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Abstract

To limit the detrimental impacts of climate change, large-scale and rapid decarbonisation is required. China announced the plan to peak carbon emission before 2030 and to reach neutrality by 2060, which is faced with challenges posed by the energy sector including rising energy consumption and historical coal-based electricity generation. To complement the rigorous research being undertaken on the national neutrality trajectory, this research focuses on subnational carbon neutrality pathways with for two leading Chinese cities: Beijing and Hong Kong.

This research employed mixed methods to recommend a portfolio of energy-related climate policies for Beijing and Hong Kong. The Low Emissions Analysis Platform modelling tool was first employed to forecast the future energy supply, demand and greenhouse gas emissions under existing policies to provide a technical foundation. Through 32 expert interviews conducted with four stakeholder groups in both cities (academia, green groups, industries, regulatory bodies), it was uncovered that importing green electricity and generating local renewable energy were perceived as the most important policies by respondents.

With the aim to understand how policy measures can be prioritised for outsized emissions reduction, sensitive intervention points (SIPs) were applied as a framework to identify city-level policy interventions with high impact, speed, feasibility, persistence and low risk based on literature review and feedback surveys. With all attributes combined, leveraging the global cost declines in renewable energy is the shared pathway for both cities, facilitated by policies and institutional arrangements to promote importing low-carbon energy and accelerate transport electrification. Alignments were observed between the final SIPs and policies perceived as important by stakeholders, indicating that SIPs are generally intuitive, but policy prioritisation is likely influenced by other individual and collective factors. SIPs are therefore valuable not only for countries, but also for city governments to utilise as a harmonised climate policy prioritisation framework.

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List of Abbreviations

AR6	IPCC Sixth Assessment Report
BECCS	Bioenergy Production with Carbon Capture and Storage
BMCT	Beijing Municipal Commission of Transport
CCS	Carbon Capture and Storage
CDR	Carbon Dioxide Removal
CHP	Combined Heat and Power
CLP	China Light and Power Ltd
CO_2	Carbon Dioxide
CPR	Commercial, Public and Residential sector
EP	Existing Policies Scenario
ETC	Energy Transitions Commission
ETS	Emissions Trading Scheme
EU	European Union
EV	Electric Vehicle
FIT	Feed-in Tariff
FYP	Five-Year Plan of China
GBA	Greater Bay Area
GHG	Greenhouse Gas
GDP	Gross Domestic Product
GWP	Global warming potential
HEC	Hong Kong Electric Ltd
HKENB	Hong Kong Environment Bureau
HKEPD	Hong Kong Environmental Protection Department
HKSARG	The Government of Hong Kong Special Administrative Region
ICEV	Internal Combustion Engine Vehicle
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JJJ	Jing-Jin-Ji Region
LCC	Low Carbon Cities initiative of China
LEAP	Low Emissions Analysis Platform
NBS	National Bureau of Statistics of China
NCSC	National Centre for Climate Change Strategy and International Cooperation
NDC	Nationally Determined Contribution
NDRC	National Development and Reform Commission of China
NEA	National Energy Administration
NET	Negative Emissions Technology

OECD	Organisation for Economic Co-operation and Development
PA	Paris Agreement
PV	Photovoltaic
RE	Renewable Energy
RPS	Renewable Portfolio Standard
SCA	Scheme of Control Agreement
SDC	Hong Kong Council for Sustainable Development
SGCC	State Grid of China Corporation
SIP	Sensitive Intervention Point
SR1.5	IPCC Special Report on Global Warming of 1.5°C
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute
WWF	World Wildlife Fund

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Chapter 1: Introduction

1.1 Motivation and Background

"China will scale up its Intended Nationally Determined Contributions by adopting more vigorous policies and measures. We aim to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060."
– Xi Jinping, President of People's Republic of China, September 2020

"Stabilising the climate will require strong, rapid and sustained reductions in greenhouse gas emissions, and reaching net-zero CO_2 emissions."
– Panmao Zhai, Co-Chair of IPCC AR6 Working Group I, August 2021

At the 75th United Nations General Assembly, China surprised the world by announcing a climate pledge of reaching carbon neutrality before 2060, which has substantial implications for global low-carbon development and multilateralism (BBC, 2020; Colenbrander et al., 2021). Around a year later, the IPCC Sixth Assessment Report (AR6) was released. Based on more rigorous scientific evidence, AR6 states it is "unequivocal" that human influence has warmed the planet, and net-zero emissions must be achieved by around 2050 to limit warming within 1.5°C (IPCC, 2021). Only one out of the five illustrated scenarios can keep warming within 1.5°C, which is the "very low carbon emissions (SSP1-1.9)" scenario. As described by IPCC Co-Chair, Chinese climatologist Panmao Zhai, it has become clear that "strong, rapid and sustained" emissions reduction is required to minimise climate-induced adverse impacts on the ecosystem and human society.

China is currently the world's largest producer of greenhouse gases (GHGs), accounting for 27% of global emissions (Mikhail, Hannah, & Larsen, 2021). Reducing emissions of China is not only critical at the national level, it is closely intertwined with other countries owing to China's status as the "world factory". Studies show the rapid growth of export in China is a key factor for its rising carbon emissions, with 22% of the emissions embodied in net export in trading (Qi et al., 2014; Zhang, Guo, & Hewings, 2014). Liu et al. (2020) illustrate that trading between China and the US leads to an annual transfer of 242 Mt CO_2 from the US to China. This highlights the significant contribution of decarbonising

electricity generation and industrial processes in China to the global fight against the climate crisis.

Over the last decade, China has been demonstrating increased effort in pollution control and climate change mitigation in accordance with the country's eco-modernisation development discourse (Geall & Ely, 2018). The 2060 carbon neutrality pledge steps up China's nationally determined contribution (NDC) under the Paris Agreement and extends the climate strategy horizon to 2060, acknowledging the need for long-term action in addition to prior peaking plans for 2030 (Wagner, 2020). It is estimated this pledge, if achieved, can lower global warming projections by 0.2 to 0.3°C (Climate Action Tracker, 2020). However, there are scepticisms around whether China will be able to achieve the goal, given its reliance on fossil fuel and heavy industry for economic development and consumption from the growing middle class. Normile (2020) points out it would require China to drastically reduce fossil fuel consumption in electricity generation and transportation, and actively pursue offsetting through carbon capture and storage (CCS) and afforestation. However, a high-level official of China claimed it is an objective reality that the current energy structure of China is dominated by coal. Due to intermittency and instability of renewable energy, China may need to "use coal power as a point of flexible adjustment" for a period of time (Cheng, 2021). Chinese officials repeatedly stress that coal development has entered into a new era of "very high efficiency and extremely low emissions", and China will strive to offset coal-related emissions through CCS (International Energy China, 2021). If China decides to rely on coal power in the near term, there is risk of infrastructure lock-in for the built capacity of fossil fuel power plants (Tong et al., 2019), reducing the likelihood of attaining the designated carbon neutrality target.

Energy-related sectors account for approximately 78% of GHG emissions in China, highlighting energy policy as the key factor influencing whether China can deliver the ambitious commitment (Qi et al., 2020). This research is positioned to investigate carbon neutrality through the lens of energy supply and demand policies. The scope of the study is narrowed down to the city level, as sufficient research effort is concentrated on national decarbonisation strategies (see Energy Foundation China, 2020; He, 2020; WRI, 2020), with less attention on local level implementation. Such a gap can be bridged through investigating effective interventions at a subnational level that promote the rapid emissions reduction required to align with the national goals.

China has an established history of strategic planning and target setting for development parameters, such as poverty alleviation and pollution control. Mandatory

environmental targets are proposed by the central government and distributed to provinces, subsequently divided into the city and lower-level administrative units for implementation (Wang, 2021). Field studies in China reveal it is mostly internal rather than external forces that push for environmental enhancements, which is strongly influenced by local power structures (Sheng, 2019). Through the case studies of Beijing and Hong Kong, this analysis explores the carbon neutrality pathways of two unique economically advanced Chinese cities and seeks ways to accelerate the progress by identifying sensitive intervention points (SIPs) in energy-related sectors. Context-specific constraints in policy implementation will also be investigated. There is a practice of using "Beijing" to represent the Chinese central government, but "Beijing" in this research refers to the Beijing municipal city government not the central government.

Beijing and Hong Kong are high-density cities with advanced economic development, characterised by the dependence on tertiary sectors. The two cities face challenges in decarbonising energy supply, demand and pursuing offsets. Given that electricity generation is dominated by fossil fuel, Beijing and Hong Kong city governments have plans to reduce emissions by transitioning from coal to natural gas and sourcing renewable energy. "Natural Gas Transition City" configuration is observed in both cities, leading to the risk of locking-in natural gas as substitutes for renewables (Tozer & Klenk, 2018). One defining difference between the cities is the electricity import from outside of local electric grids. Beijing imports close to 65% of electricity from other parts of China. Hong Kong imports 25% of electricity from mainland China, one of the lowest fractions of imported electricity among major cities in China (Qu, Liang, & Xu, 2017). In addition, policies in Beijing are largely shaped by the central government. Hong Kong has developed political institutions rather different from the mainland overtime, with a high degree of autonomy in energy and climate policymaking (HKSARG, 2021).[1] Comparing these two cities provides insights on how the spectrum of urban carbon neutrality plans may look like for cities in China.

[1] In 2019-2020, 33.5 billion HKD of the government's expenditure is dedicated to "Environment and Food", which is approximately 5.51% of the total budget expenditure. The value changes every fiscal year based on internal negotiations and lobbying by various stakeholders.

1.2 Research Objectives and Questions

Three objectives are addressed in this thesis, with relevant a research question proposed for each objective. The first objective aims to understand the perceptions and conceptualisations of "carbon neutrality" among key stakeholders in Hong Kong and Beijing. The discussion covers diverse perspectives of academia, industry, green groups and the government, to gain a comprehensive overview for establishing the foundation for this research.

The second objective is to identify sensitive intervention points (SIPs) for attaining carbon neutrality in the two cities, asking the question of "What are the SIPs for carbon neutrality pathways in Beijing and Hong Kong?".

The final objective is to explore the underlying factors and embedded structures that influence carbon neutrality pathways in the two cities. Both energy supply and demand infrastructures will be considered, with a focus on the sectors of electricity generation, built environment, transport and industry. The research question is "What underlying factors (including the perceptions of carbon neutrality) facilitate or constrain the carbon neutrality pathways in Beijing and Hong Kong?" The research objectives and questions are summarised in the following table.

Table 1. Research Objectives and Questions

Objectives	Research questions
1. To understand the perceptions of "carbon neutrality" in Beijing and Hong Kong	• How do different stakeholders in key sectors perceive carbon neutrality in Beijing and Hong Kong?
2. To identify sensitive intervention points (SIPs) for attaining carbon neutrality in Beijing and Hong Kong	• What are the potential SIPs to accelerate progress towards carbon neutrality in Beijing and Hong Kong?

3. To determine the factors influencing carbon neutrality for energy sectors in Beijing and Hong Kong	• What underlying factors (including the perceptions of carbon neutrality) facilitate or constrain the carbon neutrality pathways in Beijing and Hong Kong?

1.3 Structure of Thesis and Chapters Overview

The content of this thesis revolves around two interconnected themes related to urban carbon neutrality, with an interrogation of Beijing and Hong Kong as case studies. The first theme is the conceptualisation of carbon neutrality and the factors influencing it. This links to the second theme of exploring city-level SIPs to accelerate the progress towards carbon neutrality. The two parts are connected through seeking the implications of stakeholders' interpretation of carbon neutrality on policy preferences, illuminating future pathways to accelerate decarbonisation.

Beginning with Chapter 1 to introduce the research background and objectives, Chapter 2 provides a literature review on defining key terms, exploring the current state of environmental governance and climate action in Beijing and Hong Kong, as well as on methods to prioritise climate policies with an emphasis on the SIPs framework.

Chapter 3 outlines the mixed methods approach used in this research, detailing the data collection processes, the rationale behind and assumptions.

Findings on the two themes of carbon neutrality perceptions and policy prioritisation are presented in Chapter 4. The results are complemented with tables, graphs and plots for easy visualisation of the data.

Chapter 5 untangles the narratives, nuances and controversies highlighted in the results, drawing upon literature on sociotechnical transitions (Geels et al., 2017a) and knowledge politics (Turnhout, 2018).

The thesis is concluded by Chapter 6, where insights on the two themes are consolidated, with answers summarised on the three key research questions. Limitations of the research are examined, illuminating avenues for further research in hopes of enriching urban carbon neutrality literature and informing better decision-making at the city-level.

Chapter 2: Literature Review

The literature review is structured by three interlinked questions of "what-where-how". "What" represents the context of research, which includes key concept definitions and the current state of carbon neutrality. "Where" is "where" the research takes place, hence outlining the existing environmental governance and climate policies of Beijing and Hong Kong. "How" is the main research approach and theoretical framework of complex systems thinking, walking through the literature on different methods to prioritise climate policies. After presenting different approaches, the choice SIPs framework is justified, followed by in-depth discussion of SIPs.

2.1 What – Defining key concepts and current state of carbon neutrality

This section sets the scene for the research, defining the key concept of "carbon neutrality" and discusses key differences with the associated climate terminologies. The scope of the research is also clearly defined, with major assumptions explained. Actions around carbon neutrality in countries and cities are reviewed, with a focus on by the role of energy policy in achieving carbon neutrality.

2.1.1 Defining Carbon Neutrality

Since President Xi announced the carbon neutrality target in September 2020, there has not been a clear definition of the term and what it means for China. A Chinese article "What is carbon neutrality? (何谓碳中和？)" published in early 2021 by Tsinghua academics, with the involvement of National Climate Centre, has become an influential document containing the working definitions around carbon neutrality and an overview of where China stands in climate action compared with the rest of the world (Deng, Xie, & Teng, 2021). The article adopts the definition from IPCC (2018), where "carbon neutrality" refers to a state of balance between carbon dioxide (CO_2) emitted to the atmosphere and CO_2 removed from the atmosphere In other words, carbon neutrality is achieved when every ton of anthropogenic CO_2 emitted is compensated with an equivalent amount of CO_2 removed (Levin, Song, & Morgan, 2015). Carbon neutrality is generally regarded as synonymous with "net-zero carbon emissions", as they both mean a balance between carbon emissions and carbon removal. However, one point of difference is that carbon neutrality can be achieved domestically with offsets from other jurisdictions, whereas this is not necessarily the case with "net-zero" (Levin et al., 2015). This research adopts the mainstream definition of

"carbon neutrality" and "net-zero carbon emissions", and thus uses the two terms interchangeably, but we will use the term "carbon neutrality" to align with its use in President Xi's climate pledge at the UNGA (McGrath, 2020).

In addition to the technical definition, Tozer & Klenk (2018) have explored the ontological politics of carbon neutrality through discourse analysis and textual network analysis of urban governance documents. Carbon neutrality embodies sociotechnical imaginaries, which are visions of scientific and technological progress. The configurations of sociotechnical objects, such as the built environment and electricity grid, vary across different regions. Such distinctive configurations feed into sociotechnical imaginaries, leading to policy outcomes which in turn influences the urban space (Tozer & Klenk, 2018). The process is illustrated in Figure 1.

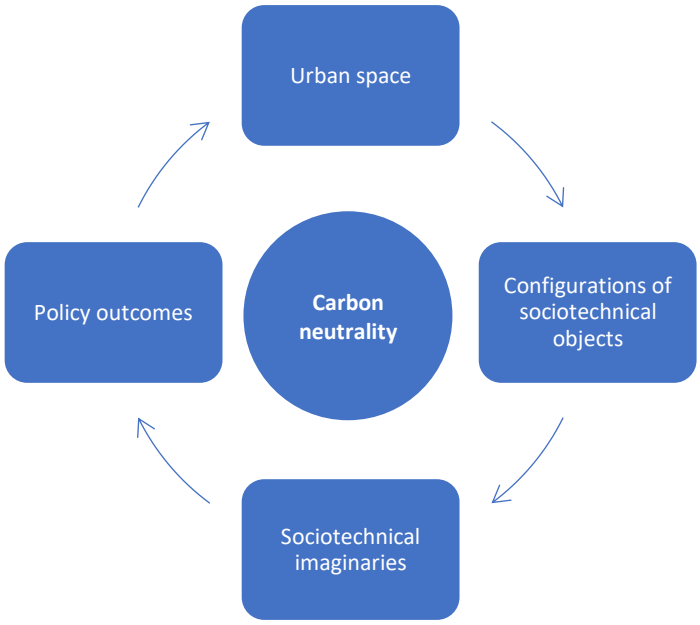


Figure 1. The construction of carbon neutrality through urban climate governance (Source: Author, based on Tozer & Klenk, 2018)

Carbon neutrality may be confused with other terminologies in the climate change glossary, including "climate neutrality" and "decarbonisation". "Climate neutrality" is a broader term that covers all GHG emissions instead of only CO_2 (Sausen et al., 2005). Climate neutrality is achieved when CO_2 and other anthropogenic GHG emissions are balanced by removal. Research shows the need to account for other GHG such as methane and nitrous oxides in mitigation efforts given their contributions to warming (see Gambhir et al., 2017; Zhang et al., 2015). As part of the AR6, Co-Chair Zhai (2021) states that "limiting

other GHG and air pollutants, especially methane, could have benefits for health and the climate", confirming the need to cut non-CO_2 GHG emissions. The challenge then lies in quantifying the warming potentials for different GHGs because of their varying lifetime in the atmosphere. Global warming potential (GWP) provides a common unit to measure heat absorbed by any GHG in the atmosphere. The time horizon of 100 years is commonly used (i.e. GWP_{100}), but it falls short in calculating the warming impact of short-lived GHG. This concern is also raised in the seminal Chinese article, where the authors claim the risk of overestimating the warming impact of methane will become prominent under the carbon neutrality target and should be solved by adjusting accounting mechanisms in the future (Deng et al., 2021). GWP* (determined by changes in emission rate) is therefore proposed as an alternative metric to reflect the contrasting impacts of short- and long-lived GHG (Lynch et al., 2020). This measurement can improve the accuracy of climate neutrality assessments, in particular for sectors emitting different compositions of GHG (Lynch et al., 2020).

Among countries that have committed to Paris-aligned pathways, the European Union (EU) set the goal of reaching climate neutrality by 2050. The target was made a legal objective under the provisional agreement on the European Climate Law in 2021 (European Commission, 2021). For China, although the national pledge is termed "carbon neutrality", multiple sources suggest it covers non-CO_2 GHG, equivalent to the EU "climate neutrality" target. For instance, at the Global Asset Management Forum 2021, China's Special Envoy for Climate Change Xie Zhenhua describes China's 2060 carbon neutrality pledge as fulfilling the Paris Agreement objective to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (NCSC, 2021). He further confirms that the carbon neutrality target covers "not only carbon dioxide, but also non-carbon dioxide greenhouse gases such as methane and hydrofluorocarbons". This differs from China's other NDC goal of *peaking* CO_2 emissions by 2030 (NCSC, 2021). Scenario forecasts by He (2020) demonstrate that under the 1.5°C pathway, all GHG emissions have to be reduced by 90% in 2050 compared with the peak year, with 70% reductions required for the 2°C pathway. With a "climate neutrality" interpretation, the 2060 carbon neutrality target of China is compatible with the Paris Agreement 1.5°C pathway. Whilst acknowledging that China's target likely covers non-CO_2 GHG, this study only focuses on CO_2 reduction to limit the scope of work. This opens up avenues for future research on examining strategies for reducing all types of GHG for Hong Kong and Beijing.

"Decarbonisation" is another term relevant to carbon neutrality, with differences that require clarification. Decarbonisation describes the process of reducing or removing CO_2 from anthropogenic activities (IPCC, 2018). It strives to reduce carbon intensity, which is the CO_2 output per unit of electricity generated. The term decarbonisation is most often used with energy generation and consumption, such as the production of low-carbon electricity and enhancement in energy efficiency (EE). Decarbonising the economy and society is the key process for limiting warming, especially with the "deep decarbonisation" likely required for carbon neutrality. For example, deep transport decarbonisation with more than 90% of emission reduction can be achieved with electric vehicles using low-carbon primary energy, bioenergy production plus carbon capture and storage (BECCS) under a high carbon tax scenario (Gelfand et al., 2020; Pietzcker et al., 2014). Both decarbonisation and carbon neutrality therefore involves bringing down the level of CO_2 emissions, but decarbonisation does not include the process of offsetting difficult-to-abate emissions. Hard-to-decarbonise sectors like aviation, steel and cement industry may require offsetting and negative emission technologies (NETs) to achieve carbon neutrality. In other words, carbon neutrality is an end goal, whereas decarbonisation is one of the indispensable processes, along with offsets and NETs, to attain this goal.

2.1.2 The Role of Carbon Offsets and Removals

Carbon offsets refer to activities that reduce or avoid emissions to compensate for emissions made elsewhere. The existing atmospheric CO_2 level is assumed to not be affected by this balancing transaction. Common carbon offset approaches include CCS and afforestation. Carbon dioxide removal (CDR) aims at completely removing CO_2 from the atmosphere, reducing the absolute level of atmospheric CO_2. CDR is achieved through three broad categories of negative emissions technologies (NET), which are biological, technological and geochemical (EASAC, 2018). Most climate mitigation pathways produced for the IPCC show carbon offsets and removals are required to reach carbon neutrality. As shown by integrated assessment models (IAMs) in the IPCC Special Report, three of the four illustrative emissions pathways for 1.5°C warming require large-scale CO_2 storage (IPCC, 2018). The maximum rate of abatement is found to be around 2 $GtCO_2$/year, using methods of CCS on fossil fuel power generation, CCS on heavy industries and BECCS. These global model outputs are deemed problematic because they miss out on some key environmental, social and governance concerns (Smith et al., 2016). There are important regulatory,

commercial, political and technological barriers to overcome before NETs can be scaled up for substantial global contribution (Haszeldine et al., 2018). As argued by Meadowcroft (2013), high reliance on CDR to achieve large emissions reduction in the future may delay efforts for immediate reduction. For some, rapid decarbonisation should be the first priority regardless of whether NETs become more prominent in the long run (Eyre et al., 2018). The fact is, the more rapidly we can reach net-zero, the fewer carbon offsets or removals we need to rely on. There is a need to balance between actions to abate emissions and the use of carbon offsets/removals to ensure net-zero can be realised.

Carbon offsets are likely to be included in city-level climate strategies to achieve net-zero. Current commercially viable offset options are dominated by biological sequestration, the process in which carbon extracted from static geological sources and turned into mobile biological carbon (Ellis, Maslin, & Lewis, 2020). However, the credibility of certain certified offset credits is in doubt based on several issues, such as permanence, additionality, leakage and verification (Richards & Huebner, 2012). Some researchers propose CO_2 must be sequestered in the form from which it has been extracted to achieve sustainable "hard net-zero" through methods like geological sequestration and direct air capture. However, these methods have low commercial viability in the near term due to high costs (Shafeen et al., 2004; Xie & Economides, 2009).

Apart from the carbon reduction capacity of offset projects, system boundaries should be clearly defined in order to determine whether an offset can be deemed acceptable. In other words, delineating system boundaries is a prerequisite to assess progress towards carbon neutrality. In the conceptual analysis of "carbon neutral tourism", Gossling (2009) points out that the tourism industry cannot be carbon neutral by itself as emissions produced have to be compensated by non-tourism sectors. Hence, it is potentially controversial to claim an industry or sector as carbon neutral. For the conceptualisations of carbon-neutral cities, Hsu et al. (2016) emphasise the need to assess emissions embodied in goods and services of cities to ensure that their carbon neutrality goals are practically implemented. Failure to include out-of-boundary emissions in carbon footprint accounting diminishes the practicality of carbon neutrality claims.

Zooming into the cities of interest, Beijing and Hong Kong adopt different city boundaries when assessing city-level GHG emissions and subsequently the progress towards carbon neutrality. The Chinese government uses scope 1 and 2 emissions to assess the performance of local governments. The official GHG inventory of Hong Kong also accounts for scope 1 and 2 emissions. Both Beijing and Hong Kong neglect scope 3 consumption-

based emissions, including those from the import of goods and transboundary mobility (HKENB, 2017). The difference in system boundary delineation leads to different evaluations on carbon neutrality, which would be captured in the stakeholder interviews. Although it is the most accurate to measure all scope 1-3 emissions, but scope 3 emissions are hard to quantify (Dou et al., 2021). When evaluating the progress of decarbonisation with the LEAP model, scope 1 and 2 emissions will be calculated in both Beijing and Hong Kong for the ease of comparison.[2]

2.1.3 Actions around Carbon Neutrality

2.1.3.1 Country-level Pledges

Since the establishment of IPCC in 1992, the climate as a public good is deemed to be governed by transnational and intergovernmental networks (Andonova, Betsill, & Bulkeley, 2009; Grasso, 2001). Annual climate change conferences are held for state negotiations and have resulted in two landmark international agreements, Kyoto Protocol and Paris Agreement, which assign "common but differentiated" responsibilities to states for climate change mitigation.

Under the Paris Agreement negotiated at COP21, parties agreed to submit regular Intended Nationally Determined Contributions (INDCs) on GHG emission reduction. These contributions are designed to be voluntary and flexible, allowing countries to reduce emissions based on their capabilities and developmental needs. Aggregating the NDCs submitted to UNFCCC, the world is on track for more than 3°C of warming, which is not in line with the Paris Agreement target of keeping warming "well below 2°C" (UNFCCC, 2015). As scientific research and the increased occurrence of extreme events demonstrate the urgency of achieving net-zero to control warming and minimise devastating climate impacts, there has been a surge of multilevel actors committing to net-zero targets, including nation-states, cities and private organisations. The United Kingdom (UK) took the lead as the world's first major economy to pass the UK Climate Change Act in 2008, which was recently updated to set net-zero as legally binding target (Committee on Climate Change, 2019). Small nations vulnerable to climate impacts have also set out ambitious decarbonisation roadmaps, such as Costa Rica's National Decarbonisation Plan with a 2050 net-zero commitment (UNEP, 2019). By November 2020, 126 countries have net-zero targets

[2] This is further explained in Chapter 3 of Methodology.

adopted, announced or under consideration, accounting for 51% of global GHG emissions (UNEP, 2020).

G20 members bear special responsibility for climate action, as they collectively contribute to around 80% of total global emissions, [3] presenting unique opportunities to draw down global GHG emissions. As a member of G20, China is influenced by the ambitions and pledges of other members while the country seeks to take an enhanced role in global climate governance (L. Dong, Miao, & Wen, 2021). Research by ECIU (2021) shows 15 members of the G20 have announced or legally enshrined long-term emissions-reduction targets by mid-2021.[4] Despite the encouraging number of pledges, literature and reports highlight the vagueness of many carbon neutrality/net-zero goals (Dyke, Watson, & Knorr, 2021; Nature, 2021; Rogelj et al., 2021). Some entities do not have an accurate understanding or defined scoping of "net-zero", some lack a feasible long-term roadmap (Rogelj et al., 2021). UNEP Emissions Gap Report finds that current policies in many countries are not on track to reach the pledges. None of the G20 members officially submitted new or updated NDC to UNFCCC, revealing the inconsistency between ambitious long-term goals and underwhelming NDCs for 2030 (UNEP, 2020). Rogelj et al. (2021) suggest three ways to improve the effectiveness and clarity of net-zero pledges, which are specifying the scope of GHG covered, disclosing why actions considered are "fair and adequate", setting up milestones and implementation plans. Along similar lines, UNEP demands countries to develop concrete Paris-aligned climate strategies and to officially update or set new NDCs that are compliant with net-zero goals (UNEP, 2020). Currently, rigorous disclosure is required by NDCs for near-term national mitigation actions. Yet long-term targets lack transparency and rigour. These studies reveal metrics to evaluate China's carbon neutrality pledge.

