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Policy mixes and the policy learning process of energy transitions: Insights from the feed-in tariff policy and urban community solar in Hong Kong

Daphne Ngar-Yin Mah[1,2]; Darren Man-wai Cheung[1,2]; Michael K. H. Leung[3,4]; Maggie Yachao Wang; Mandy Wai-ming Wong[1,2]; Kevin Lo[1,5]; Altair Tin-fu Cheung[3,4]

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[1] Department of Geography, Hong Kong Baptist University
[2] Asian Energy Studies Centre, Hong Kong Baptist University
[3] School of Energy and Environment, City University of Hong Kong
[4] Ability R&D Energy Research Centre, City University of Hong Kong
[5] David C. Lam Institute for East-West Studies, Hong Kong Baptist University

Correspondence to author: Darren Man-wai Cheung, dmcheung@hkbu.edu.hk.

Policy mixes and the policy learning process of energy transitions:
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[1] Department of Geography, Hong Kong Baptist University
[2] Asian Energy Studies Centre, Hong Kong Baptist University
[3] School of Energy and Environment, City University of Hong Kong
[4] Ability R&D Energy Research Centre, City University of Hong Kong
[5] David C. Lam Institute for East-West Studies, Hong Kong Baptist University

Abstract

Effectiveness of renewable feed-in tariff (FiT), a commonly used renewable policy around the world, varies. Designing policy mixes – a package of policy instruments – to optimise normative effect of FiT – is critical but has remained challenges and under-studied. This paper brings together the key concepts of policy mixes and policy learning to examine how the efficacy of renewable policies can be improved, with reference to the recent FiT policy in Hong Kong focusing two prospective solar communities. Based on 97 in-depth interviews and workshop discussions involving 57 householders, we found that FiT was an effective policy in stimulating growth of new solar projects in some sub-sectors in Hong Kong, but has not yet been mainstreamed at the community and city levels. The FiT was insufficient to address multiple non-economic barriers perceived by community householders. The limited policy impacts of the FiT indicated policy makers were able to attain technical learning, but faced major constraints in advancing to conceptual and social forms of policy learning. This paper concludes that policy makers should give closer attention to policy mixes and higher orders of policy learning than choosing a single "most effective" policy instrument to unlock the under-used community solar potentials.

Keywords: Renewable feed-in tariff; policy mixes; policy learning; prospective solar communities; Hong Kong

1. Introduction

The urgency to develop effective climate/ low carbon strategies and the rapid decline in solar photovoltaic (PV) costs has given rise to a global trend of urban solar developments in recent years. New York, London, Seoul, Tokyo, and Singapore are among the leading international megacities which have set ambitious solar targets supported by major solar policies and programmes.

In the last two decades, renewable energy feed-in tariffs (FiTs) have emerged as one of the most effective and popular policies for scaling up renewable energy (RE) generation around the world, including the U.S., the EU, China, and Japan (Jenner et al., 2013). FiTs are generally referred to as obligations for utilities to purchase, at a set price, the electricity generated by any renewable energy source) (Rowlands, 2005). It is however still debatable whether FiT is as effective as other policies, such as a mandatory renewable quota (i.e. renewable portfolio standards; RPS), or a direct subsidy. National and city governments have also reacted differently to FiT. In South Korea, the national government once abandoned FiT policy from 2012 to 2017 due to heavy financial burden but Seoul has decided to continue with a city-level FiT (Jang, 2018; Kim, 2017b). Germany, Spain, and the UK, for example, have kept revising FiTs in order to manage tariff increases and reflect market changes (Muhammad-Sukki et al., 2013). To an extreme, Singapore has opted for the market and decided not to introduce FiT – it has adopted models of solar leasing and centralised tendering to scale up solar photovoltaics (PV) deployment in social housing (Wong et al., 2013). A growing body of RE studies suggests that policy enactment alone cannot guarantee effectiveness of FiT policies. Policy design features, market characteristics and other local contexts such as electricity tariff level may affect policy effectiveness of FiT policies (Jenner et al., 2013).

This study is a case study of Hong Kong. We examine the effectiveness of the FiT Scheme in Hong Kong since it first launched in October 2018. The Hong Kong experiences of FiT worth study for two reasons. First, Hong Kong is a significant case of FiT. Hong Kong offers one of the most generous FiT rates in the world: The Hong Kong FiT offers a long-term contract (i.e. up to 2033) to solar or wind energy producers with a fixed and favourable subsidy (HK$3-5/kWh; USD 0.38-0.64/kWh, depending on capacity). The FiT Scheme is expected to achieve a policy impact in reducing the payback period of solar PV systems. Second, urban solar has increasingly become a global trend in major cities in the world. While Hong Kong has moderate solar resources compared to other world cities, Hong Kong has been lagging behind other major world cities in the development of urban solar. How effective the FiT Scheme can promote urban solar in Hong Kong is of significant research value and provide insights to the research of RE policy instruments.

