related to the structure of the product and provide details on whether food is fraudulent or safe.

For example, IBM and Walmart worked together on a pilot study to show the benefits of tracing food products on blockchain. It was demonstrated that tracking information using blockchain could be done in 2.2 seconds – a process that would take almost seven days using previous methods. This process will help reduce response times when contaminated foods are discovered as well as make it possible to perform selective recalls. IBM has now established the IBM Food Trust, engaging food and agriculture players on its blockchain-based traceability system.[223]

Target problems: "Due to the highly complex nature of global supply chains, few agribusiness companies or grocers can seamlessly track and trace food products throughout the supply chain."[224]

Beyond food safety issues, lack of traceability makes it difficult for consumers to validate where their food came from; crack down on fraud; and meet health, nutrition or environmental goals.[225] Consumers are increasingly concerned about the provenance and safety of their food. A study shows that 71% of China's population believes that food safety is a big or moderately big problem.[226]

Impact: Traceability technologies have the potential to address several pain-points in food systems. These technologies will create improved supply chain visibility and transparency for food production practices while improving information about food products to consumers, reducing fraud, improving food safety and increasing optimization in food supply chains, including the reduction of food loss.[227]

Barriers: Technology-enabled traceability has a promising potential for improving food supply chains. However, "it is likely to entail more demanding requirements, including added cost." In the absence of effective support, "these requirements risk favouring larger producers or companies in developed countries that can more easily absorb the added cost and adjustments." To ensure that benefits are maximized, there is a need to focus on "pathways to scale" – policies, standards and economic models – that will allow small-scale producers and consumers from underserved communities to benefit from the technology deployment.[228]

Tech 3: Indoor/vertical farming

Description: Indoor/vertical farming refers to the development of high-productivity agriculture in urban environments, applying innovative technologies and methods, such as hydroponics, urban vertical farming, modern LED lighting, and seed breeding for species and varieties that thrive in these indoor environments. This method of farming consists of growing plants indoors, often in vertically stacked layers to save space and using LED lighting and hydroponics.[229]

Hydroponics is a method of growing plants in a liquid that is rich in mineral nutrients. Variants such as aeroponics spray a fine mist on roots. The benefits of this technology are that soil is not required and water can be recycled and reused. Moreover, nutrition levels can be controlled, thus reducing waste, cutting costs and eliminating unintended consequences such as fertilizer run-off into waterways.[230] Hydroponics can be used on roofs or in indoor farms in urban environments.

LED lighting is a highly efficient source of light that consumes very little energy. In recent years, the price of LED bulbs has dropped dramatically while the efficacy has risen from 40 lumens/watt in 2010 to near 150 lumens/watt today (as compared to 16 lumens/watt for an incandescent bulb) and could reach 200 by 2030[231].

These two trends continue to improve the economics of indoor farming. LEDs are helping farmers to grow vegetables and other crops with bigger yields per plant and greater nutritional value than those grown in certain external environments. LEDs can produce light at exactly the right frequency required for photosynthesis to maximize efficiency.

Target problems: In 2011, China became a majority urban country.[232] In this context, the need for food availability and security within urban areas is increasing. Moreover, the cultivated land in the country is around 0.08 hectares per person – which is 40% of the world average – and agricultural land is decreasing at a rate of 300 km^2 per year.[233] Indoor farming can help provide benefits in terms of utilization of underleveraged urban land, sustainability and access to healthy and nutritious foods.

Impact: Indoor/vertical farming can provide urban residents with local, high-value fresh produce, including salads, herbs, fruits and vegetables etc., which can all lead to a more balanced diet. [234]

Some early-stage research suggests that, globally, more than 70,000 km^2 would be available for urban farming projects, 80% of which would be provided by vacant urban plots. China has 14,000 km^2 available: if the country filled all that space with farms, it could produce around 36 million extra tons of food each year.[235] Indoor farming can be created in repurposed warehouses, thereby generating a more circular use of high embedded emissions materials such as cement.[236]

Over the past years, some examples of indoor and vertical farming have emerged with several cities and start-ups attempting to use these technologies. For example, in Guangzhou, the population is expected to reach 15.17 million in 2020 (almost double that in 2017).[237] There, 14 hydroponic systems have been installed on a rooftop measuring 1,600 ft^2 (about 149 m^2) and producing $6,000 worth of vegetables annually – twice the 2015 annual minimum wage in the city.[238] Another example is Galuku, a company selling hydroponic growing systems in China that helped farmers achieve yield increases of 50%-150%.[239]

Barriers: In addition to the high initial investment costs of the system (which are beginning to decrease due to scale and other factors), other barriers to implementation may be represented by the need for trained personnel; the potential spread of pathogens; the reaction of the plants to a wrong or poor nutrition and the restricted variety of plants that can optimally be grown using these advanced techniques.[240]

Example: Singapore is setting targets to expand urban agriculture projects[241,242]

Context: In an effort to improve the city state's food security, last year Singapore Food Agency set the target to raise the share of locally produced food to 30% by 2030 (the current figure is slightly less than 10%) to reduce exposure to volatilities of the global food market, such as the impact of climate change, export bans and transport route disruptions.

Enablers to reach that goal:

- Using technology to grow more with less, e.g. automatic systems, robots and sensors
- Encouraging urban farming in alternative spaces such as rooftops or empty buildings
- Developing local talent by partnering with local universities to create degree programmes and specialists in aquaculture and agriculture technology, urban farming and planning etc. The government has also made efforts to import international best practices. For example, in 2017, a group of Singaporean farmers visited high-tech farms in China and an aquaculture technology exhibition in Norway
- Encouraging consumers to support local products through educational and PR initiatives, such as partnerships with supermarkets to organize local produce fairs

When implementing policies that promote modern urban farming, cities could be considered in an integrated food system that includes the countryside. If not, there is a risk that environmental targets would be confused with self-sufficiency ones, and impact the livelihoods of farmers in the rural settings. A clearer and more deliberate rural-urban link should be considered while implementing these policies.

If adopted, the technologies and methods mentioned above could contribute to improving consumption of vegetables, therefore leading to healthier, sustainable and safe food for the urban population. If innovative techniques work well in urban contexts, they could also be applied in rural ones.

Pillar 6: Water

China has 21% of the world's population, but only 7% of the world's freshwater resources, meaning that water conservation and reuse has been high on the political agenda for a number of years.[243] Water can be considered the most important resource in a city, meaning that there is an (often-ignored) imperative to create a circular economy for water that prioritizes reuse over the use of fresh supplies.

This circular system will reduce not only water insecurity but also energy use and, in some cases, generate energy. The technologies outlined demonstrate how cities can build a circular economy for water by reusing wastewater, better absorbing and storing water, and cutting down on inefficiencies such as leaks.

Tech 1: Wastewater treatment (WWT), the circular economy of water

Description: Wastewater treatment consists of a combination of physical, chemical and biological processes aimed at removing solids, organic matter and, sometimes, nutrients and pathogens from wastewater[244]. It is typically made up of three phases: primary treatment, which involves the sedimentation of solid waste within the water; secondary treatment, which includes biofiltration, aeration and oxidation, and aims to purify wastewater; and tertiary treatment, to remove phosphates and nitrates to allow ejection into a fragile ecosystem (e.g. estuaries, low-flow rivers, coral reefs).[245,246]

Target problems: According to a United Nations study in 2017, globally, more than 80% of wastewater is discharged into the environment without treatment, generating health hazards and potential negative impacts on economic activities.[247]

Over the last two decades, due to a rapid growth in urbanization and economic activity, wastewater discharges have significantly increased, from 41.5 billion m^3 in 2000 to 69.9 billion m^3 in 2018.[248,249,250] Pollution of groundwater wells in China is also an issue that the government is working hard to tackle.[251]

Impact: WWT can have positive impacts on both society and the environment, mitigating health risks, safeguarding biodiversity and bringing sizeable economic benefits. If properly implemented, it can:

- Remove pollutants
- Increase the quality and quantity of recycled water
- Generate energy from the by-products of wastewater treatment
- Decrease the cost of downstream water treatment for consumption
- Enhance the urban water cycle as part of a transition to a circular economy

Also, it is important to recognize that wastewater is the only water resource that is "growing" and becoming increasingly available in areas of high-water demand (cities).

Broader wastewater treatment networks and higher quality WWT plants can help China's goal of dealing with the "black and stinky water"; China would need nearly $150 billion to build massive networks of wastewater pipelines to prevent polluted water from being released into urban rivers.[252] An improved WWT plant can recover up to 90% of methane gas, generating clean sources of urban power generation and optimizing the urban waste cycle.[253,254]

Barriers: A robust WWT strategy requires significant commitment with a goal of 100% coverage and a long-term plan for system management and safe and productive reuse. The main challenge is finding the right business model for treatment and reuse, with the aim of "making wastewater into an economic good".[255]

A major barrier for scaling up is a lack of adequate financing for the upfront cost of the infrastructure investment and the recurring costs of chemicals, plant maintenance and operations. The implementation of a proper WWT strategy needs robust financing. Currently, the main sources of investment come from public budgets, but there are no dedicated governmental investment funds.

Regulatory capacity is also a barrier. According to a study by Tsinghua and East China Normal Universities, China lacks comprehensive legislation for WWT implementation and effluent control[256] Moreover, there are no policies or mechanisms for the "polluter pays principle", which would represent an important source of revenue for WWT plants.

Other pillars:

- Energy: WWT plants use anaerobic sludge digestion to generate heat and electricity on site. During anaerobic digestion, microorganisms break down organic materials from wastewater. The methane gas produced from this process is then used to generate heat and electricity, which is used in plant operations[23]
- Buildings: Water treatment processes can isolate other useable by-products, e.g. gypsum, which can be used to make bricks
- Food: WWT can also facilitate nutrient-capture processes for the creation of fertilizers. An example is represented by the partnership between Veolia (French multinational waste handling business) and Yara (fertilizer manufacturer) to recover fertilizer minerals from a variety of by-products, surplus materials and waste streams across Europe[257]

Example: eMalahleni, a model for water reclamation in South Africa[258,259]

Context: Commissioned in 2007 by Anglo American, the eMalahleni WWT scheme treats mining wastewater from active mining operations. Thanks to the wise management of water discharges, it represents a sustainable model of mining wastewater conversion, addressing the interests of both the mining industry and the local community. At the end of 2015, the plant purified 30 m^3/day, covering up to 20% of the total potable water demand of the area.

Actions taken to reach that goal

- Implementation of high-recovery precipitating reverse osmosis (HiPRO) process to meet WHO Drinking Water Quality Guidelines and DWAF Aquatic Ecosystem Guidelines
- Double quality control system to guarantee the compliance of drinking water to SANS241 standards; water not complying with SANS241 is not added to the municipal water supply and is instead returned to the WWT plant for re-processing
- Batch-wise storage in reservoirs
- Partnership with South Africa's power utility, Eskom, to develop research projects
- Engagement of mining competitors in the Highveld coalfields and local authorities to build a win-win cooperation

Tech 2: Urban flood and stormwater management

Description: Urban flood and stormwater management includes a set of technologies and techniques aimed at reducing rainwater outflow into streets, lawns and other sites, and at improving water quality.[260] Examples include sponge cities, wetland management systems, 50L homes and adaptive city designs.

A sponge city is an urban design concept that aims to exploit several ecologically friendly techniques to passively absorb, purify and use excess rainfall and integrate flood control into urban planning. These techniques include permeable roads, rooftop gardens, rainwater harvesting, rain gardens, ponds and lakes.[261,262] A pilot project was started in 2014 in China, involving 30 metropolises, including Shanghai, Qian'an, Zhenjiang, Pingxiang and Wuhan.[36,263]

Wetlands management consists of conserving, adapting and managing wetlands to control urban flooding and improve water quality as well as to safeguard the environment.

The adaptive city design is a planning concept based on the theory of urban resilience. It encompasses a more flexible approach to flood management, with the integrated ability to modify and adapt to urban floods.[264]

Target problems: By causing "heavy or prolonged rains, storm surge, sudden snowmelt", climate change is exacerbating "urban ills", such as urban flooding.[265,266] Poor urban drainage (flood/stormwater management) can have a devastating impact on urban dwellers and the economy. Of the 654 largest cities in China, 641 are regularly hit by urban floods, and the situation is even worse in coastal metropolises.[267]

So far, local administrations, usually counselled by municipal water engineers, have addressed this problem through the realization of grey infrastructure and relying on hard engineering-based approaches.[268] Yet, grey infrastructure, carrying stormwater away from cities, tends to elevate risks downstream, as expanded volumes of water introduce energy and power into rivers, causing ecological and infrastructure damage.

Impact: The sponge city concept can have two positive impacts on Chinese metropolises: improving water management at the urban level and mitigating the impact of urbanization on natural ecosystems. By taking measures on "the improvement of water permeation, water detention, water storage, water purification, water drainage, water saving and water reuse", this combination of technologies can mitigate floods, reduce the rainwater run-off, facilitate groundwater replenishment and increase its availability for various purposes (industrial, agricultural, household).[269,270]

Surveys conducted in 2017 on the 30 pilot sponge cities confirm a potential 70%-90% reuse capacity of rainwater.[271] Also, according to a study by the City University of Hong Kong, implementation of the concept can reduce the nearby temperature by up to 1.3°C, potentially opening new opportunities to tackle climate change and rising temperatures in large cities.[272,273]

Barriers: Urban flood and stormwater management initiatives require a holistic and sustained effort to successfully face several challenges, including technical/physical, financial and regulatory ones.

There are at least four types of technical/physical barriers: geographical location, i.e. some techniques may not fit with the geographical and weather characteristics of an area; land scarcity in urban areas: China's metropolises are densely populated, with an average of 153 people per km^2, roughly six times the world average; urban planning deficits, i.e. situations in which cities' growth outpaces planning; and soil conditions: clay soils, for example, are not well suited to the aforementioned techniques.[274,275]

Financial barriers refer mainly to difficulties in fundraising. The implementation costs are significant and mostly borne at a local level although the central government allocates $60-90 million per town every three years, amounting to 15%-20% of total costs.[276,277]

Other pillars: Energy: Wetlands and urban gardens can reduce urban temperatures, lessening the need for energy to cool buildings.[278]

Example: Lingang area aims to lead in sponge city concept implementation

Context: In 2014, China launched the Sponge City Initiative, investing in projects that focus on absorbing floodwater. Initially, 30 cities were involved, including Shanghai, Wuhan and Xiamen. The aim of the initiative was by 2020 to enable these pilot cities to reuse at least 70% of their rainwater.[57] Surveys conducted in 2017 on the 30 pilot sponge cities confirmed a potential 70%-90% reuse capacity of rainwater.[279]

A notable example is Lingang area (Shanghai district). With the ambition of being China's largest sponge city project, Lingang invested $119 million in retrofits and innovations that, according to the Shanghai Municipal Engineering Design Institute, can represent a model for the majority of Chinese cities lacking modern water infrastructure.[58,59,280] The total area of 79 km^2 includes 5 km^2 of new parks, and 40 km of new waterways and artificial lakes covering 510,000 m^2; the total storage capacity amounts to 900,000 m^3 of rainwater.[281]

Actions taken to reach that goal

- Implementation of passive design (e.g. water-permeable roads, water penetrating bricks) and rain gardens design (e.g. grass ditches, greenery rooftops) to absorb and store rainwater
- Use of smart management system (IoT, big data analysis, cloud computing) to better transfer and discharge the stored water

Example: Colombo (Sri Lanka) has been accredited with the RAMSAR convention[282,283]

Context: To deal with the increasing frequency and intensity of flooding events in Colombo – which result, on average, in losses amounting up to 1% of the GDP per year – the Sri Lankan government developed over the last decade a comprehensive strategy to enhance urban wetlands management.