2.1.3.2 City-level Commitments

In recent decades, the value of subnational and non-state actors in steering climate action has been reinstated. Cities have become the locus of climate action based on two main reasons. Firstly, there is the rapid growth of urban population and expansion of cities. At present, 55% of global population are living in cities, and the figure will rise to 70% by 2050 (The World Bank, 2020). IPCC (2014) estimates that urban areas account for 67-76% of

[3] Excluding land-based emission sources
[4] Data is updated until 31 May 2021

global CO_2 emissions and energy consumption, illustrating the immense potential of cities to contribute to the Paris target. Assessing the GHG emissions inventories of 167 cities worldwide, the top 25 mega-cities account for 52% of total urban emissions. Among them, 23 of them are Chinese cities and Beijing is ranked 5th (Wei, Wu, & Chen, 2021). In addition, cities are the most basic administrative units to implement climate policies (Han et al., 2020; Shan et al., 2016), allowing for concrete actions that simultaneously address environmental and societal needs (Lombardi & Sonetti, 2017). ADB (2021) predicts that in the coming one to two decades, there is "growing momentum for leading global cities to achieve carbon neutrality".

Globally, an increasing number of initiatives are set up to equip and mobilise cities for more ambitious climate action. C40 is a network created by city governments in 2005, focused on knowledge exchange related to climate leadership among 97 members. Beijing and Hong Kong have both been part of C40 since the initial stage, and Hong Kong is currently part of the network's steering committee. At the 2019 C40 China Regional Forum, the C40 Climate Action Planning China Programme was launched for capacity building and sharing of best practices on inclusive climate mitigation and adaptation plans that accrue wider socioeconomic benefits (C40, 2019). Carbon Neutral Cities Alliance was founded in 2014, comprising of 17 cities to facilitate transformative policies and planning towards carbon neutrality. During COP21 Climate Change Conference, 400 mayors signed the Compact of Mayors to pledge emissions reduction for cities, potentially avoiding over 740 million tonnes of CO_2 by 2030 (Dasgupta, 2015). Leading up to the COP26, the "Cities Race To Zero Campaign" was launched and joined by 733 cities, which have pledged net-zero goals by 2040 or 2050 at the latest (UNFCCC, 2021). These alliances highlight the growing significance of cities and municipal actors in attaining net-zero.

Carbon neutrality pathways of cities vary due to a range of underlying factors. For emissions reduction, driving factors that influence emissions include physical environment, population density, economic structure and energy consumption pattern (Kennedy, Ibrahim, & Hoornweg, 2014). When we use Kaya Identity to decompose CO_2 emissions related to energy systems, similar factors can be drawn, which are population, GDP per capita, energy intensity and CO_2 intensity (Raupach et al., 2007; Xiangzhao & Ji, 2008). For the component of neutralising hard-to-abate emissions, the choice of offset options or NET is dependent on the availability of technology and affordable options. It may involve looking at surrounding cities or regions in the country. Overall, cities with different emission inventories and socioeconomic characteristics require different policies to achieve carbon neutrality. A mix

of technological and societal policy interventions is required (Ramanathan et al., 2016), with technical solutions to enhance EE and reduce carbon intensity of fuel; social solutions to encourage lifestyle change, modal shift and population control.

2.1.4 Energy Policy and Carbon Neutrality

Globally, over 76% of GHG emissions is linked to energy consumption (IPCC, 2014b), revealing the fact that climate change mitigation hinges largely upon energy policies. Energy is a multidimensional problem that requires systems thinking to unpack. The conventional dimension is splitting into supply and demand sides, exploring how energy is generated and consumed. Energy infrastructure must not be missed in the picture, which includes sociotechnical systems that support the transmission and distribution of energy services. Electricity networks, energy storage facilities and petrol stations are examples of infrastructure. Another dimension is energy service demand, considering whether resources are used for generating electricity, heat or transportation fuel (Steubing, Zah, & Ludwig, 2012). There are parameters which both influence and become influenced by different dimensions of energy, such as policy, technology, behaviour, economics and equity. Energy policy carries an additional level of significance because it can guide technological development, social behaviour, the flow of capital and just transition. As the nexus of energy flows, cities have emerged across national and global energy policy arenas with cross-sectoral decarbonisation agendas (ADB, 2021). The vital role of cities is manifested in the policies made around transportation planning, building design, district heating and cooling system, electricity grid management.

When formulating energy policies, it is critical to recognise the co-existence of supply, demand and infrastructure; and changes in one influence another. In the energy systems, every demand must be matched with a supply. A policy only focused on supply may not be feasible, because it may pose stress or challenge on demand management or supporting infrastructure. For instance, ramping up to 100% solar and wind energy in a city can bring about substantial GHG reduction, but intermittency of RE leads to conditional changes in level of energy consumption, which potentially causes power outages (Yekini Suberu, Wazir Mustafa, & Bashir, 2014). Under such circumstance, energy storage systems or fuel cells are necessitated to mitigate the stochastic deficiencies in RE (Yekini Suberu et al., 2014). For hard-to-abate sectors, options to neutralise GHG could include purchasing

carbon credits, burning fossil fuel with CCS or direct air capture (DAC). The consideration of these options also constitutes part of energy policy. As aforementioned, the arena of carbon offsets and removal is contested. However, there is consensus from IAMs and bottom-up assessments on the critical role of upscaling renewable energy and reducing total demand of energy services to accelerate decarbonisation (Eyre et al., 2018; IPCC, 2014a). IEA (2021) forecasts fossil fuels will shift to electricity, RE and hydrogen based on the announced net-zero pledges, increasing the share of electricity from 20% to 30% in 2050. To ensure a holistic overview, energy policy interventions in this study cover supply side, demand side, infrastructure-based solutions to cope with electricity, heat and transport.

Energy policies are not the only policies that influence energy use. Policies related to other sectors, such as education and healthcare, may have indirect influence on energy consumption. It is also noted that COVID-19 pandemic brought about changes in energy policies, but most of them are short-term fiscal measures which do not have long-term implications on the clean energy transition (Akrofi & Antwi, 2020). The focus of this study is limited to policies with direct influence on electricity generation, and energy use in transport, buildings and industry.

2.2 Where – Baseline conditions of Beijing and Hong Kong

The role of China evolved rapidly in the last two decades, transitioning from a country with expanding infrastructure and inefficient coal-powered electricity system to a global leader in renewable energy (Weber et al., 2008), with an estimated 85% decline in coal for electricity consumption during 2020 and 2050 (IEA, 2021; Yang et al., 2016). This section lays out the background contexts of China, Beijing and Hong Kong, offering a comprehensive review of their current energy policies and carbon neutrality strategies.

2.2.1 Environmental Governance in China

Granted the stability in political leadership, the planning of China takes on long time horizons. Environmental planning trajectories are largely determined by top-down targets set in the regular five-year plans (FYP), high-level policy documents outlining different aspects of development in the next five years. From popularising solar PV to alleviating air pollution, major successes in the environmental management of China in the past decade are attributed to this distinctive model of goal-based environmental governance (Kanie & Biermann, 2018). Multiple existing studies describe the national environmental governance of China as

authoritarian environmentalism, characterised by a top-down, mono-centric and non-participatory policy processes (Eaton & Kostka, 2014; Gilley, 2012; Zhang et al., 2013). In addressing imminent threats from climate change, authoritarian environmentalism in China is effective in driving rapid responses and policy outcomes, with some risks of lock-in effect due to excluding social actors (Gilley, 2012).

In a high-level leadership meeting discussing the formulation of 14th FYP and long-term goals for 2035[5], China sets out the ambition to complete the green transition of socioeconomic development, accelerate low-carbon development and further increase resource efficiency. These priorities show clear alignment with President Xi's carbon neutrality pledge announced one month prior to the meeting. It is also the first time that China did not propose a GDP target for economic growth. This is an important indication of China's determination to embrace the "Economic New Normal", characterised by economic deceleration, resulting from slowed energy demand growth and structural shift to sectors with lower energy intensity (Liu et al., 2015; Qi et al., 2020). These conditions establish the basis for more pronounced emissions reduction for the years to come.

In previous intergovernmental COP meetings, China did not express its intention to be a leader in climate action. Through analysing the performance of China and the US in the Paris Agreement negotiation, Eckersley (2020) shows that China mostly acted predominantly as a "defensive co-operator" and has yet to see its role as leading the world in climate action. Under de-globalisation and decrease of multilateralism, China is experiencing a narrowing space of national development (Liu, 2021). The 2060 carbon neutrality goal and subsequent commitments written in the 14th FYP send a strong signal to the world, indicating China's determination to progress from the "learner" to the "leader" position in the global tide of green transformation (Liu, 2021). Apart from gaining soft power and reputation, Chinese leaders are also motivated to take the greener route as they see the mutually beneficial relationship between environmental quality and development, as opposed to the conventional beliefs presented by the Environmental Kuznets Curve (EKC) (Alexander & Rutherford, 2019). This explains the state's adoption of "ecological modernisation" narrative in guiding concrete policy changes (Geall & Ely, 2018). Yet, it is argued that the narrative has yet to be fully incorporated into the Chinese socioeconomic environment under broader strategic planning (Liu, 2021). Apart from upgrading the industrial structure, fundamental lifestyle and

[5] The Fifth Plenary Session of the 19th Central Committee of the Communist Party of China, "Proposals of the Central Committee of the Communist Party of China on Formulating the Fourteenth Five-Year Plan for National Economic and Social Development and Long-Term Goals for 2035" was reviewed and approved.

consumption behaviours may have to be altered to truly decouple China's economic growth from rising carbon emissions.

Decentralisation of policymaking and implementation is a prominent feature of the environmental governance of China. Despite the prevailing perception that China operates on authoritarian environmentalism, most evidence points to the national level of low-carbon governance. For the local level, it is a mixture of authoritarian and liberal governance. This "de factor neoliberal environmentalism" is a result of the difficulty for the Chinese central government to control different levels of local actors (Lo, 2015). Local governments are given high degree of flexibility and authority for policy design and implementation to achieve their assigned policy targets (Xu, 2020). Energy-intensive enterprises also have the freedom to manage their own energy consumption (Lo, 2015). Due to a lack of monitoring capacity and competing policy priorities, there could be large discrepancies in the expected and actual environmental performance at a locality, such as Beijing (Kostka, 2014; Xu, 2020).

This research aims to mend the gap through gaining a deeper understanding of decision-making processes at the city-level. The case for Hong Kong is different because of its status as a Special Administrative Region (SAR). The legislation and governance structure are largely separated from mainland China, with high degree of autonomy to plan and execute climate and other policies. Nevertheless, recent years have seen the increasing integration of Hong Kong and mainland China, with Hong Kong officials being "tasked" to fulfil specific national targets (Lui, 2020). In the environment and climate arena, Hong Kong and mainland China are even more interlinked because Hong Kong's NDC must be incorporated into the national submission to UNFCCC. Limited studies explore the relationship between the climate governance of Hong Kong and mainland China. In-depth exchanges with stakeholders, especially government officials, can provide insights on the evaluation mechanisms behind local energy and climate policies, and how the decision-making process is influenced by national climate governance.

2.2.2 Grid Structures in Beijing and Hong Kong

Beijing and Hong Kong operate on different electricity grid systems. Beijing follows the national grid for mainland China, whereas Hong Kong has an electricity market operated by two vertically integrated power companies. The national grid of China is divided into six geographical regions as displayed in Table 2 (China Electricity Council, 2015). Beijing belongs to the Northern region, served by the North China Grid.

Table 2. Regional division of the electricity grid in China

Region	Provinces	Electricity Grid
North	Beijing, Tianjin, Hebei, Shanxi, Shandong, and West Inner Mongolia	North China (Huabei) Grid
Northeast	Liaoning, Jilin, Heilongjiang, and East Inner Mongolia	Northeast Grid
Northwest	Xinjiang, Gansu, Qinghai, Ningxia, Tibet, and Shaanxi	Northwest Grid
Central	Hubei, Hunan, Jiangxi, Sichuan, Chongqing, and Henan	Central China (Huazhong) Grid
East	Shanghai, Jiangsu, Zhejiang, Fujian, and Anhui;	East China (Huadong) Grid
South	Guangdong, Guangxi, Yunnan, Guizhou, and Hainan, regions	Southern Grid

The National Development and Reform Commission (NDRC) is the highest authority of the Chinese Central Government that oversees major developmental issues of China, one of which is energy. The National Energy Administration (NEA) is a subordinate bureau under NDRC, responsible for policy planning for energy supply. The State Grid of China Corporation (SGCC) is a state-owned enterprise in charge of the technical and operational processes of transmission and distribution in different geographical regions. In the 1990s to 2000s, China encountered the challenge of a power deficit as energy supply and infrastructure were unable to match with rising demand driven by rapid economic growth. This led to the government implementing reforms in the power industry, which can be characterised in three stages (Ngan, 2010). The first phase (1986–1996) was "raise capital", the second phase (1997–2001) was "market-oriented restructuring", third phase (2002–"present") [6] was "introduce competition".

The electricity market in Hong Kong is monopolised by two vertically integrated private electricity utilities, namely CLP Power (CLP) and HK Electric (HEC). The government signs the Scheme of Control Agreement (SCA) to regulate the utilities, requiring them to safeguard supply reliability, energy security at affordable prices and minimal

[6] "Present" in the literature refers to 2010, when the research was published. But the electric power industry is still under the same stage of introducing competition.

environmental damage. In exchange for their performance, the utilities receive a statutory "Rate of Return" from the government, which is a fraction of their investment in assets (Woo, Horowitz, & Tishler, 2006). The regulatory framework of SCA has yielded high electricity supply reliability of 99.999% for both CLP and HEC, at the same time ensuring affordable tariff rates comparable to Singapore and London (CLP, 2020). Grid resilience under extreme weather events is also found to be enhanced by the SCA, which provides incentives for timely investment in grid infrastructure and rapid restoration after power interruptions (Chung & Xu, 2020). Despite these benefits, the existing regulated electricity market may not be conducive to cheap and efficient RE development in Hong Kong given the lack of competitive market players. Research and development of large-scale RE is currently dominated by the two utilities, which then propose solutions for government approval. The government has low bargaining power against such monopolies. An offshore wind project proposed in 2010 by CLP was rejected by the government due to the high cost, reflecting that at the time the affordability of tariff has high priority. Proposals to reform the electricity market exist (Chan, 2006), but there is a general lack of debate in society.

2.2.3 Carbon Neutrality Baselines

2.2.3.1 Existing Targets

Rigorous research has been conducted by government-affiliated institutions in China before the pledge announcement, which has laid the foundation for establishing and subsequently achieving the carbon neutrality target. A shared narrative among the reports is national energy policy and green energy transition are crucial for China to deliver its commitments, as 60% of overall emissions is tied with energy sectors (Qi et al., 2020).

Back in 2015, China submitted NDC to UNFCCC with the plan to reduce 60-65% carbon intensity by 2030 compared with 2005 levels, aiming to peak total carbon emissions in 2030 (Chen et al., 2017). The 13th FYP set the target of absolute carbon reduction of 18% from 2016 to 2020. A number of international and national studies indicate China has been on track to deliver and even exceed its first NDC (Qi et al., 2020; UNEP, 2020).

The 14th FYP was published in March 2021, following the 2060 carbon neutrality target announcement. The FYP encompasses GHG reduction targets and energy decarbonisation strategies. China's carbon neutrality roadmap can be separated into three stages as shown in Figure 2.

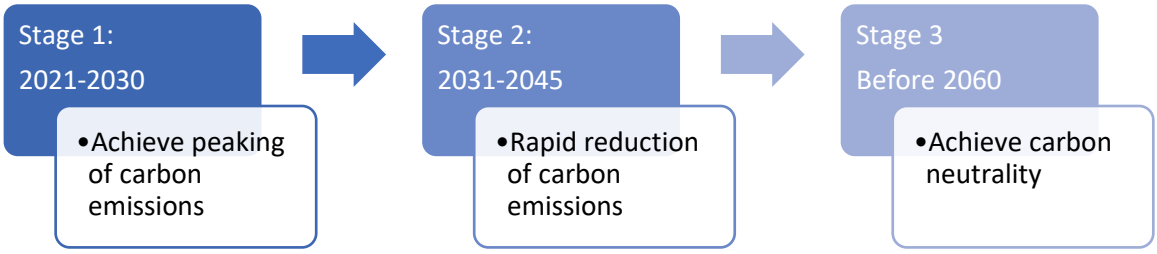


Figure 2. Three stages in the carbon neutrality roadmap of China

In thr latest FYP, China commits to 18% carbon intensity reduction and 13.5% energy intensity reduction during 2021 and 2025.[7] The targets are the same as those in 13th FYP, thus deemed "underwhelming" by some experts (Cheong, 2021). At high-level meetings, numerous experts stressed the need for 14th FYP to include overall targets, in addition to previous intensity-based "efficiency targets" (Ma, 2020). However, overall targets were not included in the 14th FYP. Based on an estimate using previous emissions data, assuming China's GDP growth rate is 5.5% during 2021 to 2025, overall carbon emission will increase 1.1% annually (Shi, 2021).

Targets for non-fossil fuel sources for primary energy consumption increased from 16% to 20% by the end of 14th FYP reporting period to accelerate the development of RE. Policies are in place to attract investments for green industries. An authoritative study on long-term low-carbon transition illustrates four distinctive scenarios, namely the policy scenario, reinforced policy scenario, 2°C scenario and 1.5°C scenario (He, 2020). In the 1.5°C scenario, CO_2 emission from power generation should have reached carbon neutrality by 2050, with over 90% of electricity generated by non-fossil energy and less than 5% by coal. Critics question whether this pathway is achievable, given China presently owns over half of the coal capacity in the world.

NDRC and NEA are proactive in establishing strategies and roadmaps for specific industries. In addition to clean energy generation, the state authorities recognise new energy storage technologies and pumped storage are the fundamental backbone to supporting the green energy transition. They also bring about the co-benefits of grid resilience under low solar and wind periods and extreme events and safeguarding energy security and ultimately

[7] Intensity targets are based on per unit GDP.

promoting high-quality energy development (NDRC & NEA, 2021). Energy storage technology targets set for China can be found in Table 3.

Table 3. Energy storage technology targets set for China in July 2021

Year	2025	2030
Targets	- To complete the transition from early stage of commercialisation to full-scale development of new energy storage capacity - To reach 30 million kW in installed capacity for new energy storage infrastructure and facilities	- To attain full market-oriented development of new energy storage technology - To lead the world in technological developments in energy storage - To meet corresponding needs of the new energy system by installed capacity

At the city level, Beijing pledged to peak carbon emission by 2020 back in the city's 2011 development plan (WRI, 2020). More recently, Beijing published its 14th FYP and 2035 Vision, detailing the plan for low-carbon energy transition (BMCDR, 2021). Carbon emissions are envisioned to "decrease with stability (稳中有降)" after peaking. Although the mention of "carbon emissions" in the document has increased from previous years, showing heightened awareness on the subject matter, the strength of commitment under the Beijing municipal government is still considered weak. The plan is to reduce emissions "steadily", unmatched with the rapid reduction required for mitigating climate change.

In Hong Kong, the first climate target published dates back to 2010 when the Environment Bureau pledged to reduce carbon intensity by 50-60% before 2020 based on 2005 levels (Environment Bureau, 2015b). The target faced similar challenges to the intensity targets in FYP, due to its measurement of relative reductions instead of absolute reduction. Since the Paris Agreement entered into force in November 2016, Hong Kong has been obliged to submit our own NDC to China for incorporation. Hong Kong's Climate Action Plan 2030+ was published in 2017, showcasing the ambition of 65-70% of carbon intensity

reduction by 2030. This time, the government translated the targets absolute reduction of 26-36% and per capita carbon footprint of 3.3-3.8 tonnes per annum (HKENB, 2017). To prepare for the NDC update scheduled for COP26, the government conducted a public engagement exercise in envisioning the long-term decarbonisation plan for Hong Kong. The outcome of which was to confirm a city-level carbon neutrality target by 2050, endorsed by the Chief Executive as a statutory policy in 2020.

2.2.3.2 Emission Profiles and Existing Policies

Energy consumption in China has surged from 400 million tonnes of oil equivalent (Mtoe) in 1978 to 3248 Mtoe in 2018, with an annual growth rate of 5.4% (NBS, 2018). This has led to significant CO_2 emissions growth, substantially increasing the relative contribution of China to global emissions (Zheng et al., 2020). GDP per capita and CO_2 emissions per capita over this period have been strongly coupled (Lu et al., 2019).

Beijing city does not publish an official GHG inventory, but the total emissions and sectoral emissions are estimated in different reports. The figures vary when different climatic models and data sets are used. From an estimate by WRI, Beijing emitted 158 million tonnes CO_2-eq in 2018 (Xi, Jiang, & Fong, 2017). The current sectoral emissions breakdown for Beijing is 43% from building, 31% from industry, 24% from transport and 2% from other sources. The built environment, including commercial and residential buildings, have the highest emissions. For Hong Kong, the Environmental Protection Department releases GHG inventory annually. In 2018, 40.6 million tonnes of CO_2-eq were emitted (HKEPD, 2020). For sources of GHG emissions in 2018, electricity generation accounts for the majority of around 65%, followed by 18% of emissions from transport, 7% from waste, 4% from industry and 6% from others (HKEPD, 2019). According to another government report, around 90% of emissions from electricity generation are spent on buildings (HKENB, 2017). Thus, the estimated GHG from buildings is 59%. As shown in Table 4, the emissions profiles of Beijing and Hong Kong are largely similar, except for the prominence of industrial emissions in Beijing which is absent in Hong Kong. Buildings contributes the most to emission as both cities have high building and population densities. Building stocks are also dominated by aged buildings of over 30 years of age, with low energy efficiency.

Table 4. Comparison of the emissions profile of Beijing and Hong Kong

	Beijing	**Hong Kong**	**World**
2018 emissions (CO_2-eq tonnes)	158 million	40.6 million	53.5 billion
Building	43%	59%	18%
Industry	31%	4%	29%
Transport	24%	18%	16%
Electricity Generation (overlaps with building sector)	No data	65%	73% (also overlaps with transport and industry sectors)

Beijing is one of the pilot low carbon cities (LCC), which is a sustainable urbanism initiative in China (Hunter et al., 2019). Using a city development-stage framework to analyse the driving factors for carbon emissions in Beijing, Shen et al. (2018) find that LCC initiative has fostered structural change in industries, leading to more green industries and increased employment. The industrial structural change during Beijing's second development stage (1991-2004) led to significant emissions reduction, which corresponds to results from other studies (see Mi et al., 2015; Xu et al., 2016). While economic output is identified as the primary factor leading to increase in carbon emissions across different stages. Enhancing energy efficiency (EE) is regarded as one of the key approaches for Beijing to achieve carbon reduction along with sustainable economic growth (Shen et al., 2018). Low carbon mobility is an active initiative promoted among LCC. Microsimulation model shows that Beijing can attain 43% reduction in daily travel carbon emissions in 2025 compared with 2015 with the combined effect of transport improvement, public bike development, energy efficiency improvement, and electric vehicle development (Yang et al., 2017).

The prevalence of extreme weather events in China has increased under climate change, leading to a higher dependence of residents on household electrical appliances for thermal comfort (Lin et al., 2014). Sheng et al. (2021) investigate factors that influence residential electricity demand to optimise power demand management and power allocation for meeting global emission reduction targets. In terms of electricity demand, household appliances including lighting and cooling contribute to a significant amount of residential electricity consumption (Liang et al., 2013). Adopting a real-time pricing strategy for

electrical appliances is shown to reduce peak load and maximise utility on both supply and demand sides (Yan et al., 2019).

Table 5. Factors driving carbon emissions changes in Beijing (1991-2022) (Based on Shen et al., 2018)

Beijing	**1991-2004**	**2004-2022**
Factors for increase in carbon emissions (+)	• Economic output • Production scale	• Economic output • Production scale • Energy structure
Factors for decrease in carbon emissions (-)	• Industrial structure	• Energy intensity

Since the mid-20th century, Hong Kong experienced rapid socioeconomic development and urbanisation, reaching 100% urbanisation in 1993 (World Bank, 2020b). Akin to Beijing, economic growth (indicated by GDP per capita) is the main driver for increasing GHG emissions from energy use from 2000 to 2017 (Civic Exchange, 2020). Using Logarithmic Mean Divisia Index with the Kaya decomposition method, the contributions of factors to GHG fluctuations are found and presented in table x below. Although the time periods are different and hard to compare, there are key similarities in factors increasing and decreasing emissions in Beijing and Hong Kong. Energy intensity plays a declining role in emissions reduction for Hong Kong, because most low-hanging fruits in EE measures have been reaped. However, as a large volume of emissions from Beijing still originate from manufacturing industries (31% in 2018), technological innovations and investments in more efficient industrial processes has been crucial for Beijing's quest to drive down emissions in the coming decade.

Table 6. Factors driving GHG emissions changes in Hong Kong (2000-2017) (Based on Civic Exchange, 2020)

Hong Kong	**2000-2009**	**2010-2017**
Factors for increase in GHG emissions (+)	• Economic output • Energy mix	• Economic output (declining) • Energy structure

Factors for decrease in GHG emissions (-)	• Energy intensity	• Energy mix • Energy intensity (declining)

In the same report, Hong Kong is demonstrated to have the capacity to achieve close to carbon neutrality in 2050 (Civic Exchange, 2020). Projected using the Energy Policy Simulator, the "Current Policy Scenario" draws down GHG emissions from 37 million tonnes CO_2-eq in 2017 to 22 million tonnes CO_2-eq in 2050. In the "2050 Decarbonisation Scenario", only 3.9 million tonnes CO_2-eq remain in 2050, representing a 90% reduction from 2017. The remaining 10% of emissions is recommended for offsetting. In the proposed decarbonisation scenario, the fuel mix is split into 60% of imported renewable and nuclear energy, 35% from local natural gas plants with CCS, and 5% from local renewable energy and waste-to-energy facilities (Civic Exchange, 2020). In another study, Xu & Liu (2015) propose an alternative "CCS plan" for the fuel mix in Hong Kong, which includes 60% of coal with CCS, 20% of natural gas and 20% of nuclear power as indicated in figure x. The Hong Kong-Yacheng natural gas pipeline is identified as suitable to be converted for CO_2 transport (Xu & Liu, 2015). However, there are concerns over the high operational cost of CCS due to technological immaturity.

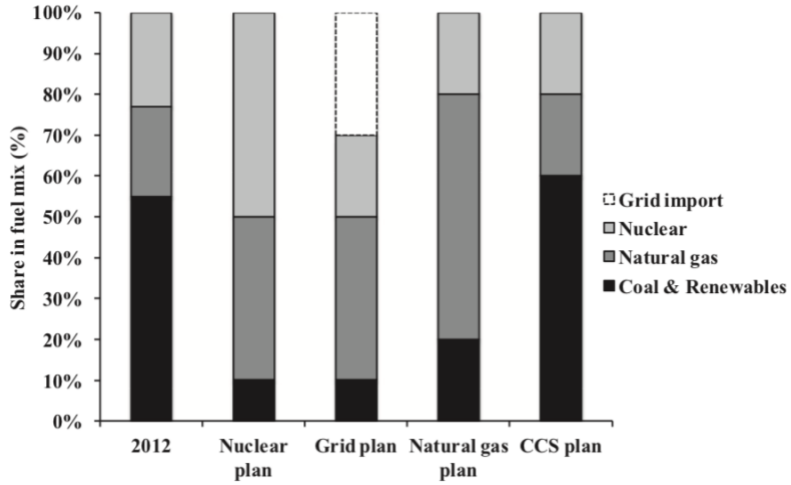


Figure 3. Existing government options and alternative CCS plan for the fuel mix of Hong Kong[8] (Source: Xu & Liu, 2015)

[8] The share of renewable energy is very small in Hong Kong, so they are combined with coal in the graph

2.3 How – Methodological approaches in prioritising climate policies

This part of the literature provides an overview of conventional and new methods to prioritise climate and energy policies, explaining the need for complex systems thinking to cope with the climate crisis. We then delve into details of sensitive intervention points (SIPs) framework and explore the defining attributes of SIPs.