In light of these policy developments in renewable energy globally as well as in Hong Kong, it is important to understand how policy-making process processes can influence the pace and pathways of energy transitions. The growing body of the literature on policy mixes and policy learning has emerged to provide a better understanding of the policy dimensions of sustainable energy transitions. Designing policy mixes – a package of policy instruments – in which a FiT can be embedded and optimise its normative effect – are critical but has remained challenges and under-studied. Policy learning provides a useful perspective to evaluate policy mixes focusing on the capability of policy makers to go beyond a search of technocratic fixes and to advance higher forms of policy learning that emphasis on reflection, redefining goals, and inclusive policy-making (Glasbergen, 1996; Gouldson et al., 2008). While these two concepts offer complementary perspectives to the policy dimensions of energy transitions, the conceptual and empirical advancements have been limited. This paper therefore aims explore the theoretical linkages between the concepts of policy mixes and policy learning. We then apply the theoretical perspectives to examine and explain the evolutions of the FiT policy in Hong Kong. Specifically, we address these questions:

(1) What are the barriers to solar deployment perceived by prospective solar householders in the two case communities in Hong Kong?
(2) To what extent and how the Hong Kong FiT policy can address the barriers from the perspectives of policy mixes and policy learning?
(3) In what ways a policy-mix and policy learning approaches could better address the barriers perceived by community energy householders?

This study analyses the development of community solar in Hong Kong. Global leading cities e.g. London and Seoul are strengthening community energy (which conserves, generate and store energy locally) as an important part of urban low-carbon policies in recognition of (i) the potential aggregate, practical impacts of individual efforts at community levels; (ii) communities are a key action site where critical problem-solving linkages such as social networks, social experimentation, social learning, and trusting relationships emerge and diffuse, and (ii) *full* value of community energy to the wider economy include cultural and values changes such as a shift from private interests to the pursuit of collective goals (Burchell et al., 2014). Our analysis on community scale solar development in Hong Kong will provide interesting insights into policy impacts of the FiT by examining the interactions of energy technological changes and policy innovations.

This paper is structured in the following ways. First, we discuss the theoretical perspectives of policy mixes and policy learning. We then explain the methodological approaches adopted in this study. This is followed by a detailed examination of the case study of Hong Kong. We will examine how policy mixes took place in Hong Kong and critically evaluate the impacts of the FiT policy from a policy learning perspective. This is then followed by conclusions and policy recommendations.

2. Understanding energy transitions from the policy perspectives: FiT policies, policy mixes and policy learning

2.1. The role of renewable energy policies in energy transitions

Deep and rapid energy transitions is required in order to meet the climate change target of 2°C. In an increasingly recognition of the limits of large-scale low-carbon technologies such as nuclear power in delivering deep decarbonisation, there has been a substantial increase in the uptake of residential solar PV systems in global leading cities in recent years (Ford et al., 2017). In recent years community-based solar initiatives have rapidly emerged in many major cities such as London, New York City, and Seoul, as solar costs continue to decline and there is urgency for policy-makers to seek effective approaches, practices, and policy instruments to effectively deliver carbon reduction targets (Mah, 2019; Appendix 1 for details of solar profiles in major cities). However, despite some progress has been made, such decentralised renewable systems in many cities have not yet destabilised traditional electricity systems.

A rapidly growing body of the literature on socio-technical energy transitions shed light on the barriers to mainstreaming renewable energy by emphasising the importance of the co-evolution of technological advancements, institutions, market, user practices, and norms. There has been considerable attention in the energy transition literature to various economic, technical, institutional, and social constraints to renewable energy developments. (Proka et al., 2018; Walker & Cass, 2007). Regarding household installation of solar PV panels, major barriers include economic (e.g. high upfront costs and long payback), market (e.g. lack of trusted experts), social (mistrust, aesthetic impacts, inertia), institutional (e.g. uncertainty around regulations, lack of organisational and institutional support), physical (e.g. poor compatibility with existing energy infrastructure) (Palm, 2018).