The implementation of this project brought several benefits for Colombo, including:

- Mitigation of flood damage to urban areas
- Energy savings from artificial cooling systems, mainly due to lower temperature in wetland areas
- Improved WWT and reuse
- Environmental pollution mitigation connected with carbon sequestration

Thanks to these robust results, in 2018, Colombo was accredited as a RAMSAR wetland site.[284]

Actions taken to reach that goal

- Improvement of the existing retention capacity of the hydric system of the city through the integration of a network of natural and man-made wetlands[285]
- Establishment of three urban wetland parks (one for children is still in the planning phase) to generate extra revenue from recreational activities – up to $13 million per year, according to experts[286]
- Multistakeholder approach, moving beyond the top-down approach in favour of the proactive engagement of the community in protecting the wetlands[287]
- Arrangement of legal protection and interagency coordination to guarantee the preservation of the urban wetland complex[288]

Tech 3: Managed aquifer recharge (MAR)

Description: MAR is a nature-based solution for water storage that can hold wet season flows for use in dryer seasons by using underground, naturally occurring aquifers as active reservoirs. It requires less land area and loses less water to evaporation than surface reservoirs. MAR can provide water for drinking, irrigation and industrial purposes or can contribute to the achievement of environmental goals e.g. groundwater balance restoration.[289,73]

Target problems: The key issues MAR technology addresses are water scarcity, water storage, over-exploitation of water resources and groundwater imbalances in Chinese cities. With economic development and subsequent advances in living standards, the level of water stress (i.e. the ratio between freshwater withdrawals and resources) increased in China from 20% to 23% between 2008 and 2018.[290,291,292] Also, more than 50 metropolises (including Shanghai and Beijing) suffer from subsidence, which is when land surfaces sink as a consequence of the depletion of groundwater aquifers.[293]

Impact: MAR can be very valuable in cities with underlying or surrounding aquifers. It can secure and enhance water supply, mitigating the issues of groundwater scarcity/imbalance in Chinese cities.[294] Based on scientific evidence from countries where this technology is more advanced (India, Netherlands, Australia), MAR can serve – in areas where groundwater systems are distressed – as much as 10% of total water demand.[295,296,297]

However, MAR contribution in China is still minor (0.1% MAR as percentage of groundwater use). According to a study published by the *Hydrogeology Journal*, there is significant potential for uptake of MAR in China due to the country's high groundwater use and wide variety of climate and lithologies, and demand for drinking and irrigation water.[298]

Barriers: The main hindrances to the implementation of MAR technology are economic, operational and administrative in nature.

Apart from relatively high capital requirements, site selection is the prime prerequisite in a MAR scheme. To identify the presence of aquifers and their suitability for MAR, local hydrogeological knowledge is required. Lands should be evaluated and ranked according to their potential for natural recharge. This process can be assisted by geographic information system (GIS) tools, which can identify potential recharge sites' location by analysing data such as slope, infiltration rate, depth of groundwater, water quality and land use.[299,300,301]

Example: MAR project in Salisbury, South Australia, exploited green technologies to provide additional drinking water

Context: Launched in 2005 and tested for the first time between 2006 and 2009, the Aquifer Storage, Transfer and Recovery (ASTR) project in Salisbury, South Australia, represents a virtuous demonstration of MAR technology to produce drinking water through green technologies and natural treatments.[302]

In an effort to deal with the difficult catchment of stormwater (due to low average annual rainfall and high summer evaporation rates in Salisbury), the Australian government launched the ASTR project to rebalance groundwater and increase freshwater availability.[303] So far, the 200,000 m^3 of stormwater harvesting capacity of the system has allowed the successful storage of the run-off caused by the short and intense precipitation, which characterizes the area.[89,93]

Actions taken to reach that goal

- Passive treatments implementation (stormwater harvesting, ASTR)[93]
- Synergic exploitation of green technologies/natural treatments (e.g. through wells, wetlands, ponds) to provide cost-effective and natural ways to pre-treat, inject and abstract stormwater[93]
- Investments in advanced water treatment technologies, e.g. pressure membrane infiltration, advanced oxidation processes[93]
- Effective communication with the public to ensure that environmental and public health concerns are addressed[93]

Tech 4: Non-revenue water (NRW) management

Description: As stated by the World Bank, "non-revenue water is water that is placed into a water distribution system but is not billed to customers", due to both theft and faulty infrastructure, i.e. leakages at the point of customer metering, at utility storage tanks and/or on transmission and distribution (physical losses).[304,305] NRW management is a holistic and proactive approach aimed at reducing the amount of water that is lost before it reaches the customers. It includes leak detection, pipeline assessment, pressure management and hydraulic modelling.[306]

Target problems: According to the *Urban Water Supply Statistical Yearbook 2016*, the Chinese water loss rate is, on average, 12%-14% per year,[307] although this is considerably lower than 34%, the world average, but much higher than the 5% maintained by leading cities such as Copenhagen.[308] NRW represents one of the most serious problems in municipal water systems.[309]

Impact: NRW management can help Chinese cities in at least four ways:

1. Reducing water consumption: An effective implementation of NRW management can significantly lessen water consumption, thanks to a strict control of leakages along the hydric distribution network

2. Reducing energy demand: When water losses reduce the need for groundwater decreases and pumping operations slowdown;[95] this would save energy and diminish GHGs emissions; evidence from Brazil and Abu Dhabi shows how large energy savings can be, ranging from 0.75 kWh to 4 kWh per m^3 of water.

3. Increasing climate resilience: These energy savings, coupled with slower GHGs emissions and water consumption, can also contribute to climate change mitigation[310]

4. Enhancing the financial performances of water utilities:[311] Enhanced financial performances of water utilities depend on improved operations: analyses performed by the Belize Water Service demonstrate that NRW-reduction increases operating revenues (i.e. through the sale of saved water) and lowers operating costs (i.e. linked to producing and pumping water)[95]

Barriers: The main barriers for NRW management are both utilities-specific and systemic in nature. Water utilities are not making effective progress in NRW reduction due to weak capacity, poor financial discipline and the disproportionate effort required to detect and fix leaks, compared to building new treatment facilities.[96] Systemic barriers relate to inefficient systems of incentives (i.e. need to draft more complete and performance-based contracts). [98,99,312,313]

Other pillars: Energy: as NRW rates reduce, water utilities need to produce much less water to comply with clients' contracts. This results in substantially lower energy consumption.

Section 3: Cross-cutting issues

As outlined above, there are a number of technologies and groups of technologies that can be effective in greening Chinese cities. However, none of these technologies nor the pillars themselves sit in isolation. The city is a system and, as such, there are some important frameworks and topics that cut across all aspects of green technology implementation. Circular economy, the Fourth Industrial Revolution, data governance, and gender have been prioritized as cross-cutting issues based on the scale of social and environmental returns as well as potential for green growth and job creation.

Issue 1: The Fourth Industrial Revolution

The importance of the Fourth Industrial Revolution for green urban development

The Fourth Industrial Revolution is a confluence of new technologies – including AI, robotics, IoT, autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing[314] – which is changing the way people live, work, interact and access urban services. Fourth Industrial Revolution enables cities to have the potential to deliver a sustainable future for all. Yet, positive change is not inevitable, and city leadership must be forward-looking and agile enough to steward this change to the benefit of all society.

The major characteristics of the Fourth Industrial Revolution are velocity, scope and system impact. According to Klaus Schwab, Founder and Executive Chairman of the World Economic Forum, "When compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. Moreover, it is disrupting almost every industry in every country it can be characterized by a range of new technologies that are fusing the physical, digital and biological world."[315]

In cities, the Fourth Industrial Revolution can be thought of as the layering of a series of technologies that brings physical infrastructure into the digital realm. Ubiquitous connectivity is provided by the internet and the high bandwidth of the 5G network; this enables the IoT of a city, which consists of sensors that can detect and digitalize everything from the temperature of buildings to leaks in pipes and the prevalence of viruses in wastewater. The digitalization of the physical space creates a digital twin of the city in the form of data streams, which can be manipulated using AI algorithms or logged and traded on blockchains (e.g. energy or water). This manipulation of digital data, in turn, controls the physical infrastructure of the city opening, huge possibilities.

The Fourth Industrial Revolution across the report pillars

The Fourth Industrial Revolution can positively affect urban areas in a number of ways: First, the development of mixed **land use** can significantly benefit from Fourth Industrial Revolution technologies. In fact, digital technologies can help reprogramme, flex and optimize urban spaces, maximizing their potential. For example, AI coupled with online platforms could monitor and adapt spaces based on local citizens' habits and consumer demands.[316]

Second, intelligent urban assets can unlock the **circular economy** potential, reducing waste and improving resource efficiency for societies.[317] The IoT can provide data on the location, condition and availability of an asset (from the location and availability of a shared bike or the condition of a water pipe), this data enables extending the life of an asset (through predictive maintenance), greater utilization (by sharing) or more use cycles (through product reuse).[318]

Third, as outlined in the **energy pillar**, Fourth Industrial Revolution technology can enable the transition to a smart grid or the internet of energy with decentralized renewable power generation systems, including from BIPV. Innovations such as blockchain enable decentralized energy networks, including peer-to-peer transactions in locally generated energy, dynamic pricing and optimal demand-supply balancing.[319]

Blockchain can also contribute to resolving **water scarcity**. A blockchain-based smart water market could effectively allocate water resources by providing accounting, auditing and trading platform replacing intermediaries. Based on a study modelled on Los Angeles County, blockchain-enabled trading could reduce water inequality by facilitating water trades between systems with a surplus and systems with a deficit; incentivize water systems to look for extra supplies such as rainwater, wastewater and stormwater; facilitate the diversification of water supply; and create incentives for wastewater recycling.[320]

Fourth, smarter risk forecasting and regenerative materials can anticipate and reduce the hazards of **climate shocks and natural disasters**, respectively.[321] Predictive AI analytics, IoT and sensors can help early identification of cities' tremors or sea-level changes, anticipating earthquakes, hurricanes, floods and tornados, and quickly triggering adequate urban responses.[322] Advanced materials, such as self-healing concrete, can absorb energy and thus help buildings resist earthquakes.[323] During the COVID-19 pandemic, the world geared up to apply these technologies for quarantine enforcement, contract tracing and flow modelling in the efforts to contain and prevent the spread of the disease.[324]

Last, in the not too distant future, a new generation of **quantum sensors** will also vastly increase what can be sensed and digitized in a city. Quantum sensors are able to measure minute changes in gravitational and magnetic fields by manipulating and sensing atoms. Early uses of these could be the ability to see deep underground, creating an map of where existing pipes and cables are located and allowing for better urban **construction** and maintenance; building better LiDAR (a base technology for autonomous vehicles) based on photons rather than lasers; and eventually enabling the monitoring of individual neurons, allowing for direct brain-computer interaction.[325]

Enabling the Fourth Industrial Revolution in Chinese cities

Benefiting from the investment capacity and clear long-term vision of the government, China has emerged as a global power in the transition towards the Fourth Industrial Revolution and smart urban development. China is one of the largest investors and adopters of digital technologies in the world.[326] Three of the world's internet giants, Baidu, Alibaba and Tencent, are creating multifaceted and disruptive digital ecosystems, profoundly changing the rules of e-commerce, payments and digital interconnectedness.[327] China is specializing in "breakthrough" innovations and is home to many companies that are experts in AI and 5G technology, such as Huawei, the world's leading telecom hardware provider.[328]

So far, 31 Chinese provinces have invested more than $7 trillion in 22,000 projects for new smart infrastructure construction. In March 2020, China re-affirmed the New Infrastructure initiative, targeting investment in projects that will cover seven areas, including the 5G network, big data, ultra-high voltage transmission, intercity transport, artificial intelligence, industrial IoT and new energy vehicle charging stations. In addition to this, the three major Chinese telecom operators are planning to build 550,000 5G base stations, providing the technological enablers for AI, IoT and machine learning deployment in the public sector.

Governance approaches to successfully implement the Fourth Industrial Revolution

The complex, transformative and dynamic nature of the Fourth Industrial Revolution requires new governance approaches to address the interlinked dynamics of emerging technologies and to accelerate the positive societal implications of digital transformation while minimizing the potential drawbacks.[329]

Over the next few years, Chinese governance will be inevitably called to face two major challenges:

- Development of a long-term human-centred vision around technology integration

- Development of an agile approach to embrace, rather than hinder, innovation

The rapid technological change of the Fourth Industrial Revolution calls for a new model of more purposeful technology integration that puts citizens at the centre.[330] For example, in the case of urban sprawl, the advent of the autonomous vehicle might push it to the extreme level by providing the option for people to live much further away and use the commute time to work or sleep. Planners need to anticipate this and plan for more dense cities which serve the population as a whole, being more **human-centric and long term**.

Second, Fourth Industrial Revolution technologies mature at a rapid pace and therefore require an agile approach to governance. This can involve prototyping new approaches and adapting based on results as well as working closely with other stakeholders such as the private sector and academia. China can adopt an **agile and proactive approach to harness the Fourth Industrial Revolution technologies**. Some tools useful for this purpose can be:

- **Pilot cities:** Cities that are selected as incubation zones for new technologies or new sets of technologies. Working with the private sector and academia, policy-makers can use the data gathered in pilot cities to replicate the innovations elsewhere, as well as to support policy-making. Pilot cities could be an innovative way of testing the technologies outlined in this report.

- **Policy labs:** Initiatives aimed at designing new policies and public services to steer emerging innovations towards sustainability and inclusion.[331] The UK Cabinet Office's Policy Lab brings new policy tools and techniques to the UK government through a creative space where policy teams can develop the knowledge and skills in a more open, data-driven, digital and user-centred way.[332,333]

- **Regulatory sandboxes:** Safe spaces for companies to test innovative products, services and business models without needing to face the normal regulatory and financial hurdles (i.e. licensing) of engaging in their experimental activities.[334] Examples of jurisdictions and their regulatory sandboxes include Sweden for autonomous vehicles (Drive Sweden), Bahrain for financial technologies, and Singapore for energy innovation.[335,336,337]

Systemic efficiency

Among all the primary energy produced globally (~14,035 Mt[338]), only 33% is converted into useful energy. The remaining 67% is lost due to inefficiencies in electricity generation, transport, heavy industry and buildings. These inefficiencies can be addressed through sector optimization (e.g. electrification, grid efficiency, building and industry energy efficiency), as well as cross-sector optimization (e.g. optimized usage of energy mix through better design at the intersection of sectors). Addressing these inefficiencies in a systemic manner can be termed systemic efficiency, i.e. the optimization of energy across sectors to create a net-zero carbon future.

Cities represent one of the main opportunities to demonstrate the advantages of systemic efficiency. To deliver on the UN Sustainable Development Goals, Paris Agreement and New Urban Agenda, it is important to have a city-centric approach that addresses the principles of the energy triangle – sustainability, resilience and affordability – in both the energy system and buildings.

Urbanization, growing populations and climate change are key challenges cities must address. There is a limited window of opportunity for cities to rethink urban planning, energy policy and the built living environment to ensure sustainable ecosystems and human wellness. This is crucial because growing populations in urban areas will face more frequent and extreme weather events, in addition to increasing average temperatures.

Growing urban populations will further boost energy demand due to an increase in materials necessary to build and improve infrastructure. Thus, solutions must also address embodied carbon and circular principles in architectural and engineering design.

To accelerate the transition to a more sustainable future in cities, stakeholders have identified the following key areas of focus that will activate systemic efficiency:

- Flexibility and energy optimization measures to reduce energy demand across energy, buildings and transport, including solutions for heating and cooling
- Accelerated electrification of end uses – especially in buildings and transport – powered by clean, renewable energy and connected to modern and digitalized grids to increase overall system resiliency
- Digitalization to enable flexible use of city infrastructure, redefining the way electricity is produced, distributed and consumed
- Urban services that leverage digital platforms to meet the transforming needs of cities currently facing unprecedented challenges
- Circularity of materials for building

Issue 2: Data governance

The importance of data governance for green urban development

Data has been called the "new oil" and is as important to the Fourth Industrial Revolution as steam was to the first.[339] Each day, more than 2.5 quintillion bytes of data are generated, with much of it coming from IoT devices in urban areas. This data is a potentially rich source of information that could be used to improve the delivery of urban services, management of urban systems and quality of life for citizens.

Unfortunately, only a very small amount (less than 1%) of this data is used to drive decisions and create value. Data is normally held by many different players, stored on different systems and lacks interoperability, meaning it is unable to release its full potential.[340] Building better data governance by creating well-designed, regulated and trusted frameworks that enable data opening, connection and sharing has the potential to unlock enormous social and economic value for cities.

Through smart data governance, city managers, the private sector, academia and other agencies can collect, analyse and understand data to make better-informed decisions and solve many challenges for green development, such as limited land, resource efficiency, waste collection and traffic congestion.[341]

The impact of data governance across the six pillars

There are essentially two types of data generated in cities. **Public-sector data** refers to data "generated, collected and stored by international, national, regional and local governments and other public institutions, as well as data created by external agencies for the government or related to government programmes and services." **Private-sector data** refers to information "generated, collected and owned by private companies or individuals, such as customer activity data, personal data, business operational data and industrial data."[342]

In the case of public-sector data, governments can implement open platforms to share data for free covering critical sectors such as geography, climate, water resources, road structure, traffic maps, buildings, energy, air pollution etc. This is already happening to some extent in countries such as Germany, the Netherlands, the United States, Canada, Brazil and India.[343] This type of open data-sharing can improve the state of every pillar of this report. Examples include:

The city of Berlin, as part of its Open Data Initiative, has created an open data platform that has 935 datasets freely available. Within this, datasets on **mobility** cover everything from real-time public transport data to the location of bicycle accidents. This data platform allows companies to build applications that act as an interface to help citizens navigate the city. In Amsterdam, transport data is released, including available parking spaces, congestion and the location of cycle lanes and taxi stands.[344] This data-sharing is an essential building block of a SIMSystem.