2.3.1 Methods to Prioritise Climate and Energy Policies

Climate and energy policies have risen to the top of the agenda for many city governments because of their intersectionality with issues related to economic development, food production, public health and safety. Cost-benefit analysis (CBA) is a conventional approach to policy evaluation and prioritisation, weighing the direct and indirect costs and benefits of selected policies. This approach can quantify policy effects using monetary value, generating a unified language among stakeholders for an "objective and legitimate" policy response. However, CBA fails to capture uneven temporal or spatial distribution of costs and benefits, and cumulative environmental impacts. It also cannot account for incommensurable impacts such as social consequences and irreversible environmental damages. Cost-effective analysis (CEA) is another appraisal method, which begins with a policy target and seeks the most cost-effective policies to achieve it. Abatement cost curves are one approach employed to perform a CEA. Compared with CBA, CEA makes fewer assumptions on parameters such as social cost of carbon, discount rate or damage functions. Nevertheless, the optimal pathways sought may not be achievable under political or technical circumstances in the reality.

For prioritisation frameworks, "stabilisation wedges" was first proposed in 2004, assuming that global mitigation of climate change required flat emissions rates for the next 50 years (Pacala, 2004). To stabilise emissions, different wedges that represent a mitigation action are needed to fill the stabilisation triangle. Due to increased emissions, the number of wedges required to fill the triangle increase from 7 to 9 in an updated paper in 2011. This represents a static, quantitative approach to generate a portfolio of climate actions, through associating percentage of emission reduction to climate policies, such as wind power and enhancing vehicle fuel efficiency. In an attempt to guide low-carbon energy policies, the amount of emission reduction of policies is quantified, and added up to achieve the reductions needed by 2050 for the Paris Agreement (Harvey, Orvis, & Rissman, 2018). For example, building codes and appliance standards are expected to contribute 5.2% of the reductions necessary for the 2°C target (Harvey et al., 2018). An important aspect is the

synergies between policies are also quantified, which is a useful strategy for more comprehensive policy appraisal. In a study on transport decarbonisation, Lam and Mercure (2021) show that imposing carbon tax makes transport more expensive. If an incentive scheme is introduced at the same time to make EVs more affordable on the market, the public will move away from internal combustion engine vehicles (ICEVs) to EVs. The two policies combined together yield large synergetic effect for deeper decarbonisation (Lam & Mercure, 2021).

The stabilisation wedges approach has been criticised for its use of static thinking, which misses important synergies and feedback, as well as the effect of learning (J. D. Farmer et al., 2019). A new perspective is warranted to rethink the prioritisation of climate policies, given the limited time to reach carbon neutrality in less than 30/40 years. The magnitude and rate of transition may seem unattainable, yet feedbacks in the complex system illuminate hope. As confirmed by Geels et al. (2017b), focusing on "dynamic policy mixes rather than single, static instruments" is an important policy lesson from successful low-carbon transitions in energy systems.

2.3.2 The SIPs Framework

In order to achieve net-zero emission by mid-century, global emissions have to be reduced by 25 GT in the next ten years, meaning the pace of decarbonisation must be extremely rapid. The study of complex systems dynamics offers a potential solution to accelerate global emissions reductions. The climate system is characterised as a complex dynamic system within the nested and interlinked subsystems (Snyder, Mastrandrea, & Schneider, 2011). Similarly, the economy is recognised as a complex adaptive system that exhibits nonlinear interactions triggered by reinforcing and balancing feedbacks (Abson et al., 2017; Meadows, 1999). Farmer et al. (2019) propose the concept of sensitive intervention points (SIPs), which are interventions capable of propagating disproportionately large effects on systems at criticality. Two broad types of interventions are kicks and shifts, with the former modifying the outcome without changing the system (such as investment in renewables with consistent cost declines), whereas the latter involving a change to the underlying rules of the system (such as enacting a climate change act into law) (J. D. Farmer et al., 2019; Hepburn et al., 2020). Social tipping intervention (STI) and upward scaling tipping points (USTP) are similar concepts, which can activate the contagious spreading of technologies, behaviours and social norms in the complex planetary socioeconomic system

(Otto et al., 2020; Sharpe & Lenton, 2021). The availability of intervention points allows diverse stakeholders to prioritise actions that generate the most significant impacts, enabling opportunistic instead of aimless climate mitigation actions.

There are four main positive feedback loops, namely self-reinforcing expectations, network and coordination effects, learning effects, and economies of scale. The widespread manufacturing and utilisation of clean technologies with consistent cost declines, such as solar PV panels, can be facilitated by all four types of feedbacks. Most intervention points serve to unlock investments in new clean technologies, thus accelerating decarbonisation (Ives et al., 2021). The six key defining features of SIPs are feedback, criticality, speed, impact, scalability and persistence. An intervention is usually defined as one that can reduce a region's emission by at least 10%, with the combined aim of halving emissions by 2030.

Table 7. The defining features of SIPs

Attributes	**Defining features of SIPs**
1. Feedback	Positive feedback loop that is self-reinforcing
2. Criticality	Systems "ripe for change" or "windows of opportunity"
3. Impact	Large impact
4. Speed	Trigger transitions that can happen quickly
5. Scalability	High scalability
6. Persistence	High persistence

SIPs can be adopted to guide policymaking towards carbon neutrality targets. In a policy advisory report submitted to the UK Committee on Climate Change, expert elicitation and literature review are employed to identify 40 SIPs divided into nine categories. These SIPs translate to policy-relevant recommendations to accelerate net-zero pathway of the UK (Hepburn et al., 2020). On top of expert elicitation, an expert workshop is held for data collection in identifying STIs to speed up global decarbonisation (Otto et al., 2020).

Unlike the concept of STIs that have been reviewed with stakeholder consultation (e.g. Van Ginkel et al., 2020), SIPs have yet to be tested extensively with stakeholders concerned with decarbonisation policies. This research fills the gap by employing an alternative method to identify SIPs for the energy decarbonisation pathways of Beijing and Hong Kong with stakeholder interviews and surveys. The hope is that through understanding

critical points that kick or shift the systems, the fastest route to carbon neutrality can be revealed. Nevertheless, maintaining a portfolio of interventions is crucial owing to the uncertainties in the actual impact delivered by non-linear dynamics (Hepburn et al., 2020). Given the complexity of our socio-economic systems, some SIPs may face too great an opposition, or not work effectively, but others that work could make up for the intended progress. It is therefore important that a number of different SIPs are identified and triggered. Based on four recent studies about interventions in complex systems (SIPs, STIs and USTPs), some common interventions are identified in the following table.

Table 8. Common interventions in literature

Category	**Examples of interventions**	**Farmer et al., 2019 (Sensitive intervention points)**	**Otto et al., 2020 (Social tipping interventions)**	**Hepburn et al., 2020 (Sensitive intervention points)**	**Sharpe & Lenton et al., 2021 (Upward scaling tipping points)**
Energy technology	• Remove fossil fuel subsidies • Divest from fossil fuel assets • Align incentives to support research and development of low carbon energy technologies • Redirect capital in	v	v	v	v

	favour to technologies that develop rapidly				
Engagement	• Public engagement and consultation • Moral education and political mobilisation	v	v	v	x
Financial market	• Financial disclosure on GHG emission	v	v	x	v
Institution	• Government reorganisation for climate leadership • Political mobilisation • Corporate engagement	v	x	v	v
Legal	• Enhance legal framework • Establish climate change related law	v	x	v	x
Urban configuration	• Set up carbon neutral cities	x	v	v	x

	• Facilitate learning and capacity building • Land use rezoning				

2.3.3 Difference between SIPs and stabilisation wedges

After explaining different policy prioritisation frameworks, this section illustrates the difference between adopting SIPs and the conventional "stabilisation wedges" approach. Taking the development of global solar PV as an example, International Energy Agency's (IEA) Sustainable Development Scenario using something similar to the wedges static, linear approach (Figure 4) is contrasted with the Decisive Transition Scenario applying an approach that recognises the positive feedback in learning-by-doing that has helped generate the stunning non-linear declines in key renewable technologies (Figure 5) (Ives et al., 2021). In the IEA scenario, does not account for non-linear dynamics associated with learning-by-doing, global solar PV cost is predicted in 2020 to decrease gradually in the coming decades. This results in gradual decline in CO2 emissions, shown in the graph on the right. While for the Decisive Transition Scenario, accounting for the non-linear dynamics of continued exponential growth in solar PV, the predicted cost decline is much more rapid. Note that for this Decisive Transition the total amount of fossil fuels in the global energy system does not change for the first 5 years but declines non-linearly and dramatically after 2025. Such dynamics are what we try to identify and exploit through identifying SIPs.

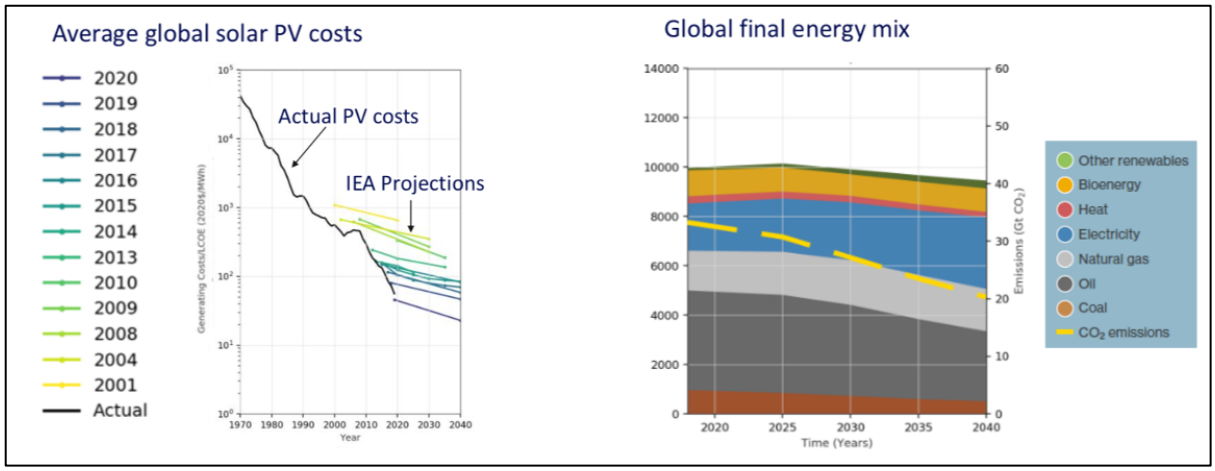


Figure 4. International Energy Agency's Sustainable Development Scenario (Ives et al., 2021)

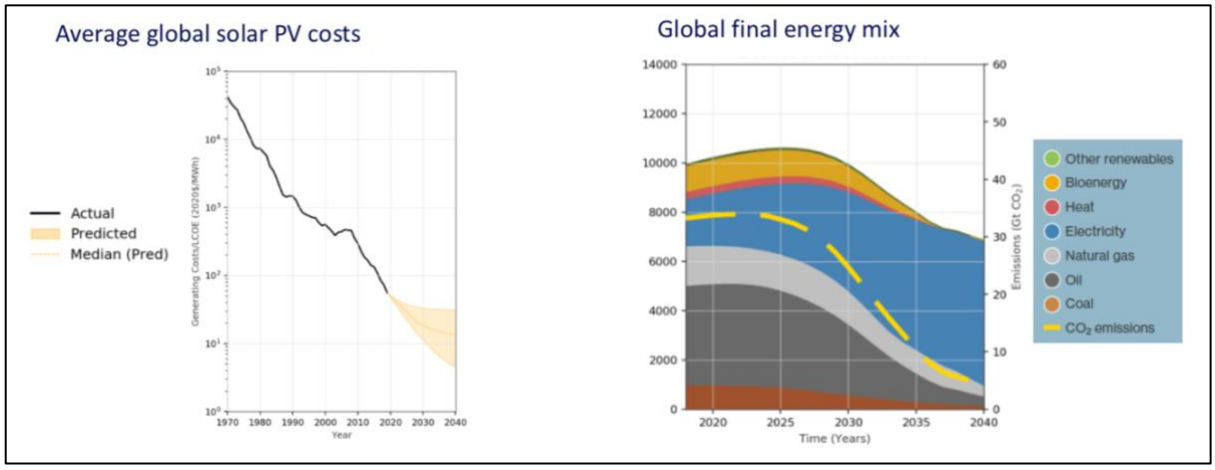


Figure 5. Decision Transition Scenario (Ives et al., 2021)

2.4 Research Gaps and Contributions

From the literature review, most carbon neutrality studies in China are focused on national level interventions. This study complements the net-zero emissions literature in China with a geographical focus on two cities, where many national climate policies will be implemented on the ground. As the world's largest greenhouse gas emitter, China has the highest number of publications on decarbonisation, low carbon development and transition during the period of 1995 to 2019 (Wimbadi & Djalante, 2020). Over 77% of these research focuses on the national level, the remaining is spread across regions, provinces, cities and smaller administrative units (Wimbadi & Djalante, 2020). Given 85% of the country's total emissions comes from urban energy use (Shan et al., 2019), there is a need for a more in-depth investigation on how climate action takes place in Chinese cities, especially in energy-

related sectors. Through collecting primary data from interviews and surveys, this research contributes to a comprehensive narrative on how carbon neutrality is conceptualised and attained with energy policies in Beijing and Hong Kong, filling the epistemic gap.

Another element of academic novelty is employing SIPs to establish a prioritisation framework for climate policies at the city level. As shown in the earlier section, SIPs are traditionally applied to the global or national contexts to seek climate solutions with outsized impacts (J. D. Farmer et al., 2019; Hepburn et al., 2020). While cities are influenced by global or national SIPs, this study strives to explore SIPs that underlie concrete actions by local actors in hopes of accelerating decarbonisation. The body of literature related to SIPs can therefore be enriched with city-level insights and multilevel perspectives.

For policy implications, the choice of Beijing and Hong Kong as the spatial scope of the study is strategically significant. Latest reports forecast economically advanced cities will be the first to lead China towards carbon neutrality, including the Jing-Jin-Ji Region (JJJ) and the Greater Bay Area (GBA) (WRI, 2020). As the leading cities in JJJ and GBA, Beijing and Hong Kong collectively set benchmarks for other Chinese cities through showcasing the best practices and lessons learnt in carbon neutrality planning. This research intends to explore how two different governance structures influence the decisions made in climate and energy policies in these two cities that fall under the same national regime. As the capital of China where key decision-making authorities are situated, a lot of pressure is exerted on Beijing to achieve carbon neutrality after President Xi's pledge. With the track record of being the command-and-control centre of China, policies in Beijing are expected to align with the top-down authoritarian governance at the national level (Hu, 2015). Meanwhile, climate policies in Hong Kong rely more on market mechanisms and are more influenced by different stakeholders. Policy prioritisation framework is sought under the varying governance structures, highlighting factors that influence policy adaptability, outcomes and challenges. Understanding these underlying factors can potentially lead to more effective decision-making for climate and energy policies in cities with such different governance structures.

Chapter 3: Methodology

The chapter begins with an overview of the research ontology and epistemology that explain the use of mixed methods approach. The research process is explained, followed by the rationale for using case studies. Next, three quantitative and qualitative research methods are detailed, which are the LEAP model, first-round expert interviews and second-round feedback surveys. Research ethics and data handling are explained, concluding with limitations and remedies of the methodology.

3.1 Overview of Methodology

This research is grounded in the paradigm of critical realism, a philosophical framework that enables researchers to explain social events and put forward practical policy recommendations (Fletcher, 2017). The pathways for energy sectors Beijing and Hong Kong to attain carbon neutrality are partly regarded as "facts" that can be modelled and projected (e.g. energy supply and demand). Yet, the "facts" are also subjective because they are socially constructed through processes like policy evaluation and prioritisation, deliberation among key stakeholders. This ontology justifies the use of mixed method approach, with an attempt to link quantitative and qualitative data for holistic knowledge on the "objective" and "subjective" facts related to urban carbon neutrality (Miles & Huberman, 1994). A hybrid energy model LEAP was employed to understand the GHG reduction potentials of existing policies in a quantitative manner. Semi-structured interviews and follow-up surveys were subsequently conducted to collect qualitative data about future strategies for reaching carbon neutrality.[9] The research process was organised with four components as follows:

The LEAP model was employed to project the GHG emissions trajectories under the existing climate and energy policies of Beijing and Hong Kong (2018-2060)
First-round expert interviews with stakeholders in Beijing and Hong Kong were conducted to understand their perceptions on carbon neutrality and perceived important policies to accelerate progress towards carbon neutrality ("Stakeholder Rank")
Literature review of academic research and reports on SIPs to identify and rank the preliminary SIPs for Beijing and Hong Kong ("Preliminary SIPs Rank")

[9] The purpose of having multiple data sets was not intended for validation through procedures like triangulation, because validity relates to the relationship with things that it is intended to be an account of under critical realism (J. Maxwell, 1992).

Feedback surveys with the same group of stakeholders were conducted to rank the SIPs identified in the literature ("Final SIPs Rank")

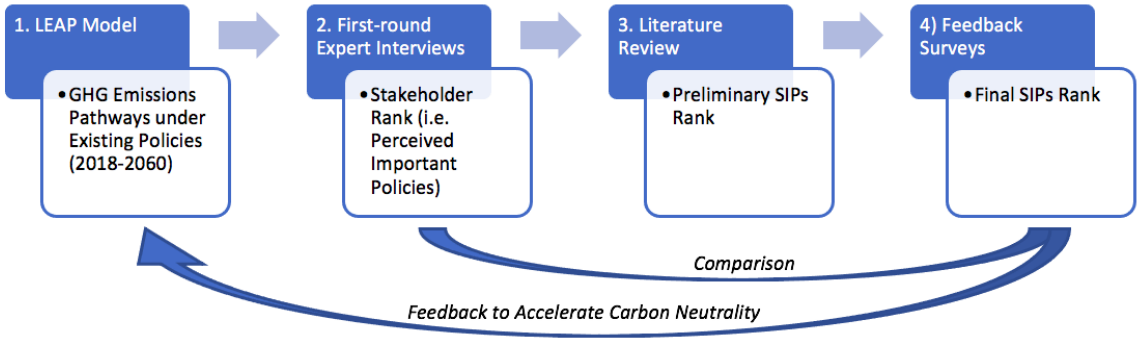


Figure 6. Overview of the research process

As illustrated in Figure 6, the research process consists of four methods to collect data. The main expected results are shown in the boxes below. The research process is not linear, it is a dynamic and iterative process. For instance, the final SIPs rank is compared with the stakeholder rank obtained earlier to find out how well they align. The final SIPs for Beijing and Hong Kong can also feedback to the LEAP model to generate a "Carbon Neutrality Scenario" with policies able to accelerate decarbonisation.

3.2 Case Study

Granted my objective to gain an in-depth understanding of city carbon neutrality pathways, the case study approach was adopted. This approach enables researchers to employ contextual analysis to probe into a complex phenomenon in real-life (Yin, 2014). Case studies may have low replicability and may risk confirming researcher biases. Nevertheless, they remain powerful for obtaining rich insights on context-specific phenomenon through the conceptual development of key concepts (Flyvbjerg, 2006), which would be urban carbon neutrality, energy decarbonisation and offsets in this research.

Beijing and Hong Kong were chosen for the comparative case study because they are indicative of the range in urban carbon neutrality, given the different levels of electricity imports and varying degrees of adherence to the central government policies. Compared with Hong Kong, Beijing imports a much higher ratio of electricity and aligns closer with the central government climate policies. The two cities are outliers on either ends of the self-reliance spectrum, as such offer a contrasting range against which we can infer some ideas of

how national targets might translate into local-level action across various Chinese cities. The policy solutions proposed for the two cities would form a spectrum, where other major Chinese cities largely fall in between.

Aside from the contrasts, Beijing and Hong Kong share the status of leading cities in China with advanced climate policies for other cities to learn from. As part of the core economic development zones (Jing-Jin-Ji and Greater Bay Area), Beijing and Hong Kong are characterised by heavy reliance on fossil fuel and high energy consumption. But they are ready to become the exemplars in low carbon initiatives with sufficient financial resources and relatively high political momentum in decarbonisation. Therefore, sharing the cases of Beijing and Hong Kong can foster policy learning of other Chinese cities (Lee & van de Meene, 2012).

3.3 Quantitative and Qualitative Methods

3.3.1 LEAP

3.3.1.1 Introduction of LEAP

The research process begins with a review of the baseline conditions of Beijing and Hong Kong, in their existing progress to carbon neutrality. The review was conducted by quantitative modelling with Low Emissions Analysis Platform (LEAP), based on historical data and forecasts in documents outlining the climate strategies of the two cities.

Developed by the Stockholm Environment Institute, LEAP is a scenario-based analysis and climate change assessment modelling tool. The main function of LEAP is to develop scenarios of projected energy demand and GHG emissions based on the generation, transformation, and consumption of energy in a given region. For model operation, the electricity system is simulated, which links resources to end-users. The flow of energy into the model is matched with the energy demand of the city.

LEAP is a hybrid model with good technical and end-user details, along with a flexible data structure for easy adjustments and modifications (Heaps & Kollmuss, 2008). Owing to the model flexibility, there is a long history of utilising LEAP for forecasting energy supply and demand in different regions of the world through model adaptations. The model has been employed extensively to predict the environmental impacts and potential problems of energy policies. The outcomes are useful in informing energy policy decisions at the local, national, or global levels. The primary reason for choosing LEAP over other

models is the ease of disaggregation to the city level and the flexibility to alter model assumptions.[10]

In the context of China, LEAP has been used to develop scenarios to illustrate the low-carbon economy pathway of China (Tao, Zhao, & Changxin, 2011). Building onto the research, Feng and Zhang (2012) use LEAP to analyse the future trends of energy demand, energy structure and carbon emission in Beijing during 2007 and 2030. Different parameters which reflect characteristics of the region are inputted into the model, including population, technology uptake, GDP, per capita income and inflation (Cai et al., 2008). This broadens the analysis of energy demand trends beyond only considering the economic growth rate.

3.3.1.2 Application in this Study

For this study, one scenario of existing policies (EP) is built. EP is the baseline scenario with planned energy policies modelled to reflect the city's decarbonisation pathway. The timeframe of the LEAP model is selected to be from 2018 to 2060. 2018 was chosen as the base year in part because it was the year before the COVID-19 pandemic occurred. Whilst it is recognised that the pandemic has influenced the economic performance and productivity of various sectors, the longer-term impact of the pandemic remains difficult to predict accurately. Research shows that despite the economic recession, global greenhouse gas emissions have only fallen by 7% under the pandemic, and unsustainable consumption patterns in the Asia Pacific region prevails (Helm, 2020; Tollefson, 2021). Given the uncertainties in subsequent years, 2018 was used as the base year to make projections with the assumption that things will revert to look more like what they would have been prior to the pandemic. 2060 was the selected end year to align with the carbon neutrality target of the Chinese government. From the scenario analysis, key differences between the two cities that influence the progress and speed moving towards the net-zero target can be captured. These differences can be explained by interview findings.

In building the LEAP-Beijing and LEAP-Hong Kong models, references were drawn from the LEAP-Beijing model developed by Feng and Zhang (2012). On the demand side, six end-use sectors were included, which are agriculture, industry, construction, transport,

[10] Energy Policy Simulator (EPS) was the first choice for quantitative modelling because it is very simple to use and the effect of different energy policies are already built-in, backed by empirical data and learning curves. One issue is that Hong Kong EPS was built in 2019 but Beijing EPS did not exist. I contacted the team at Energy Innovation to explore the possibility to disaggregate China EPS to create a Beijing EPS, but they said it will take very long for one researcher to do it. This is a potential limitation of research under time constraint.

commercial and household. The driving factors include economic growth, population, industrial structure adjustment, technological progress, efficiency gains and more.

LEAP-Beijing model was updated with current demographic and economic development data. Four out of the six end-use sectors are covered, which are industry, transport, commercial and household. Main sectoral energy data were obtained from the Statistical Yearbook of Beijing. In addition, data were collected from Beijing city's 13th Five-Year Plan, Beijing Overall Urban Planning (2004–2020), Energy-Saving in Long-term Special Program, and the Outline of Beijing Traffic Development (2004-2020). Modelling result was verified using an updated forecast of China's carbon emissions peak and reduction under three policy scenarios of "basic policy", "strengthened policy" and "climate aspirations" (Qi et al., 2020).

The LEAP-Hong Kong model has not been developed by researchers in the past. This model was created for this research based on the available data in government climate change assessment documents and represents a key contribution of this research to the modelling community. Data sets used in Energy Policy Simulator for Hong Kong were also utilised for supplementary purposes. For demand sectors, the four used for LEAP-Beijing were kept in Hong Kong for consistency. The results were verified using the Energy Policy Simulator for Hong Kong (WRI, 2019).

3.3.2 First-Round Expert Interviews

3.3.2.1 Interview format and design

Semi-structured in-depth individual interviews were conducted with a diverse range of stakeholders from Beijing and Hong Kong. Respondents were interviewed on their perceptions of carbon neutrality, their perceived important policies and any future planning strategies. Semi-structured interviews were chosen because key guiding questions can ensure adequate response to the research questions, while the content and sequence of questions can be modified based on unanticipated responses arising during the interviews (Hay, 2016). Interviews can be probed by specific follow-up or clarification questions to offer new insights to the research. Most questions are designed to be open-ended to obtain in-depth answers, but there are also close-ended questions related to the scoring and ranking of decarbonisation policies.

The interviews are divided into three sections. The first section contains factual questions on the background and expertise of respondents, ensuring they are the experts with

sufficient knowledge to inform the research. Questions related to personal experience and memories were added to create a friendly atmosphere and build rapport (Bryman, 2008). For example, one question is "When you were young, how were the main ways you and your family used energy and how have they changed now?". This question switches the subject from the high-level carbon neutrality policies to respondents' energy lives, soliciting more personal remarks or commentary that are missed in official responses. After establishing closer relationships with interviewees, the second part involves questions on the conceptualisations of carbon neutrality in Beijing/Hong Kong. The third section discusses energy demand and supply-side measures to achieve carbon neutrality in the two cities. Factors enabling and hindering energy decarbonisation are also explored in the section. Some questions are designed to link up different sections. For instance, "What is required for energy supply and demand to reach carbon neutrality?" was asked at the start of the third section to understand how much emphasis the stakeholders place on supply, demand and carbon offsets/removals. This question can shape the questions that follow, probing further on factors that respective stakeholder group values and the reasons behind.

Pilot interviews were conducted with two energy researchers to test how they perceive the questions and the framing. Changes were made to clarify ambiguous or misleading terms and to rearrange the sequencing of questions. For the question "How easy or hard it is to attain net zero energy-related sectors?", one researcher suggested segregating it into four separate questions to obtain detailed insights in each sector. Eventually, five separate questions were asked - "How easy or hard it is to decarbonise (1) electricity generation/ (2) transport/ (3) buildings/ (4) industry?" and "(5) How easy or hard is it to achieve carbon neutrality through CCS or negative emissions technologies?

3.3.2.2 Sampling method

Previous studies related to the decision-making process of energy policies are reviewed to inform the sampling strategy. In a qualitative study on building a climate-resilient electricity system, three stakeholder categories of regulators, engineers and investors are interviewed (Metz, Darch, & Workman, 2016). Additional to government and industry representative, this study broadens the scope to cover academics and green groups because energy is viewed as a socio-technical system that interacts with the civil society. Four groups of stakeholders were interviewed in Hong Kong and Beijing: regulators and government advisors (R), industry practitioners (I), academics (A) and green group representatives in the

civil society (G). A total of 32 interviews were conducted, equally split between Beijing and Hong Kong experts, and equally split across the four stakeholder categories for parallel comparison. For example, 4 Hong Kong academics and 4 Beijing academics were interviewed. Although overall interview structures were the same, some questions were modified to cater for the expertise of each stakeholder group to elicit in-depth responses based on their experience. For instance, respondents from the government (R) were prompted to reflect more on the institutional structure and how it influences the city's carbon neutrality strategy. The full interview question list can be found in Appendix I.