A theme of the transition literature focuses on the important roles of government interventions in overcoming barriers associated with new energy technologies. The literature suggests that government policies have at least five important roles: (1) Governments can develop visions and clear policy objectives in order to create stable market conditions for future investment (IEA, 2015; Mah, 2020; Quitzow, 2015; Shen et al., 2014; World Economic Forum, 2010); (2) public policies can introducing pricing signals and incentive structure to influence the uptake of different types of energy technologies (Quitzow, 2015); (3) – governments can set the rules, monitors and regulates behaviours of incumbent utilities as well as new market players (Mah, 2020); and (4) government can facilitate cost reduction through economies of scale (Trindade et al., 2017).

Public policies, as a form of government intervention, are needed to overcome barriers associated with new energy technologies. Public policy studies generally distinguish **four main types of policy instruments**: command-and-control (e.g. renewable portfolio standards), economic measures (e.g. FiTs), market-based instruments (e.g. renewable energy certification systems), and voluntary measures (e.g. educational programmes) (Gunningham et al., 1998). FiTs, a typical economic instrument, is one of the most commonly adopted renewable policies around the world. Each of these policy instruments has its strengths and limitations (Table 1). In comparison with other types of renewable energy policies, FiT has the strengths in its effectiveness in promoting expansion of renewable energy capacity and encouraging a steady growth of small to medium-scale produces (Mendonça, 2007; Rowlands, 2005). Remarkable successes of FiT in stimulating substantial growth of new installations of wind power and solar, and attracting private investment have been recorded in many countries, most notably in Germany (Hoppmann et al., 2014; Onifade, 2015). However, an extensive body of empirical studies on FiTs show that policy outcomes of this popular instrument have been mixed. FiTs also presented major problems in Spain, the UK and Japan (Onifade, 2015). In particular, FiT may create growing fiscal burdens that limit its continuation (Rosenbloom et al., 2019).

Although the empirical studies on FiT have been extensive, we still lack a good understanding of the dynamics at play when policy makers introduce FiT as a governmental intervention to stimulate technological diffusion of renewable energy.

Table 1. A comparison of four major types of renewable policy instruments.

	Features	Strengths	Weaknesses
Renewable Energy Feed-in Tariff (FiT)	-A premium payment per unit of electricity guaranteed for a long period of time (e.g. 15-20 years) (Jacobs & Sovacool, 2012)	-Effective in promoting expansion of renewable energy capacity (Rowlands, 2005) -Effective in promote costly technology specific renewable energy (e.g. solar PV) (Jacobs & Sovacool, 2012) -Encourage technological learning through renewable energy deployment (Rowlands, 2005) -Encourage steady growth of small to medium-scale producers (Mendonça, 2007) -Security with guaranteed payment (Rowlands, 2005; Stennett, 2010) -Flexible, quick and easy to establish, and low transaction costs (Mendonça, 2007; Rowlands, 2005)	-FiT consumers may pay unnecessarily high prices in absence of timely FiT adjustment (Mendonça, 2007) -Risk of tariff impact upon vulnerable groups/communities -Difficult to set suitable FiT rates (Rowlands, 2005) -Risk of unexpected boom of renewable energy (del Río & Mir-Artigues, 2012) -Difficult to predict number of market players and RE projects (Jacobs & Sovacool, 2012) -unstable FiT remuneration may reduce investor confidence (Couture & Gagnon, 2010) -Non-solar PV owners may need to cross-subsidise solar PV owners (+ref)
Renewable Portfolio Standards (RPS)	-A policy which requires a utility to produce certain percentage of its electrical generation from renewable energy (Iselin, 2014)	-Cost and administratively effective, (EPA, 2015) -Straight-forward and easy to measure (Leon, 2013) -able to create market demand for renewable energy (Rader & Hempling, 2001) -Flexible to adjust relevant policies (Forte et al., 2017)	-May increase electricity tariffs (Divounguy & Nichols, 2016) -Difficult to predict costs (Rader & Hempling, 2001) -Allows the existence of free-riders (Square, 2006) -Requires constant adjustment (Leon, 2013) -May lead to job losses due to closure of conventional power stations (Materia & Ziedars, 2017)
Net Metering	-Agreement between prosumers and local utility or grid operator to purchase excess renewable electricity produced by prosumers (Jacobs & Sovacool, 2012)	-can offset peak load (Jacobs & Sovacool, 2012) -Income generation for prosumers when coupled with time-of-use rates (Jacobs & Sovacool, 2012) -Lower costs to utilities, homeowners and communities (Poullikkas, 2013) -Potentials to foster early adoption (Darghouth et al., 2011)	-Fluctuating in electricity tariffs could minimise economic benefits of PV systems under net metering (Darghouth et al., 2011) -Bill savings dependent on the electricity tariff structure (Darghouth et al., 2011) -Potential loss of utility revenues (Beach & McGuire, 2013) -May lead to increase in network usage costs for both PV prosumers and non-PV consumers (Eid et al., 2014) -Difficult to increase market penetration (Mendonça, 2007) -Low investment security (Jacobs & Sovacool, 2012)
Renewable energy certificates (RECs)	-RECs represents the "attributes" of renewable energy generation from the actually produced electricity (Cory & Swezey, 2007) -Used to verify utility compliance with RPS and claims made by voluntary purchasers (Holt et al., 2011)	-Rely on market forces to promote least-costly projects (Holt & Bird, 2005; Mendonça, 2007); Allow REC purchasers to seek lowest –cost RECs regardless of source of REC generation (Holt & Bird, 2005) -Frees renewable energy producers from need to deliver renewable electricity in real time to end-users (Cory & Swezey, 2007; Holt & Bird, 2005) -Can reduce cost of RPS compliance by lowering transmission and distribution costs, and provide compliance flexibility by facilitating market trading and increasing market liquidity (Cory & Swezey, 2007) -Facilitate transactions across regional boundaries, as they are not constrained geographically as commodity electricity (Holt & Bird, 2005)	-Challenges in verifying renewable energy system output and ownership of RECs (Cory & Swezey, 2007) -Tendency to favour large, centralized plants with smaller investor risk (Mendonça, 2007) - May require demanding and complex market infrastructure (Bauner & Crago, 2015); Complex in design, administration, and enforcement (Mendonça, 2007) -Long term contracts not a guaranteed element of RECs (Holt et al., 2011; Stennett, 2010) -Potential lack of understanding of RECs among different parties (e.g. generators, electricity providers, regulators and consumers) (Holt & Bird, 2005) -Price fluctuation in thin markets (Mendonça, 2007) -Demand uncertainty (eg. due to policy instability), low or uncertain prices (Holt et al., 2011) -Risk of tariff impact (Stennett, 2010)