In the United States, the Great Lakes Observing System is developing a platform to share data gathered from buoys and underwater probes in Lake Erie. The platform aims to connect people with real-time data related to harmful algal blooms: water sensors installed in buoys and underwater probes can trigger a text that is sent to users whenever data related to **water** contamination levels exceed certain thresholds. This platform has the potential to help 11 million people who rely on Lake Erie for drinking water and are continuously threatened by harmful toxin-producing algae.[345]

In the case of private-sector data, as with any privately owned assets, it is often traded among companies or individuals. However, there are successful examples of private-sector data-sharing by companies that are directly involved in green technology and urban planning. For example:

Uber Movement, a software, is giving city planners and members free access to anonymous data gathered from millions of Uber trips in more than 700 cities across the world. The data shared by the software enables urban planners to better address city **mobility** challenges and make informed decisions on a variety of matters, such as traffic congestion mitigation, GHG emissions reduction and road safety improvement.[346]

Creating an internet of energy will mean that energy utility companies will have to manage not only the energy grid, but also a data grid that must be interoperable with IoT devices from numerous manufacturers. Smart appliances, smart meters, EVs and renewable energy generated at a building or household level all create data that need to be understood and analysed by the utility. Strong data governance and standards will be needed to facilitate sharing between this network of devices, the utility and third parties.[347]

Actions governments can take to effectively implement data governance

Effective implementation of data governance is possible only if stakeholders trust the data-sharing platforms that are being used. Thus, the proper management of data requires that **necessary restrictions and regulations** are in place.[348] In fact, opening public-sector data without restrictions and allowing private-sector data trading activities without regulations could decrease the general level of confidence in data-sharing platforms.

Some of the essential elements that characterize a robust data regulatory framework are:

– **Data privacy**, which should be guaranteed throughout the whole process of data collection, sharing and use (e.g. by giving clear declarations on the scope of authorized use and life cycle of the shared data)

– **Data security** to avoid cyberthreats such as unauthorized access to data and data impairment (e.g. by implementing secure protocols to reduce data tampering or loss such as transport layer security or IPsec)

– **Data interoperability**, which allows data-sharing and use across systems, platforms, locations and jurisdictions (e.g. by establishing and adopting standards for data formats and structures)

– **Data accountability**, which should be addressed by "validating and declaring the data provider, evaluating for potential bias, securing transparency and traceability of the data source and data flow" (e.g. by implementing risk assessment processes to understand the reliability of data that would be otherwise be used to make decisions)

– **Eligibility of operators**, which ensures that whoever operates on the platform has the legal right to do so and is constantly monitored by legislation

– **Promote further unlocking of value** by creating platforms for the sharing of private-sector data to improve green development in cities, while also encouraging companies and industry associations to facilitate the sharing of data[349]

Issue 3: Circular economy

The importance of a circular economy in green urban development

The circular economy is a restorative and regenerative-by-design systemic approach to economic development, aiming to decouple growth from the consumption of finite resources. The model[350] is designed to benefit business, society and the environment. It is particularly relevant for cities since, globally between 2010 and 2040, material consumption will more than double from 40 billion tonnes to 90 billion tonnes.[351] China was among the first countries in the world to legislate for a circular economy by implementing the Circular Economy Promotion Law.[352]

Circular economy across the six pillars

The circular economy touches all pillars outlined in the report, as it deals with the flows of resources around a city. These flows are complex systems that intersect different aspects of the city. Therefore, the implementation of the circular economy is intimately tied to systems analysis and thinking, a process that involves taking a step back to see the whole picture, identifying the levers in the system and then making interventions to shift the system towards a circular one. Illustrations of this approach in food, buildings and consumer waste show how changes at different points of the cycle can shift the whole system.

For example, the urban **food system** touches on the **food, water, mobility** and **energy pillars** and is a good example of where the circular economy can be applied. Key raw material inputs into food production are nitrogen, phosphorous and potash, of which China consumed 54.16 million tons in 2015.[353] China is self-sufficient in nitrogen and phosphorus but dependent on potash imports (43.8% dependence degree in 2017) mostly from Russia, Canada and Belarus.[354,355] Fertilizers such as phosphorus, if overused, can become organic waste which pollutes rivers, lakes and oceans, threatening **water** quality around the world.

Food then enters the city by truck, affecting **mobility** by adding to traffic and pollution. Before it is eaten, globally, one-third of all calories are lost in the form of food waste either at the transport, processing or retail stage or in individual households.[356] Globally, food production methods and consumption patterns are generating significant costs to the society: for every $1 spent on food, society pays $2 in health, environmental and economic costs.[357]

Under a circular system enabled by green technology, **land** and **water** would be used as efficiently as possible and, where appropriate, food could be grown locally with some degree of vertical farming. In urban environments, this could be located in underutilized space, saving **water** by using hydroponics in a closed water system while decreasing **traffic** from transport. **Food** waste would be minimized along the value chain and in the home, in part using digital platforms. Any unavoidable waste would be converted into usable products or processed industrially using anaerobic digestion. This would produce an output of methane gas for renewable **energy** production and compost to be returned to food production.[358]

Sewage sludge can also be harvested and used as an input to agriculture. For example, in the Netherlands, the Amersfoort sewage treatment plant produces 900 tonnes of high-grade fertilizer per annum as well as purifying wastewater for reuse in cities.[359] According to government figures, wastewater in China contains nearly 120,000 tonnes of phosphorus, which could be better captured with the implementation of the right technology.[360]

In **buildings**, there is also significant scope for circular approaches, particularly by leveraging new technologies. Globally, the built environment is one of the heaviest users of material: the sector consumes 42.4 billion tonnes of material per year and is responsible for one-fifth of global emissions. By 2050, China's building stock is predicted to grow by a further 135%. Very little of the world's construction waste is reused and accounts for 35% of the world's landfill.[361,362]

There are many interventions and technologies that could better use construction waste, including the 3D printing of new buildings using waste materials.[363] However, the most important lever comes at the design stage. Buildings such as Circl, a mixed-use restaurant and office building in Amsterdam, are designed and built with eventual disassembly in mind – a concept known as "buildings as material banks".[364] To accompany these buildings and record the valuable materials inside, developers create materials passports; these log a blueprint of the building, including the value and location of valuable components, to allow for easy disassembly and assessment of embedded material value, leading to higher recycling rates. Material passports have been piloted in the European Union by the Buildings as Material Banks Platform and by Netherlands company Madaster.[365,366]

A circular approach to construction is a key lever to drive down emissions in the built environment, conserve resources, reduce waste and minimize the environmental impact of the materials used.[367] For instance, using recycled steel uses only 16%-20% the energy of virgin steel while, in the case of aluminium, the number goes down to 5%.[368]

Companies such as Miniwiz have demonstrated new applications for post-consumer waste as a building material. One example, the Jackie Chan Stuntman Training Center in Tianjin, saw the retrofitting of an old cinema complex using building materials made from old DVDs, car tires and plastic bags.[369]

Another common application of the circular economy in cities is managing **municipal and industrial waste**. China produces 210 million tonnes of post-consumer waste annually, as well as 3.3 billion tonnes of industrial waste, making it one of the largest generators of waste in the world.[370,371]

Many green urban technologies are underpinned by the connectivity of electronic products such as IoT devices, base stations and mobile phones. However, at a global level only 20% of waste of electrical electronic equipment (WEEE) is formally collected and recycled.[372] These products can be a source of scarce and valuable materials. The global value of WEEE is estimated to be more than $60 billion.[373]

A study by the World Economic Forum and Tsinghua University found that, in China, only 10% of aluminium, 6% of tin, 0.6% of cobalt and 0% of rare earths are captured from scrap electronics products. If 100% of these metals were recycled, the material value alone would be worth $3.3 billion by 2030.[374] The Ellen MacArthur Foundation has predicted that, in China, using circular business models such as product-as-a-service, designing products using circular design principals as well as scaling up reuse and recycling could cut emissions from the sector by 22% in 2040.[375]

China has also outlined ambitious policies for the **circular economy in industry**. The State Council has set a target of recycling 50% of key products by 2025 and the inclusion of 20% recycled materials in all new products. Many companies with production facilities in China have also made commitments to the circular economy and the use of recycled material in products. There is a significant opportunity for public and private stakeholders to come together around this goal.[376]

Designing the circular economy into urban planning

There are a number of ways that circular economy can be implemented into urban planning and the application of green technology.

First, it is important to have a master plan, based on a system analysis of the city. This plan should outline the opportunities for all stakeholders, including start-ups, research institutes, government departments, urban planners and the private sector, as well as aiming to engage citizens in the circular economy.

For example, the *London Circular Economy Route Map* provides guidance on accelerating the British capital's transition to a circular economy. Guidelines include clearly communicating the benefits of the circular economy to guarantee greater adoption; ensuring that everybody in the supply chain benefits from the prescribed changes (e.g. by creating a hub to promote conversation among businesses, the public sector and academia); enhancing the availability of affordable capital (e.g. supporting circular economy SMEs from start-up to maturity through incubation, venture capital and private equity funds); incentivizing companies to gain a competitive advantage by offering circular economy approaches; and demonstrating the positive effects of a circular economy approach through successful projects and business model pilots. The route map could bring London net benefits worth £7 billion (about $8.87 billion) every year by 2036, mainly in the sectors of built environment, food, textiles, electricals and plastics.[377]

Second, policy and taxation should be aligned with the goals of the circular economy, for example, charges that take into account the negative externalities of single-use items, such as plastic bags; tax breaks for the use of recycled materials in products; and incentive mechanisms, such as extended producer responsibility. Unproductive policies, such as those that inhibit or tax waste movements in and out of manufacturing zones or subsidize virgin feedstocks can also hinder the circular economy by stopping or substituting productive movement of material to be recycled and should be re-examined.

Third, facilitate investment into innovation with government funds to support the development of the circular economy or blended finance models where government funding can help de-risk investment in circular business models.[378] Banks can also be encouraged to set up innovation funds or companies innovation challenges to spur entrepreneurship. Governments can also examine public procurement to stimulate demand for circular products and services.

Governance of the circular economy

Governance of the circular economy can be complex; as outlined above, often material flows in cities across many different areas and departments. Changing an entire system to implement the circular economy in cities requires collaboration with many stakeholders including the private sector, which is responsible for much of the innovation and implementation; citizens, who need to change how they use resources; and academia, which has specialized knowledge.

Due to the cross-cutting nature of the circular economy, many cities, regions or countries have made use of a platform approach, which brings together all of the key players in a structured way to collaborate on implementing the circular economy in a city or region or around a particular challenge. Examples include:

– The European Sustainable Phosphorus Platform (ESPP), Despite being a finite resource essential to soil fertility and crop growth, phosphorus is not being treated sustainably, jeopardizing the world's food security. In this context the ESPP works with a diverse range of stakeholders and ensures knowledge-sharing; creates network opportunities in the phosphorus management field; and addresses regulatory obstacles.[379]

– The Platform BAMB – Buildings As Material Banks – connecting 15 partners from seven European countries to create circular solutions in the building sector, avoiding extra waste. Cities can be characterized by cycles of construction, demolition and reconstruction, due to poor building design. The objective of BAMB is to enable a systemic shift from a linear and static building environment to a circular and dynamic one. Through design and circular value chains, BAMB aims to increase the value of building materials. This way, at the end of their life, buildings become banks of valuable materials, instead of these materials being wasted.[380]

– The Platform for Accelerating the Circular Economy (PACE) is a global convening platform and project accelerator to help speed the transition to a circular economy, it was launched at the World Economic Forum Annual Meeting 2017 in Davos and is now hosted in the Netherlands. The platform provides a leadership platform for CEOs, ministers and heads of international organizations to come together to collaborate; it runs and supports high-impact projects and works with partners on sharing knowledge and learning. The platform has successfully created projects on e-waste in Nigeria, plastics in Indonesia, Ghana and Viet Nam, and circular manufacturing of electronics in China.[381]

– The Ellen MacArthur Food Initiative brings together key actors to stimulate a global shift towards a regenerative food system based on the principles of a circular economy. The initiative engages municipalities such as London, New York, and São Paulo as flagship cities, local and global businesses, and resource managers to work together in new ways to drive systemic change.

Similar platform approaches could help the transition towards a circular economy in Chinese cities where there is a strong alignment between the goals of government, the private sector and significant specialized knowledge in academia.

Issue 4: Gender equality

The importance of gender equality in green urban development

The United Nations has long identified the need for gender-sensitive responses to the effects of climate change, in particular stressing women's role in sustainable development and transition to an inclusive green economy.

The Rio Declaration on Environment and Development[382] recognized the essential role of women in environmental management and sustainable development. In this context, green urbanization means not only green technology, urban planning and design, but also a deep understanding of the underlying impact and opportunities for all genders.

Moreover, according to the United Nations Development Programme, equality is a "multiplier" for sustainability, and closing the gender gap will help build green cities and economies.[383] Therefore, proactive gender-sensitive policies are necessary to ensure that the whole community will benefit from green urbanization.[384]

Three demonstrable areas where women's empowerment can affect green urbanization are the sustainable consumption of natural resources, renewable energy, and the prevention and management of natural disasters.

First, women are important actors in the sustainable consumption of natural resources, as they most often manage household activities, like cooking, obtaining drinking water, washing, grocery shopping and family activity planning. In fact, globally, they control up to 70% of household spending and contribute to more than 60% of all consumption impact.[385,386,387]

Green consumption should not be seen exclusively as a woman's prerogative: with eco-friendly campaigns and product claims largely aimed at female audiences, advertisers run the risk of creating an "eco-gender gap", which may wrongfully imply that sustainable lifestyle choices are exclusively women's responsibility.

Second, renewable energy is one of the most powerful tools to increase the effectiveness of women in climate change mitigation.[388] According to the International Energy Agency, gender diversity in the energy sector is fundamental to driving more innovative and inclusive solutions for clean energy transitions all over the world.[389,390] However, women are underrepresented in the energy field: they usually do not hold positions of influence, represent only 32% of the labour force and are listed in fewer than 11% of patent applications related to the sector.[391,392,393]

Third, women can also significantly improve both prevention and management of natural disasters. This is due to several reasons:

– Women's practical expertise and alternative, gender-differentiated perspective on risks can decrease the likelihood of a crisis

– Women can improve the efficiency of after-disaster responses, facilitating disaster relief and reconstruction work

– Women can enhance societal resilience as promotors of community cohesion

Some projects supported by the World Bank have shown strong improvements in community resilience by including women in programme design and implementation for post-flooding reconstruction in Argentina, El Salvador, India, Indonesia, Mozambique and Viet Nam. Such projects were designed to understand the gender dimensions of disaster impacts and of promoting equality during the recovery process.

Recommendations coming from these projects led to standard guidance developed by the World Bank, which identifies three critical factors:

– Entry points for the integration of gender concerns in policy development and the project cycle

– Implementation of tools for gender-informed monitoring and evaluation

– Practical tools for integrating gender issues in community-based disaster risk management

Achievements and challenges on gender issues in Chinese cities

In recent years, China has made significant strides in the direction of gender equality. Data in 2015 show that Chinese female workers contributed 41% of China's GDP in 2015, above the 37% world average.[394]

Women's empowerment in China has made significant progress in both education and employment. For instance, 50.6% of Chinese postgraduates in 2016 were women, exceeding the percentage of men for the first time,[395,396] and the gap is widening. A larger share of female postgraduates is a significant milestone given that, overall, there are more men than women in China.

As of 2019, women made up 43.7% of the Chinese workforce, outperforming the 40% target set in the 2011-2020 Program for the Development of Chinese Women.[397,398] The government estimates that women set up 55% of new internet companies in China and more than one-quarter of all entrepreneurs there are women, which is a much higher number than in any other country.[399]

The next wave of New Infrastructure technologies in China will lead to disruptive innovations that change people's lives in unimaginable ways; but this is a double-edged sword, which can either empower women for a robust green economy by deploying gender-sensitive actions covering whole value chains across sectors or build invisible barriers to women becoming the driven force for green innovation and champions for green consumption.

For example, gender equality in the AI industry can be enhanced by involving more women in the data collection process, including in design and surveys of candidates; Further, recruiting more women to build the algorithms could better meet the demand from women for new products and services.

It is believed that the main challenges for China are how to design, implement and evaluate green development policies with the consideration of gender equality in every aspect; bring more women into decision-making roles, and provide tools and resources to promote and engage women in green development. Women's important role in green development has not been adequately recognized from the top; thus, it has not been sufficiently implemented in action plans.