Purposive sampling was used to identify interviewees with rich information on carbon neutrality and energy policies (Palinkas et al., 2015; Patton, 2002) Experts working at higher levels with decision-making power were selected, as they were expected to understand the potential gains and underlying challenges in decarbonising the electricity system and managing infrastructures of demand to cope with supply-side transitions. Their opinions on the role of emissions offsetting and removal were also considered valuable.[11] The literature suggests that energy supply, demand and infrastructure decisions are all equally important for realising carbon neutrality. Therefore, an effort was also made to balance stakeholders with expertise in these aspects. Among the 16 interviewees from Beijing and Hong Kong, there were specific experts on electricity generation, transport, building and industry. This ensures policy recommendations correspond with the cities' emissions profiles. After purposive sampling to confirm a list of experts that fit the above criteria, the intension was to reach out to them through institutional contacts. This approach was informed by a researcher with experience of interviewing more than 400 stakeholders in China on poverty alleviation. She highlights the benefit of accessing interviewees through local institutional channels, which can maintain informality and research independence, opening room for more in-depth discussions (Ang, 2016).

3.3.2.3 Execution and Logistics

In terms of logistics, all interviews were planned to be face-to-face during fieldwork in Beijing and Hong Kong from December 2020 to February 2021. Fieldwork in Beijing was especially important because the approach of cold emailing experts was not effective, unlike the case for Hong Kong. I gained access to a few professors based in Beijing through

engaging in a China-UK research project.[12] The professors contacted promised to arrange other informants for interviews when I arrive in Beijing for the fieldwork. Snowball sampling was the planned strategy to connect with more interviewees, especially government officials and industry representatives as their personal contact information was hard to identify.

Due to the COVID-19 pandemic and stringent quarantine requirements in Beijing, the fieldwork there was cancelled despite gaining risk assessment approval. As a local citizen, I was able to travel to Hong Kong for fieldwork in December 2020. "Digital fieldwork" was conducted in Hong Kong from December 2020 until February 2021, during which virtual interviews were also conducted with Beijing experts under a more convenient time zone. In the end, 32 interviews were conducted. Only 6 of which were conducted in-person with Hong Kong experts, because the interview period coincided with a community pandemic outbreak. The remaining 26 interviews were conducted virtually on Zoom andWeChat video call.

Another challenge encountered was the difficulty to access Beijing government officials due to fieldwork cancellation. Although there were referrals to a few Beijing bureaucrats and civil servants, those informants were reluctant to attend virtual interviews out of concerns for information security and privacy. Through speaking with Beijing academics with close connections with the government, it was discovered that government-affiliated research institutions have close working relations with the national and city governments. Although they are not directly working on writing policies, they can share useful anecdotes about the policymaking processes in the government through their first-hand experience. Such insights may even be more useful than those solicited from government officials, because the latter may not be allowed to share thoughts outside of the formal regime. Therefore, interviews were conducted with government advisors who are commissioned to research climate and energy policies for the government. The final list of interviewees and their anonymising codes are summarised in Table 9.

[12] I began engaging with the Economics of Energy Innovation and System Transition as a research assistant in December 2020. Leading universities in China such as Tsinghua University and Beijing Normal University are collaborative partners in the project, enabling me to establish personal relationships with some renowned energy and climate researchers in Beijing.

Table 9. Interviewees by stakeholder groups.[13]

Stakeholder group	**Description**	**Number of interviewees (anonymising codes)**	
		Beijing	*Hong Kong*
Academia (A)	Representatives from Hong Kong and Beijing NGOs that have a strong presence for climate change issues (Beijing: includes state-funded public universities, non-governmental think tanks)	4 (B·A1, B·A2, B·A3, B·A4)	4 (H·A1, H·A2, H·A3, H·A4)
Green group (G)	Representatives of environmental advocacy groups in the civil society (Beijing: includes foreign-funded environmental NGOs operating in Beijing)	4 (B·G1, B·G2, B·G3, B·G4)	4 (H·G1, H·G2, H·G3, H-G4)
Industry (I)	Industry practitioners from energy utilities and renewable energy industries	4 (B·I1, B·I2, B·I3, B·I4)	4 (H·I1, H·I2, H·I3, H·I4)
Regulatory body (R)	Civil servants and members of government advisory committees responsible for energy and climate policies (Beijing: includes research institutes funded by the government)	4 (B·R1, B·R2, B·R3, B·R4)	4 (H·R1, H·R2, H·R3, H·R4)

[13] Anonymising codes of respondents shown in brackets were designed to enable readers to easily see the type of respondent. The first letter represents the city (B=Beijing, H=Hong Kong), the second letter the stakeholder group, and the number signifies the different persons in each group.

3.3.2.4 Analysis Method

The flexible deductive approach was employed to guide the coding and analysis of qualitative data obtained from the first-round expert interviews. Critical realism has been critiqued for the lack of methodological development in empirical studies (Edwards, O'Mahoney, & Vincent, 2014; Yeung, 1997), but more research have been conducted to illustrate the concrete application of critical realism with clear explanation of its methodological implications (Ronkainen, 2019). Some research use grounded theory for coding and analysis (see Maxwell, 2012; Yeung, 1997), while Fletcher (2017) proposes reasons why the flexible deductive approach is more consistent with the ontology and epistemology of critical realism. This research follows the flexible deductive approach with initial codes drawn from literature review on carbon neutrality and SIPs (Hsieh & Shannon, 2005). During the process of coding, the codes were modified, eliminated and supplemented, ultimately reformulating the theory from which the initial codes were deduced (Gilgun, 2011). Using this approach, narratives on how Beijing and Hong Kong experts conceptualise "carbon neutrality" were generated.

For questions based on scoring, responses were analysed by taking averages across the categories or cities of stakeholders. One major interview question explores the top three most important energy policies for carbon neutrality from experts' perspectives. The most important policy was assigned a score of 3, the second-most important scored 2 and the last scored 1.[14] Similar policies were given the same code and grouped together for scoring. Policies with higher scores (hence higher perceived importance) were ranked higher. As these ranking was based on stakeholders' perceptions, they are known as "Stakeholder Rank". In another interview question, the respondents were asked to score on a scale of 1-10 their confidence in Beijing/Hong Kong to achieve carbon neutrality. The average scores were calculated and compared across the stakeholder groups.

A journal was kept throughout the data collection process to capture reflections immediately after conducting the interviews. I noted down up to three "most memorable points" for each interview. The notes were reviewed when writing up the discussion section and helped identify important quotes directly relevant to the research questions. The findings

[14] In the case of interviewees raising three equally important policies, identical scores of 2 were assigned to each policy. For a few special cases where interviewees considered one policy significantly more important than the other two, that policy is given a score of 4, and the other two given scores of 1.

were further supplemented by literature review and document analysis on government and non-governmental carbon-neutral strategies from Beijing and Hong Kong.

3.3.3 Preliminary SIPs from Literature Review

Six attributes of SIPs were identified from the literature review, that are feedback, criticality, impact, speed, scalability and persistence. 10 policies that fulfil most of these six attributes and have close relevance to the contexts of Beijing and Hong Kong from the literature review were selected as the SIPs. Ranking of the 10 SIPs was based on two attributes, impact and speed, because literature and government documents provide ways to estimate the magnitude of these attributes for the SIPs.

SIPs with a track record of large impact were given green colour, medium impact indicated by yellow and low impact by red. Similarly, SIPs shown to deliver impact quickly were in green, medium in yellow and slow in red. The colour green is equivalent to score +1, yellow 0 and red -1. Aggregating the scores resulted in rankings, where SIPs with higher scores would gain a higher rank. As this is a subjective evaluation of the SIPs, the options were deliberately restricted to three (green, yellow, red) in recognition of the imprecision of the approach. Based on this scoring rubric, the "Preliminary SIPs Rank" was obtained.

3.3.4 Second-Round Feedback Surveys

After obtaining the "Preliminary SIPs Rank", the results were presented to all 32 experts in the first-round interviews through feedback surveys. Simple questions were designed for experts to validate and critique the SIPs based on impact, speed and persistence. Extra parameters of feasibility and potential risks were also added to reveal constraints and challenges in local policy implementation. Experts were asked to evaluate and score each of the l0 listed SIPs. Modes were taken for most of the scores. At times when experts had vastly different views on the scoring, their reasoning will be reviewed to decide which side to support. High scores translate to higher ranking, formulating the "Final SIPs Rank".

The purpose of second-round surveys is twofold. For one, it can solicit feedback from interviewees on the impact of SIPs to inform the result of first-round interviews. Through assessing the impact and speed of the various SIPs derived, individual interviewees could gain a perspective of what their peers and other stakeholder groups perceive of mitigation solutions to in their respective cities. The survey also serves as an awareness-raising exercise that demonstrates the value of SIPs as a framework for prioritising climate action. This

exercise could potentially change the way how key players such as policymakers and advocacy groups design and plan policy measures to create the maximum community impact. Employing SIPs framework at the city level is a good way to test testing the theory in real world.

3.4 Research Ethics and Data Handling

Research ethics were carefully considered as the methodology involves interaction with human subjects through interviews and surveys. At the stage of recruiting expert interviewees, Participant Information Sheets were sent out in the invitation emails, clearly listing the research background, objectives and data handling method to build trust. Contact details of the researcher and supervisors were provided, allowing interviewees to raise questions before or after the interviews. As energy policy is high-level subject with ties to national security, interviewees may encounter pressure from their organisations on disclosing sensitive information or related controversies. To protect the interviewees and create conditions for them to speak openly about the topic, the views and identities of interviewees were fully anonymised. Anonymising codes were used to represent them, without exposing identifying information. When the respondents were uncomfortable with answering specific questions during the interview, the questions were skipped to maintain a friendly atmosphere.

Under the Hong Kong National Security Law, there are risks for researchers in carrying out politically sensitive research in mainland China. In response to that, risk assessment approval was obtained from the University of Oxford based on a series of risk mitigation actions. Before starting the research, I have spoken to 5 Beijing residents, including researchers, professors, government officials, to check its political sensitivity and risk level. They all indicated the topic was appropriate, with minimal political implications. Researchers with experience in conducting fieldwork in mainland China were consulted when designing the interviews, who shared skills to phrase the interview questions and present myself in humble way to put interviewees at ease. Data collected from the interviews and surveys were stored in an encrypted file on a cloud drive for security and backed up in an encrypted hard drive. These practices not only protected the interviewees, but also protect me as a researcher from Hong Kong.

3.5 Limitations and Remedies

For the model limitations of LEAP, it is a sector-based model that forecasts the GHG impact of individual actions. However, it is unable to simulate synergies or trade-off of different policies. Owing to time limitation, it was challenging to quantify the effects of policy synergies and trade-offs to feed into the LEAP model. This was remedied by reviewing relevant literature and adding the insights to complement the result qualitatively.

Another limitation was the difficulty to access government sector stakeholders for Beijing. As previously mentioned, stakeholders with close working relationships and in-depth knowledge with the government were interviewed. If this research period were to be extended, a hybrid interviewing approach could be adopted to train natives in conducting interviews with sensitive stakeholders (Ang, 2016). The size of the sample was also limited, with only 4 stakeholders in each city's stakeholder group. This may affect the credibility of comparative trends drawn from the results. This could be improved by supplementing results with literature on stakeholder behaviour around urban climate governance. Finally, there may be sampling bias based on the choice of available contacts for stakeholders. Organisation representatives may only choose to disclose information desirable for their organisations to avoid repercussions (Kim & Kim, 2016). This is especially prominent for the Chinese organisations that operate with stringent information security guidelines. With hopes to mitigate the bias, views from the civil society allow for cross triangulation. Other media reports were scrutinised to verify the credibility of claims made by government and industry affiliated representatives.

Chapter 4: Results

After exploring the literature contributions to the conceptualisation of carbon neutrality, semi-structured interviewed were conducted to collect stakeholder's perspectives on framing carbon neutrality in Beijing and Hong Kong. This section explores the interpretation of carbon neutrality by the 32 stakeholder interviews from four groups in Beijing and Hong Kong.

4.1 Interpretation of Carbon Neutrality

What is your interpretation of carbon neutrality? This simple interview question gave rise to intriguing answers, revealing multi-layered understandings that capture the underlying differences between Beijing and Hong Kong. Carbon neutrality is a constructed concept to shape social behaviour, which is simultaneously shaped by social agents with continually evolving ways to define it. Stakeholders approached this question differently. Some shared a formal definition of the term, whereas others mentioned how to operationalise the concept. Below are the themes and sub-themes identified for analysis:

Table 10. Themes and sub-themes for analysis

Theme	Sub-theme
Formal definition	- Offset o CCS - Low-carbon transition
Wider implications	- Political statement
Measurement	- Boundary of emissions - Fairness/Distribution of responsibility

4.1.1 Term Definition

For formal term definition, the majority (80%) of respondents from Beijing and Hong Kong define carbon neutrality as "net-zero" or "balance between the emission and absorption of CO_2". The conceptualisation of carbon neutrality also "changes the focus of government

research from decarbonisation to achieving net-zero", [15] as pointed out by a Beijing government-affiliated interviewee (B·R1). A clear consensus among respondents is that carbon neutrality exceeds what is required for decarbonisation in terms of the timeframe and scale of change. In other words, carbon neutrality is one step beyond decarbonisation, because it involves long-term planning and requires offsetting after achieving the maximum level of carbon reduction (B·A1, B·R1, H·A2).

When defining the "balance" of emissions, "offsetting" was mentioned by over 60% of respondents in both Hong Kong and Beijing. Therefore, it was selected as a theme in this analysis. The most discussed offsetting solution (52%) being carbon capture and storage (CCS). CCS was seen as a viable option to remove CO_2 emissions, especially for targeting hard-to-abate sectors, the final fraction of emissions that cannot be decarbonised effectively (B·A2, B·A3, B·R2). Almost all of the IPCC's stylised pathways, and those produced for China's carbon neutrality (Myllyvirta, 2020) to net-zero carbon emission require CCS to capture carbon emission, showing its prominence as an offsetting solution. Besides CCS, some narratives in Beijing pointed towards offsetting by afforestation (B·A4). B·G1 legitimised continued carbon emission patterns of Beijing as long as "carbon emission can be captured and absorbed", by CCS and other carbon sinks like forests and oceans. One of the interviewees estimated that "Beijing might use CCS for the last 8-10% of hard-to-abate emissions" (B·R2). This echoes with studies carried out on CCS for coal-fired power plants in China (Wang & Du, 2016). Among respondents who mentioned CCS, 1 out of 6 in Beijing and 2 out of 6 in Hong Kong believed CCS should not be the priority for reaching neutrality, because they were concerned about CCS diverting attention from more effective or progressive policies (B·G1, H·A1, H·A2). An academic pointed out the insignificant share of hard-to-abate sectors in Hong Kong does not necessitate CCS, stating that "CCS should not be the first priority for Hong Kong because there are no large-scale industrial plants" (H·A2). The respondent added that if Hong Kong needs CCS capacity, "we need to work with mainland China". Another academic from Hong Kong even claimed that "CCS is only relative zero carbon" because of the energy consumed during the process, and that "biofuel is the real negative emission technology" (H·A1).

The concept of "transition" emerged among Beijing stakeholders, but not in Hong Kong. (B·R1, B·G4). One green group representative defined carbon neutrality as a "deep

[15] For a discussion on the differences in the definition of carbon neutrality and decarbonisation see Chapter 2 Literature Review.

low-carbon transition in energy and economy" (B·G4). A government advisor opined that policy priority should be placed on facilitating the low-carbon transition of energy systems instead of NETs (B·R1). The advisor further added that "China's energy transition pathway will follow that of the USA with capacity to produce zero-carbon energy, including renewable and nuclear energy. Whereas the transition pathway of cities will be more similar to smaller countries like Korea and Japan" (B·R1). Cities need to rely more on energy carriers like green hydrogen to assist the transition. Carbon neutrality pathway is influenced by path dependency. Whether the long-term energy decarbonisation can be achieved depends on capacity built by energy infrastructure decades before (Tong et al., 2019). The approach of prioritising energy system transitions "instead of NETs" may lead to insufficient capacity of carbon storage by 2060, which cannot be matched despite aggressive policies in a few years' time.

A government advisor explained carbon neutrality as a balancing act between energy consumption and net-zero transition (B·R2). By contrast, the sub-theme "transition" did not appear among stakeholders in Hong Kong when they were asked to define carbon neutrality. Sustainable transition pathways have long been a subject of interest in the academic and policy space, where most discussions centre around the low-carbon transition of national energy systems (Smith, Stirling, & Berkhout, 2005). Factors driving sustainable energy transitions are revealed to be energy technology innovations, the energy market and socio-technical regimes (Guo et al., 2019; Tyfield, Ely, & Geall, 2015). The absence of the "transition" theme in Hong Kong demonstrates a potential lack of systems thinking and a weak connection with China's national strategic planning on carbon neutrality.

4.1.2 Wider Implications

Carbon neutrality is not merely a technical term but embodies wider implications. Multiple interviewees repeatedly iterated the important political implications of the Chinese President announcing a carbon neutrality goal (B·G2, B·R1, B·R2, H·A2, H·A4). The grand magnitude of changes implied by the announcement is not only felt by Beijing regulators (B·R1, B·R2), but also by academics in Hong Kong (H·A2, H·A4). One respondent framed carbon neutrality as a "grand target that changes national development goals" (B·R1), driving a total revolution of China (H·A2). "The announcement indicates China has entered in the global race for net-zero technological advancements", as described by a green group representative from Beijing (B·G2). The representative further proposed a twofold definition

of carbon neutrality. For government officials, carbon neutrality is a political aspiration, representing a target to be attained. Whereas for NGOs, civil society and research communities, carbon neutrality serves as a science-based target with practical implications for follow-up actions on advocacy and research (B·G2).

4.1.3 Measurement of Carbon Neutrality

When it comes to measuring carbon neutrality, most stakeholders were conscious of the system boundary when accounting for emissions as they frequently brought up this topic of discussion. This is of little surprise because emissions accounting is an increasingly contentious subject for city-level emissions (Hsu et al., 2016). As Hong Kong is reliant on the import of goods, interviewees proposed the city should account for consumption-based or trade-embedded emissions when planning for carbon neutrality (H·G3, H·I4). Analytical work a decade ago showed Hong Kong was among regions where net imports make up the largest fraction of consumption emissions (Davis & Caldeira, 2010). This explains the call to focus on addressing emissions from imports, which has been neglected for long.

For Beijing, several industry practitioners shed light on scope 1-3 emissions and lifecycle analysis for a comprehensive carbon neutrality accounting methodology (B·1, B·I2). One of them proposed the theme of "fairness", claiming that it is only fair for China if lifecycle and trade-embedded emissions are fully traced and accounted to importing countries rather than manufacturing bases in China (B·I2). Another point brought up by a Beijing regulator was that the adoption of "carbon neutrality" sets a rigid framework for absolute carbon measurement, "moving away from relative measurements such as carbon intensity targets in previous FYPs" (B·R2). This allows for less growth in carbon emission, demonstrating "stronger determination of the government" (B·R2). For the choice of target year, the theme of fairness emerged again. China pledged to reach carbon neutrality before 2060, which is 10 years later than the EU and many other regions. A Beijing professor described China as a "developing country that has yet to fully industrialise". Thus, a later target than the fully industrialised EU is more reasonable. 2060 carbon neutrality is a long-term vision for China, technological advancements happen from now to then, and the carbon neutrality target year has to be constantly updated (B·R3). A Beijing green group expert suggested it is more important to "define near term action and policy levers that Beijing and the rest of China should take in the next five years". Important themes and key ideas on the interpretation of carbon neutrality is summarised in the figure below.

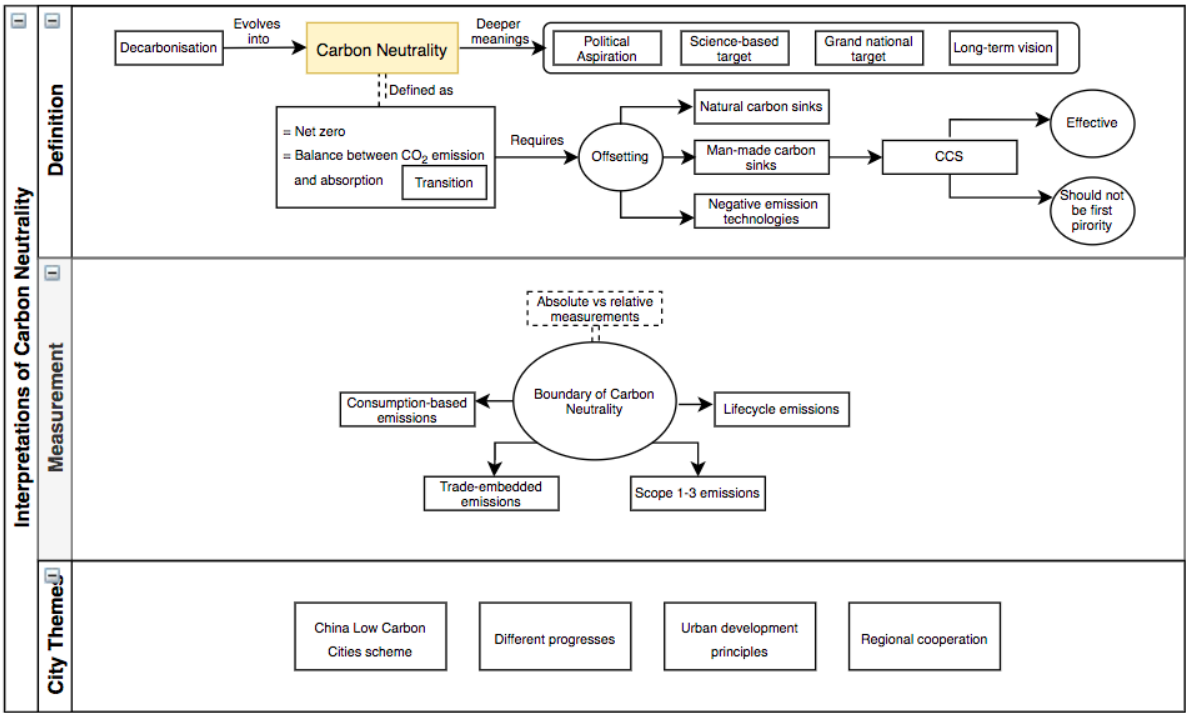


Figure 7. Summary of themes derived from stakeholders' interpretations of carbon neutrality

4.2 Prioritisation of Energy Policies for Carbon Neutrality

4.2.1 Existing Policies

GHG emissions are calculated under the Existing Policies Scenario (EP) are presented in Figure y calculated through an application of existing energy demand and supply data and planned policies for the future of Beijing and Hong Kong. It can be observed that existing policies are unable to bring Beijing and Hong Kong to carbon neutrality by 2050 or 2060.

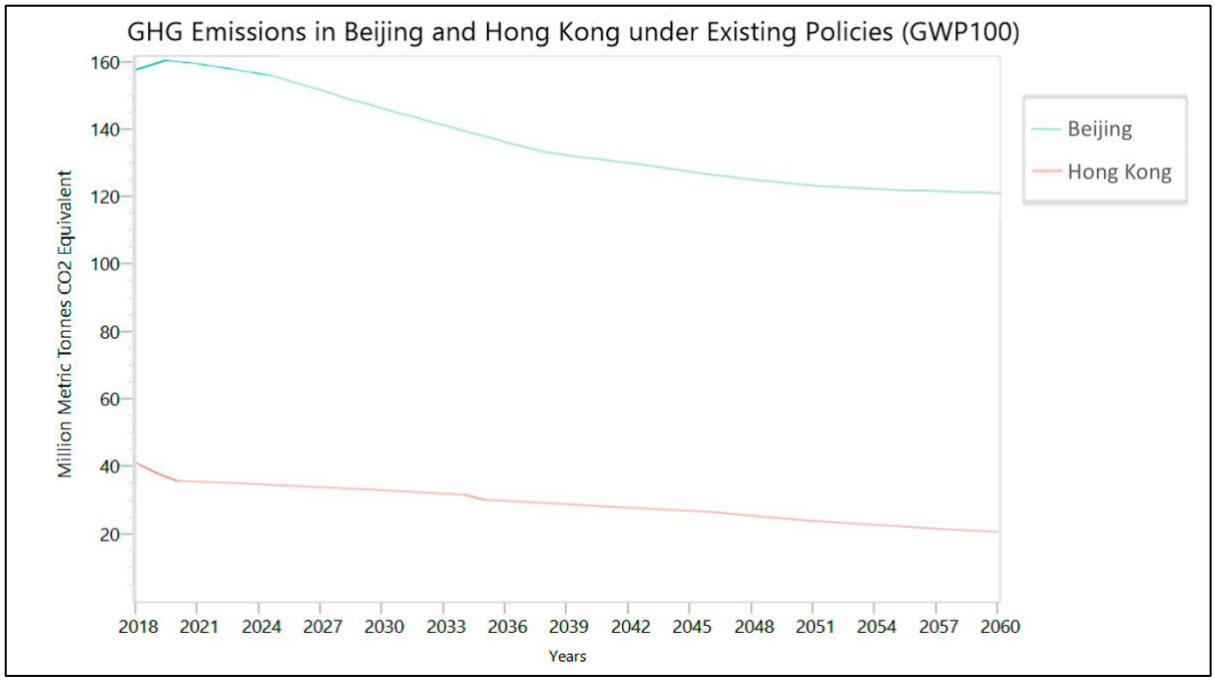


Figure 8. GHG emissions of Beijing and Hong Kong under Existing Policies

Further breaking down to sectoral emissions by demand, the change in GHG compositions in Beijing and Hong Kong are presented in the graphs in Figure 9 and Figure 10 respectively. The graphs present direct emissions from demand sectors and indirect emissions from transformation allocated to demand sectors. There are steady decreases in emissions from the commercial sectors in both cities, attributed to policies to enhance office building efficiency and energy consumption for businesses. Transport emissions decrease slightly over the years with government policies to encourage electrification of public transport in Beijing and policies to popularise EV in Hong Kong. Industrial emissions in Beijing decrease constantly with heavy industries moving away and the use of cleaner fuels, such as switching from coal to natural gas. Hong Kong has a noticeable portion of emissions from “others”, which is largely contributed waste treatment and the associated methane emissions. The emissions inventory of Beijing does not list “waste” as a separate emissions source, which is likely covered in the industry emissions.