2.2. Policy mixes and renewable energy policies

In the light of these policy developments of renewable energy globally as well as in leading cities including Hong Kong, it is important to understand how policymaking processes can influence the pace and pathways of socio-technical energy changes (Edmondson et al., 2018). A theme of the energy transition studies focus on the policy mix concept to explain the complexity of energy transition policymaking processes and outcomes (Magro & Wilson, 2018). The concept of policy mix has been built on policy studies. Policy mix generally is a policy process that utilises the combinations of policy instruments and actors, and to take advantages of various synergies and complementarities between them in an effort to attain policy goals (Kern et al., 2017; Rogge et al., 2017). Policy mixes are generally referred to as pre-designed portfolios of instruments, or as a coherent, mutually supportive set of instruments that can be achieved through better coordination (Matti et al., 2017).

The literature argues that policy mixes are required to realise deep energy transitions because policy-making processes of such transitions are complex and full of uncertainties (Ritzenhofen & Spinler, 2016) and a single policy intervention would not be sufficient to resolve different types of barriers and achieve the required changes (Magro & Wilson, 2018; Rosenow et al., 2017). Normatively, policy mixes can address multi-faceted barriers to renewable deployment. The complex and uncertain nature of FiT policies suggest that the concept of policy mix seems to highly relevant to explain the dynamics at play (Reichardt & Rogge, 2016; Stokes, 2013; Zhi et al., 2014).

A growing body of the literature on policy mixes suggests that there are at least five dimensions of policy mixes. These include:

(1) *Policy instrument mixes*: the optimal combination of use of multiple types of policy instruments to achieve specific policy goals. There are four main types of policy instruments - command-and-control, economic incentive-based instruments, market-based instruments, information and voluntary measures (Arimura et al., 2008; Boisvert et al., 2013; Schmidt & Sewerin, 2018);
(2) *Horizontal policy mixes*: the optimal combinations of joined-up interventions from different policy domains (e.g. energy, industry, technology and innovation policies) and government bodies (Cunningham et al., 2013; Matti et al., 2017; Meissner & Kergroach, 2019);
(3) *Multi-level policy mixes*: the optimal interplay between multi-level public interventions across supra-national (e.g. EU), national, regional, and local levels (Kern & Howlett, 2009; Matti et al., 2017; Meissner & Kergroach, 2019);
(4) *Temporal dimension of policy mixes* with a focus on policy-cycle: outputs and feedback from each stage of a policy cycle of an energy policy, from agenda setting, policy formulation, implementation, monitoring, to evaluation (Ceron & Negri, 2016; MacDonald, 2011) are looped back into the policy cycle; and
(5) Mixes of actors in different governing modes: the optimal combination of public-private-societal cooperation (Citroni et al., 2013; Jänicke & Quitzow, 2017; Magro & Wilson, 2018).