Gender issues across the six pillars

Urban planning shapes the environment in which people live; technology pervades everything in people's lives. Both play an important role in determining how we work, move and rest; they define societal opportunities for participation, decision-making and, thus, empowerment.[400]

Yet, urban planning and technology have, in most cases, historically been designed for men and by men. They tend to reflect traditional gender roles and fit better for heterosexual and able-bodied men than they do for women, girls and people with disabilities. In urban areas, challenges to gender equality manifest in various forms, such as persistent gender bias in urban economies (e.g. the work participation rate and wage gap), inadequate infrastructure, higher violence rates against women in public spaces and low governmental representation.

Each of the pillars of this study have a gender component, such as:

- In **mobility**, according to a study by the World Bank, public transport systems are usually designed to meet only male workforce needs, serving commuting trips to/from industrial and business work areas and disregarding women's necessity to engage in continuous and varying off-peak movements.[401] Cars are also designed with men's safety in mind: crash test dummies are made to resemble the typical adult male, meaning women are 73% more likely to be injured in a car accident.

- For **land use and planning**, mixed use areas – which combine commercial and residential property – decrease travel distances and therefore can benefit citizens with less access to cars, such as women and young people. These mixed-use areas also help citizens (often women) combine care-giving and employment. Better public-space design and management will also make women feel safer.

- A multi-country study on urban planning and women's safety by the UN-Habitat and Women in Cities International made **recommendations for increasing women's sense of safety and use of public space, by improving various elements of the built environment and changing community behaviours and local government policies.** The "Women's Safety Audit" is a tool for evaluation of the urban environment to help decision-makers understand the different impact on men vs women, and seeks to increase civic participation in local governance.[402]

- For **buildings**, the ambient interior temperature is usually attuned to men's requirements; stairs are often too high and wide for women to comfortably use. More generally, the size of screens on mobile phones are calibrated to the dimension of men's hands; and first aid courses are usually taught on mannequins resembling men.

- In general, gender-inclusive planning and design in the building sector requires a fundamental re-alignment, including time, expertise and resources, to establish gender principles throughout project planning, design, implementation and operation stages. A report by the UN Office of the High Commissioner for Human Rights shows that universal accessibility adds less than 1% to construction costs.[403]

Mainstreaming gender equality into the planning of Chinese cities

To improve gender equality and unleash women's potential to drive green development, three key steps must be implemented: **recognize women's role in green urbanization** at the highest level within the Chinese government and reflect it in high-level policy papers to guide implementation and evaluation; fully recognize that women and men have **different needs but equal rights** in urban societies;[404] and use a **gender-responsive method to plan** with women's involvement and for women.

- The **first step is a top-down approach to recognize women's important role in green urbanization in high-level policy papers**, such as the Five-Year Plan, by adding "gender analysis" to governmental policy development processes to guide the implementation and evaluation at the sub-national and local levels. There should be an analysis of challenges and opportunities at the national and regional levels that identify priority sectors and intervention points and assesses existing policies across all relevant domains.

- **The second step is about culture**: Planning cities without explicitly taking diversity into account can result in inadequate access to urban infrastructure and services, which disproportionately affects women and other minorities.[405] Here, it is important to mention the "Right to the City" concept, an inclusive approach "which treats cities as urban commons".

- **The third step is an operational one regarding city design and planning**: Case studies of successful, gender-inclusive projects around the world show that the proactive participation of women in urban projects can yield innovative solutions that serve everyone, i.e. women, men and minorities, better.[406] Take Vancouver, Canada. In a climate action plan to become the "greenest city in the world", Vancouver placed significant importance on one body for women's empowerment:[407] the governmental Women's Advisory Committee, which has a mandate to "advise Council and staff on enhancing access and inclusion for women and girls to fully participate in city services and civic life."[408]

With the fast advancement of new infrastructure technologies in China, the development of mobile platform technologies for data collection and the analysis of gender-disaggregated data can play a focal role to create conditions for equal opportunities and benefits.[409] This understanding is vital both to tailor policy responses around women's contributions in urban settings and to find effective ways to engage women in urban decision-making.[410]

As suggested by the United Nations, policy-makers all over the world, including China, should adopt a multi-level and multistakeholder approach, cutting across sectors and national boundaries, and designing tools to enact gender-responsive policies and interventions[411] to support green cities and sustainable development goals.

Conclusion and next steps

This report will be presented to the China Council for International Cooperation on Environment and Development (CCICED) as a supporting document to the Special Policy Study on Green Technologies and as a supplement to the joint work of the CAUPD and World Economic Forum. The recommendations from this report were used as input into the CCICED's annual policy recommendations to China's State Council.

At the time of publication, the global COVID-19 pandemic has had a devastating effect on the health and economic strength of many countries. As countries start to rebuild after this unprecedented crisis, including implementing stimulus packages, green technologies in cities could provide an investment opportunity that can stimulate the economy and improve the lives of citizens, while also yielding positive environmental outcomes.

As demonstrated in this report, this implementation is not necessarily about selecting one technology or approach, but rather a process of putting in place the right structural frameworks, standards and people-centred approaches, while taking a step back to view the urban system as a whole and the connections between its seemingly disparate parts.

The evolving crisis can be seen as a critical juncture, and has been termed a "Great Reset".[412] The World Economic Forum looks forward to continuing to collaborate with partners at the CCICED and the CAUPD as well as all of the experts involved in this study to collectively imagine the future of Cities in China and the rest of the world in this rapidly changing context.

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“International Energy Community - China” is a global platform based in China focused on re-accelerating global energy transition. The platform facilitates dialogue between global energy executives and links projects/alliances dedicated to energy transition with governments and organizations willing to contribute. This platform, launched in early 2019 by the World Economic Forum, is supported by a multistakeholder community of 30 organizations, government entities and academics, who meet regularly in a neutral environment.

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Endnotes

1. United Nations (2018), "68% of the world population projected to live in urban areas by 2050, says UN", available at: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
2. World Bank (2020), "Urban Development Overview", available at: https://www.worldbank.org/en/topic/urbandevelopment/overview
3. Ellen MacArthur Foundation, World Economic Forum (2018), Cities and the Circular Economy for Food, available at: https://www.ellenmacarthurfoundation.org/publications/cities-and-circular-economy-for-food
4. Xinhua (2018), China makes steady progress in urbanization, available at: http://www.xinhuanet.com/english/2018-09/10/c_137458990.htm
5. Xinhua (2018), China's urbanization rate hits 60.6 pct, available at: http://www.xinhuanet.com/english/2020-01/19/c_138718450.htm
6. IEA (2016), "Cities are at the Frotntline of the Energy Transition", available at: https://www.iea.org/news/cities-are-at-the-frontline-of-the-energy-transition
7. C40 (2019), "City Action to Address the Climate Emergency", available at: https://www.c40.org/other/city-commitments
8. RMS (2006), "Ranking of the World's Cities Most Exposed to Costal Flooding", available at: https://climate-adapt.eea.europa.eu/metadata/publications/ranking-of-the-worlds-cities-to-coastal-flooding/11240357
9. Klaus Schwab (2016), "The Fourth Industrial Revolution: what it means, how to respond" https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/
10. Earth Policy Institute (2001), "Eco-Economy: Building an Economy for the Earth"
11. IEA (2019), Carbon Emissions to Peak in 2022, available at https://www.iea-coal.org/carbon-emissions-from-china-to-peak-sooner-than-expected-in-2022/
12. IEA (2020), "China", available at: https://www.iea.org/countries/china
13. Fraunhofer ISE, Energy charts, Monthly electricity generation 2019, available at: https://www.energy-charts.de/energy.htm?source=all-sources&period=monthly&year =2019 (Link as of 06/01/2020)
14. IEA (2020), "China", available at: https://www.iea.org/countries/china
15. R. Wile (2013), "Solar Power Could Be A Total Game-changer — But They Still Need To Figure Out One Thing", available at: https://www.businessinsider.com/renewable-energy-storage-problem-2013-11?IR=T
16. http://www.nea.gov.cn/2020-02/28/c_138827923.htm
17. 1kWh = 0.00012284 tons of standard coal; 1 kg standard coal = 2.493 kg CO_2.
18. http://www.nea.gov.cn/2020-02/28/c_138827910.htm
19. J. Yang, Q. Liu, X. Li, X. Cui (2017), "Overview of Wind Power in China: Status and Future", available at: https://www.mdpi.com/2071-1050/9/8/1454
20. F. Kahrl, J. Lin, X. Liu, J. Hu (2019), "Sunsetting Coal Power in China", available at: https://eta.lbl.gov/publications/working-paper-007-sunsetting-coal
21. C. Vest (2017), "China turns to energy storage to push renewables", available at: https://www.chinadialogue.net/article/show/single/en/9635-China-turns-to-energy-storage-to-push-renewables
22. Z. Boren (2017), "Data: China is wasting lots of renewable energy", available at: https://unearthed.greenpeace.org/2017/04/19/china-wind-solar-renewable-curtailment-energy-wasted/
23. International Renewable Energy Agency (2019), "Innovation landscape for a renewable-powered future: Solutions to integrate renewables", available at: https://www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future
24. IRENA, Electricity Storage and Renewables, 2017, available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017_Summary.pdf?la=en&hash=2FDC44939920F8D2BA29CB762C607BC9E882D4E9
25. N. Abhyankar, J. Lin, X. Liu, F. Sifuentes, 2020, "Economic and environmental benefits of market-based power-system reform in China: a case study of the Southern grid system", *Resources, Conservation and Recycling*.
26. World Economic Forum and Tsinghua University, 2019, Recovery of Key Metals in the Electronics Industry in the People's Republic of China, available at: http://www3.weforum.org/docs/Recovery_Key_Metals_Electronics_light.pdf
27. https://wedocs.unep.org/bitstream/handle/20.500.11822/30950/2019GSR.pdf?sequence=1&isAllowed=y
28. https://iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/GEA_Chapter9_transport_hires.pdf

29. R. Ray (2018), "Removing Barriers for Energy Storage", available at: https://www.power-eng.com/2018/02/22/removing-barrier-for-energy-storage/

30. World Energy Council (2019), "Energy Storage Monitor Latest trends in energy storage", available at: https://www.worldenergy.org/assets/downloads/ESM_Final_Report_05-Nov-2019.pdf

31. European Parliamentary Research Service (2019), "Common rules for the internal electricity market".

32. International Renewable Energy Agency (2019), "Future of wind: Deployment, investment, technology, grid integration and socio-economic aspects (A Global Energy Transformation paper)", available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf

33. International Renewable Energy Agency (2018), "Renewable Energy Benefits: Leveraging local capacity for offshore wind", available at: https://www.irena.org/publications/2018/May/Leveraging-Local-Capacity-for-Offshore-Wind

34. The European Green Deal, https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

35. "2030 climate & energy framework", https://ec.europa.eu/clima/policies/strategies/2030_en

36. Proposal for a Regulation of the European Paliament of the council, estbalishing the Just Transition Fund, https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12113-Fast-track-interservice-consultation-on-the-SEIP-including-a-JTM-and-the-JTF-

37. Batstorm (2018), "Battery Promoting Policies in Selected Member States", available at: https://ec.europa.eu/energy/en/topics/technology-and-innovation/energy-storage/batteries#documents

38. Smart Energy International (2019), "Research shows massive growth in UK energy storage projects", available at: https://www.smart-energy.com/industry-sectors/storage/research-shows-massive-growth-in-uk-energy-storage-projects/

39. IEA (2019), "China Power System Transformation", available at: https://www.iea.org/reports/china-power-system-transformation

40. Bartol, Nadya and Michael Coden. 2017. Our Critical Infrastructure Is More Vulnerable than Ever – It Doesn't Have to Be that Way. https://www.bcg.com/en-us/ publications/2017/engineered-products-critical-infrastructure-vulnerable-doesnt-have-to-be-that-way.aspx (link as of 26/11/18)

41. CERRE (2019), "Smart Consumers in the Internet of Energy", available at: https://www.cerre.eu/publications/smart-consumers-internet-energy

42. G. Erbach, J. O'Shea (2019), "Cybersecurity of critical energy infrastructure", available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/642274/EPRS_BRI(2019)642274_EN.pdf

43. ENEL, Sustainability Report, 2018 https://sustainabilityreport2018.enel.com/en/sustainable-value-created/open-innovability-and-digitalization/cyber-security

44. D. Gagne, E. Settle, A. Aznar, R. Bracho (2018), "Demand Response Compensation Methodologies: Case Studies for Mexico", available at: https://www.osti.gov/biblio/1452706-demand-response-compensation-methodologies-case-studies-mexico

45. Building Energy Research Center of Tsinghua University (2018), "China Building Energy Use 2018", available at: https://berc.bestchina.org/Files/CBEU2018.pdf

46. D. Benazeraf (2017), "Heating Chinese cities while enhancing air quality", available at: https://www.iea.org/commentaries/heating-chinese-cities-while-enhancing-air-quality

47. IEA, 2019, The Future of Cooling in China, availabile at: https://www.iea.org/reports/the-future-of-cooling-in-china

48. The Climate and Clean Air Coalition, https://ccacoalition.org/en/initiatives/hfc

49. IRENA/IEA-ETSAP Technology Brief (2015), "Solar Heat for Industrial Processes", available at: https://www.irena.org/publications/2015/Jan/Solar-Heat-for-Industrial-Processes

50. T. Jia, J. Huang, R. Li, P. He, Y. Dai (2018), "Status and prospect of solar heat for industrial processes in China", available at: https://www.sciencedirect.com/science/article/abs/pii/S1364032118301643

51. E. R. Masanet *et al.*, *Global Data Center Energy Use: Distribution, Composition, and Near-Term Outlook*, Evanston, IL, 2018.

52. Building Energy Research Center of Tsinghua University (2018), "China Building Energy Use 2017 & China Building Energy Use 2018", available at: https://berc.bestchina.org/Files/CBEU2018.pdf & https://berc.bestchina.org/Files/CBEU2017.pdf

53. STATISTA (2018), "Territorial carbon dioxide emissions in China from 2001 to 2017", available at: https://www.statista.com/statistics/239093/co2-emissions-in-china/

54. IEA, 2019, Country Profile, China, https://www.iea.org/countries/china

55. Amol Phadke, Nihar Shah, Jiang Lin, Won Young Park, Yongsheng Zhang, Durwood Zaelke, Chao Ding and Nihan Karali, 2019, "China policy leadership could cool global air conditioning impacts", BTJRC working paper 005, LBNL

56. McKinsey & Company (2013), "Sizing the potential of behavioral energy-efficiency initiatives in the US residential market", available at: https://www.mckinsey.com/~/media/mckinsey/industries/electric%20power%20and%20natural%20gas/our%20insights/giving%20us%20energy%20efficiency%20a%20jolt/sizing%20the%20potential%20of%20behavioral%20energy%20efficiency%20initiatives%20in%20the%20us%20residential%20market.ashx

57. S. Malaviya, S. Chandiwala (2018), “How Behavioral Science Can Boost Household Energy Efficiency”, available at: https://www.wri.org/blog/2018/06/how-behavioral-science-can-boost-household-energy-efficiency

58. R. Metcalfe (2018), “Using Multiple Social Nudges to Reduce Peak Energy Demand”, available at: https://www.behavioraleconomics.com/using-multiple-social-nudges-to-reduce-peak-energy-demand/

59. Global CCS Institute, Global Status of CCS, 2019, https://www.globalccsinstitute.com/resources/global-status-report/

60. The Boston Consulting Group, 2019, The Business Case for Carbon Capture, available at: https://www.bcg.com/en-ch/publications/2019/business-case-carbon-capture.aspx

61. IPCC (2018), “Global Warming of 1.5 °C”, available at: https://www.ipcc.ch/sr15/

62. IEA, 2019, Country Profile, China, https://www.iea.org/countries/china

63. Material Economics, 2019, Industrial Transformation 2050, Pathways to Net-Zero Emissions from EU Heavy Industry, https://www.climate-kic.org/wp-content/uploads/2019/04/Material-Economics-Industrial-Transformation-2050.pdf

64. The Boston Consulting Group, 2019, The Business Case for Carbon Capture, available at: https://www.bcg.com/en-ch/publications/2019/business-case-carbon-capture.aspx

65. Material Economics, 2019, Industrial Transformation 2050, Pathways to Net-Zero Emissions from EU Heavy Industry, https://www.climate-kic.org/wp-content/uploads/2019/04/Material-Economics-Industrial-Transformation-2050.pdf

66. The Boston Consulting Group, 2019, The Business Case for Carbon Capture, available at: https://www.bcg.com/en-ch/publications/2019/business-case-carbon-capture.aspx