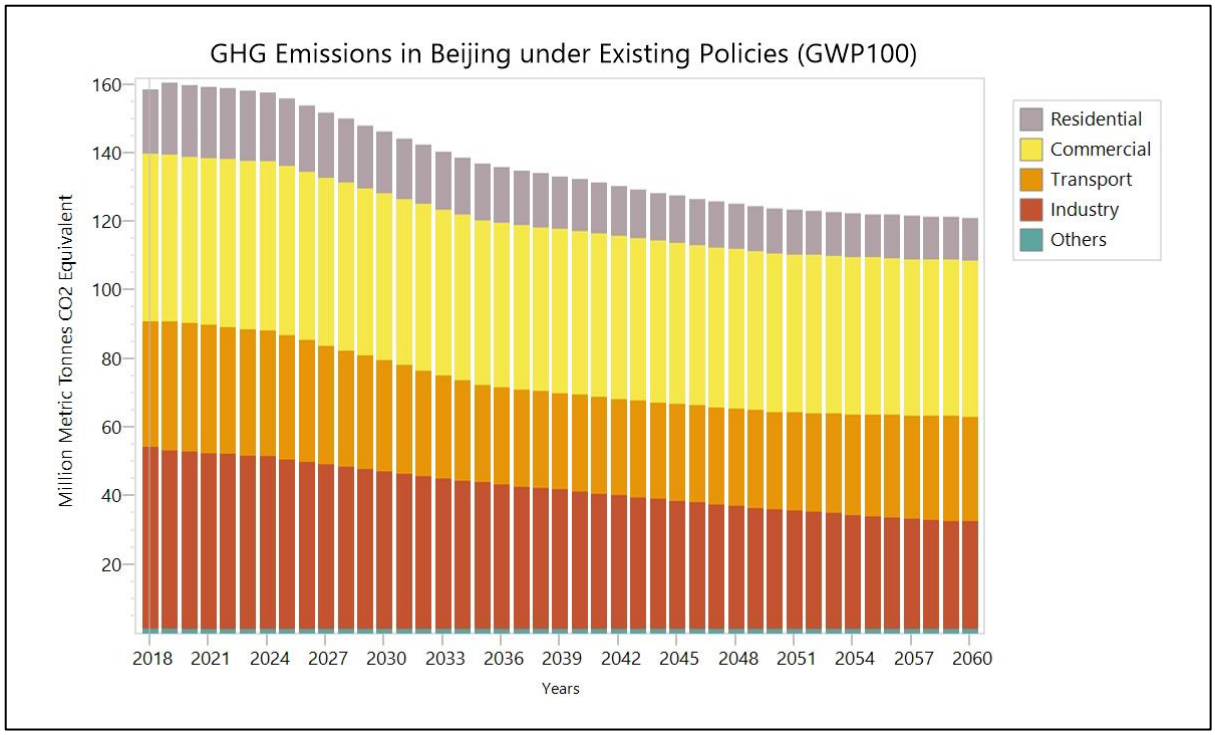


Figure 9. GHG Emissions by Demand Sectors in Beijing under Existing Policies

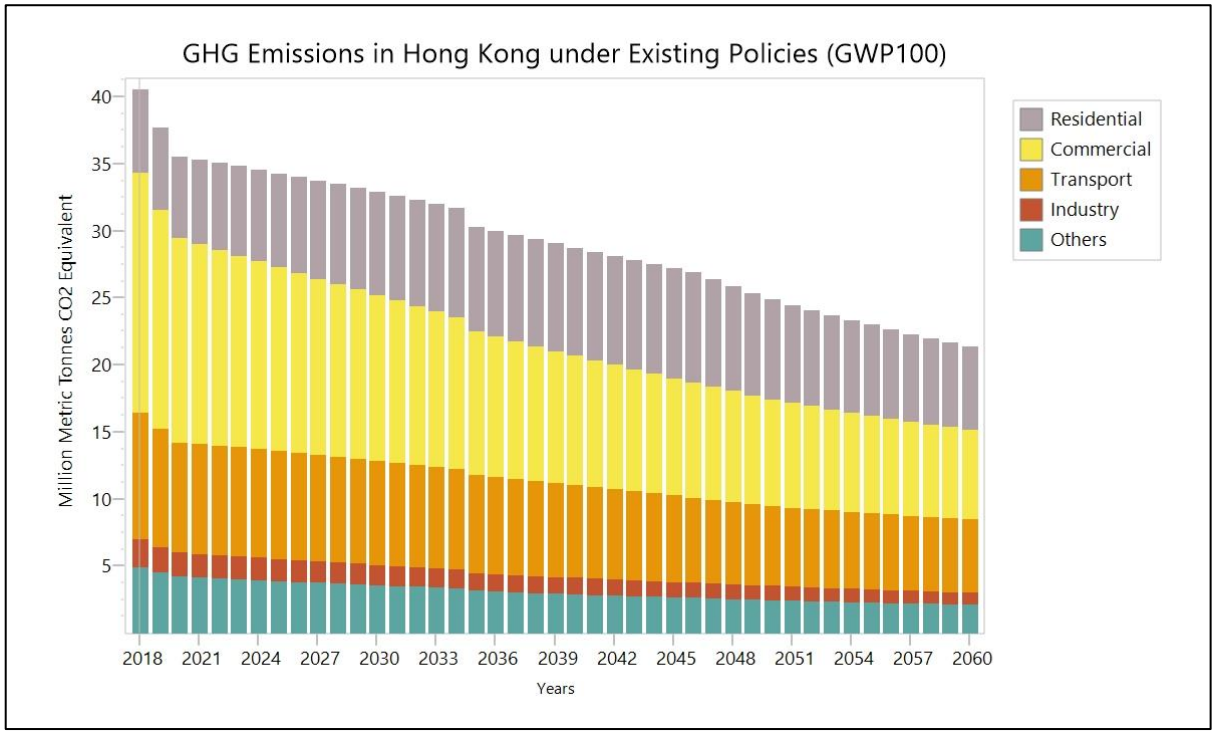


Figure 10. GHG Emissions by Demand Sectors in Hong Kong under Existing Policies

4.2.2 Perceived Importance of Policies

4.2.2.1 City-level Comparison

We turn to a review of policies to decarbonise energy-related sectors in Beijing and Hong Kong. Given the scale of change necessary for reaching carbon neutrality by 2050/2060 and the importance of early emissions reductions (IPCC, 2021), policy prioritisation becomes extremely important. Following on from the analysis of stakeholders' interpretations of carbon neutrality, we examine their perceptions on existing and future net-zero energy policies. Stakeholders were asked to list their "top three most important energy policies" for Beijing and Hong Kong to attain carbon neutrality. "Important" was intentionally used instead of specific criteria like "effective" or "efficient" to allow respondents to employ their unique prioritisation frameworks. The overall results are summarised in Table 11 below, and the top five most important policies are presented in Table 12 based on the ranking of scores in each city.

Table 11. Most important policies for attaining carbon neutrality in Beijing and Hong Kong across stakeholder groups, where the numbers are scores of importance assigned by stakeholders and darker shading denotes higher scores[16]

[16] Scoring rubric see Chapter 3 Methodology.

Energy Sector	Policy	City	Academia (A)	Green Group (G)	Industry (I)	Regulator (R)	Total Score	
Electricity Generation	Generate local renewable energy	BJ	3	0	0	1	4	BJ: 36 HK: 45
		HK	7	2	6	3	18	
	Import low-carbon energy (BJ: Import renewable energy from other parts of China; HK: Import low-carbon energy)	BJ	3	2	4	12	21	
		HK	2	1	7	6	16	
	Incentivise the use of renewable energy (HK: Modify the Scheme of Control to increase renewable energy provision)	BJ	0	2	2	0	4	
		HK	0	0	4	1	5	
	Liberalise electricity market to enhance flexiblity	BJ	0	0	4	0	4	
		HK	0	0	0	0	0	
	Deploy green hydrogen for energy storage	BJ	0	0	2	1	3	
		HK	2	2	2	0	6	
Transport	Promote electric vehicles	BJ	0	1	0	4	5	BJ: 16 HK: 10
		HK	0	3	0	3	6	
	Electrify public transport	BJ	6	1	2	0	9	
		HK	1	0	0	0	1	
	Limit the number of motor vehicles	BJ	1	1	0	0	2	
		HK	2	1	0	0	3	
Building (Commercial and Residential)	Increase building energy efficiency	BJ	3	2	2	1	8	BJ: 20 HK: 20
		HK	4	5	0	2	11	
	Retrofit existing building stock	BJ	0	4	0	1	5	
		HK	2	0	2	3	7	
	Switch from coal to natural gas or electricity for warming	BJ	3	0	0	3	6	
		HK	0	0	0	0	0	
	Improve energy efficiency of electrical appliances	BJ	0	1	0	0	1	
		HK	0	0	1	1	2	
Industry	Increase industrial energy efficiency	BJ	2	0	2	1	5	BJ: 7 HK: 0
		HK	0	0	0	0	0	
	Prohibit energy intensive industries	BJ	2	0	0	0	2	
		HK	0	0	0	0	0	
Cross-Sector	Implement city-level emissions trading scheme with cap on maximum emission level	BJ	0	3	5	0	8	BJ: 17 HK: 21
		HK	0	1	0	2	3	
	Educate the public on carbon neutrality	BJ	0	3	0	0	3	
		HK	2	3	2	0	7	
	Educate relevant professionals on carbon neutrality	BJ	1	1	0	0	2	
		HK	0	0	0	0	0	
	Redevelop urban area and change land use	BJ	0	0	0	0	0	
		HK	0	1	0	3	4	
	Mobilise citizens for climate action	BJ	0	0	0	0	0	
		HK	1	3	0	0	4	
	Set sectoral carbon reduction targets	BJ	0	2	0	0	2	
		HK	1	1	0	0	2	
	Regulate to cap maximum emissions	BJ	0	1	1	0	2	
		HK	0	1	0	0	1	
Total Score for Policy Importance		BJ	24	24	24	24	192	
		HK	24	24	24	24		

Table 12. Top five most important policies for Beijing and Hong Kong perceived by stakeholders, with exact scores shown in brackets

Beijing		Hong Kong	
Rank	**Policy**	**Rank**	**Policy**
1 (S=21)	• Import renewable energy from other parts of China	1 (S=18)	• Generate local renewable energy
2 (S=9)	• Electrify public transport	2 (S=16)	• Import low-carbon energy
3 (S=8)	• Tighten building energy efficiency standards	3 (S=11)	• Tighten building energy efficiency standards

	• Implement city-level emissions trading scheme with a cap on maximum emission level		
		4 (S=7)	• Retrofit existing building stock • Educate the public on carbon neutrality
5 (S=6)	• Switch from coal to natural gas or electricity for warming		

For the interview coding process, policies of similar attributes are grouped to form sub-themes. The energy sector was organised into electricity generation, transport, commercial, residential and industry. Policies that contribute to more than one sectors are grouped under "cross-sector". On the whole, policies of the highest perceived importance are related to electricity generation, followed by building, and cross-sectoral categories. Hong Kong stakeholders have a higher reliance on supply-side energy policies for carbon neutrality than Beijing. Despite the significant contribution of the transport sector towards urban carbon emission (24% and 18% of Beijing's and Hong Kong's overall GHG emissions in 2019 respectively), transport-related policies have lower perceived importance among the interviewees. Measures on the industrial sector are raised by respondents in Beijing but not in Hong Kong, which can be explained by the minimal presence of industry in the economic structure of Hong Kong.

Zooming into the top-scored policies listed in Table 2, importing clean energy is ranked highly important for both Beijing (rank 1st) and Hong Kong (rank 2nd). The two cities encounter the shared challenge of lacking natural resources to generate local renewable energy on a mass scale to meet local energy demand. The import of clean energy is especially valued by government officials and advisors interviewed in Beijing. It is deemed important by government officials and utility representatives from Hong Kong, but to a lesser extent. Instead, Hong Kong respondents regarded local RE generation as even more important (rank 1st) given the untapped potential for offshore wind (World Bank, 2020a). Several interviewees pointed out the Hong Kong government rejected an offshore wind farm project ten years ago due to high cost, but it should be actively pursued given the cost declines in RE installation in recent years (BEIS, 2020). An academic demanded the government to "actively push for offshore wind and solar PV technologies" (H·A1). According to the

interviewees, there are spaces in the outlying islands and on water surfaces for building more solar PV panels (H·A1, H·G3). The Hong Kong government was described as "too conservative" and "risk-adverse" when it comes to RE development (H·G3). The government should reconsider its risk analysis and lead by example, such as installing solar PV panels in all government buildings first (H·G3). Numerous interviewees believed that local RE potential should be fully utilised first before importing RE from elsewhere grounded on the need to preserve local energy security and self-sufficiency (H·G3, H·I4).

Tightening building energy efficiency standards is another top-ranked policy shared by Beijing and Hong Kong. Experts from Hong Kong also flagged retrofitting existing building stock as an important measure, because the average age of buildings in Hong Kong are over 40. "If we only focus on new buildings, there is no future", this remark was made by a green building professional highlighting the urgent need to focus on retrofitting existing buildings (H·G2). The importance was based on the relative number of new and old buildings, as there are over 43000 existing buildings in Hong Kong but only around 300 new buildings every year. Although rigorous assessments like BEAM Plus have been done on the 100-200 new buildings per year, the respondent described "we need at least 100 more years to completely retrofit the inefficient building stocks, even if we fix 430 per year" (H·G2). Further, the expert made reference to Hong Kong's emissions profile, in the remark that "Retrofitting in Hong Kong needs to start urgently, as building contributes to 90% of GHG from electricity generation" (H·G2). However, some other interviewees are opposed to retrofitting buildings because it is not cost-effective. From the resource allocation point of view, it is a lot more cost-effective to tackle electricity supply rather than retrofitting all buildings, because "60% of GHG emissions is related to electricity generation but expensive retrofitting measures may only lead to 10% of GHG reduction at most" (H·I4). These reveal stakeholders' inclinations to measure importance through quantification, but their metrics for impact might be different. Beijing respondents pay special attention to decarbonising warming with natural gas or electricity in replacement of coal. Cross-sectoral policies of emissions trading scheme and civic education make into top five for Beijing and Hong Kong respectively.

While most policies have similar meanings for experts in Beijing and Hong Kong, "import green energy" entails divergent strategies and pathways for the two cities. In Beijing, this policy largely refers to importing renewable energy from neighbouring cities or provinces in China. Beijing currently imports around 25% of electricity to meet the local demand (China Statistics Bureau, 2019). The fraction of electricity imported is a result of

planning by the Beijing city government and interprovincial coordination. Consideration of electricity import has been based on the need to meet "sustained growth in local consumption needs with reliability and security" (Su, 2014), but starting to incorporate planning for emissions reduction in recent years (Wen, 2021). Provinces negotiate the capacity, duration and tariff of electricity transfers. Once agreements are reached, the State Grid is in charge of the transfer process (B·A2). When Beijing imports electricity from another city, the percentage of renewables or low-carbon energy typically follows the fuel mix of the exporting city. Beijing has the freedom to demand a designated capacity of green energy, but whether it can be supplied depends on the available capacity and interprovincial negotiation processes. For instance, it is virtually impossible for Beijing to import 100% green energy at present, because no region can supply 100% green energy. The only possibility is for Beijing government to directly purchase electricity from a green energy producer like wind farms (B·A1, B·A2). A Beijing government interviewee pointed out if the central government requires all Chinese cities to attain carbon neutrality, cities like Beijing that do not have sufficient local renewable energy capacity need to "purchase wind power potentials" from surrounding areas" (B·R2). Along similar veins, numerous respondents proposed importing wind power from Zhangjiakou and Inner Mongolia (North China Grid) as a crucial measure to decarbonise electricity generation (B·A2, B·A3, B·G2, B·R1, B·R2, B·R3). This can be interpreted as buying wind power directly from producers in the region rather than trading at the provincial level.

For Hong Kong, the discussion of energy import was more diverse, involving debates on what form the import should take, such as renewable energy only or with nuclear energy and import from mainland China or other regions. The general public in Hong Kong is concerned about nuclear safety (Xu & Liu, 2015), which makes importing more nuclear power an unpopular option. One government advisor emphasises the "global sourcing of clean energy from mainland China and other parts of the world", offering examples of Australia and Japan (H·R4). Akin to Beijing, respondents recognise the geographical constraint of Hong Kong with limited land and natural resources for local renewable energy generation, making a case to "rely on importing different types of low-carbon energy and renewables for huge improvements in decarbonisation" (H·R4). These views echo with the Public Engagement on Long-Term Decarbonisation Strategy of the Hong Kong Council for Sustainable Development (SDC) (SDC, 2020). The engagement report begins with gauging the public's views on further enhancing regional cooperation to increase the proportion of zero-carbon energy in the fuel mix. As the consultation period intersected with anti-

extradition social movements in Hong Kong, it was overwhelmed with submissions from the public to voice opposition against importing electricity from mainland China. This can also explain the emphasis on local RE generation as a less controversial solution with higher public acceptance. Although "regional cooperation" did not intend to be limited to mainland China, this ambiguous term was no longer found in the final recommendations. Based on public opinion gathered through consultation, "sourcing zero-carbon energy globally through diversified means of "investment, cooperation and importation" is the recommended solution for Hong Kong to reach carbon neutrality (SDC, 2020). It is noteworthy that the scope extends beyond importing zero-carbon energy via cables or energy carriers, but also includes "investment" and "cooperation" with zero-carbon energy project in other regions. Direct investment in clean energy production is a way to secure import agreements, particularly when demand is high and parties need to compete for purchasing green energy (H·I1, H·I2, H·I4, H·R4). Such investment and cooperation can also serve as "offsets" for using fossil fuel energy in Hong Kong (H·I2).

Another key theme in Hong Kong is strong opinions about nuclear energy. Hong Kong began to import nuclear energy from mainland China in 1994. Around 25% of the current electricity demand is supplied by imported nuclear, with an agreement on similar imported capacity until 2034. A government report claims this arrangement secures "electricity from carbon-free source for the medium term" (HKENB, 2017). Some green group representatives and industry professionals are very much in favour of importing even more nuclear energy from mainland China (H·G4, H·I1, H·I4). A utility staff mentions it is "unavoidable" for Hong Kong to use nuclear energy as intermediate energy due to the variability of RE which affects reliability. This point is substantiated by utility reports and literature, illustrating Hong Kong's exceptionally high standard of supply reliability (Chung & Xu, 2020; Woo et al., 2006). Intending to balance supply reliability and environmental sustainability, a "blend of RE and nuclear energy" is a viable option that emerges from the public engagement exercise. This solution "at least works for the short term" to meet consumer demand and "stabilise carbon emissions" (SDC, 2020).

4.2.2.2 Stakeholder Group Comparison

After contrasting the two cities, scores indicating policy importance are summed up by each stakeholder group to explore how different backgrounds and positions may influence stakeholders' prioritisation frameworks. As shown in Figure 1 below, clear trends can be

observed. In general, industry professionals and regulators have stronger preference for supply-side measures in electricity generation. The scores of regulators and academics are well-aligned for policies related to all sectors. Green groups are substantially more in favour of cross-sectoral policies such as civic education, carbon trading, and social mobilisation.

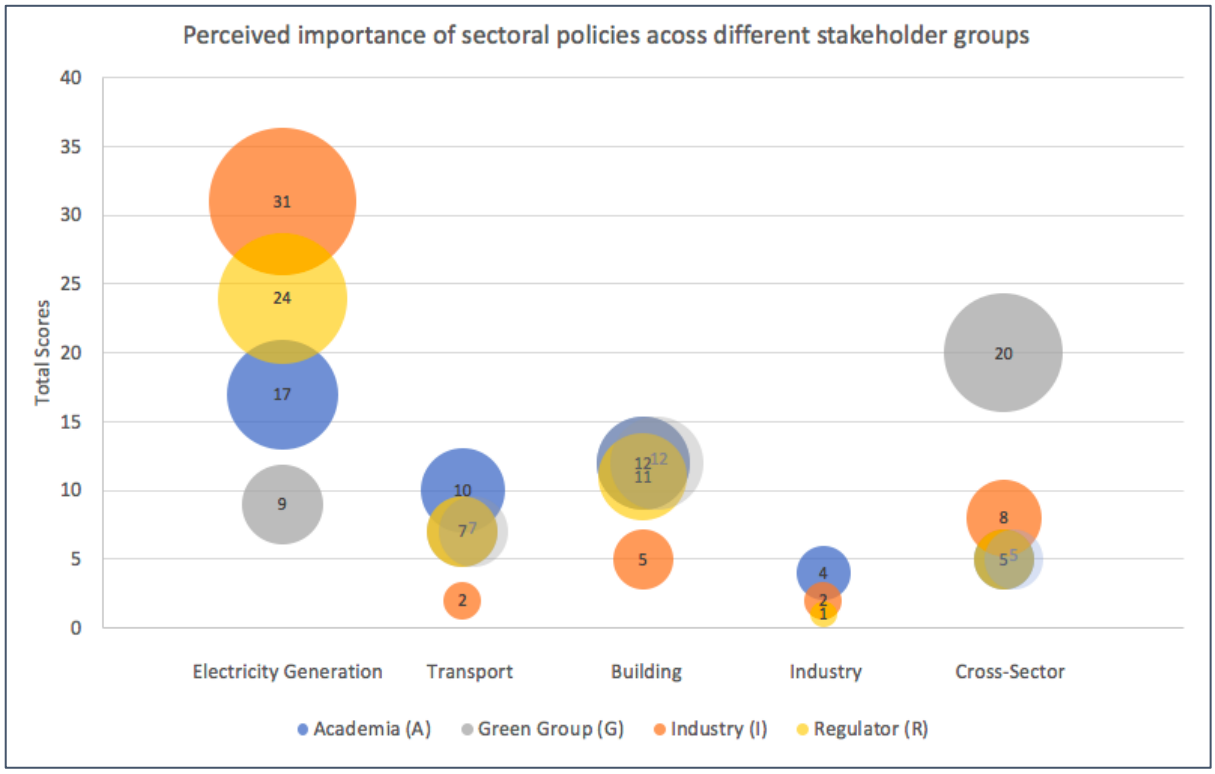


Figure 11. Perceived importance of sectoral policies across different stakeholder groups in Beijing and Hong Kong, where larger bubble size denotes higher policy scores[17]

4.2.2 Identifying SIPs for Beijing and Hong Kong

SIPs for Beijing and Hong Kong were identified from literature analysis, supplemented by expert elicitation in the first-round interviews. Based on section 2.3.2, interventions that exhibit qualities of SIP fall under six main categories, which are energy technology, engagement, financial market, institutions, legal, and urban configuration (Hepburn et al., 2020; Otto et al., 2020; Sharpe & Lenton, 2021). Among the list of interventions, those related to energy technology and financial markets focus primarily on bringing down the cost of deploying clean energy. For example, directing capital to clean energy technology is repeated in all studies. Through incentivising renewable energy, the cost

[17] Note that there are three cases of same scores, resulting in bubble overlaps: (1) Transport: G and R; (2) Building: A and G; (3) Cross-sector: A and R. The frequency table can be found in Appendix III.

will be brought down through market competitiveness and the endogenous feedback loop associated with learning-by-doing – the more we deploy, the more we learn, the more costs decline, the more we demand (Ives et al., 2021). The declining cost of key renewable energy technologies such as solar PV, wind, batteries, and hydrogen electrolysers exhibits a strong non-linear dynamic, enabling rapid, low-cost energy decarbonisation.[18]

Another crucial aspect is engagement and education, which forms a shared vision for enabling imaginaries of urban carbon neutrality (Tozer & Klenk, 2018). This intervention links to the research question on perceptions of carbon neutrality among stakeholders in Beijing and Hong Kong. Environmental awareness and education level may affect public acceptance of climate policies. As an example, Ziegler (2017) shows that in China and Germany, the high levels of education has significant positive effect on the willingness to pay for the price premium of climate-friendly products. The support for carbon pricing also rises with education level as indicated in several studies. On intervening system dynamics to bring about transformation, the power of change and transcend paradigms are identified as "deep leverage points" that have great potential but are under-researched (Meadows, 1999). Environmental education is a means to change mindset, behaviour and world views. Once such a leverage point is triggered, it has the potential to enable large-scale sustainability transformations in the long run. The one key downside being that the rate of change in such deep leverage points is usually over multiple decades.

The design of institutions is a differentiating feature between Beijing and Hong Kong based on different governance structures. The Chinese Central Government has been determined to implement stringent atmospheric control to improve air pollution, and has extended a similar approach to control carbon emissions (Hepburn et al., 2020). While Beijing follows many of these command-and-control policies from the central government, Hong Kong adopts the approach of collaborative environmental governance, characterised by multi-level participation and community engagement (Cheng & So, 2015). Identifying institutional interventions is crucial because it can accelerate system transitions on its own and has flow-on effects on other social aspects. Institutional change has strong interactions with interventions related to education that improve people's connection with nature and the production of knowledge (Abson et al., 2017). For instance, establishment of expert committees in the government can facilitate the inclusion of knowledge in environmental policymaking processes.

[18] The further explanation is provided in Chapter 2 Literature Review.

For urban planning, land use arrangement affects mobility patterns and commuting distances that in turn affect transport emissions. Setting up carbon neutral cities as regional leaders can incentivise neighbouring cities to follow suit, creating cascading feedback with the potential to amplify carbon reductions. This is relevant for this research when evaluating the roles of Beijing and Hong Kong, comparing their contributions to the national target.

To sum up, four categories of SIPs relevant to Beijing and Hong Kong emerged from the literature, that are (1) Energy Technology, (2) Engagement, (3) Institutional Arrangement and (4) Urban Configuration. 10 SIPs under these four categories were listed based on the literature and mentions by experts in first-round interviews, subsequently deriving the following tables with preliminary findings. The tables were then presented to the experts again through second-round feedback surveys for fine-tuning.

Table 13. Preliminary SIPs Rank for Beijing

Beijing SIP	Category of SIP	Preliminary SIPs Rank	Stakeholder Rank	Impact Green = Largest Yellow = Medium Red = Smallest	Speed Green = Fastest Yellow = Medium Red = Slowest
A. Import renewable energy from other parts of China	Energy technology	1	1		
B. Electrification of public transport	Energy technology	5	2		
C. Tighten building energy efficiency standards	Energy technology	7	3		
D. Implement stringent emissions trading scheme at the city level	Engagement	3	3		
E. Promote electric vehicles	Energy technology	4	6		

F. Civic education on carbon neutrality for general public	Engagement	10	8		
G. Incorporate market mechanism in the electricity grid for demand management	Institution	9	7		
H. Prohibit energy intensive industries	Urban configuration	2	9		
I. Electrification of warming	Energy technology	8	5		
J. Regulation to cap city emissions	Institution	6	9		

Table 14. Preliminary SIPs Rank for Hong Kong

Hong Kong SIP	Category of SIP	Preliminary SIPs Rank	Stakeholder Rank	Impact Green = Largest Yellow = Medium Red = Smallest	Speed Green = Fastest Yellow = Medium Red = Slowest
A. Import low-carbon energy	Institutional arrangement	1	2		
B. Local renewable energy generation	Energy technology	6	1		
C. Tighten building energy efficiency standards	Energy technology	3	3		
D. Decarbonise existing building stock	Energy technology	2	4		
E. Promote electric vehicle	Energy technology	5	7		

F. Civic education on carbon neutrality for general public	Energy technology	10	4		
G. Hydrogen for energy storage	Energy technology	9	6		
H. Urban redevelopment and land use change	Energy technology	8	9		
I. Modify the Scheme of Control to increase renewable energy provision	Energy technology	4	7		
J. Social mobilisation for climate action	Engagement	7	9		

4.2.2.3 Finalised SIPs in Beijing and Hong Kong

From the second-round feedback surveys, experts scored the preliminary SIPs based on their impact, speed, feasibility and persistence. The SIPs were then re-ranked based on their composite scores, with new SIPs created and some eliminated as suggested by majority of stakeholders. This is how the "Final SIPs Rank" was generated, shown in Table 15 (Beijing) and Table 16 (Hong Kong). Some SIPs are more relevant at the local level that can be controlled by city governments, whereas the others are linked with global trends that have to be closely observed.

Table 15. SIPs for reaching carbon neutrality in energy-related sectors of Beijing

Final SIPs Rank	#	Beijing SIPs	Mentions	Impact	Speed	Persistence	Feasibility	Risks
1	A	Import renewable energy from other parts of China	21	10	8	H	H	B, F
2	H	Prohibit energy-intensive industries	2	8	8	H	H	S, T
3	C	Tighten building energy efficiency standards	8	8	5	H	H	F
4	B	Electrify public transport	9	6	6	H	H	F
5	E	Promote electric vehicles	5	7	5	M	H	E, H
6	D	Implement city-level emissions trading scheme with a cap on maximum emission level	8	5	4	H	M	V
6	J	Educate relevant professionals on carbon neutrality	2	8	1	M	H	/
8	F	Educate the public on carbon neutrality	3	7	1	M	H	/
9	G	Incorporate market mechanism in the electricity grid for demand management	4	5	3	M	L	P
9	I	Switch from coal to natural gas or electricity for warming	4	5	3	H	M	F

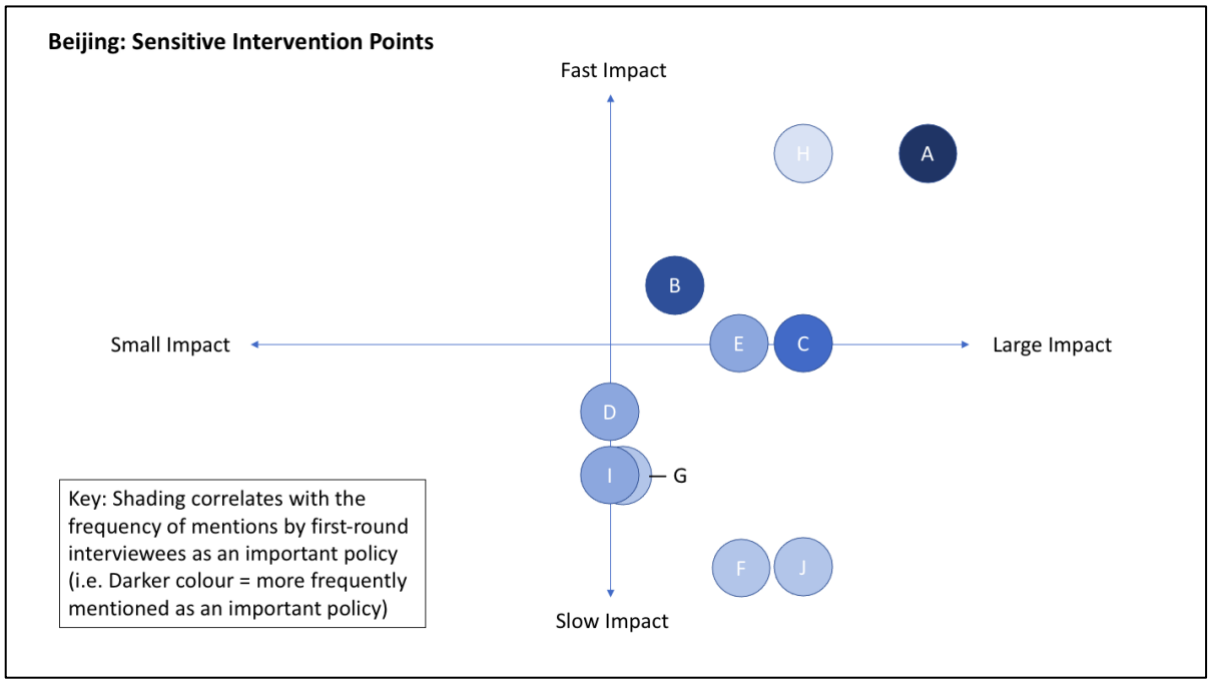


Figure 12. The Beijing SIPs shown graphically on axes of scale and speed of impact. Shading correlates with the frequency of mentions by first-round interviewees as an important policy.

Table 16. SIPs for reaching carbon neutrality in energy-related sectors of Hong Kong

Final SIPs Rank	#	Hong Kong SIPs	Mentions	Impact	Speed	Persistence	Feasibility	Risks
1	A	Import low-carbon energy	16	9	6	H	M	F, P, S
2	E	Promote electric vehicles	5	8	5	H	H	/
3	B	Promote the generation and utilisation of local renewable energy	18	6	7	M	H	B
4	C	Tighten building energy efficiency standards	11	7	6	M	H	F
5	I	Modify the Scheme of Control to increase renewable energy provision	5	8	5	M	L	P
5	J	Mobilise citizens for climate action	4	6	7	M	L	/
7	H	Redevelop urban area and change land use	4	7	4	M	M	/
8	D	Decarbonise existing building stock	7	6	4	M	M	F
8	F	Educate the public on carbon neutrality	7	7	4	L	M	/
10	G	Deploy green hydrogen for energy storage	6	6	2	L	L	F

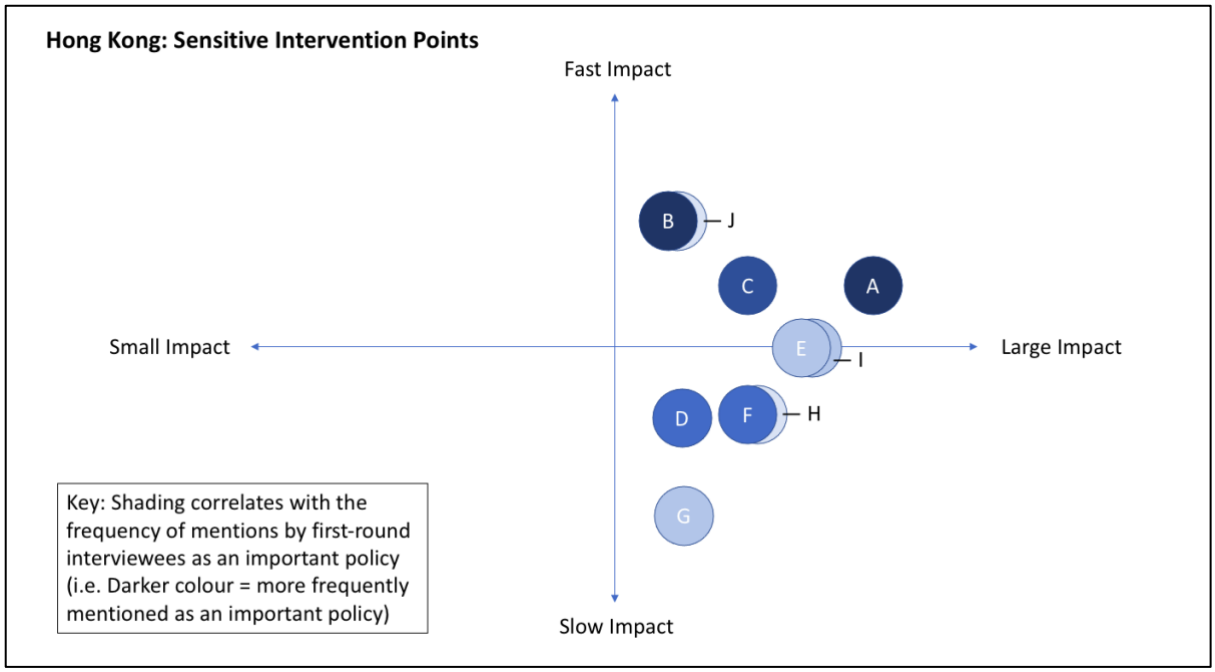


Figure 13. The Hong Kong SIPs shown graphically on axes of scale and speed of impact. Shading correlates with the frequency of mentions by first-round interviewees as an important policy.

Table 17. Legend for the SIPs figures

Type	Category	Impact	Speed	Persistence | Feasibility	Risks
Explanations	ET: Energy technology EG: Engagement IN: Institutional arrangement UC: Urban configuration	Score 1-10 10: Largest impact 1: Smallest impact	Score 1-10 10: Fastest impact 1: Slowest impact	H: High M: Medium L: Low	B: Biodiversity loss E: Environmental damage F: Financial burden on government or citizens H: Public health and safety P: Private sector interest harmed S: Social inequality, underprivileged community lose out T: Transition risk for workers, unemployment V: Lack of monitoring and verification, potential false reporting

I) Electricity Generation – Import clean energy, modify the electricity market

As shown in the above figures, importing low-carbon energy is the top SIP ranking 1st in both Beijing and Hong Kong. It is relevant for the local context because cities can influence institutional arrangements that foster or hinder the import of energy. With regards to importing RE, the impact of this SIP also depends on the global trends of the maturity and development of RE technologies. For Hong Kong, importing nuclear energy is seen as important by several respondents (H·R4), while Beijing focuses more on importing wind and solar power from Inner Mongolia and Zhangjiakou. Hong Kong has its geographical

limitation and a lower level of integration with the renewable energy market of mainland China. This potentially explains to greater attention on CCS and nuclear energy in Hong Kong. Supply availability and reliability are key concerns of many stakeholders. Interviewees highlighted the need for appropriate regulatory frameworks to facilitate RE import from mainland China and to capture the first batch of available supply (H·I4, H·R4). Hong Kong stakeholders expressed concerns over insufficient RE for export from mainland China to Hong Kong, making the long-term contracts with nuclear plants more attractive as a stable option. On the contrary, stakeholders from Beijing, especially representatives from research institutes and the academia, are generally confident in the production capacity of RE to match the growing demand. This is in line with research reports which show China has the capacity to generate enough RE for net-zero by 2050 as explained by a few Beijing academics (ETC & RMI, 2019) (B·A1, B·A2). This might also be due to the closer relationship Beijing has with other Chinese cities, which enables transfer of RE more easily.

Promoting local RE through subsidising research and deployment is a SIP ranked 3rd for Hong Kong but absent in Beijing's list. Local RE production, especially in a small city of Hong Kong, is unable to trigger the virtuous cycle by driving costs down like the case for global deployment. However, it is still beneficial because Hong Kong people will learn to accommodate variable renewables through local deployment, which makes them more capable of importing more variable renewables. It also helps with just transition of workers from fossil-based electricity generation to offshore wind power that require similar skillsets. Indeed, local RE generation in Hong Kong demonstrates positive feedback dynamic as the popularisation happened "very quickly with the right policy" (H·I1). In 2018, the government launched the first Feed-in-Tariff (FIT) programme to incentivise the installation of rooftop solar PV panels, starting out with "receiving only 150 applications in the first few months" (H·I1). By the end of 2019, the number of applications exceeded 7000, generating over 3.75 million kWh of solar energy and reducing 1983 tonnes of CO_2-eq (HKSARG, 2020). This could explain why most stakeholders agreed on the fast speed of this SIP (Speed=7), as it has the potential to accelerate, riding on the decreasing cost of investment. However, the impact is not as high (Impact=6) because of the limited total area in Hong Kong for building PV panels and wind turbines.

With regards to the RE development potential in Hong Kong, there is a general split of views in the society. In the updated official climate change plan, the government estimated the realisable RE potential to be 3-4% of total energy demand (HKENB, 2017). The estimation remained unchanged as of late 2020 (Legislative Council, 2021). The estimate has

been criticised as “too conservative” by green groups since 2017 (Greenpeace, 2017; WWF, 2019). The same controversy was also observed in the interviews. Two interviewees cited the same study on the maximum potential of local solar PV to generate around 10% of energy consumption in Hong Kong (H·G3, H·I4). The study mentioned is the geospatial research by Wong et al. (2016), which uses remote sensing technologies and GIS to survey rooftops in the city. 233,000 buildings are identified as suitable for installing a total of 39 km^2 PV panels, reaching 4,674 GWh of annual solar energy output. However, some academics and regulators regarded this research to be overly optimistic. One government representative doubted the assumptions behind the research, ignoring complicated land ownership and the physical environment around the rooftops (H·R3). The report was accused to be too idealistic, assuming all rooftops can generate RE, ignoring other concerns such as types of rooftop and arrangements (H·R3). The respondent recommended an official report commissioned by the Electrical and Mechanical Services Department (EMSD) to assess solar PV potential of building rooftops. The result is a maximum of 880 GWh annual electricity generation, which is around 80% lower than the university study (EMSD & Meinhardt, 2019). In fact, the same discussion happened in a Legislative Council meeting. A legislator cites the university study to argue that solar PV has great untapped potentials, and the Deputy Secretary for the Environment cited the commissioned government study to prove that PV installation in Hong Kong is “subject to many restrictions” (Legislative Council, 2021). Matching research with implementation is another gap that needs to be bridged. A utility practitioner cited the example of a local university invented high efficiency solar cell, but it is still in the laboratory (H·I1). This intervention is targeted to stimulate the “utilisation” of RE in addition to research.

Offshore wind is another option of local RE that Hong Kong has yet to exploit. Onshore wind potential for Hong Kong is low because most winds are gusts rather than consistent winds (H·I1). A study shows the estimation for offshore wind power potential based on one-year field measured wind data in Hong Kong can go up to 32.2% of electricity consumption in 2017 (Gao et al., 2019), even higher than the aggressive estimate for solar PV (Wong et al., 2016). Offshore wind farm infrastructure installation is also easier from the political perspective, without the need to deal with fragmentated ownerships and building regulations. However, as mentioned in section 4.2.2, offshore wind projects proposed by the utilities were turned down by the government due to “high cost” in 2010. One major hindrance is the absence of effective wind energy development policy (Gao et al., 2019). In addition to cost concerns and government mindset lock-in, interviewees pointed out certain

green groups oppose strongly to offshore wind farm due to the negative ecological impacts (H·A4, H·G3), although none of the green group representatives interviewed opposed to wind energy. This came as no surprise, as the Hong Kong Dolphin Conservation Society protested against a large-scale offshore wind farm by Guangdong government 10km off the shore of Lantau Island for threatening the endangered dolphins (Yuen, 2016). Hong Kong does have the geographical conditions, technical expertise and social capital for offshore wind development, but there is low social awareness and public pressure on the government and power companies (Gao et al., 2019). The government and utilities also have the tendency to opt for investments with quick and high return, which cannot be offered by RE yet. This links to SIPs I (modify the Scheme of Control), J (social mobilisation) and F (public education). For example under SIP I, a fixed FIT for wind power can be implemented to cover the high initial investment for more wind energy providers to enter the market. As Gao et al. (2019) propose, the government can modify the permitted return on RE fixed assets to motivate power companies invest despite the long payback period.

Apart from the direct decarbonisation potential of local RE generation, it can generate synergistic relationship with public education on emissions reduction. As the respondent working at a power company described, "I strongly believed in RE investment because it demonstrates the commitments of government and utilities to net-zero and creating green jobs for engineers, generating positive feedback on SIPs J (social mobilisation) and F (public education)" (H·I2). The maximum local RE potential in the long term estimated by the practitioner is 10%, which includes sea areas for offshore wind power despite being unproven and complicated by navigation channelling (H·I2). Similarly, an academic highlighted the social benefits of local RE generation in community mobilisation (H·A4). Stakeholders like tenants, installation companies, power company representatives are drawn together and educated through the application and installation of community RE infrastructure. This shows how energy technology SIPs can link with SIPs on engagement to generate co-benefits.

II) Transport – Promote EVs, local RE generation

For the transport sector, EV promotion is a prominent SIP (2^{nd}) for Hong Kong and moderately significant (5^{th}) for Beijing, whereas electrification of public transport is a SIP for only Beijing that ranks even higher (4^{th}) than EV promotion. From the literature, electrification of private vehicles and mass transit exhibit qualities of SIPs because more electrified systems can better leverage the cost declines of RE and hydrogen-based storage on the grid. When coupled with smart grid technologies, electrified systems can serve as

distributed storage to deal with the intermittency of RE. For instance, EV-based energy storage can supply electricity to buildings with vehicle-to-grid technology with proven successes (Gough et al., 2017; Nezamoddini & Wang, 2016). Hence, electrifying the transport system can generate reinforcing feedback with RE deployment.

EV promotion is more effective in Hong Kong for carbon neutrality because the charging infrastructure is relatively mature, accompanied with tax concessions for changing from an old ICEV to EV and long-term visions for an EV-friendly city.[19] As reflected in the survey, a Hong Kong regulator described EV promotion as a "key strategy to strive for carbon neutrality", because it is "interlinked with the low-carbon transition of power supply" (H·R3). Another government advisor believed EV promotion will be a persistent policy in Hong Kong, given it is led by both ENB and the Financial Secretary, and a recent roadmap was published, announcing the ban on sales of fossil-fuel powered cars from 2035 (HKENB, 2021) (H·R4).

Having a clear timeline on banning ICEVs is what Beijing lacks, in the eyes of several respondents (B·A4). The city's action is "speeding up but can be more aggressive" as a Beijing academic commented, such as setting up an agenda for the ban on ICEV and faster development of charging infrastructure (B·A4). A green group representative claimed promoting EV in Beijing now will be "wasted effort", because the supporting infrastructure and the supply chain are not ready (B·G1). Therefore, the respondent proposed to focus on improving electrification of public transport. This point was echoed by an academic who claimed that Beijing would not implement a petrol vehicle ban "just for the sake of delivering the climate target", because unlike the case for Hong Kong, the price and quality of EVs are not on par with ICEVs yet in Beijing (B·A2). This reveals the climate strategy of Beijing prioritises a holistic development perspective as opposed to pure delivery of targets. It has to be coordinated with the market conditions and harmonisations, which may be seen as a conservative approach.

Another key difference between Beijing and Hong Kong is that for Beijing, restrictive policies on private vehicles are already in place, and the government has been actively promoting low-carbon mobility modes (B·R3). There is a government order in Beijing that ICEVs can only be used to go to work every second day while EVs can go every day. This is

[19] In 2019, the Hong Kong Government launched a $2 billion HKD pilot subsidy for residential buildings to install EV charging facilities for free.

a “shift” in SIPs terminology, related to the rules of the game which can accelerate change. EVs are an example of a SIP that has both kicks and shifts.

The interviewee cited the “3510 plan” promoted by the Beijing Municipal Commission of Transport (BMCT) as an example, that encourages the public to “walk within 3km, cycle within 5km, take public transport within 10km distances” (BMCT, 2020). This may explain the reasons for Beijing to focus on enhancing electrification of mass transit rather than promoting EVs. Another point to note is respondents from Beijing identify risks with promoting EVs, but not for Hong Kong. Several respondents mentioned the financial burden on government for subsidising EVs (B·A4, B·R3), while some worried that retired battery would harm water and soil quality (B·I4).

Urban redevelopment is ranked 7th for Hong Kong. This SIP can unleash opportunities for decarbonisation, in particular through transport emissions reductions. A Hong Kong government official described the urban planning of new development areas encourages low-carbon living by decentralising job opportunities to reduce commuting distances (H·R2). Through land use change and rezoning, walkability and cyclability of the city can be promoted to reduce transport emissions sources.

III) Buildings – Tighten buildings energy efficiency standards, decarbonise building stock

Related to the buildings sector including commercial and residential buildings, tightening buildings energy efficiency standards is ranked 3rd and 4th among SIPs in Beijing and Hong Kong respectively. For Hong Kong, decarbonise existing building stock is listed as a separate SIP ranked 8th. Both measures are considered SIPs because changing standards and regulations is a “shift” that changes the rules of the systems for amplified impacts. For example, such change in standards can facilitate innovation in building technologies and household electrical appliance for further efficiency enhancements. If stringent buildings energy efficiency standards are in place, it can stimulate the design of nearly zero energy buildings (B·R1). Relevant building technologies to for nearly zero energy consumption are already tested and commercially viable, such as designs with high thermal sensitivity and air tightness (Moran, Goggins, & Hajdukiewicz, 2017). Although there may not be substantial emissions reductions from efficiency enhancements, the impact scores are quite high (Impact is 8 for Beijing and 7 for Hong Kong). This could potentially be explained by the significant emissions from buildings in the two cities (43% for Beijing, 59% in Hong Kong). As shown in the LEAP model, residential and commercial emissions will not reduce substantially under existing policies, and will remain as the overwhelming portion of emissions in the coming

decades (see Figure 9 and 10). Therefore, even though individual efficiency gains might be small, the impact could be exponential if the same scheme is adopted by every building.

Many respondents in the two cities pointed out that energy efficiency standards for buildings and efficiency labelling for household electrical appliances are already in place at the city level. But the effectiveness of such schemes is limited as they are not reviewed and tightened "in time" (B·G3, B·R3, H·G3). Insufficient or incomplete data is a common reason for the lack of regular review of the standards. Several Beijing respondents mentioned EE targets in Beijing were set ahead of other Chinese cities with one of the tightest standards (B·A3, B·A4, B·R1). However, an academic described a phenomenon in Beijing that "policies are there but not implemented well" (B·A3). It was pinpointed in the buildings sector that data is lacking for Beijing. There are building regulations mandating government buildings to audit their energy consumption, but the auditing did not translate into efficiency enhancements (B·A3). For Guangzhou and Chengdu with data such as total built area, they are able to perform modelling and forecast for buildings-related energy consumption that lay the foundation for effective standards (B·A3). Along the same lines, a Hong Kong green group representative suggested data, technology and third-party verification are the criteria to ensure the effectiveness of building regulations (H·G2). The energy consumption of each building has to be known for setting targets like yearly caps. The data should then be validated by third-party organisations impartially rather than through self-reporting (H·G2). EE improvement data should also be thoroughly analysed, tracked and stored to inform future policymaking. In addition to EE standards, the respondent suggested carbon trading among buildings one the caps are set based on data. This draws reference from the Tokyo's ETS, which was the first ETS to regulate GHG emissions from office buildings (H·G2). The Tokyo government reported 25% emissions reduction from regulated buildings, and research finds half of the reduction is a result of the ETS (Arimura & Abe, 2021). This feeds in the cross-sectoral policy of stringent carbon markets discussed later in part V.

On the speed of impact, Beijing respondents believed tightening buildings energy efficiency standards delivers decarbonisation objectives relatively slowly (Speed=5). "It will take a long time for building energy efficiency to drive reductions in Beijing", as described by a green group representative (B·G3). Time is required for zero-carbon building technologies to mature to meet the continually tightening energy efficiency standards. Apart from the building materials at the construction stage, amenities and appliances inside the buildings also influence EE. Therefore, time is required for the public to accept and adapt to low-carbon lifestyle in accordance with this intervention.

Decarbonise the existing building stock is a SIP for Hong Kong as some experts opined that the low-hanging fruits of buildings energy efficiency have been reaped, it is time for Hong Kong to retrofit buildings for deeper decarbonisation (H·I2, H·G3). Many respondents doubted the feasibility of building retrofitting due to the high costs potentially involved. The progress to retrofit the large stock of old buildings would also be. This explains the low rank (8th) this SIP for Hong Kong. An alternative perspective was offered by a green group representative, stating that monetary incentives and financing mechanisms for retrofitting already exist but not fully utilised (H·G2). At the city level, there are matching funds for owners of old buildings to upgrade EE, but ignorance and lack of consensus from owners hinder the fund utilisation. At the global level, there are available financing facilities and institutional investors interested in green buildings because the electricity tariff savings can cover the retrofitting costs for large-scale projects in the long run. To activate this particular SIP, the Hong Kong government should raise the awareness of building owners on EE to generate consensus for retrofitting. The government also plays an important role in facilitating institutional investment for building decarbonisation through offering tax rebates and interest concessions. By mobilising global capital for large-scale retrofitting projects in Hong Kong, the government does not need to bear the financial burden.

IV) Industry – Prohibit energy-intensive industries

As shown in the literature review and the LEAP model, a significant portion of GHG emissions of Beijing originate from the industrial sector but not for Hong Kong. Therefore, a SIP related to industry, prohibiting energy-intensive industries, is listed for Beijing and holds the 2nd rank. From government reports and survey responses, the Beijing city government has already been moving heavy industries away from the city centre by different phases. Although the measure can rapidly reduce a large volume of emissions within the city boundary, the involved companies may move to neighbouring cities with looser policies, resulting in "emissions leakage" (B·R4). Therefore, regional policy coordination must be considered when implementing this measure. Another problem is workers in the energy-intensive industries may be displaced or laid off. Several studies have estimated a likely increase in jobs through a transition to green energy (Garrett-Peltier, 2017; ILO, 2018) but there will still be local difficulties in finding employment for workers in other industries particularly those with low education and very specific skills. The biggest problem is the loss of jobs in a particular region, which can result in social problems of unemployment, poverty, and loss of community cohesion. "While climate change is a global problem we strive to

address, we also want to avoid this phenomenon (social problems related to transition)" (B·R4). It reveals the priority for officials to balance social welfare with the race to decarbonisation. A way to alleviate the risks is by implementing measures to ensure a just transition, such as enhancing the social safety net of health, offering unemployment insurance and skills training (He et al., 2020).

III) Cross-Sectoral – Emissions trading scheme, public education, stakeholder education, social mobilisation

Carbon trading was frequently mentioned in the first-round interviews among Beijing and Hong Kong experts (B·A3, B·G2, B·G4, B·I1, B·R2, B·R3, B·R4, H·G2, H·I1, H·R4). One green group representative from Beijing described offering subsidies and piloting carbon credit trading as "equally essential" for devising energy policies to reach net-zero (B·G2). Such cross-cutting policies are classified as "shifts" rather than "kicks" in SIPs parlance, designed to re-organise or transform the fundamental system structures (Farmer et al., 2019). They are associated with deeper leverage points related to system rules and structures, that have enormous potential for decarbonisation although they can be difficult to enact (Meadows, 1999). Hence, establishing a stringent city-level emissions trading scheme (ETS) was a suggested institutional policy in the second-round expert survey. Although, as pointed out by Beijing experts, a sufficiently high emissions cap is necessary for an ETS to be truly effective. The policy is less effective if implemented in the short term, because "cap and trade will not be stringent under the current political environment" (B·A4). Similarly, a Beijing industry professional noted that "ETS is unlikely to produce meaningful results quickly, but strong caps would drive the decarbonisation process" (B·I1). These explain the relatively low speed (Speed=4) for the SIP. The dynamic of this SIP is further enhanced in the success of piloting carbon markets in Guangdong and seven other regions. The successful pilot scheme eventually led to the official launch of nation-wide ETS in 2021 (ICAP, 2021). The positive feedback of successful pilot cases resulted in the scheme to be scaled up quickly with faster impact. One potential challenge is that state-owned enterprises (SOEs) may be "reluctant to sell emission rights no matter what the price is" (B·I1), given their abundant financial resources. To counter this risk, mechanisms can be added to the ETS to mandate transactions over a designated timeframe.

Education for the general public carbon neutrality and social mobilisation are SIPs derived from the literature (Hepburn et al., 2020). After presenting them to the stakeholders through feedback surveys, most Beijing and Hong Kong experts saw large potential for

education to form the basis of support for the sectoral policies mentioned above, hence suggested to raise the impact score of education. They agreed that education takes long time to deliver its impact, indicated by the low "Speed" score. This is linked to the conceptualisation of carbon neutrality presented in Chapter 2, where some experts suggested carbon neutrality assessment to include consumption-based emissions. If consumption-based accounting approach is adopted, educating the public to make low-carbon consumption choices is regarded as crucial because Hong Kong relies on imported commodities (H·R4). The persistence of civic education is "low in Hong Kong but high in mainland China with national commitment", as described by a Hong Kong academic (H·A2). Education also influences the persistence of other SIPs, as Beijing green group representative underscores the role of education in ensuring other SIPs last long on top of stable political leadership (B·G3). It was explained that "transition could be held back in the long run unless there is broad public support based on awareness and understanding on carbon neutrality" (B·G3). There may be social pushback for other SIPs if civic education is not done well (B·I1).

Two Beijing experts suggested adding a SIP on education of relevant professionals. One of them explained that Beijing is still at the initial stage of mainstreaming carbon neutrality, creating the need to "educate a relevant group of professional audience on emission reductions, including city planners, consultants, architects, business leaders etc" (B·G3). Their roles are "far more important" than the general public in the short term (B·G3). Although educating the professionals did not make it to the SIPs list for Hong Kong, some experts share similar views. A green group representative mentioned the adequate competence of engineers and professionals is required to "help formulate and, more importantly, implement these SIPs" (H·G2).

Social mobilisation is a unique SIP for Hong Kong. The overall rank of social mobilisation (4^{th}) is higher than public education (8^{th}), mainly driven by the faster speed to achieve impact by influencing political agendas and policies. While social mobilisation is traditionally seen as linked with civil society and the third sector, mainland China also has "state-led mobilisation of the public" as described by a Hong Kong academic (H·A2). Table 6 summarises the top five SIPs identified for Beijing and Hong Kong to trigger accelerated decarbonisation in the demand sectors.

4.2.3 Correlation between Final SIPs Rank and Stakeholder Rank

Comparing the derived SIPs (Final SIPs Rank) and policies perceived important by stakeholders (Stakeholder Rank) in the two cities, moderate alignment or correlation can be

observed. This shows SIPs are generally intuitive, at least among the experts from various fields.

Overall, the stakeholder ranking correlates better with SIPs in Beijing than in Hong Kong. Two of the top SIPs in Beijing (import RE, tighten building energy efficiency standards) have the exact same rank among the stakeholders. Import low-carbon energy is also a prominent SIP and considered important among Hong Kong stakeholders. It is worth noting that most of the important measures from stakeholders' perspectives are aligned with SIPs at the national or global level instead of the city level. For example, high deployment of EVs at the global level has high potential of driving cost down from learning and experiment, which leads to increase RE generation, encouraging more EVs to be manufactured and used. However, the scale of EV deployment in individual cities like Beijing and Hong Kong may not result in economies of scale to trigger a direct price reduction of EVs. Despite so, electrification at the city level remains the most effective means to take advantage of the modelled global cost declines from RE and green hydrogen storage on the grid (Ives et al., 2021). This points to interventions such as electrification of public transportation, private vehicles and warming for the case of Beijing.

There are some significant misalignments, indicating that experts may not always be able to deduce the most effective climate policies based on their knowledge and experience. For Beijing, prohibiting energy-intensive industries is the 2nd ranked SIP but almost the least important policy from stakeholders' perspectives. This may be explained by the risks involved, posing severe impact on social welfare and causing emissions leakage. In Hong Kong, promoting EVs was not perceived as important for stakeholders. Many respondents argued that transport electrification does not contribute much to decarbonisation until energy supply becomes cleaner. They may have missed out the dynamic of promoting EV to motivate and stimulate RE development through feedback mechanisms.