67. Global CCS Institute, Global Status of CCS, 2019, https://www.globalccsinstitute.com/resources/global-status-report/

68. https://www.iea.org/reports/tracking-power-2019/ccus-in-power#abstract

69. https://www.netzeroteesside.co.uk/news/bp-eni-equinor-shell-and-total-form-consortium-to-develop-the-net-zero-teesside/

70. Building Energy Research Center of Tsinghua University (2018), “China Building Energy Use 2017 & China Building Energy Use 2018”, available at: https://berc.bestchina.org/Files/CBEU2018.pdf & https://berc.bestchina.org/Files/CBEU2017.pdf

71. Chinese Standard (2019), “Nearly Zero Energy Buildings Technology Standard (GB/T51350-2019)”

72. Building Energy Research Center of Tsinghua University (2018), “China Building Energy Use 2017 & China Building Energy Use 2018”, available at: https://berc.bestchina.org/Files/CBEU2018.pdf & https://berc.bestchina.org/Files/CBEU2017.pdf

73. Ibid.

74. STATISTA (2018), “Territorial carbon dioxide emissions in China from 2001 to 2017”, available at: https://www.statista.com/statistics/239093/co2-emissions-in-china/

75. Team analysis

76. STATISTA (2018), “China Qinhuangdao coal spot price from 2003 to 2018”, available at: https://www-statista-com.easyaccess1.lib.cuhk.edu.hk/statistics/383534/asian-coal-marker-price/

77. https://www.convert-me.com/en/convert/energy/mtce/mtce-to-kwh.html?u=mtce&v=986

78. Renewable and Sustainable Energy Reviews (2019), “A comprehensive analysis on definitions, development, and policies of nearly zero energy buildings in China”, available at: https://www.sciencedirect.com/science/article/pii/S1364032119305222

79. Ibid.

80. E&E News (2015), “Chinese developers get active building passive energy homes”, available at: https://www.eenews.net/stories/1060012314

81. Singapore Building and Construction Authority (2014), 3rd Green Buildings Masterplan, https://www.bca.gov.sg/GreenMark/others/3rd_Green_Building_Masterplan.pdf

82. World Economic Forum (2018), “Agile cities: preparing for the Fourth Industrial Revolution”, available at: http://www3.weforum.org/docs/WP_Global_Future_Council_Cities_Urbanization_report_2018.pdf

83. EPFL (2017), The school with the largest solar façade in the world, https://actu.epfl.ch/news/the-school-with-the-largest-solar-fa-cade-in-the--5

84. https://www.vaillant.info/architects-planners/reference-projects/green-arena-zurich/

85. V. Shabunko, M. Bieri, T. Reindl. Building integrated photovoltaic facades in Singapore: Online BIPV LCC Calculator. Proceedings of the 2018 IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC), pp. 1231-1233

86. Energy and Buildings (2019), “Holistic economic analysis of building integrated photovoltaics (BIPV) system: case studies evaluation”, available at: https://www.sciencedirect.com/science/article/pii/S0378778819315907

87. Lu, Y., Chang, R., Shabunko, V., & Yee, A. T. L. (2019). The implementation of building-integrated photovoltaics in Singapore: drivers versus barriers. *Energy*, *168*, 400-408.

88. The European Portal for Energy Efficiency in Buildings (2019), “Building integrated photovoltaics (BIPV) as a viable option among renewables”, available at: https://www.buildup.eu/en/news/

overview-building-integrated-photovoltaics-bipv-viable-option-among-renewables

89 [89] Bloomberg New Energy Finance(2019),"New Energy Outlook 2019". Available at: https://about.bnef.com/new-energy-outlook/

90. U.S. Green Building Council (2015). "What is WELL?", available at: https://www.usgbc.org/articles/what-well

91. Westwood Net Lease Advisors (2018), "Does WELL certification really pay off?", available at: https://westwoodnetlease.com/well-certification-really-pay-off/

92. U.S. Green Building Council (2015), "What is WELL?", available at: https://www.usgbc.org/articles/what-well

93. World Green Building Council (2018), "Doing right by planet and people: the business case for health and wellbeing in green building", available at: https://www.worldgbc.org/sites/default/files/WorldGBC%20-%20Doing%20Right%20by%20Planet%20and%20People%20-%20April%202018_0.pdf

94. C. Hallstrom (2019), "WELL certification cost: what is the ROI of WELL?", available at: https://www.alpinme.com/well-certification-cost/#:~:text=WELL%20has%20a%20direct%20and,on%20employees%20and%20their%20productivity.

95. World Green Building Council (2018), "Doing right by planet and people: the business case for health and wellbeing in green building", available at: https://www.worldgbc.org/sites/default/files/WorldGBC%20-%20Doing%20Right%20by%20Planet%20and%20People%20-%20April%202018_0.pdf

96. J. Matos (2015), "WELL Building Standard introduced in China", available at: https://resources.wellcertified.com/articles/well-building-standard-introduced-in-china/

97. The Guardian (2018), "Inside the Beijing 'office' inhabited by human guinea pigs", available at: https://www.theguardian.com/cities/2018/jul/18/inside-the-beijing-office-where-humans-are-monitored-like-guinea-pigs

98. The Elders (2014), "What is 'carbon neutrality' – and how can we achieve it by 2050?", available at: https://www.theelders.org/news/what-carbon-neutrality-%E2%80%93-and-how-can-we-achieve-it-2050

99. World Green Building Council (2018), "Barangaroo South honoured in WorldGBC Asia Pacific Leadership in Green Building Awards", available at: https://www.worldgbc.org/sites/default/files/PRESS%20RELEASE%20-%20APN%20Awards%20-%20Barangaroo%20South_FINAL.pdf

100. China Development Bank Capital (2015), "Hammarby Sjöstad: an urban development case study of Hammarby Sjöstad in Sweden, Stockholm", available at: https://hammarbysjostad20.se/wp-content/uploads/2019/06/Hammarby-Sjostad_report_eng.pdf

101. BCA, Singapore Government (2014), "3rd Green Building Masterplan, Building and Construction Authority", available at: https://www.bca.gov.sg/GreenMark/others/3rd_Green_Building_Masterplan.pdf).

102. Eco-business (2018), "The missing piece in Singapore's green building puzzle", available at: https://www.eco-business.com/news/the-missing-piece-in-singapores-green-building-puzzle/

103. Shijiazhuang Municipal People's Government Documents (2018), "Implementation opinions on accelerating the development of passive ultra-low-energy buildings", available at: http://www.sjz.gov.cn/col/1520233915276/2018/03/07/1520410483452.html

104. Xinhuanet (2019), "China Focus: Int'l efforts push for low-energy building", available at: http://www.xinhuanet.com/english/2019-10/11/c_138461784.htm

105. Mobility Lab, "What is TDM?", available at: https://mobilitylab.org/about-us/what-is-tdm/

106. Shaheen, Susan and Cohe, Adam (2020) Mobility on demand (MOD) and mobility as a service (MaaS): early understanding of shared mobility impacts and public transit partnerships, https://tsrc.berkeley.edu/publications/chapter-3-mobility-demand-mod-and-mobility-service-maas-early-understanding-shared

107. Gasgoo (2020), "China's private car parc exceeds 200 mln for first time", available at: http://autonews.gasgoo.com/m/Detail/70016758.html

108. Ben Dror, Maya; Qin, Lanzhi and An, Feng (2019), The gap between certified and real-world passenger vehicle fuel consumption in China measured using a mobile phone application data, Energy Policy, Volume 128, May 2019, Pages 8-16, available at: https://www.sciencedirect.com/science/article/abs/pii/S0301421518308449

109. Federal Highway Administration (2019), "Congestion pricing: environmental benefits", available at: https://ops.fhwa.dot.gov/congestionpricing/resources/enviro_benefits.htm#:~:text=Congestion%20pricing%20can%20improve%20the,generated%20by%20accelerations%20and%20decelerations

110. Nearshore Americas, "Mexico City the Most Traffic Congested Place on Earth", https://nearshoreamericas.com/mexico-city-traffic-congested-country-earth/

111. Centre for Public Impact (2016), "London's congestion charge", available at: https://www.centreforpublicimpact.org/case-study/demand-management-for-roads-in-london/

112. International Council on Clean Transportation (2018), "China's New Energy Vehicle mandate policy (final rule)", available at: https://theicct.org/sites/default/files/publications/ICCT_China-NEV-mandate_policy-update_20180111.pdf

113. Drive to Zero (2019), available at: https://globaldrivetozero.org/tools/zero-emission-technology-inventory/

114. Ben Dror, An (2018), Government Policy and Regulatory Framework for Passenger NEVs in China https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/04/OEF-112.pdf p.38

115. Reuters (2019), "China wants New Energy Vehicle sales in 2025 to be 25% of all car sales", available at: https://www.reuters.com/article/us-china-autos-electric/china-wants-new-energy-vehicle-sales-in-2025-to-be-25-of-all-car-sales-idUSKBN1Y70BN

116. Reuters (2020), China says no significant cut in new energy vehicle subsidies in 2020, https://www.reuters.com/article/us-china-autos/china-says-no-significant-cut-in-new-energy-vehicle-subsidies-in-2020-idUSKCN1ZA09Z

117. B. Wang (2019), "China Cleaned Up Beijing Air First and Now Targets Big Truck Pollution", available at: https://www.nextbigfuture.com/2019/01/china-cleaned-up-beijing-air-first-and-now-targets-big-truck-pollution.html#:~:text=Particulate%20air%20pollution%20kills%20about%201%20million%20people%20per%20year.&text=Tackling%20truck%20emissions%20has%20become,just%207.7%20percent%20in%202017.

118. Saarinen (2018), "Hydrogen fuel cells: do hydrogen cars have a future?", available at: https://www.autoexpress.co.uk/car-news/electric-cars/93180/hydrogen-fuel-cell-do-hydrogen-cars-have-a-future

119. GBTimes (2018), "Vehicle emissions become major source of air pollution in China", available at: https://gbtimes.com/vehicle-emissions-become-major-source-of-air-pollution-in-china

120. Belfer Center (2019), "The role of electric vehicles in decarbonizing China's transportation sector", available at: https://www.belfercenter.org/publication/role-electric-vehicles-decarbonizing-chinas-transportation-sector

121. Union of Concerned Scientists (2014), "How clean are hydrogen fuel cell vehicles?", available at: https://www.ucsusa.org/resources/how-clean-are-hydrogen-fuel-cell-vehicles

122. World Economic Forum (2019), "A Vision for a Sustainable Battery Value Chain in 2030", available at: http://www3.weforum.org/docs/WEF_A_Vision_for_a_Sustainable_Battery_Value_Chain_in_2030_Report.pdf

123. Saarinen (2018), "Hydrogen fuel cells: do hydrogen cars have a future?", available at: https://www.autoexpress.co.uk/car-news/electric-cars/93180/hydrogen-fuel-cell-do-hydrogen-cars-have-a-future

124. UC Berkeley Transportation Sustainability Research Center (2018), "The Potential of Ride Hailing and Pooling", available at: https://escholarship.org/uc/item/46p6n2sk#:~:text=Shared%20mobility%20with%20pooled%20rides,to%20create%20livable%20urban%20communities.&text=Innovative%20mobility%20services%20premised%20on,and%20reduce%20greenhouse%20gas%20emissions.

125. New Mobility Coaliton (2020). Available at: https://www.weforum.org/projects/global-new-mobility-coalition

126. World Economic Forum (2019) "SEAM Mobility Governance Frameworks",https://www.weforum.org/whitepapers/shared-electric-and-automated-mobility-seam-governance-framework-prototype-for-north-america-and-europe

127. Proceedings of the National Academy of Sciences of the United States of America (2018), "On-demand high-capacity ride-sharing via dynamic trip-vehicle assignment", available at: https://www.pnas.org/content/114/3/462

128. ITF (2016), "Urban Mobility System Upgrade", available at: https://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf

129. AlphaBeta (2017), "Rethinking urban mobility in Indonesia: the role of shared mobility services", available at: https://www.alphabeta.com/wp-content/uploads/2018/08/fa-uberreport-indonesia_english.pdf

130. S. Shaheen, "Ridesharing in North America: Past, Present, and Future", Transport Reviews, available at: https://www.researchgate.net/publication/232849706_Ridesharing_in_North_America_Past_Present_and_Future

131. World Economic Forum, Deloitte (2018), "Designing a Seamless Integrated Mobility System (SIMSystem): A Manifesto for Transforming Passenger and Goods Mobility", available at: http://www3.weforum.org/docs/Designing_SIMSystem_Manifesto_Transforming_Passenger_Goods_Mobility.pdf

132. McKinsey & Company (2019), "The road to seamless urban mobility", available at: https://www.mckinsey.com/business-functions/sustainability/our-insights/the-road-to-seamless-urban-mobility

133. World Economic Forum, Deloitte (2018), "Designing a Seamless Integrated Mobility System (SIMSystem): A Manifesto for Transforming Passenger and Goods Mobility", available at: http://www3.weforum.org/docs/Designing_SIMSystem_Manifesto_Transforming_Passenger_Goods_Mobility.pdf

134. McKinsey & Company (2019), "An integrated perspective on the future of mobility, part 3: setting the direction toward seamless mobility", available at: https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/the%20road%20to%20seamless%20urban%20mobility/an-integrated-perspective-on-the-future-of-mobility-part-3-vf.ashx

135. McKinsey & Company (2019), "The road to seamless urban mobility", available at: https://www.mckinsey.com/business-functions/sustainability/our-insights/the-road-to-seamless-urban-mobility

136. McKinsey & Company (2019), "An integrated perspective on the future of mobility, part 3: setting the direction toward seamless mobility", available at: https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/the%20road%20to%20seamless%20urban%20mobility/an-integrated-perspective-on-the-future-of-mobility-part-3-vf.ashx

137. World Economic Forum, Deloitte (2018), "Designing a Seamless Integrated Mobility System (SIMSystem): A Manifesto for Transforming Passenger and Goods Mobility", available at: http://www3.weforum.org/docs/Designing_SIMSystem_Manifesto_Transforming_Passenger_Goods_Mobility.pdf

138. European Environment Agency (2019), "Fiscal instruments favouring electric over conventional cars are greener", available at: https://www.eea.europa.eu/themes/transport/electric-vehicles/taxes-and-incentives-promoting-electric

139. Embassy of the Kingdom of the Netherlands in Norway, "E-Mobility in Norway"

140. E. Lorentzen, P. Haugneland, C. Bu, E. Hauge (2017), "Charging infrastructure experiences in Norway - the worlds most advanced EV market", available at: https://elbil.no/wp-content/uploads/2016/08/EVS30-Charging-infrastrucure-experiences-in-Norway-paper.pdf

141. Ibid.

142. World Economic Forum (2018), "The Oslo model: how to prepare your city for the electric-vehicle surge", available at: https://www.weforum.org/agenda/2018/08/the-oslo-model-how-to-prepare-your-city-for-electric-vehicles/

143. Ibid.

144. Real Urban Emissions Initiative (2018), "In-use vehicle exhaust emissions in London in 2018", available at: https://www.trueinitiative.org/media/597545/true-london-summary-fact-sheet.pdf

145. CRCOG, *Best Practices Manual*, Chapter 5 Transit Oriented Development, available at: https://crcog.org/wp-content/uploads/2016/07/Ch05_FactSheet_TOD.pdf

146. World Bank, Development Research Center of the State Council, the People's Republic of China, *Urban China: Toward Efficient, Inclusive, and Sustainable Urbanization,* 2014, available at: https://openknowledge.worldbank.org/handle/10986/18865

147. World Bank, *Reducing Traffic Congestion and Emission in Chinese Cities*, November 2018, available at: https://www.worldbank.org/en/news/feature/2018/11/16/reducing-traffic-congestion-and-emission-in-chinese-cities

148. Transit Cooperative Research Program, *Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects*, 2004, available at: https://www.valleymetro.org/images/uploads/general_publications/TCRP-Report-102_TOD-in-the-US-Experiences-Challenges-and-Prospects_10-04.pdf

149. Ibid.

150. CRCOG, *Best Practices Manual*, Chapter 5 Transit Oriented Development, available at: https://crcog.org/wp-content/uploads/2016/07/Ch05_FactSheet_TOD.pdf

151. Swilling, M., Hajer, M., Baynes, T., Bergesen, J., Labbé, F., Musango, J.K., Ramaswami, A., Robinson, B., Salat, S., Suh, S., Currie, P., Fang, A., Hanson, A. Kruit, K., Reiner, M., Smit, S., Tabory, S., *The Weight of Cities: Resource Requirements of Future Urbanization*, A Report by the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya, 2018, available at: https://www.resourcepanel.org/sites/default/files/documents/document/media/the_weight_of_cities_full_report_english.pdf