Table 18. Correlation between Final SIPs Rank and Stakeholder Rank for the top 5 SIPs

Beijing			**Hong Kong**		
Final SIPs Rank	**Stake-holder Rank**	**SIP**	**Final SIPs Rank**	**Stake-holder Rank**	**SIP**

1	1	• Import renewable energy (electricity generation)	1	2	• Import low-carbon energy (electricity generation)
2	9	• Prohibit energy intensive industries (industry)	2	7	• Promote electric vehicles (transport)
3	3	• Tighten building energy efficiency standards (building)	3	1	• Local renewable energy generation (electricity generation)
4	2	• Electrification of public transport (transport)	4	3	• Tighten building energy efficiency standards (building)
5	6	• Promote electric vehicles (transport)	4	7	• Modify Scheme of Control Agreement to encourage renewable energy provision (electricity generation)

4.3 Potentials to Achieve Carbon Neutrality

In order to gauge a sense of the potentials for Beijing and Hong Kong to achieve carbon neutrality, stakeholders were asked to give a score out of 10 based on how confident they are in the first-round interviews. The average scores for each stakeholder group are presented in Table 19.

Table 19. Interviewees' scores on how confident they are in Beijing/Hong Kong to achieve carbon neutrality before 2060/2050 (Score ranges from 1 to 10, 10 is the most confident)

	Academia	Green Groups	Industry	Regulator
Beijing	8	7.44	6.75	7.75
Hong Kong	4.88	3.88	5.25	8.25

In general, Beijing stakeholders are more confident in Beijing achieving carbon neutrality than Hong Kong. Except for regulators, all the other three groups of experts in Beijing gave substantially higher scores than those in Hong Kong. Although the national target is to achieve carbon neutrality before 2060, many experts were confident that Beijing can achieve carbon neutrality before 2050, some believed as early as 2040. The reason is Beijing has actively phased out coal-fired power plants and heavy industries in the past decade, making the city easier to decarbonise compared with the others. If China has to achieve carbon neutrality by 2060, Beijing has to achieve the target earlier to make up for cities that will be slower due to their needs to rely on heavy industries and fossil fuel for the early stages of economic development. Industry professionals in Beijing generally were less confident on the net-zero target. This is mainly attributed to the lower priority of carbon neutrality than other considerations related to the grid, such as energy security. Quoting an industry expert from Beijing, "I doubt that decarbonisation is one of the top three priorities of the Beijing city government, grid reliability is the most important" (B·I1). Grid reliability is undoubtedly the first priority for utilities, and even for the government, as it directly links with the economic output and stability of a city.

For Hong Kong, the confidence score is exceptionally low among green group representatives, who collectively raised issues with "regulations not being stringent enough" (H·G1) and "no concrete action plans are available" (H·G2). A building expert (H·G2) gave a failing score of 4 based on the progress of past policies and infrastructure development, revealing the mentality of path dependency. "The Central-Wanchai Bypass took over 30 years to be built. Similarly, we only have 30 years left to achieve carbon neutrality… The current pace of change is unmatched with the scale of challenge we are facing" (H·G2). Under the lack of driving forces, the slow pace of policymaking and implementation is a barrier to achieve carbon neutrality by 2050. "Societal awareness" was brought up as another factor enabling carbon neutrality (H·G1), yet Hong Kong was described as a place with insufficient climate awareness among the private sector and the general public. Some interviewees even critiqued the authenticity of targets, claiming that "I suspect the government would make sure the numbers in reports show net-zero by 2050. If they are not honest enough, carbon neutrality would simply become a number game" (H·G3). The issues of system boundary and accounting method were brought to attention, because respondents believed Hong Kong can reach carbon neutrality easily if the government continues to neglect all consumption-based (scope 3) emissions.

4.4 Overcoming the Challenges to Attain Carbon Neutrality

4.4.1 Balance with Supply Reliability

One main challenge to achieve carbon neutrality is the high priority for supply reliability in Beijing and Hong Kong as economically advanced cities. Most stakeholders including government advisors agreed that Beijing and Hong Kong governments may not prioritise decarbonisation over supply reliability and economic growth, especially for electricity generation. As the capital of China, Beijing holds an important role as the political and cultural centre of the country. Electricity supply reliability is of utmost priority. A Beijing academic respondent supported this argument by citing the case of National Energy Administration having swiftly upgraded the grid following blackouts caused by an extreme weather event in 2018 (B·A2). Electricity reliability is equally important to maintain the economic rigour of Hong Kong. In the 80% carbon reduction by 2050 scenario created by a power company, fossil fuel facilities will be kept to "provide electricity when the demand is very high in order to meet the reliability requirements" (H·I2). Hence, maintaining reliability can be a barrier to achieve carbon neutrality if carbon offsets or removals are not planned ahead.

Noting that RE is intermittent, academics, officials and industry practitioners in both cities called for more active research and development (R&D) on energy storage technology (B·A3, B·R2, H·A1, H·I3, H·I4, H·R1).[20] A government advisor from Beijing suggested that energy storage, grid control and demand management are particularly important when Beijing reaches potentially 40-60% RE in the future fuel mix (B·R2). However, these measures to improve grid flexibility and adaptability are faced with not only technical difficulties, but also "institutional and political barriers" (B·R2). The design of grid has to be altered to accommodate energy storage and grid control measures. Demand management practices often require public acceptance to implement, such as assigning times for people to cook dinner to manage the peak load (B·R1). This argument is in line with sociotechnical transition literature, which shows accelerated low-carbon transitions depend on social acceptance and business support in addition to financial and technological requirements (Geels et al., 2017a).

[20] Energy storage with green hydrogen was a SIP for Hong Kong, as most respondents made references to green hydrogen when describing energy storage.

4.4.2 Market Reform for Increased Green Energy Imports

Importing green energy is a highly valued policy to decarbonise Beijing and Hong Kong. It is a top-ranked SIP for both cities, considering the positive feedback dynamics of renewable deployment demonstrated by global experience (Ives et al., 2021). When it comes to actual implementation, there are challenges identified by stakeholders. In mainland China, internal electricity transfers on the grid historically follow a rigid mechanism with low flexibility. As a government advisor pointed out, despite the central government spending a significant sum of money to build smart grids, online electricity trading and other mechanisms to achieve energy balance, "flexible electricity trading is still underdeveloped" (B·R2). This suggests that electricity market reform and addressing fossil fuel subsidies are important SIPs to unlock greater adoption of renewables in Beijing.

For Hong Kong, apart from the arrangement with Daya Bay Nuclear Plant, there are no existing mechanisms to import renewable energy from mainland China. Some stakeholders emphasised the urgency to establish a "formalised electricity transfer mechanism governed by regulatory regimes of both Hong Kong and mainland China" for Hong Kong to source RE directly from specific renewable or nuclear energy producers in the mainland (H·I1, H·I2). A regulator from Beijing suggested Hong Kong leverage the GBA, relying on "cooperation with the Southern Grid which has huge renewable potential" to accelerate electricity decarbonisation and subsequently mass electrification (B·R3). Institutional set-ups of the electricity markets in Beijing and Hong Kong require updating in different ways, with the mutual goal of facilitating green energy transfer.

4.4.3 Role and Responsibility of a City

As the capital of China, Beijing is designated as a focal point which allows the government to demonstrate the country's best progress and cases on emissions reduction. This explains the city's pledge to peak early by 2020 in the 13th Five Year Plan (Beijing Daily, 2021). Although official targets have not been released for the whole city, several leading districts within Beijing have published their carbon neutrality plans. A number of interviewees expected Beijing to reach carbon neutrality by as early as 2040 based on its capital status (B·R1, B·E3). Accounting for some sources suggesting Beijing has already peaked in 2020, or close to peaking, the LEAP model predicted that Beijing has peaked around 2019-2020 and then plateau until 2025 (see Figure 9). A government advisor expressed the aspiration to increase Beijing's competitiveness in low-carbon development,

eventually to become a leading green city in the world (B·R1). The respondent expressed in the survey that SIPs are important drivers to "pace the road for Beijing to be the centre of new technology R&D and zero carbon cultural hub with progressive regulations" (B·R1). The major challenge is to generate a strong consensus on the ground to mobilise stakeholders in various sectors to work towards the goal of Beijing to become the leading carbon neutral city in China.

Like Beijing, Hong Kong has untapped potentials to take on a more prominent role in climate action. As a utility practitioner described, Hong Kong has top institutions and experts, only lacks pushes from the government and professional bodies like the Hong Kong Institution of Engineers (H·I1). The two utilities have investments in low-carbon energy generation outside of Hong Kong, such as green hydrogen production in mainland China to supplement its natural gas production. The interviewee therefore questioned, "If it can be done in the mainland, why not utilise our potentials and do it in Hong Kong? Green hydrogen can be generated locally with RE". Though there are also respondents being less confident in the city's capacity to innovate on new clean energy technologies due to the lack of government support and innovative culture (H·A2, H·R3).

Establishing exemplar carbon neutrality cities can propagate changes across systems through learning and feedback. A strong SIP would be setting up mechanisms for cities to learn best decarbonisation practices from one another, sharing case studies on what work and do not work. Beijing interviewees from the industry and government (B·R1) highlight the significance of industrial parks as a testing ground for new technology. Specifically, Hong Kong was recommended to "learn from the Zhongguancun Technology Hub" which is rapidly growing in Beijing (B·R1).

Chapter 5: Discussion

What are the underlying structures that might enable or hinder these transformative interventions in major cities? The emissions structures of the two cities examined in this report are similar, both dominated by electricity generation and buildings emissions. But Beijing largely follows the mainland Chinese ruling system, whereas Hong Kong operates under a free-market economy. Reviewing the leverage points proposed by Meadows (1999), these are the system rules and structures currently in place, supported by paradigms of thinking. Governance structures are the underlying paradigms that clearly differ between the two cities, leading to differences in infrastructure development, utility planning, institutional set-ups, climate governing models and many other attributes. This chapter examines the similarities and differences in the SIPs derived for both cities, explaining the reasoning behind them through the lens of a socio-technical transitions perspective (Geels et al., 2017b). Solutions to break through such paradigms and to shift the dominant regimes are also proposed to complement the SIPs for effective climate action.

5.1 Exploring the Similarities

5.1.1 Increasing RE in the fuel mix

Increasing RE in the fuel mix is the top SIP for both Beijing and Hong Kong, because it can leverage the global trend of cost declines in RE and feed off progress in other systems like transport. Based on positive reactions from stakeholders and the outcomes delivered, feed-in tariffs (FITs) are an effective policy to promote local RE installation in Hong Kong which can be further extended. Through increasing flexibility and responsiveness to technological development, FITs can mitigate negative cost-related and distributional outcomes (Fagiani, Barquín, & Hakvoort, 2013). However, tight tariffs with cost caps are found to lower incentives for innovation (Toby et al., 2010). Such incentives can be added directly on top of FIT pricing or by implementing complementary policies (Sun & Nie, 2015). However, for wind power development, sociotechnical lock-in and path dependency for Hong Kong government officials has led to stagnant progress over the past decades. New R&D should be carried out on a regular basis by the government instead of relying on the private utility companies. With the rapid cost declining trends in solar PV and offshore wind (Ives et al., 2021), Hong Kong should be proactive in reaping such benefits.

For Beijing, importing green electricity can be achieved by enhancing the existing electricity transfer mechanism. Supported by the literature, Beijing can import 30-41% of its electricity demand from renewable sources in Zhangjiakou (Huang, Zhang, & Zhang, 2020). While this is out of the remit of city government, Beijing city government can concentrate on researching the high potential of community-scale microgrids powered mainly by RE. Hybrid system with wind power as main energy source, supplemented with solar PV is found to be the most cost-effective option. Using battery for energy storage in the system will not only enable higher uptake of RE, it could potentially increase security, cut cost and reduce environmental impact when paired with RE (He et al., 2018).

5.1.2 The Role of CCS

CCS is an important component for defining the term "carbon neutrality" among the experts, showing an understanding of the "net" concept and the role of offsetting. At the national level, China is actively researching nature-based solutions for sequestration, such as the "blue carbon" plan of sequestrating carbon in ocean algae. Yet, CCS was rarely mentioned in the "top 3 most important policies for carbon neutrality", and also not on the list of SIPs for both cities. Given most of the IPCC (2018) scenarios highlight the significant role of CCS in achieving net-zero, this suggests a disconnection between the modelling community and decision-makers on the ground. Beijing and Hong Kong are large cities that should have the power to decide on CCS. Despite research suggesting the alternative CCS plan for future fuel mix (Xu & Liu, 2015), the recent government plans only focus on importing more low-carbon energy sources like nuclear and RE.

Investigating the underlying reasons behind the disconnect, stakeholders brought up offsetting as a crucial part of carbon neutrality, yet they assumed CCS is dealt with at the national level. As a Hong Kong industry representative clearly states, "Energy supply-side technology like CCS is not a Hong Kong issue, but a global one" (H·I3). Respondents also regarded CCS as "far-fetched", which does not require action at this point. Yet, in the most aggressive Paris Agreement scenarios, IPCC scenarios suggest we need to start building at least a million tonnes CCS facility every 3 days for the next 80 years to achieve net-zero (IPCC, 2018). When compared with RE, which is perceived as most important, CCS is less "visible" possibly because it is not linked with daily life. RE technologies like solar PVs are modular from the engineering perspective, people have had them in calculators for decades and the progress in solar PV development has been a major discussion point - they are

ingrained in mindsets and conversations. These features make RE more a part of decision-making at the mesoscale city level, while CCS remains at the national level and relatively undiscussed. This case illustrates a problem with carbon neutrality targets that they can be influenced by multi-level dynamics and hindered by disconnections between different levels of governance.

5.1.3 Rebound Effect on SIPs related to Energy Efficiency

Implementing energy efficiency standards are SIPs for both cities. This SIP has to be taken with caution as per Jevons Paradox, or the "rebound effect", which states that increased resource efficiency will lead to an increase in resource consumption over the long term. Indeed, research finds that energy efficiency measures are not as effective as expected in reducing electricity consumption in Beijing, owing to the direct and indirect rebound effect ranging from 24%-56% (Wang, Han, & Lu, 2016). Resources would be better utilised through investing in energy-saving technologies and products. Nevertheless, the rebound effect for Beijing is much lower than the whole of China, which has been estimated as high as 165.2%, suggesting that for those cities energy efficiency measures may still do more good than harm (Lin & Liu, 2013). Policy measures such as carbon tax and restructuring the energy industry with more clean energy are potential measures to restrain rebound effects (Wang et al., 2016). This aligns with the findings of Wang & Ye (2017), recommending the Chinese government to adopt differentiated decomposition of mitigation targets due to the uneven landscape of carbon emissions at subnational levels. Given that income increase may not necessarily lead to carbon reduction, EE and carbon taxes are the recommended measures for carbon reduction.

5.2 Navigating the Differences

5.2.1 Measurementality and Knowledge Politics

The first round of individual interviews revealed policy priorities of different stakeholders and the second round of surveys challenged them with the proposed SIPs based on literature and first-round consensus to identify the deeper nuances and controversies. In general, Hong Kong experts had a higher level of disagreement across stakeholder groups than in Beijing. In the survey, some experts strongly opposed the evaluation of particular policies, sometimes supported by their personal professional experience or references to scientific research. These phenomena can be explained by knowledge politics and

measurementality prevalent in Hong Kong, as well as freedom of speech safeguarded by the Basic Law.

All interviewees selected are high-level decision-makers in their respective organisations, hence the "elite actors". This may explain their tendency to cite scientific research to support their reasoning for policy prioritisation. However, the dependence on science may not always be conducive to generating effective and feasible climate solutions, with the risk of excluding "non-elite actors" (e.g. general public) in climate discussions. It may also polarise policy debates to a "dead end", as illustrated in the following example.

The debate on local RE generation potential in Hong Kong was an area of intense controversy between the regulators and other stakeholder groups. Experts from green groups and industries supported their arguments by citing academic research that surveyed rooftop areas to estimate the solar energy potential. The research was subjected to the technocratic discourse, using technical methods of modelling and remote-sensing to map available areas for solar PV (Wong et al., 2016). Regulators then critiqued the research as failing to capture the political and social components in environmental governance (Turnhout, 2018), saying that the research missed out on realistic social and political factors that hinder the potential of some rooftop areas for building PV. However, the argument was again backed by another technocratic report conducted by the government with a consultant (EMSD & Meinhardt, 2019). While green groups claimed the government estimate "far too prudent" (H·G3), the government described the other research as "too idealistic" (H·R3). Measurementality logic underlies the debate on "true" RE potential in Hong Kong (Turnhout, Neves, & de Lijster, 2014). Both sides try to argue against each other with the belief that science provides policy-neutral input to inform decision-making, under a flawed vision of linear science-society relations (Beck, 2011). On this note, it is critical to see environmental knowledge production and decision-making as "mutually constitutive", and to reflect on what interests science serves and fails to serve (Turnhout, 2018).

Related to this example, energy and climate models were found to play a major role in guiding policy and decision-making processes of government advisors and utilities in Hong Kong. Utilities develop their own internal models to perform emissions scenario analysis for designing their carbon neutrality strategies (H·I2). The interviewee representing power companies suggested the government to improve their internal analytical modelling capability in order to understand what the utilities propose in the Scheme of Control

Agreement.[21] It was genuinely expressed that the government is positioned at a disadvantage compared with the utilities in negotiations, and hence advising the government to set up a separate unit in charge of energy development with technical expertise to increase their bargaining power (H·I2).

A government department in Hong Kong uses LEAP for energy supply and demand forecasts. The interviewee explained it is only for internal use to guide policies and make future plans, not for public scrutiny. Even for utilities that employed models to perform emissions scenario analysis and craft their net-zero pathways, the models are all "invisible" to people affected by the policies. Such "black box modelling" becomes more problematic as cities get closer to net-zero with increasing abatement costs. For instance, the UK has a detailed energy market management system with high renewable subsidies for wind and solar power. The level of subsidy is based on energy policy models run by BEIS, which is not open-sourced. The public has to pay the additional bills or increased tax without being made aware of where the numbers originate. If policymaking is only based on modelling, the persistence of policies tends to be low. This is particularly true for policies that impose a significant financial burden on the government, which will be trickled down to the general public through increased electricity tariffs or taxes. Once such measures affect livelihoods severely, there is a risk of the public declining the entire model output, leading to failure in policy implementation.

To realise deep decarbonisation in cities, urban climate action should not be limited by traditional means of engagement with authorities (Tozer & Klenk, 2018). Although it may be time-consuming, consultations with the general public and stakeholder groups ahead of policy planning are imperative to safeguard the long-term persistence of energy policies. This point is confirmed by experts' survey responses, highlighting the importance of education to ensure the longevity of other policies. This again reinforces public and stakeholder education as a SIP to trigger long-lasting contribution to carbon neutrality.

5.2.2 Alignment with National Agenda

The discourse of aligning with the national agenda was prominent in the interviews and surveys among Beijing stakeholders, regardless of their backgrounds. Whereas for Hong Kong, only a handful of respondents made references to China's overall strategic

[21] The Scheme of Control Agreement is a bilateral agreement for Hong Kong Government to regulate the financial affairs and monitor the reliability of energy services provided by the two vertically-integrated power companies.

development. Though this can be easily explained with Hong Kong's Special Administrative Region status and a weaker connection with China's national agenda, it was surprising that the Hong Kong government officials interviewed were unaware of the overall planning of Hong Kong. The lack of horizontal communication among departments and across bureaus was apparent.

One example is in R&D investment in new energy technologies, such as green hydrogen. Green hydrogen is an important energy carrier for cities like Beijing and Hong Kong, that have limited landmass for in-situ renewable energy generation. There is a consensus among stakeholders that green hydrogen is going to play an increasingly influential role for the cities, but the commercial viability is unclear. Experts from Hong Kong showed more pronounced reluctance for green hydrogen, which is explainable because hydrogen is unlikely to become cost-effective in 10 to 15 years (IEA, 2021). For Beijing, stakeholders generally supported green hydrogen, because green hydrogen being a part of the national agenda provides confidence to address uncertainties. They saw the role of Beijing as the capital to support and align with the country's long-term development strategy. Overall, Beijing exhibits higher openness in R&D of all forms of new energy technology, not limited to green hydrogen. Beijing can gain direct support from the national manufacturing and production bases more easily, sharing resources with the cohesive network. As advised by some Beijing experts, corresponding to the country's national agenda in the 14th FYP of promoting Hong Kong-Shenzhen Innovation and Technology Park in the GBA, Hong Kong has the potential to tap in the resource network to pursue advanced green energy innovations. To ensure the progress of carbon neutrality, Hong Kong has to finalise a long-term green transition plan for its fuel mix, enabled by more aggressive policies to promote the research and uptake of low-carbon energy.

5.2.3 Practical Implications of Target Setting

The 2060 carbon neutrality national target has a strong influence in raising the morale of Beijing experts, but not as clearly in Hong Kong. As a Beijing respondent pointed out, "Once the targets are set, China can attain them eventually no matter what, just like what happened for poverty eradication" (B·G2). Although Beijing has yet to announce a city-wide carbon neutrality target, nor concrete action plans to rapidly cut emissions, experts were still confident that the city would eventually achieve carbon neutrality. Some interviewees pointed out the underwhelming commitment in Beijing's 14th FYP ("emissions will decrease

with stability") but remained confident because of President Xi's announcement of the national target. Changes in Beijing can happen "overnight", once the policies are in place. While enjoying the efficiency of top-down planning, several Beijing experts recognised the need for consensus-building and public engagement for policies to be persistent. The middle ground should be pursued between authoritarian environmentalism and a more laissez-faire approach (Kometa, Lambi, & Sunjo, 2019).

On the contrary, many Hong Kong respondents gave a low score when rating their confidence levels in the city to achieve the 2050 carbon neutrality goal because "no concrete plan" or "no detailed roadmap" was released. Noting that a government-commissioned report with 55 recommendations on long-term decarbonisation released to the public, and the Chief Executive has confirmed the 2050 city net-zero target, Hong Kong had clearer policies and stronger commitment than Beijing at the same time point. This indicates the lack of trust in the executive capacity of government, which relates to the governance structure and institutional credibility. The Hong Kong Government is often seen as reluctant to challenge free-market capitalism and opt for policies that favour the private sector. Transformative changes have been hindered because only environmental policies that reside in existing political and economic structures can be promoted (Gouldson, Hills, & Welford, 2008). Though this is how SIPs for Hong Kong attempt to turn this threat into opportunity, as there are more incentives for local RE generation and global costs for renewables decline, RE will be taken up more rapidly in Hong Kong so long as the free-market capitalist thinking in the government perpetuates.

5.3 What's more? Transcending Paradigms

5.3.1 Officials Performance Appraisal

As Meadows (1999) proposed, transcending paradigms are the deepest leverage point that can tip the system. Taking a step back from the policy measures captured in the SIPs, they are all largely planned and executed by government officials. Therefore, the ability to alter the appraisal mechanism of officials is akin to transcending the underlying paradigm, which has massive implications on decarbonisation progress.

For Beijing, the evaluation of government officials is the main driver for deliverable outcomes. Such evaluation has been based on economic growth measured by GDP in the past, which evolved to include "green GDP" in 2006 to factor environmental costs of economic growth into the conventional measure of GDP. Although "green GDP" as an

accounting mechanism was shelved within a year due to resistance from regional and local governments (Li & Lang, 2010), local governments were still held accountable for environmental quality and ecological conservation since then (Wang, 2016). Another fundamental shift in China's governing ideology has emerged in recent years, with no economic growth target proposed in the 14th FYP. Evaluation metrics of government officials can be further dissociated with economic pursuits, which is favourable for promoting progress on carbon neutrality in Chinese cities. Therefore, a new institutional SIP is proposed, which is to tie carbon emission with the performance evaluation of city governors. This approach is echoed in literature, where Chinese scholars suggest defining officials' responsibility for carbon reduction and correlating it with political promotion opportunities (Dai, Zhou, & Kuosmanen, 2020). It is expected that contradicting metrics may become present on the same scorecard, such as emissions target, citizens' complaints and tax revenues. As described by a Beijing industry professional, "The challenge will be how officials square the circles to meet both growth goals and climate actions that incur extra living costs" (B·I1). Therefore, additional incentive structures should be built into the appraisal system to motivate and empower officials to make the necessary compromises for the climate target, without facing repercussions or punishments.

Having an appraisal mechanism tied with carbon emissions will accelerate carbon neutrality of both Beijing and Hong Kong. As aforementioned, local governments tend to prioritise policies that are low hanging fruits and exhibit co-benefits. This was confirmed by Beijing respondents, who described environmental governance as "dictated by the fight against smog and air pollution". Aggressive actions were taken "regardless of cost (不计成本)" because of the acute public health and reputational damage from smog. This echoes with research showing 80% of Beijing respondents is willing to pay for urban smog mitigation, with a maximum of 914 yuan (Dong & Zeng, 2018). Comparatively, government officials and the general public have yet to strongly associated climate change with immediate and visible harms, although extreme events like dust storms have been exacerbated by drier climates. Beijing residents are willing to pay for climate change mitigation than doing nothing, but the magnitude of payment is relatively small (maximum 322 yuan) (Wu & Zhang, 2020). Assessing government officials based on carbon reduction creates incentives for bold policies which may be costly yet do not reap extra benefits. Hong Kong government currently does not follow the appraisal system of mainland China. The lack of accountability of environmental officials is a concern shared by several Hong Kong respondents, which may

prevent serious planning and concrete policies to ensure achieving carbon neutrality by 2050. Therefore, introducing a similar mechanism to hold officials accountable for carbon neutrality has the potential to accelerate climate action in Hong Kong.

5.3.2 Horizontal and Vertical Cooperation

To ensure effective urban climate governance at the local level, there should be effective cooperation horizontally among city government bureaus/departments and vertically through communications with the national government. When important emissions targets are set, it is important for policymakers in different bureaus to fully understand the targets and embed them across different policy arenas to rally support. If information is not disseminated properly, the targets might not be met, especially when external stakeholders are drawn into projects with contradicting priorities and objectives. In Hong Kong, policy bureaus on energy and climate policies have a clear segregation of duties, sometimes working in silos. The Environment Bureau (ENB) is in charge of high-level target setting and policymaking for energy market development, energy consumption, climate change mitigation and many more aspects. The Environmental Protection Department (EPD) plays the key supporting role to execute the policies. Certain policy areas are supported by other departments with relevant expertise, like energy policies supported by technical expertise at the Electrical and Mechanical Services Department (EMSD). Although the Environment Bureau may already have the decarbonisation roadmap, it is often not shared with the departments in charge of execution. As a result, each department only knows their part of the work without seeing the full picture. This hinders horizontal cooperation and limits the chance for checks and balances. Technical experts in the departments may also lack the motivation to innovate and push boundaries for maximum policy output. Rather, they aim to fulfil their assigned targets.

Another important aspect is the maintaining a close connection with the national government. Most national development strategies and frameworks affect how cities develop. For energy sectors like transport and the electricity grid, they fit into the wider national network. Holistic solutions are found at the metropolitan and national scales. If the city government only focused on their own boundary, there will be missed opportunities. As aforementioned, establishing vertical cooperation is the basis for synchronising and consolidating climate strategies.

5.3.3 Inter-municipal Learnings

After recognising the importance of vertical and horizontal communications, horizontal learning with other municipalities become crucial in pursuing urban carbon neutrality. Inter-municipal learning is not unique to a particular city, but it is a common attribute shared by successful cities leading climate action. Both Beijing and Hong Kong stakeholders referenced the need to learn from one another and best-practice examples like Guangzhou. The LCC initiative in China started over a decade ago but did not achieve significant progress in motivating decarbonisation. While the C40 network strives to build capacity among Chinese cities through setting up a tailored programme, it is limited to the participation among large cities. At present, there are no official channels for all Chinese cities to learn about things like what policy instruments work best to reduce emissions and how to best apply them with societal acceptance.

In a quantitative social network analysis to understand trans-municipal learning in C40, results show a multi-stakeholder governing body is needed to facilitate the learning process (Lee & van de Meene, 2012). Learning usually happens when there are "champions" with more advanced levels of climate policies, and when cities share similar languages and geographies. One example is the London city government has advanced energy supply decentralisation strategies, and therefore became the source of information for Sydney, which shares the common language of English (Lee & van de Meene, 2012). Along similar lines, both cases in the research, Beijing and Hong Kong, demonstrate relatively advanced climate policies in certain aspects to become information sources for other Chinese cities. On weaker aspects such as carbon trading and new energy technology, the two cities can become information seekers. This suggests the value of establishing a multi-stakeholder governing body to foster representative engagement and policy learning on climate and energy policies. Existing platforms can be shaped into conduits for city learning, like the Asia Chapter of International Network for Government Science Advice (INGSA-Asia), which involves a wide array of stakeholders to share experience and build capacities for science-based policymaking at all levels of government (INGSA, 2020). Innovation and learning should be fully incorporated in climate change governance (Bulkeley & Castán Broto, 2013). The presence of such a governing body or platform to foster learning is a well-proven SIP because the it helps to replicate successes rapidly and creates reinforcing feedback loops.

5.4 Factors Influencing Prioritisation of Climate Policies

In the earlier sections, two main ways of prioritising climate policies were explored – by experts' perceptions and through the lens of SIPs. The common underlying factors that influence policy prioritisation were identified. Coming from the perspective of a city policymaker, the factors are the alignment with national agenda, ease of implementation, availability of co-benefits and financial costs.

Alignment with the national agenda is a recurrent theme in the research. For instance, promoting EV is ranked as a more prominent SIP in Hong Kong than in Beijing because regulatory framework and incentive structures exist. These regulatory frameworks are sometimes present at the national level, and sometimes at the regional or city level. National and local policies need to meet at a point in time for climate action plans to work out successfully.

Ease of implementation is another factor for selecting climate policies, as local governments often aim for low-hanging fruits due to their brevity of term in office. Official prioritise projects that achieve outcomes within a short period of time, which aligns with the "speed" attribute of the listed SIPs. Indeed, government stakeholders in Beijing and Hong Kong have a preference for faster policies, while the civil society like green group representatives were more invested in education solutions that show impact over longer time but create deeper impact with transformative rather than incremental changes.

Local governments also value climate policies that bring about co-benefits and generate synergies. Improving efficiency of the transportation system, pollution alleviation for public health are common entry points for climate action among local governments. As for the case in Beijing, the government is much more motivated to spend human and financial resources in fighting smog because it is closely linked with other aspects like public health and tourism. The Beijing city government has yet to see the "direct" impact of climate change on the community. Similarly, in other less developed cities, local governments usually prioritise policies related to public health and environmental safety, like solid waste management. Climate mitigation and adaptation solutions are only seen as an add-on.

Financial cost is another crucial factor. Although Beijing and Hong Kong are economically advanced and have the capacity to dedicate large sum of government expenditure in climate change mitigation, economic concerns were still repeatedly brought up in the interviews. One prominent example is the Hong Kong government rejected the offshore wind construction based on the fear to raise electricity tariff and transferring the financial burden to citizens. As we can see, spending is a concern for cities at different

economic development stages. This illustrates why formulating a standardised prioritisation framework for energy and climate policies is an important first step for cities to embed climate change in the planning of future development strategies. SIPs might be particularly useful for cities with limited resources to concentrate on a suite of policies that make significant progress towards carbon neutrality.

Chapter 6: Conclusions, Implications, and Future Work

6.1 Summary of Findings

The research adopts an alternative approach to formulate a policy prioritisation framework at the city level based on the concept of sensitive intervention points (SIPs), resulting in five recommended policies for Beijing and Hong Kong respectively to accelerate their carbon neutrality transitions. This, combined with the overview of carbon neutrality and perceived important policies among the academia, government, industry and green groups, provide a novel and coherent approach for unravelling key criteria and considerations for energy policy evaluation at the city level. Challenges to adopting specific policy interventions are also revealed through surveys and literature. The principal findings of the research are threefold and specific to answering the three stated research objectives.

To begin with, the perceptions of carbon neutrality are largely similar in Beijing and Hong Kong as reflected from the 32 expert interviews. Carbon neutrality is defined as a balance between the emissions and absorption of CO_2 in the atmosphere. Beijing stakeholders are more aware of the political connotations that come with the national carbon neutrality pledge, representing China's aspiration to enter the global race for green energy and net-zero technologies. The assessment method of carbon neutrality is also brought up, where stakeholders discuss the importance of delineating system boundaries for carbon neutrality to be a meaningful concept. Beijing and Hong Kong currently include scope 1 and scope 2 emissions in their GHG emissions inventories. There are respondents calling for scope 3 consumption-based emissions to be included for a more comprehensive assessment, as the two cities rely heavily on imported goods. Following on that, the top three most important policies for energy sectors to reach carbon neutrality were proposed by stakeholders, revealing the prioritisation frameworks of different stakeholder groups. Cross-sectoral policies like education and carbon trading are the most important among green groups, while utility representatives tend to favour supply-side measures. These observations can be explained by the unique preferences for leverage points to intervene a system (Meadows, 1999), informed by knowledge, experience and worldviews.

Furthermore, this study demonstrates how policymakers can leverage SIPs to seek policies that can achieve outsized impact with reinforcing feedback to accelerate climate action for carbon neutrality. Conventional approaches for prioritising climate policies like the stabilisation wedges and cost-benefit analysis are criticised for the static thinking, missing out synergies and the effect of learning (Farmer et al., 2019). 10 SIPs are identified for Beijing

and Hong Kong respectively through literature review and expert elicitation, ranked according to impact, speed, feasibility and persistence. Beijing and Hong Kong share the same highest-ranked SIP as importing low-carbon energy from other regions, closely followed by measures like promote EVs and generate local RE. These SIPs ride on the global trend of the declining costs of RE and the ability to take more advantage of predicted continuing declines in RE costs, such as higher rates of electrification (Farmer & Lafond, 2016). While some SIPs depend on the evolving global trends, others are more in control by city governments, such as electricity market design, urban land use changes and citizen education. Although some SIPs echo with policies perceived important by stakeholders, misalignments were also observed. This suggests SIPs are generally intuitive, but there are likely to be different factors and perspectives when judging the importance or effectiveness of policies from people with a mixed range of backgrounds. SIPs are therefore valuable as they could offer a harmonised prioritisation framework that selects the fastest pathway to attain carbon neutrality based on the common target.

On determining factors that influence the choice of policies related to carbon neutrality, interview results show that the conceptualisation of carbon neutrality does not necessarily influence the course of action taken to achieve the target. Although CCS was frequently brought up when defining carbon neutrality, it was seen as a national issue that cannot be acted upon at the local level, revealing a gap between action on the ground and modelling results. Other factors that influence the choice of policies include the alignment with national agenda, economic cost, ease of implementation, availability of co-benefits. Differences in governance structures and institutional arrangements can explain most differences in the policy prioritisations of Beijing and Hong Kong.

6.2 Implications

This research identifies 10 SIPs for Beijing and Hong Kong, which exhibit strong positive feedback dynamics or paradigm shifts that could enable rapid transitions to net-zero. These SIPs provided a useful reference for policymakers to be more strategic by concentrating resources on the most effective and scalable policies to decarbonise the energy sectors. In addition, the framework proposed in this research could be formalised in the policy cycle for prioritising climate actions in other Chinese cities. The wider application of SIPs at the city level optimises resource allocation for maximum carbon reduction, which is a big stride for China in overall climate change mitigation.

6.3 Limitations and Future Work

The results and conclusions are believed to be robust, though there are several limitations to this study. Firstly, the LEAP model was employed as a simple quantitative tool to complement the qualitative analysis of the emissions trajectories of Beijing and Hong Kong under existing policies. Sensitivity analyses were not performed on the model owing to time limitation, which reduces the robustness of the model outputs given the uncertainty in key parameters. After identifying SIPs for the two cities, it would make the argument even more convincing if the SIPs could feedback to the LEAP model and generate a "Carbon Neutrality Scenario" for Beijing and Hong Kong. However, there are substantial challenges in quantifying the impact of SIPs, especially in capturing the complex system dynamics. Thus, analyses adopting advanced complex systems modelling to quantify the abatement potentials of various policy measures represent a worthwhile effort to complement this research.

The application of SIPs can expand beyond policy prioritisation to policy appraisal, such as under the risk-opportunity framework designed to accommodate the systems dynamics that are the focus of SIPs (Sharpe et al., 2021). As such, evidence-based policy prioritisation can be achieved to aid stakeholders in decision-making processes. Furthermore, future studies can expand on comparing and reconciling recommendations from the use of a SIPs approach with other policy prioritisation frameworks, such as the wedges approach and policy synergies (Harvey et al., 2018), exploring the possibility to combine these frameworks for more holistic assessments.

With regards to data analysis, the focus of this research is comparing between Beijing and Hong Kong. Recognising the four stakeholder groups hold unique views over some topics, it would be valuable to make those comparisons and to explain the differences. An example could be to examine on the basis for reaching the perceptions on carbon neutrality.

Filing these gaps could further improve decision-maker's understanding of how to promote carbon neutrality and energy decarbonisation in Beijing and Hong Kong. Future research might also compare the carbon neutrality pathway of Chinese cities from different economic development stages, especially those with high reliance on heavy industry. Such analysis is necessary to correct the biases of accelerating climate action in cities with economic development. Adaptation is another key area of future work which might be needed to modify city budget allocations in the face of a worsening climate crisis that without rapid decarbonisation might become too costly to avoid.

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Appendices

Appendix I – First-round Expert Interview Guide

Interview Guide (Beijing)

Theme	Interview Questions
1. Background information	- What is your current role and duties involved? - How long are you in your current role and how long have you been working in the energy related sector?
2. Personal experience	- When you were young, how were the main ways you and your family used energy? How has it changed now? - What do you think of the environmental impact of energy?
3. Conceptualization of "carbon neutrality" in Beijing	- What is your interpretation of "carbon neutrality"? o How does your research team interpret "carbon neutrality"? o What are some other interpretations or discourses around "carbon neutrality" in Beijing? - Regarding President Xi's announcement on carbon neutrality by 2060: o What are the implications on your research? o What plans will be made in response to the target?
4. Pathways to decarbonise the energy supply	- What is the role of cities in China's carbon neutrality commitment? o How important is it for cities to implement their own decarbonisation strategies?

and demand in Beijing	o Are there differences in the role played by Beijing as compared with other cities? - How are energy policy decisions made in Beijing? o What is the policymaking process concerning energy supply and energy demand policies? o What are the constraints or challenges encountered in the processes? - What are the decarbonisation strategies and timelines for energy supply and demand in Beijing? o How easy or hard is it to decarbonise electricity generation and why? o How easy or hard is it to decarbonise buildings? o How easy or hard is it to decarbonise transport? o How easy or hard is it to decarbonise industry? o How easy or hard is it to achieve carbon neutrality through CCS or negative emissions technologies? What fraction of emissions of Beijing is expected to be abated by CCS? - What are the three most important policy changes required to reach carbon neutrality for Beijing? - On a scale of 1-10, how confident are you in Beijing reaching the carbon neutrality goal for the city by 2060? (1 is the least confident, 10 is the most confident) o To what extent do you think energy policies contribute to that goal?
5. Factors influencing energy decarbonisation in Beijing	- How do the following factors hinder or facilitate energy decarbonisation of Beijing? o Physical factors – state of existing and planned buildings, industries and infrastructures o Technological factors – level and uptake of green technology, o Institutional factors – rules, norms, structures that guide behaviour o Economic factors – cost o Social factors – just transition o Political factors – governance - How does moving the jurisdiction over climate change from NDRC and fragmented units to MEE affect climate policymaking at national and city levels?

Interview Guide (Hong Kong)

Theme	Interview Questions
1. Background information	- What is your current role and duties involved?

	- How long are you in your current role and how long have you been working in the energy related sector?
2. Personal experience	- When you were young, how were the main ways you and your family used energy? How has it changed now? - What do you think of the environmental impact of energy?

3. Conceptualization of "carbon neutrality" in Beijing	- What is your interpretation of "carbon neutrality"?
	  o How does your research team interpret "carbon neutrality"?
	  o What are some other interpretations or discourses around "carbon neutrality" in Beijing?
	- Regarding the Hong Kong Government's carbon neutrality pledge by 2050:
	  o What are the implications on your research?
	  o What plans will be made in response to the target?

4. Pathways to decarbonise the energy supply and demand in Beijing	- What is the role of cities in China's carbon neutrality commitment?
	  o How important is it for cities to implement their own decarbonisation strategies?
	  o Are there differences in the role played by Hong Kong as compared with other cities?
	- How are energy policy decisions made in Hong Kong?
	  o What is the policymaking process concerning energy supply and energy demand policies?
	  o What are the constraints or challenges encountered in the processes?
	- What are the decarbonisation strategies and timelines for energy supply and demand in Hong Kong?
	  o How easy or hard is it to decarbonise electricity generation and why?
	  o How easy or hard is it to decarbonise buildings?
	  o How easy or hard is it to decarbonise transport?
	  o How easy or hard is it to decarbonise industry?
	  o How easy or hard is it to achieve carbon neutrality through CCS or negative emissions technologies? What fraction of emissions of Beijing is expected to be abated by CCS?
	- What are the three most important policy changes required to reach carbon neutrality for Hong Kong?
	- On a scale of 1-10, how confident are you in Hong Kong reaching the carbon neutrality goal for the city by 2050? (1 is the least confident, 10 is the most confident)
	  o To what extent do you think energy policies contribute to that goal?

5. Factors influencing energy decarbonisation in Beijing	- How do the following factors hinder or facilitate energy decarbonisation of Hong Kong? o Physical factors – state of existing and planned buildings, industries and infrastructures o Technological factors – level and uptake of green technology, o Institutional factors – rules, norms, structures that guide behaviour o Economic factors – cost o Social factors – just transition o Political factors – governance

Appendix II – Second-round Survey

Expert Questionnaire (Beijing)

Title: "Accelerating Carbon Neutrality in Chinese Cities: Sensitive Intervention Points for the Energy Supply and Demand Sectors of Beijing and Hong Kong"

Background information

- Sensitive intervention points (SIPs) are policy instruments or interventions that focus on ensuring maximum impact for accelerating decarbonisation[22]
- Due to the limited timeframe until 2060 to reach large scale greenhouse gas emissions to mitigate global warming, we might use SIPs to prioritise climate policy for the most effective impact
- Following interviews conducted with 16 experts in the academia, green groups, industry, and regulatory bodies in Beijing, we developed the following list of potential SIPs for Beijing. These are presented in the diagram below based on the expert elicitation, supplemented by literature review
- You are cordially invited to express your views on the SIPs identified based on your field experience, especially at the implementation level of policies

Preliminary SIPs for Beijing

Beijing SIP	Category of SIP	Stakeholder Rank	Impact 1-10? (10 = largest, 1 = smallest)	Speed 1-10? (10 = fastest, 1 = slowest)	Persistence High/Medium/ Low?	Feasibility High/Medium/ Low?
A. Import renewable energy from other parts of China	Energy technology	1				
B. Electrification of public transport	Energy technology	2				
C. Tighten building energy efficiency standards	Energy technology	3				
D. Implement stringent emissions trading scheme at the city level	Engagement	3				
E. Promote electric vehicles	Energy technology	6				

[22] Farmer, J. D., Hepburn, C., Ives, M. C., Hale, T., Wetzer, T., Mealy, P., ... & Way, R. (2019). Sensitive intervention points in the post-carbon transition. Science, 364(6436), 132-134.

F. Civic education on carbon neutrality for general public	Engagement	8				
G. Incorporate market mechanism in the electricity grid for demand management	Institution	7				
H. Prohibit energy intensive industries	Urban configuration	9				
I. Electrification of warming	Energy technology	5				
J. Regulation to cap city emissions	Institution	9				

List of Questions

1. Which SIPs do you have relevant experience or knowledge on?

Instruction: When answering the following questions 2-5, you can focus on the SIPs you are familiar with, and/or have relevant experience on. Please specify the SIPs you are referencing using the representing letter.

2. Do you agree with the assessment of the impact and speed of SIPs? Please score all the SIPs that you are familiar with on their impact (score 1-10) and speed (score 1-10).

3. How persistent do you think these SIPs are given changing socioeconomic circumstances? (eg change of government leadership, change in social trends). Please evaluate persistence of SIPs that you are familiar with(high/medium/low).

4. How feasible is it to implement these SIPs in Beijing? What are the barriers or challenges of implementing these SIPs? Please evaluate feasibility of SIPs that you are familiar with(high/medium/low).

5. What are the potential unintended negative consequences for enacting these SIPs? (eg biodiversity impact, social impact, financial burden, inequality)

The End. Thank you for your valuable time!

Expert Questionnaire (Hong Kong)

Title: "Accelerating Carbon Neutrality in Chinese Cities: Sensitive Intervention Points for the Energy Supply and Demand Sectors of Beijing and Hong Kong"

Background information

- Sensitive intervention points (SIPs) are policy instruments or interventions that focus on ensuring maximum impact for accelerating decarbonisation[23]
- Due to the limited timeframe until 2060 to reach large scale greenhouse gas emissions to mitigate global warming, we might use SIPs to prioritise climate policy for the most effective impact
- Following interviews conducted with 16 experts in the academia, green groups, industry, and regulatory bodies in Hong Kong, we developed the following list of potential SIPs for Hong Kong. These are presented in the diagram below based on the expert elicitation, supplemented by literature review
- You are cordially invited to express your views on the SIPs identified based on your field experience, especially at the implementation level of policies

Preliminary SIPs for Hong Kong

Hong Kong SIP	Category of SIP	Stakeholder Rank	Impact 1-10? (10 = largest, 1 = smallest)	Speed 1-10? (10 = fastest, 1 = slowest)	Persistence High/Medium/ Low?	Feasibility High/Medium/ Low?
A. Import low-carbon energy	Institutional arrangement	2				
B. Local renewable energy generation	Energy technology	1				
C. Tighten building energy efficiency standards	Energy technology	3				
D. Decarbonise existing building stock	Energy technology	4				
E. Promote electric vehicle	Energy technology	7				
F. Civic education on carbon	Energy technology	4				

[23] Farmer, J. D., Hepburn, C., Ives, M. C., Hale, T., Wetzer, T., Mealy, P., ... & Way, R. (2019). Sensitive intervention points in the post-carbon transition. Science, 364(6436), 132-134.

neutrality for general public						
G. Hydrogen for energy storage	Energy technology	6				
H. Urban redevelopment and land use change	Energy technology	9				
I. Modify the Scheme of Control to increase renewable energy provision	Energy technology	7				
J. Social mobilisation for climate action	Engagement	9				

List of Questions

6. Which SIPs do you have relevant experience or knowledge on?

Instruction: When answering the following questions 2-5, you can focus on the SIPs you are familiar with, and/or have relevant experience on. Please specify the SIPs you are referencing using the representing letter.

7. Do you agree with the assessment of the impact and speed of SIPs? Please score all the SIPs that you are familiar with on their impact (score 1-10) and speed (score 1-10).

8. How persistent do you think these SIPs are given changing socioeconomic circumstances? (eg change of government leadership, change in social trends). Please evaluate persistence of SIPs that you are familiar with(high/medium/low).

9. How feasible is it to implement these SIPs in Hong Kong? What are the barriers or challenges of implementing these SIPs? Please evaluate feasibility of SIPs that you are familiar with(high/medium/low).

10. What are the potential unintended negative consequences for enacting these SIPs? (eg biodiversity impact, social impact, financial burden, inequality)

The End. Thank you for your valuable time!

School of Geography and the Environment
South Parks Road
Oxford, OX1 3QY

MPhil in Environmental Change and Management
Oxford University telephone number: 01865 285070
Oxford University email: enquiries@geog.ox.ac.uk

Accelerating Carbon Neutrality in Chinese Cities: Sensitive Intervention Points for the Energy Supply and Demand Sectors of Beijing and Hong Kong

PARTICIPANT INFORMATION SHEET

Central University Research Ethics Committee (CUREC) Approval Reference: SOGE1A2020-188

1. *Why is this research being conducted?*

This research investigates the decarbonisation strategies and pathways for reaching net zero by 2050 of the energy sectors in Hong Kong and Beijing. Factors influencing energy decarbonization and climate governance in Beijing and Hong Kong will be explored. Interviews are conducted to collect in-depth insights from stakeholders, identifying the enabling factors and constraints of energy policies in the two cities.

2. *Why have I been invited to take part?*

You have been invited because of your expertise and experience related to energy policy and development.

3. *Do I have to take part?*

No, it is not compulsory to participate in the research. Before deciding whether to take part, you can ask questions about the research. If you agree to take part, you may withdraw from the research at any time, without giving a reason, and without negative consequences, by advising me of this decision. The deadline by which you can withdraw any information you have contributed to the research is 1st August, 2021. The information will be immediately removed from the research and destroyed.

4. *What will happen to me if I take part in the research?*

If you agree to participate in the research, you will have to sign a consent form. After that, you will be asked to participate in one online interview and a physical follow-up interview in your office location.

With your consent, the interview will be recorded to capture an accurate account. After transcription, the audio recording will be destroyed promptly.

5. ***Are there any potential risks in taking part?***

I understand that this is a politically sensitive and current topic and certain opinions may run the risk of public persecution. To reduce any potential risks, I am planning to pseudonymise the research data, or, should you find it necessary, fully anonymise the data.

6. ***Are there any benefits in taking part?***

If you are interested, you will be offered a copy of my finalised dissertation for your perusal.

7. ***What happens to the data provided?***

The information you provide during the study is the **research data**. Any research data from which you can be identified (your name, professional biography, answers to the interview questions, and audio recordings) is known as **personal data**.

The researcher, supervisor, and university markers will have access to your responses. Responsible members of the University of Oxford may be given access to data for monitoring and/or audit of the research. The researcher will personally transcribe the interview. All data will be stored on the researcher's personal computer and backed up on a secure cloud storage.

I would like your permission to use direct quotes against a pseudonym in any research outputs.

8. ***Will the research be published?***

The University of Oxford is committed to the dissemination of its research for the benefit of society and the economy and, in support of this commitment, has established an online archive of research materials. This archive includes digital copies of student theses successfully submitted as part of a University of Oxford postgraduate degree programme. Holding the archive online gives easy access for researchers to the full text of freely available theses, thereby increasing the likely impact and use of that research.

The research will be written up as a student's thesis. On successful submission of the thesis, it may be deposited both in print and online in the University archives to facilitate its use in future research. If so, the thesis will be openly accessible.

9. ***Who has reviewed this study?***

This study has been reviewed by, and received ethics clearance through, the University of Oxford Central University Research Ethics Committee (Reference number: SOGE1A2020-188).

10. ***Who do I contact if I have a concern about the study or I wish to complain?***

If you have a concern about any aspect of this study, please contact the primary researcher or her supervisor at _____. We will endeavour to answer your complaint or query. Your concerns will be acknowledged within 6 working days and provide you with an indication of how it will be dealt

with. If you remain unhappy or wish to make a formal complaint, please contact the Chair of the Research Ethics Committee at the University of Oxford who will seek to resolve the matter as soon as possible:

[only for applications reviewed by the SSH IDREC] Chair, **Social Sciences & Humanities Inter-Divisional Research Ethics Committee**; Email: ethics@socsci.ox.ac.uk; Address: Research Services, University of Oxford, Wellington Square, Oxford OX1 2JD

11. *Data Protection*

The University of Oxford is the data controller with respect to your personal data, and as such will determine how your personal data is used in the study.
The University will process your personal data for the purpose of the research outlined above. Research is a task that is performed in the public interest.
Further information about your rights with respect to your personal data is available from http://www.admin.ox.ac.uk/councilsec/compliance/gdpr/individualrights/.

12. *Further Information and Contact Details*

If you would like to discuss the research with someone beforehand (or if you have questions afterwards), please contact:

School of Geography and the Environment
South Parks Road, Oxford, OX1 3QY

PARTICIPANT CONSENT FORM

Central University Research Ethics Committee (CUREC) Approval Reference: SOGE1A2020-188

Accelerating Carbon Neutrality in Chinese Cities: Sensitive Intervention Points for the Energy Supply and Demand Sectors of Beijing and Hong Kong

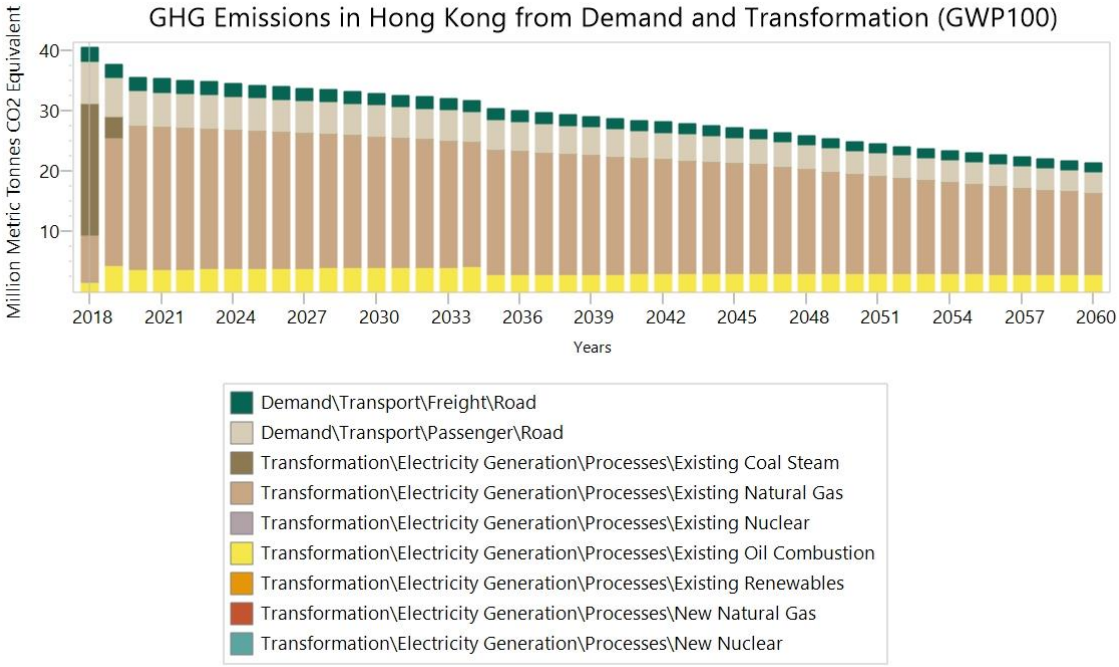
Please initial each box

1	I confirm that I have read and understand the information for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	☐
2	I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, and without any adverse consequences or penalty.	☐
3	I understand that research data collected during the study may be looked at by authorised people outside the research team. I give permission for these individuals to access my data.	☐
4	I understand that this project has been reviewed by, and received ethics clearance through, the University of Oxford Central University Research Ethics Committee.	☐
5	I understand who will have access to personal data provided, how the data will be stored and what will happen to the data at the end of the project.	☐
6	I understand how this research will be written up and published.	☐
7	I understand how to raise a concern or make a complaint.	☐
8	I consent to being audio recorded	☐
9	I understand how audio recordings will be used in research outputs	☐
10a	I agree to the use of direct quotes, attributed to my name, in research outputs **OR**	☐
10b	I agree to the use of pseudonymised quotes in research outputs **OR**	☐
10c	I agree to the use of anonymised quotes in research outputs **OR**	☐
10d	I do not wish to be directly quoted	☐
11	I agree to take part in the study. I hereby assign to the researcher all copyright in my contribution for use in all work stemming from this project and future projects.	☐

Name of Participant	Date	Signature
Name of Person Taking Consent	Date	Signature

Appendix III – Supplementary graphs

GHG Emissions in attributed to demand and transformation sectors



Scores of perceived importance of sectoral policies across different stakeholder groups in Beijing and Hong Kong

	Academia	Green Group	Industry	Regulator
Electricity Generation	17	9	31	24
Transport	10	7	2	7
Building	12	12	5	11
Industry	4	0	2	1
Cross-Sector	5	20	8	5