152. Transit Cooperative Research Program, *Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects*, 2004, available at: https://www.valleymetro.org/images/uploads/general_publications/TCRP-Report-102_TOD-in-the-US-Experiences-Challenges-and-Prospects_10-04.pdf

153. Li, W., Vehicle emissions become major source of air pollution in China, GBTimes, 4 June 2018, available at: https://gbtimes.com/vehicle-emissions-become-major-source-of-air-pollution-in-china

154. Barklage IV, T.E., *Overcoming Obstacles to Successfully Implementing Transit-Oriented Development*, May 2013, available at: https://cmt-stl.org/app/uploads/2011/10/Barklage_Capstone_FINAL.pdf

155. Transit Cooperative Research Program, *Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects*, 2004, available at: https://www.valleymetro.org/images/uploads/general_publications/TCRP-Report-102_TOD-in-the-US-Experiences-Challenges-and-Prospects_10-04.pdf

156. Ibid.

157. National Conference of State Legislatures, *Transit-Oriented Development in the States*, 2012, available at: https://www.ncsl.org/documents/transportation/TOD_final.pdf

158. Barklage IV, T.E., *Overcoming Obstacles to Successfully Implementing Transit-Oriented Development*, May 2013, available at: https://cmt-stl.org/app/uploads/2011/10/Barklage_Capstone_FINAL.pdf

159. Swilling, M., Hajer, M., Baynes, T., Bergesen, J., Labbé, F., Musango, J.K., Ramaswami, A., Robinson, B., Salat, S., Suh, S., Currie, P., Fang, A., Hanson, A. Kruit, K., Reiner, M., Smit, S., Tabory, S., *The Weight of Cities: Resource Requirements of Future Urbanization*, A Report by the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya, 2018, available at: https://www.resourcepanel.org/sites/default/files/documents/document/media/the_weight_of_cities_full_report_english.pdf

160. Brittlebank, W., *Compact cities to address climate change*, January 2014, available at: http://www.climateaction.org/climate-leader-papers/compact_cities_to_address_climate_change

161. A.J. Arnfield (2003), "Two decades of urban climate research: A review of turbulence, exchanges of energy and water, and the urban heat island", available at: https://doi.org/10.1002/joc.859

162. Zhou, B., Rybski, D., Kropp, J.P., *The role of city size and urban form in the surface urban heat island*, July 2017, available at: https://www.nature.com/articles/s41598-017-04242-2

163. Bai, L., Ding, G., Gu, S., Bi, P., *The effects of summer temperature and heat waves on heat-related illness in a coastal city of China, 2011-2013*, April 2014, available at: https://www.researchgate.net/publication/262226597_The_effects_of_summer_temperature_and_heat_waves_on_heat-related_illness_in_a_coastal_city_of_China_2011-2013

164. Pierer, C., Creutzig, F., *Star-shaped cities alleviate trade-off between climate change mitigation and adaptation*, April 2018, available at: https://iopscience.iop.org/article/10.1088/1748-9326/ab2081

165. Ibid.

166. CRCOG, *Best Practices Manual*, Chapter 5 Transit Oriented Development, available at: https://crcog.org/wp-content/uploads/2016/07/Ch05_FactSheet_TOD.pdf

167. Transit Cooperative Research Program, *Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects*, 2004, available at: https://www.valleymetro.org/images/uploads/general_publications/TCRP-Report-102_TOD-in-the-US-Experiences-Challenges-and-Prospects_10-04.pdf

168. Sanford, C., *The Responsible Business: Reimagining Sustainability and Success*, 2011, available at: https://books.google.it/books?id=rTcxBwAAQBAJ&pg=PA235&lpg=PA235&dq=Curitiba+has+more+car+owners+per+capita+than+anywhere+else+in+Brazil&source=bl&ots=o1krmCzs9P&sig=ACfU3U2xNv0ufuqy9ljs71jydK9XkQgCw&hl=it&sa=X&ved=2ahUKEwi94Py-kYToAhWMsKQKHXTrBhgQ6AEwDnoECAoQAQ#v=onepage&q=Curitiba%20has%20more%20car%20owners%20per%20capita%20than%20anywhere%20else%20in%20Brazil&f=false

169. Friberg, L., *Innovative solutions for public transport; Curitiba, Brazil Sustainable Development International 4th edition*, 2000

170. Danish Ministry of the Environment, *The Finger Plan*, Denmark 2015, available at: https://danishbusinessauthority.dk/sites/default/files/fp-eng_31_13052015.pdf

171. Sørensen, E., Torfing, J., *The Copenhagen Metropolitan 'Finger Plan'*, September 2019, available at: https://www.oxfordscholarship.com/view/10.1093/oso/9780198843719.001.0001/oso-9780198843719-chapter-12?print=pdf

172. Van Wee, B. (2011). Evaluating the impact of land use on travel behaviour: The environment versus accessibility. Journal of Transport Geography, 19(6), 530–1533. doi: 10.1016/j.jtrangeo.2011.05.011

173. Echenique, M., Barton, H., Hargreaves, T., & Mitchell, G. (2010). SOLUTIONS final report: sustainability of land use and transport in outer neighbourhoods. http://www.suburbansolutions.ac.uk/findings.htm. Accessed 10 January 2017.

174. Herzog, De Meuron (2010), "1111 Lincoln Road", available at: https://www.herzogdemeuron.com/index/projects/complete-works/276-300/279-1111-lincoln-road.html

175. Curien, R., *Chinese Urban Planning*, March 2014, available at: https://journals.openedition.org/chinaperspectives/6528?file=1

176. Litman, T., Steele, R., *Land Use Impacts on Transport How Land Use Factors Affect Travel Behavior*, November 2019, available at: https://www.vtpi.org/landtravel.pdf

177. Wang, X., Khattak, A., Zhang, Y., *Is Smart Growth Associated with Reductions in Carbon Dioxide Emissions?*, Transportation Research Record Journal of the Transportation Research Board, December 2013, available at: https://www.researchgate.net/publication/270208120_Is_Smart_Growth_Associated_with_Reductions_in_Carbon_Dioxide_Emissions

178. Litman, T., Steele, R., *Land Use Impacts on Transport How Land Use Factors Affect Travel Behavior*, November 2019, available at: https://www.vtpi.org/landtravel.pdf

179. Spears, S., Boarnet, M.G., Handy, S., Rodier, C., *Impacts of Land-Use Mix on Passenger Vehicle Use and Greenhouse Gas Emissions*, September 2014, available at: https://ww3.arb.ca.gov/cc/sb375/policies/mix/lu-mix_brief.pdf

180. Fernandez, R.A., Zubelzu, S., Martinez, R., *Carbon Footprint and the Industrial Life Cycle*, 2017

181. Harbers, A., Bakkes, J., Cities in transition, *Towards a People-Oriented Urbanisation, 2015-2025*, 2015

182. ULI Development Case Studies, *Roppongi Hills,* 2003, available at: https://casestudies.uli.org/wp-content/uploads/2015/12/C033017.pdf

183. Victoria Transport Policy Institute, *Roadway connectivity: Creating more connected roadway and pathway networks,* 2017

184. Barrington-Leigh, C., Millard-Ball, A., *Global trends toward urban street-network sprawl*, October 2019, available at: https://www.pnas.org/content/pnas/117/4/1941.full.pdf

185. Barrington-Leigh, C., Millard-Ball, A., *A global assessment of street-network sprawl*, November 2019, available at: https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0223078&type=printable

186. Barrington-Leigh, C., Millard-Ball, A., *Global trends toward urban street-network sprawl*, October 2019, available at: https://www.pnas.org/content/pnas/117/4/1941.full.pdf

187. Alba, C.A., Beimborn, E., *Analysis of the effects of local street connectivity on arterial traffic*, January 2005, available at: https://www.researchgate.net/publication/228931445_Analysis_of_the_effects_of_local_street_connectivity_on_arterial_traffic

188. World Bank and the Development Research Center of the State Council, the People's Republic of China, *Urban China: Toward Efficient, Inclusive, and Sustainable Urbanization*, 2014

189. Gipouloux, F., *China's Urban Century: Governance, Environment and Socio-Economic Imperatives*, 2015, available at: https://books.google.it/books?id=TXXhCgAAQBAJ&pg=PA107&lpg=PA107&dq=street+connectivity+china&source=bl&ots=y4BmDAkDe

8&sig=ACfU3U330p_HdHBJlXmUo2cQNqjmwniEJw&hl=it&sa=X&ved=2ahUKEwjYpLXWsoXoAhXRAxAIHYL0AugQ6AEwBnoECAoQAQ#v=onepage&q=street%20connectivity%20china&f=false

190. World Bank, *Reducing Traffic Congestion and Emission in Chinese Cities*, November 2018, available at: https://www.worldbank.org/en/news/feature/2018/11/16/reducing-traffic-congestion-and-emission-in-chinese-cities

191. Zlatkovic, M., Zlatkovic, S., Sullivan, T., Bjornstad, J., Shahandashti, S., Assessment of effects of street connectivity on traffic performance and sustainability within communities and neighborhoods through traffic simulation, 2019 (available at: https://wfrc.org/PublicInvolvement/InTheNews/AssessmentOfEffectsOfStreetConnectivity.pdf).

192. Ibid.

193. Barrington-Leigh, C., Millard-Ball, A., *Global trends toward urban street-network sprawl*, October 2019, available at: https://www.pnas.org/content/pnas/117/4/1941.full.pdf

194. Foletta, N., *Houten*, available at: https://itdpdotorg.wpengine.com/wp-content/uploads/2014/07/22.-092211_ITDP_NED_Desktop_Houten.pdf

195. Ellen MacArthur Foundation, World Economic Forum (2018), Cities and the Circular Economy for Food, available at: https://www.ellenmacarthurfoundation.org/publications/cities-and-circular-economy-for-food

196. CGIAR (2020), Emissions from the Food Sector, available at: https://ccafs.cgiar.org/bigfacts/#theme=food-emissions

197. IPBES (2020), Models Drivers of Biodviersity Ecosystem Change, available at: https://ipbes.net/models-drivers-biodiversity-ecosystem-change

198. Eat-Lancet Commission (2019), Food Planet Health, page 5, available at: https://eatforum.org/content/uploads/2019/01/EAT-Lancet_Commission_Summary_Report.pdf

199. Medical News Today (2019), “What are the best meat substitutes?”, available at: https://www.medicalnewstoday.com/articles/325608#popular-meat-substitutes

200. Impossible Foods (2020), available at: https://impossiblefoods.com/food/

201. OmniPork (2020), available at: https://omnipork.co/

202. “Importance of considering environmental sustainability in dietary guidelines”, The Lancet, available at: https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196%2818%2930174-8/fulltext

203. “Our World in Data”, Oxford Martin School, available at: https://ourworldindata.org/search?q=china+meat+consumption

204. EAT-Lancet Comission (2019), Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems, availabile at: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(18)31788-4/fulltext#tbl1

205. FAO (2016), “Food-based dietary guidelines – China”, available at: http://www.fao.

org/nutrition/education/foodbaseddietaryguidelines/regions/countries/china/fr/

206. Food Chain Research Network (FCRN) (2020), “Feed conversion efficiency in aquaculture: do we measure it correctly?” Available at: https://www.fcrn.org.uk/research-library/feed-conversion-efficiency-aquaculture-do-we-measure-it-correctly

207. Gerber, P. J. et al. Tackling Climate Change Through Livestock: A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization, 2013

208. FAO, Livestock’s Long Shadow. FAO, Rome, 2006

209. Nuveen, “The impact of African Swine Fever on the agricultural industry: a complex puzzle”, available at: https://www.nuveen.com/en-us/thinking/alternatives/the-impact-of-african-swine-fever-on-the-agricultural-industry

210. Aleksandrowicz, L., Green, R., Joy, E. J., Smith, P. and Haines, A., “The impacts of dietary change on greenhouse gas emissions, land use, water use, and health: A systematic review”, available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0165797#sec005

211. GFI (2020), “Sustainable Meat Fact-Sheet”, available at: https://www.gfi.org/sustainable-meat-fact-sheet

212. IFPRI (2019), “Alternative meat can sustain food systems”, available at: https://www.ifpri.org/blog/alternative-meat-can-sustain-food-systems

213. World Economic Forum (2019), “Meat the Future Series: Alternative Proteins”, available at: http://www3.weforum.org/docs/WEF_White_Paper_Alternative_Proteins.pdf

214. Economic Daily, China Economic Net (2020), “Food safety hotspots in 2019: artificial meat surge hits experts: safety is the foundation of scientific research and innovative development of artificial meat”, available (in Chinese) at: http://www.ce.cn/cysc/sp/info/202001/03/t20200103_34038916.shtml

215. World Economic Forum (2019) “Incentivizing Food Systems”, available at: https://www.weforum.org/reports/incentivizing-food-systems-transformation

216. Time (2020), https://time.com/5803803/china-delivery-driver-ecommerce-covid19/

217. Bloomberg (2020), Coronavirus Outbreak Drives Demand for China’s Online Grocers, https://www.bloomberg.com/news/articles/2020-02-10/coronavirus-outbreak-drives-demand-for-china-s-online-grocers

218. International Food Policy Research Institute, available at: https://www.ifpri.org/topic/food-loss-and-waste).

219.

220. Beef2Live (2020), "Top 25 Most Produced Foods in China". Available at: http://beef2live.com/story-top-50-produced-foods-china-0-120692#:~:text=China%20produces%20more%20than%20100,most%20produced%20food%20in%20China.

220. Beef2Live (2020), "Top 25 Most Produced Foods in China", available at: http://beef2live.com/story-top-50-produced-foods-china-0-120692#:~:text=China%20produces%20more%20than%20100,most%20produced%20food%20in%20China.

221. Strategies for Self-Sustainability (2017), "Little Donkey Farm", available at: http://strategiesforselfsustainability.viainteraxion.org/en/little-donkey-farm-%E5%B0%8F%E6%AF%9B%E9%A9%B4%E5%B8%82%E6%B0%91%E5%86%9C%E5%9B%AD-%E2%88%97-china/

222. World Economic Forum, McKinsey & Company (2019), "Innovation with a Purpose: Improving Traceability in Food Value Chains through Technology Innovations", available at: http://www3.weforum.org/docs/WEF_Traceability_in_food_value_chains_Digital.pdf

223. IBM News (2017), "IBM Announces Major Blockchain Collaboration with Dole, Driscoll's, Golden State Foods, Kroger, McCormick and Company, McLane Company, Nestlé, Tyson Foods, Unilever and Walmart to Address Food Safety Worldwide", available at: https://www-03.ibm.com/press/us/en/pressrelease/53013.wss

224. World Economic Forum (2019), "Where does our food come from? Here's why we need to know", available at: https://www.weforum.org/agenda/2019/01/where-does-our-food-come-from-heres-why-we-need-to-know/

225. Ibid.

226. Pew Research Center (2015), "Corruption, Pollution, Inequality Are Top Concerns in China", available at: https://www.pewresearch.org/global/2015/09/24/corruption-pollution-inequality-are-top-concerns-in-china/

227. World Economic Forum, McKinsey & Company (2019), "Innovation with a Purpose: Improving Traceability in Food Value Chains through Technology Innovations", available at: http://www3.weforum.org/docs/WEF_Traceability_in_food_value_chains_Digital.pdf

228. Ibid.

229. WhatIs.com (2017), "Vertical Farming", available at: https://whatis.techtarget.com/definition/vertical-farming.

230. AZO Cleantech (2014), "An introduction to hydroponic technology", available at: https://www.azocleantech.com/article.aspx?ArticleID=492

231. U.S. Energy Information Administration, Annual Energy Outlook 2014 Early Release, available at: https://www.eia.gov/todayinenergy/detail.php?id=15471

232. C. Jianming (2014), "Urban agriculture makes China's cities more livable", available at: https://www.chinadialogue.net/article/show/single/en/7091-Urban-agriculture-makes-China-s-cities-more-liveable

233. SmartCitiesDive (2017), "How China leads the world in indoor farming", available at: https://www.smartcitiesdive.com/ex/sustainablecitiescollective/chinas-indoor-farming-research-feed-cities-leads-world/409606/

234. International Food Information Council Foundation (2019), "Growing Upwards: Q&A on Vertical Farming", available at: https://foodinsight.org/growing-upwards-q-a-on-vertical-farming/

235. E. Bryce (2018), "What's the monetary value of urban farming – at a global scale?", available at: https://anthropocenemagazine.org/2018/01/whats-the-monetary-value-of-urban-farming-at-a-global-scale/#:~:text=Specifically%2C%20they%20homed%20in%20on,and%20vacant%20plots%20of%20land.&text=By%20insulating%20buildings%20from%20heat,a%2Dhalf%20million%20American%20homes.

236. Forbes (2017), "5 Repurposed Warehouses Turned Indoor Farms That Need No Land Or Sun To Grow Crops", available at: https://www.forbes.com/sites/bisnow/2017/06/16/5-repurposed-warehouses-turned-indoor-farms-that-need-no-land-or-sun-to-grow-crops/#7d007cf92ec9

237. K. Woodward (2017), "Hydroponics: the future of farming", available at: https://www.foodprocessing-technology.com/features/featurehydroponics-the-future-of-farming-5901289/

238. Quartz (2015), "Rooftop hydroponic systems in cities produce vegetables that are cheaper and healthier than rural farms", available at: https://qz.com/863358/rooftop-hydroponic-systems-in-cities-produce-vegetables-that-are-cheaper-and-healthier-than-rural-farms/

239. HortiDaily (2015), "China: first steps into hydroponics brought 150% yield increase", available at: https://www.hortidaily.com/article/6017274/china-first-steps-into-hydroponics-brought-150-yield-increase/

240. CRC Press (2004), "Hydroponics: A practical guide for the soilless grower"

241. Channel News Asia (2019), "Singapore aims to produce 30% of its nutritional needs by 2030, up from less than 10%", available at: https://www.channelnewsasia.com/news/singapore/singapore-produce-30-own-food-up-from-10-nutritional-needs-11320426

242. Singapore Food Agency (2020), "Food and Farming", available at: https://www.sfa.gov.sg/food-farming

243. World Bank (2018), "China: A Watershed Moment for Water Governance", available at: https://www.worldbank.org/en/news/press-release/2018/11/07/china-a-watershed-moment-for-water-governance

244. M.B. Pescod (1992), “Food and agriculture organization of the United Nations”, available at: http://www.fao.org/3/t0551e/t0551e05.htm#3.2%20conventional%20wastewater%20treatment%20processes

245. Organica (2017), “Primary, Secondary, And Tertiary Wastewater Treatment: How Do They Work?”, available at: https://www.organicawater.com/primary-secondary-tertiary-wastewater-treatment-work/

246. Khopkar, S. M. (2007), “Environmental Pollution Monitoring And Control”, available at: https://books.google.it/books?id=TAk21grzDZgC&redir_esc=y&hl=it

247. United Nations (2017), “2017 UN World Water Development Report, Wastewater: The Untapped Resource”, available at: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/2017-wastewater-the-untapped-resource/

248. China Water Risk (2017), “Good to the last drop”, available at: http://www.chinawaterrisk.org/resources/analysis-reviews/wastewater-good-to-the-last-drop/

249. STATISTA (2018), *DataHub,* available at: https://www.statista.com/statistics/282548/china-wastewater-discharge/

250. World Bank (2019), *DataHub, a*vailable at: https://data.worldbank.org/country/china

251. Institute of Public and Environmental Affairs (2019), “The Blue City Water Quality Index”, available at: http://wwwen.ipe.org.cn/reports/report_19918.html

252. Reuters (2018), “China needs nearly $150 billion to treat severe river pollution: official”, available at: https://www.reuters.com/article/us-china-pollution-water/china-needs-nearly-150-billion-to-treat-severe-river-pollution-official-idUSKBN1KG091

253. Metrovancouver (2015), “Turning wastewater into energy”, available at: http://www.metrovancouver.org/services/liquid-waste/innovation-wasterwater-reuse/wastewater-energy/Pages/default.aspx

254. World Health Organization (2015), “Improved urban waste management”, available at: https://www.who.int/sustainable-development/cities/strategies/urban-waste/en/

255. United Nations (2017), “2017 UN World Water Development Report, Wastewater: The Untapped Resource”, available at: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/2017-wastewater-the-untapped-resource/

256. Meishu Wang, Hui Gong (2018), “Not-in-My-Backyard: Legislation Requirements and Economic Analysis for Developing Underground Wastewater Treatment Plant in China”, available at: https://www.mdpi.com/1660-4601/15/11/2339/htm

257. AgriTrade News (2019), “Yara partners with Veolia to recycle plant nutrients”, available at: https://agritradenews.co.uk/news/2019/02/04/yara-partners-with-veolia-to-recycle-plant-nutrients/

258. United Nations (2012), “eMalahleni: Water Reclamation Plant”, available at: https://unfccc.int/climate-action/momentum-for-change/lighthouse-activities/emalahleni-water-reclamation-plant

259. International Water Association (2015), “The eMalahleni Water Reclamation Plant in South Africa”, available at: https://iwa-network.org/filemanager-uploads/WQ_Compendium/Cases/The%20eMalahleni%20Water.pdf

260. EEC Environmental (2018), available at: https://www.eecenvironmental.com/what-is-stormwater-management/#:~:text=Stormwater%20management%20is%20the%20effort,Environmental%20Protection%20Agency%20(EPA)

261. Harris, Mark (2015), “China’s sponge cities: soaking up water to reduce flood risks”. The Guardian. Retrieved 2019-08-24, “What is a Sponge City?”, Simplicable, Biswas, Asit K.; Hartley, Kris, “China’s ‘sponge cities’ aim to re-use 70% of rainwater – here’s how”, The Conversation., Harris, Mark (2015-10-01). “China’s sponge cities: soaking up water to reduce flood risks”, The Guardian.

262. Xiaoning Li and Xing Fang (2016), “Case Studies of the Sponge City Program in China”, available at: https://www.researchgate.net/publication/303362681_Case_Studies_of_the_Sponge_City_Program_in_China

263. Refer to the case study

264. Johanna Sörensen, Andreas Persson, Catharina Sternudd, Henrik Aspegren et al. (2016), “Re-Thinking Urban Flood Management—Time for a Regime Shift”, available at: https://www.researchgate.net/publication/305891441_Re-Thinking_Urban_Flood_Management-Time_for_a_Regime_Shift

265. Reuters (2019), “Heavy rain and flooding in China force evacuation of nearly 80,000”, available at: https://www.voanews.com/east-asia-pacific/heavy-rain-flooding-china-force-evacuation-nearly-80000

266. NATO (2019), “Flooding and climate change: everything you need to know”, available at: https://www.nrdc.org/stories/flooding-and-climate-change-everything-you-need-know

267. World Economic Forum, https://www.weforum.org/agenda/2019/06/how-china-s-sponge-cities-are-preparing-for-sea-level-rise

268. Faith Ka Shun Chan, James A. Griffiths, David Higgitt, Shuyang Xu, Fangfang Zhu, Yu-TingTang, Yuyao Xu, Colin R.Thorne (2018), “Sponge City in China—A breakthrough of planning and flood risk management in the urban context”, available at: https://www.sciencedirect.com/science/article/abs/pii/S0264837717306130

269. CNN (2018), “China’s ‘sponge cities’ aim to re-use 70% of rainwater”, available at: https://edition.cnn.com/2017/09/17/asia/china-sponge-cities/index.html

270. The Guardian (2019), “Inside China’s leading ‘sponge city’: Wuhan’s war with water”,

available at: https://www.theguardian.com/sustainable-business/2015/oct/01/china-sponge-cities-los-angeles-water-urban-design-drought-floods-urbanisation-rooftop-gardens

271. Hui Li, Liuqian Ding, Minglei Ren, Changzhi Li and Hong Wang, "Sponge City Construction in China: A Survey of the Challenges and Opportunities", available at: www.mdpi.com

272. Kyoung Jin An, Yun Fat Lam, Song Hao, "Multi-purpose rainwater harvesting for water resource recovery and the cooling effect", available at: https://www.sciencedirect.com/science/article/abs/pii/S0043135415301421

273. Reuters (2017), "Sponges, urban forests and air corridors: how nature can cool cities", available at: https://www.reuters.com/article/us-heatwave-cities-nature/sponges-urban-forests-and-air-corridors-how-nature-can-cool-cities-idUSKCN1C100Q

274. Worldometers (2019), *Annual Report*. Available at: https://www.worldometers.info/demographics/china-demographics/

275. University of Oxford (2019), *Our World in Data Report,* available at: https://ourworldindata.org/most-densely-populated-countries

276 Hui Li, Liuqian Ding, Minglei Ren, Changzhi Li and Hong Wang, "Sponge City Construction in China: A Survey of the Challenges and Opportunities", available at: www.mdpi.com

277. Embassy of the Kingdom of Netherlands in China (2016), "Factsheet Sponge City Construction in China", available at: www.nederlandenu.nl

278. Kyoung Jin An, Yun Fat Lam, Song Hao (2015), "Multi-purpose rainwater harvesting for water resource recovery and the cooling effect", available at: https://www.sciencedirect.com/science/article/abs/pii/S0043135415301421

279. Hui Li, Liuqian Ding, Minglei Ren, Changzhi Li and Hong Wang, "Sponge City Construction in China: A Survey of the Challenges and Opportunities", available at: www.mdpi.com

280. The Guardian (2017), "China's 'sponge cities' are turning streets green to combat flooding", available at: https://www.theguardian.com/world/2017/dec/28/chinas-sponge-cities-are-turning-streets-green-to-combat-flooding

281. Shine News (2019), "Lingang sponge city nears completion", available at: https://www.shine.cn/news/metro/1908220642/

282. World Bank (2018), "Urban Wetland Management in Colombo", available at: https://www.gfdrr.org/sites/default/files/publication/FINAL%20-%20Results%20in%20Resilience%20-%20Urban%20Wetlands%20Management%20in%20Colombo%20-%204.2.18.pdf

283. Daily FT (2018), "Ramsar accreditation of Colombo Wetlands: Rebranding Colombo as a Wetland City", available at: http://www.ft.lk/columns/Ramsar-accreditation-of-Colombo-Wetlands--Rebranding-Colombo-as-a-Wetland-City/4-667241?fbclid=IwAR1CmsR6VZHxJh5YHxDdWD3sZJdYCDx8FysvQ70BMkKzP3okyX56xcYgNMU

284. Environmental Foundation (2019), available at: http://www.ft.lk/columns/Ramsar-accreditation-of-Colombo-Wetlands--Rebranding-Colombo-as-a-Wetland-City/4-667241?fbclid=IwAR1CmsR6VZHxJh5YHxDdWD3sZJdYCDx8FysvQ70BMkKzP3okyX56xcYgNMU

285. World Bank (2018), "Urban Wetland Management in Colombo", available at: https://www.gfdrr.org/sites/default/files/publication/FINAL%20-%20Results%20in%20Resilience%20-%20Urban%20Wetlands%20Management%20in%20Colombo%20-%204.2.18.pdf

286. World Bank (2018), "Urban Wetland Management in Colombo", available at: https://www.gfdrr.org/sites/default/files/publication/FINAL%20-%20Results%20in%20Resilience%20-%20Urban%20Wetlands%20Management%20in%20Colombo%20-%204.2.18.pdf

287. Daily FT (2018), "Ramsar accreditation of Colombo Wetlands: Rebranding Colombo as a Wetland City", available at: http://www.ft.lk/columns/Ramsar-accreditation-of-Colombo-Wetlands--Rebranding-Colombo-as-a-Wetland-City/4-667241?fbclid=IwAR1CmsR6VZHxJh5YHxDdWD3sZJdYCDx8FysvQ70BMkKzP3okyX56xcYgNMU

288. World Bank (2018), "Urban Wetland Management in Colombo", available at: https://www.gfdrr.org/sites/default/files/publication/FINAL%20-%20Results%20in%20Resilience%20-%20Urban%20Wetlands%20Management%20in%20Colombo%20-%204.2.18.pdf

289. Department of Water and Environmental Regulation – The Government of Western Australia (2010), "Managed Aquifer Recharge", available at: http://www.water.wa.gov.au/urban-water/water-recycling-efficiencies/managed-aquifer-recharge

290. Team analysis

291. World Bank, *DataHub,* available at: https://data.worldbank.org/country/china

292. STATISTA, *DataHub*, available at: https://www.statista.com/statistics/281633/china-freshwater-resources/

293. China Water Risk (2017), "The Big Picture – Groundwater Depletion", available at: http://www.chinawaterrisk.org/the-big-picture/groundwater-depletion/

294. Elias Salameh, Ghaida Abdallat, Michael van der Valk (2019), "Planning Considerations of Managed Aquifer Recharge (MAR) Projects in Jordan", available at: www.mdpi.com

295. Peter Dillon, Joanne Vanderzalm, Jatinder Sidhu, Declan Page, Devinder Chadha (2014), "A Water Quality Guide to Managed Aquifer Recharge in India", available at: https://publications.csiro.au/rpr/download?pid=csiro:EP149116&dsid=DS2

296. PJ Stuyfzand (2018), "History of Managed Aquifer Recharge in Netherlands", available at: https://recharge.iah.org/files/2018/03/Netherlands-Stuyfzand-MAR-19sep16.pdf

297. Vanderzalm, J.L. (2015), "Economics and experiences of managed aquifer recharge (MAR) with recycled water in Australia", available at: https://core.ac.uk/download/pdf/77983989.pdf

298. P. Dillon, P. Stuyfzand, M. Sapiano (2018), "Sixty years of global progress in managed aquifer recharge (MAR)", available at: https://link.springer.com/article/10.1007/s10040-018-1841-z

299. Bahram Malekmohammadi, Majid Ramezani Mehrian, Hamid Reza Jafari (2012), "Site selection for managed aquifer recharge using fuzzy rules: integrating geographical information system (GIS) tools and multi-criteria decision making" Available at: https://www.researchgate.net/publication/232416461_Site_selection_for_managed_aquifer_recharge_using_fuzzy_rules_Integrating_geographical_information_system_GIS_tools_and_multi-criteria_decision_making

300. "In situ infiltration test using a reclaimed abandoned river bed: managed aquifer recharge in Shijiazhuang City, China" – Xiaosi Su, Wei Xu, Shanghai Du - https://link.springer.com/article/10.1007/s12665-013-2893-y

301. Declan Page, Elise Bekele, Joanne Vanderzalm, Jatinden Sidhu (2018), "Managed Aquifer Recharge (MAR) in Sustainable Urban Water Management", available at: www.mdpi.com

302. Joel Casanova, Nicolas Devau, Marie Pettenati (2016), "Managed Aquifer Recharge: An Overview of Issues and Options", available at: https://link.springer.com/chapter/10.1007/978-3-319-23576-916#Sec2

303. Jie Yuan, Michele I. Van Dyke, Peter M. Huck (2016), "Water reuse through managed aquifer recharge (MAR): assessment of regulations/guidelines and case studies", available at: https://iwaponline.com/wqrj/article/51/4/357/21646/Water-reuse-through-managed-aquifer-recharge-MAR#1041910

304. World Bank (2016), "Using Performance-Based Contracts to Reduce Non-Revenue Water", available at: https://library.pppknowledgelab.org/PPIAF/documents/3531

305. Open (2017), "Non-revenue water management, the challenge facing water and sewage companies", available at: https://www.openintl.com/non-revenue-water-management-the-challenge-facing-water-and-sewage-companies/

306. International Water Association (2015), "Reduction of Non-Revenue Water Around the World", available at: https://iwa-network.org/reduction-of-non-revenue-water-around-the-world/

307. China Urban Water Association (2016), "China Urban Water Supply Statistical Yearbook", available at: https://www.purpleculture.net/china-urban-water-supply-statistical-yearbook-bs-1448/

308. "Meeting an increasing demand for water by reducing urban water loss", https://web.archive.org/web/20160427210612/http://www.rethinkwater.dk/sites/default/files/whitepaper_nrw_rethinkwater_ver_1.1_0.pdf

309. Erin Ress, J. Alan Roberson (2016), "The Financial and Policy implications of Water Loss", available at: https://awwa.onlinelibrary.wiley.com/doi/abs/10.5942/jawwa.2016.108.0026

310. Climate Adapt (2016), "Private investment in a leakage monitoring program to cope with water scarcity in Lisbon", available at: https://climate-adapt.eea.europa.eu/metadata/case-studies/private-investment-in-a-leakage-monitoring-program-to-cope-with-water-scarcity-in-lisbon

311. Bill Kingdom, Gerard Soppe, Jenima Sy (2016), "What is non-revenue water? How can we reduce it for better water service?", available at: https://blogs.worldbank.org/water/what-non-revenue-water-how-can-we-reduce-it-better-water-service

312. Asian Development Bank (2010), "The issues and challenges of reducing non-revenue water", available at: https://www.adb.org/sites/default/files/publication/27473/reducing-nonrevenue-water.pdf

313. According to the International Water Association and the Asian Development Bank, one of the main hindrances to NRW reduction is the lack of proper incentive contracts: the issue lies in the difference between target and performance contracts. While target contracts apply bonuses/penalties for surpassing/not achieving a target, which is often arbitrary (thus resulting in low motivation for the management of water utilities), performance contracts are tailored to offer performance fees directly proportional to NRW reduction, with not specific upper/lower limits to consider. Source: Asian Development Bank (2010), "The issues and challenges of reducing non-revenue water", available at: https://www.adb.org/sites/default/files/publication/27473/reducing-nonrevenue-water.pdf

314. World Economic Forum (2016), "The Fourth Industrial Revolution: what it means, how to respond", available at: https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

315. Ibid.

316. Ibid.

317. World Economic Forum (2016), "Intelligent Assets Unlocking the Circular Economy Potential", available at: http://www3.weforum.org/docs/WEF_Intelligent_Assets_Unlocking_the_Cricular_Economy.pdf

318. Ibid.

319. World Economic Forum (2018), "Building Block(chain)s for a Better Planet", available at: http://www3.weforum.org/docs/WEF_Building-Blockchains.pdf

320. New America, "The Development of Smart Water Markets Using Blockchain Technology", available at: https://www.newamerica.org/fellows/reports/anthology-working-papers-new-americas-us-india-fellows/the-development-of-smart-water-markets-using-blockchain-technology-aditya-k-kaushik/

321. World Economic Forum (2018), “Harnessing the Fourth Industrial Revolution for sustainable emerging cities”, available at: http://www3.weforum.org/docs/WEF_Harnessing_the_4IR_for_Sustainable_Emerging_Cities.pdf

322. Ibid.

323. Flextregrity, available at: http://www.flextegrity.com/

324. Briefing: The pandemic and the state, The Economist, 28 March 2020, https://www.economist.com/briefing/2020/03/26/countries-are-using-apps-and-data-networks-to-keep-tabs-on-the-pandemic

325. Battersby (2019), “Core Concept: Quantum sensors probe uncharted territories, from Earth’s crust to the human brain” PNAS 20 August 2019, 116 (34) 16663-16665; https://doi.org/10.1073/pnas.1912326116

326. McKinsey Global Institute (2017), “China’s Digital Economy: A Leading Global Force”, available at: https://www.mckinsey.com/~/media/mckinsey/featured%20insights/China/Chinas%20digital%20economy%20A%20leading%20global%20force/MGI-Chinas-digital-economy-A-leading-global-force.ashx

327. The Economist (2018), “Chinese Tech vs American Tech: which of the world’s two superpowers has the most powerful technology industry?”, available at: https://www.economist.com/business/2018/02/15/how-does-chinese-tech-stack-up-against-american-tech

328. Ibid.

329. World Economic Forum (2018), “Agile Governance: Reimagining Policy-making in the Fourth Industrial Revolution”, available at: http://www3.weforum.org/docs/WEF_Agile_Governance_Reimagining_Policy-making_4IR_report.pdf

330. World Economic Forum (2018), “Rethinking Technological Development in the Fourth Industrial Revolution”, available at: http://www3.weforum.org/docs/WEF_WP_Values_Ethics_Innovation_2018.pdf

331. https://openpolicy.blog.gov.uk/category/policy-lab/

332. Ibid.

333. World Economic Forum (2018), “Agile Governance: Reimagining Policy-making in the Fourth Industrial Revolution”, available at: http://www3.weforum.org/docs/WEF_Agile_Governance_Reimagining_Policy-making_4IR_report.pdf

334. https://openpolicy.blog.gov.uk/category/policy-lab/

335. https://www.drivesweden.net/en and https://www.testsitesweden.com/en/projects-1/driveme

336. http://www.cbb.gov.bh/assets/Regulatory%20Sandbox/Regulatory%20Sandbox%20FrameworkAmended28Aug2017.pdf

337. https://www.ema.gov.sg/Sandbox.aspx

338. World Energy Balances 2019, IEA, avaialble at: https://www.iea.org/reports/world-energy-balances-2019

339. The Economist (2017) “The world’s most valuable resource is no longer oil, but data”, available at: https://www.economist.com/leaders/2017/05/06/the-worlds-most-valuable-resource-is-no-longer-oil-but-data

340. SmartImpact (2018), “Data Governance & Integration for Smart Cities”, available at: https://smartimpact-project.eu/app/uploads/2018/02/SmartImpact_Data-Gov-and-Intergration_A4_AW.pdf

341. World Economic Forum (Forthcoming), “Protocol - Unlocking the shared value of dynamic IoT data in smart city with trusted platforms”

342. Ibid.

343. Public-sector data refers to data “generated, collected and stored by international, national, regional and local governments and other public institutions, as well as data created by external agencies for the government or related to government programs and services.” Source: World Economic Forum (Forthcoming), “Protocol - Unlocking the shared value of dynamic IoT data in smart city with trusted platforms”.

344. European Data Portal (2017) “Analytical Report number 6”, available at: https://www.europeandataportal.eu/sites/default/files/edp_analytical_report_n6_-_open_data_in_cities_2_-_final-clean.pdf

345. Great Lakes Echo (2020), “Water sensors, data collaboration make Great Lakes smarter”, available at: https://greatlakesecho.org/2020/02/21/water-sensors-data-collaboration-make-great-lakes-smarter/

346. Uber Movement, available at: https://movement.uber.com/?lang=en-US

347. Kotagiri, Sunil (2019) “Data Quality and Governance Critical for Utilities”, available at: https://www.tdworld.com/smart-utility/data-analytics/article/20972300/data-quality-and-governance-critical-for-utilities

348. World Economic Forum (Forthcoming), “Protocol - Unlocking the shared value of dynamic IoT data in smart city with trusted platforms”

349. Ibid.

350. World Economic Forum and Ellen MacArthur Foundation (2014), “Towards the Circular Economy”, available at: http://www3.weforum.org/docs/WEF_ENV_TowardsCircularEconomy_Report_2014.pdf

351. M. Swilling, M. Hajer, T. Baynes, J. Bergesen, F. Labbé, J.K. Musango, A. Ramaswami, B. Robinson, S. Salat, S. Suh, P. Currie, A. Fang, A. Hanson, K. Kruit, M. Reiner, S. Smit, S. Tabory (2018), "The Weight of Cities: Resource Requirements of Future Urbanization", a Report by the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya, available at: https://www.resourcepanel.org/reports/weight-cities

352. Ellen MacArthur Foundation (2018), "The Circular Economy Opportunity for Urban and Industrial Innovation in China", available at: https://www.ellenmacarthurfoundation.org/publications/chinareport

353. J. Cai, X. Xia, H. Chen, T. Wang, H. Zhang (2018), "Decomposition of Fertilizer Use Intensity and Its Environmental Risk in China's Grain Production Process", available at: https://www.researchgate.net/publication/323152227

354. S. Dong (2019), "Reduce Potash Import Dependence in China", available at: https://iad.ucdavis.edu/sites/g/files/dgvnsk4906/files/inline-files/Sisi%20Dong_capstone%202019_1.pdf

355. GPCA (2018), "China Fertilizer Industry Outlook", available at: https://gpca.org.ae/wp-content/uploads/2018/07/China-Fertilizer-Industry-Outlook.pdf

356. FAO (2020), "Food Loss and Food Waste", available at: http://www.fao.org/food-loss-and-food-waste/en/

357. World Economic Forum and Ellen MacArthur Foundation (2017), "Project MainStream Urban Biocycles", available at: http://www3.weforum.org/docs/WEF_Project_MainStream_Urban_Biocycles_2017.pdf

358. Ibid.

359. Nutrient Platform, "Phosphorus From Wastewater In Amersfoort", available at: https://www.nutrientplatform.org/en/success-stories/phosphorus-from-wastewater-in-amersfoort/

360. China Statistical Yearbook (2018), available at: http://www.stats.gov.cn/tjsj/ndsj/2018/indexeh.htm

361. Circle Economy (2019), "The Circularity Gap", available at: https://www.legacy.circularity-gap.world/built-environment

362. The Conversation (2019) "How Can we Recycle More Buildings" https://theconversation.com/how-we-can-recycle-more-buildings-126563

363. Winsun (2020), http://www.winsun3d.com/En/Product/pro_inner/id/1

364. Property Week (2020), "How developers in the Netherlands are addressing the climate crisis", available at: https://www.propertyweek.com/insight/how-developers-in-the-netherlands-are-addressing-the-climate-crisis/5106718.article

365. BAMB (2020), "Materials Passports", available at: https://www.bamb2020.eu/topics/materials-passports/

366. Madaster, "Madaster Origination: Material Matters", available at: https://www.madaster.com/en/about-us/why-a-materials-passport

367. United States Environmental Protection Agency (US EPA), "Sustainable Materials Management", available at: https://www.epa.gov/smm/basic-information-about-built-environment

368. BAMB (2019), *Metals Value Chain Report*, available at: https://www.bamb2020.eu/wp-content/uploads/2019/02/Metals-Value-Chain.pdf

369. Miniwiz (2020), http://www.miniwiz.com/about.php

370. World Economic Forum (2018), "China generates more waste than any other country. How does it deal with it?", available at: https://www.weforum.org/agenda/2018/12/no-chopsticks-with-my-takeaway-how-china-is-tackling-food-waste-with-digital-innovation/

371. China Statistical Yearbook (2018), available at: http://www.stats.gov.cn/tjsj/ndsj/2018/indexeh.htm

372. ITU (2017), Global E-waste Monitor, https://www.itu.int/en/ITU-D/Climate-Change/Pages/Global-E-waste-Monitor-2017.aspx

373. World Economic Forum (2019), "A New Circular Vision for Electronics", available at: http://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf

374. World Economic Forum (2019), "Recovery of Key Metals in the Electronics Industry in the People's Republic of China", available at: https://www.weforum.org/reports/recovery-of-key-metals-in-the-electronics-industry-in-the-people-s-republic-of-china

375. Ellen MacArthur Foundation (2018), "The Circular Economy Opportunity for Urban and Industrial Innovation in China", available at: https://www.ellenmacarthurfoundation.org/publications/chinareport

376. World Economic Forum (2019), "Recovery of Key Metals in the Electronics Industry in the People's Republic of China", available at: https://www.weforum.org/reports/recovery-of-key-metals-in-the-electronics-industry-in-the-people-s-republic-of-china

377. LWARB (2017), "London's circular economy route map", available at: https://www.lwarb.gov.uk/wp-content/uploads/2015/04/LWARB-London%E2%80%99s-CE-route-map_16.6.17a_singlepages_sml.pdf

378. World Economic Forum (2019), Harnessing the Fourth Industrial Revolution for the Circular Economy Consumer Electronics and Plastics Packaging . http://www3.weforum.org/docs/WEF_Harnessing_4IR_Circular_Economy_report_2018.pdf

379 European Sustainable Phosphorus Platform, "About the European Sustainable Phosphorus Platform (ESPP)", available at: https://www.phosphorusplatform.eu/platform/about-espp

380 BAMB (2020), "About BAMB", available at: https://www.bamb2020.eu/about-bamb/

381. About PACE (2020) accessed at: https://pacecircular.org/

382. Rio Declaration on Environment and Development, Rio de Janeiro, 3-14 June 1992, Principle 20, https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_CONF.151_26_Vol.I_Declaration.pdf

383. United Nation Development Programme (2018), *Sustainable Development Goals*. Available at: https://www.sdfinance.undp.org/content/sdfinance/en/home/sdg/goal-5--gender-equality.html

384. The Donor Committee for Enterprise Development (2012), "Women's participation in green growth – a potential fully realised?", available at: https://www.enterprise-development.org/wp content/uploads/Womens_participation_in_Green_Growth.pdf

385. China Briefing from Dezan Shira & Associates (2012), "Consumption Trends and Targeting China's Female Consumers", available at: https://www.china-briefing.com/news/consumption-trends-and-targeting-chinas-female-consumer/

386. China Daily (2016), "60 percent of Chinese women control family finances: report", available at: https://www.chinadaily.com.cn/china/2016-08/31/content_26656826.htm

387. United Nations Development Programme (2015), "powerful synergies gender equality economic development and environmental sustainability", available at: https://www.undp.org/content/undp/en/home/librarypage/womens-empowerment/powerful-synergies.html

388. United Nations Women (2016), "Sustainable energy for all: the gender dimension", available at: https://www.unido.org/sites/default/files/2014-02/GUIDANCENOTE_FINAL_WEB_s_0.pdf

389. International Energy Agency (2020), "Gender diversity in energy: what we know and what we don't know", available at: https://www.iea.org/commentaries/gender-diversity-in-energy-what-we-know-and-what-we-dont-know

390. International Energy Agency (2018), "Gender diversity in energy sector is critical to clean energy transition", available at: https://www.iea.org/commentaries/gender-diversity-in-energy-sector-is-critical-to-clean-energy-transition

391. United Nations Women (2016), "Sustainable energy for all: the gender dimension", available at: https://www.unido.org/sites/default/files/2014-02/GUIDANCENOTE_FINAL_WEB_s_0.pdf

392. International Energy Agency (2017), "Energy and gender: a critical issue in energy sector employment and energy access", available at: https://www.iea.org/topics/energy-and-gender

393. International Energy Agency (2020), "Gender diversity in energy: what we know and what we don't know", available at: https://www.iea.org/commentaries/gender-diversity-in-energy-what-we-know-and-what-we-dont-know

394. Statista, "Percentage of GDP contributed by female workers, as of 2015, by region", available at: https://www.statista.com/statistics/523838/women-share-of-gdp-region/

395. XinhuaNet (2018), "China further boosts gender equality", available at: http://www.xinhuanet.com/english/2018-10/29/c_137566727.htm

396. En.people.cn (2017), "Women dominate higher education in China", available at: http://en.people.cn/n3/2017/1028/c90000-9285962.html

397. Catalyst (2019), "Women in the Workforce – China: Quick Take", available at: https://www.catalyst.org/research/women-in-the-workforce-china/

398. The State Council Information Office of the People's Republic of China (2015), "Program for the Development of Chinese Women (2011-2020)", available at: http://www.scio.gov.cn/zfbps/ndhf/2015/Document/1449894/Image/201509221449894_336090.pdf

399. "How Women Won a Leading Role in China's Venture Capital Industry", available at: https://www.bloomberg.com/news/features/2016-09-19/how-women-won-a-leading-role-in-china-s-venture-capital-industry

400. Center for Study of Science, Technology and Policy (2016), "Localising the gender equality goal through urban planning tools in South Asia", available at: http://southernvoice.org/localising-the-gender-equality-goal-through-urban-planning-tools-in-south-asia/

401. World Bank (2006), Including Gender in the World Bank Transport Strategy, available at: http://documents.worldbank.org/curated/en/968841468147567926/pdf/841800WP0Trans0Box0382094B00PUBLIC0.pdf

402. UN Habitat (2009), Women's Safety Audits, What Works and Where?, available at: https://unhabitat.org/womens-safety-audit-what-works-and-where

403. Disabilities, Office of the High Commissioner for Human Rights, United Nations, 2007, available at: https://www.ohchr.org/Documents/Publications/training14en.pdf

404. Center for Study of Science, Technology and Policy (2016), "Localising the gender equality goal through urban planning tools in South Asia", available at: http://southernvoice.org/localising-the-gender-equality-goal-through-urban-planning-tools-in-south-asia/

405. World Bank (2020), "Handbook for Gender-Inclusive Urban Planning and Design", available at: https://www.worldbank.org/en/topic/urbandevelopment/publication/handbook-for-gender-inclusive-urban-planning-and-design

406. Ibid.

407. City of Vancouver (2015), "Greenest City 2020 Action Plan", available at: https://vancouver.ca/files/cov/greenest-city-2020-action-plan-2015-2020.pdf

408. City of Vancouver (2015), "Women's Advisory Committee", available at: https://vancouver.ca/your-government/womens-advisory-committee.aspx

409. United Nations ESCAP (2017), "Gender, The Environment and Sustainable Development in Asia and the Pacific", available at: https://www.unescap.org/publications/gender-environment-and-sustainable-development-asia-and-pacific

410. Institute for Women's Policy Research (2015), "Gender Urbanization and Local Governance White Paper", available at: https://www.ndi.org/files/Gender%20Urbanization%20and%20Local%20Governance%20White%20Paper.pdf

411. United Nations ESCAP (2017), "Gender, The Environment and Sustainable Development in Asia and the Pacific", available at: https://www.unescap.org/publications/gender-environment-and-sustainable-development-asia-and-pacific

412. The Telegraph (2020), Prince Charles to Lauch Great Reset Initiative, available at: https://www.telegraph.co.uk/royal-family/2020/05/22/prince-charles-launch-great-reset-project-rebuild-planet-wake/

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