While policy mixes theory emphasises the potential for governments to recognise and respond to multi-faceted barriers to renewable deployment, the concept of policy mixes has a major limitation in providing an evaluative perspective. How, then, do we know if policy mixes work? How would we evaluate effectiveness of policy mixes? These are important questions to be answered. Work by, for example, (Schmidt & Sewerin, 2018), provides a quantitative analysis on measures policy mixes in terms of intensity and technology specificity. But the policy mix literature has been scant in conceptualising the evaluative dimensions of policy mixes.

2.3. Policy learning as an evaluative perspective of policy mixes dynamics

An emerging theme in energy transition literature adopts the concept of policy learning to conceptualise the dynamism of policy-making processes (Boon & Bakker, 2016).As a relatively well developed concept in the broader governance studies, policy learning is a policymaking process in which policy makers and policy stakeholders deliberately adjust the goals, rules and techniques of a given policy in response to experiences and new information (Hall, 1993; Mah & Hills, 2014).

Central to the concept of policy learning is the differentiation of three types of learning, which provides an important evaluative aspect of policy processes. The distinction of the three orders of learning provides a set of indicators of the progression of policy-making process from broad learning to deep learning (Schot et al., 2016). *Technical* learning is a weak form of policy learning, referring to a policy-making process that is based on technocratic search for more effective forms of policy intervention. This form of policy learning lacks fundamental discussion or adjustment of policy objectives and basic strategies (Fiorino, 2001; Gouldson et al., 2008; Hall, 1993). *Conceptual* learning is an intermediate form of policy learning. It is a process in which policy goals are redefined, problem definitions debated, and problem-solving strategies adjusted (Glasbergen, 1996). *Social* learning is the most advanced form of policy learning. Social learning emphasises the interplay between societal actors that improve policies (Glasbergen, 1996). It also emphasises cooperative relations among policy stakeholders and the collective responsibility for policy implementation (Fiorino, 2001; Glasbergen, 1996).

This conceptualisation of the progression from technical to conceptual and social forms of learning is highly relevant for a better understanding of how energy policy-making can be improved. This progression is key to energy transitions because it creates favourable conditions for the development of new policies which reflect significant departures from previous responses to public problems (Deyle, 1994). The literature also emphasises that policy learning relates not only to particular policies, but also to the institutions as well as visions, ideologies which guide the formulation, implementation, and evaluation of policies (Gouldson et al., 2008).

While the concepts of policy mixes and policy learning offer two important complementary perspectives of the interplay of policy processes and energy transitions, there are two important knowledge gaps. Firstly, although there are a variety of forms, motivations, and outcomes for implementing FiT policies, little research explores the extent to which and how FiT policies can effectively foster renewable developments from the analytical perspective of policy mixes. Second, policy mix studies often fall short of reflecting the complexity and dynamics of actual policy mixes, in particular the evaluation of the impacts of policy mixes (Rogge & Reichardt, 2016).

2.4. Towards an integrated framework: Linking renewable energy policies with policy mixes and policy learning

To partially fill the knowledge gaps, this study develops an integrated framework for evaluating the effectiveness of renewable energy policies from the perspectives of policy mixes and analysing the co-evolution of policy mixes and policy learning. Figure 1 shows our research framework as derived from the literature at the outset of our study.

Building upon Glasbergen's distinction of three orders of policy learning, technical, conceptual, and social, we assume that the policy mix, with its various policy instruments and approaches, can address a set of barriers as policy effects, and stimulate progress from technological learning to conceptual and social learning as effects of policy mixes on socio-technical systems. These policy processes are expected to be influenced by contextual factors including physical context (for example, topography, renewable resource availability and existing energy infrastructure), technology factors (such as cost of different renewable energy technologies, the maturity of the technology; the energy needs and demand profile), institutional and political contexts (including structure of the energy market, regulatory environment, laws, renewable energy policies especially incentives for renewable energy), and social context (such as culture with existing energy and other relevant institutions, trust, knowledge and skills available) (Hicks & Ison, 2018).

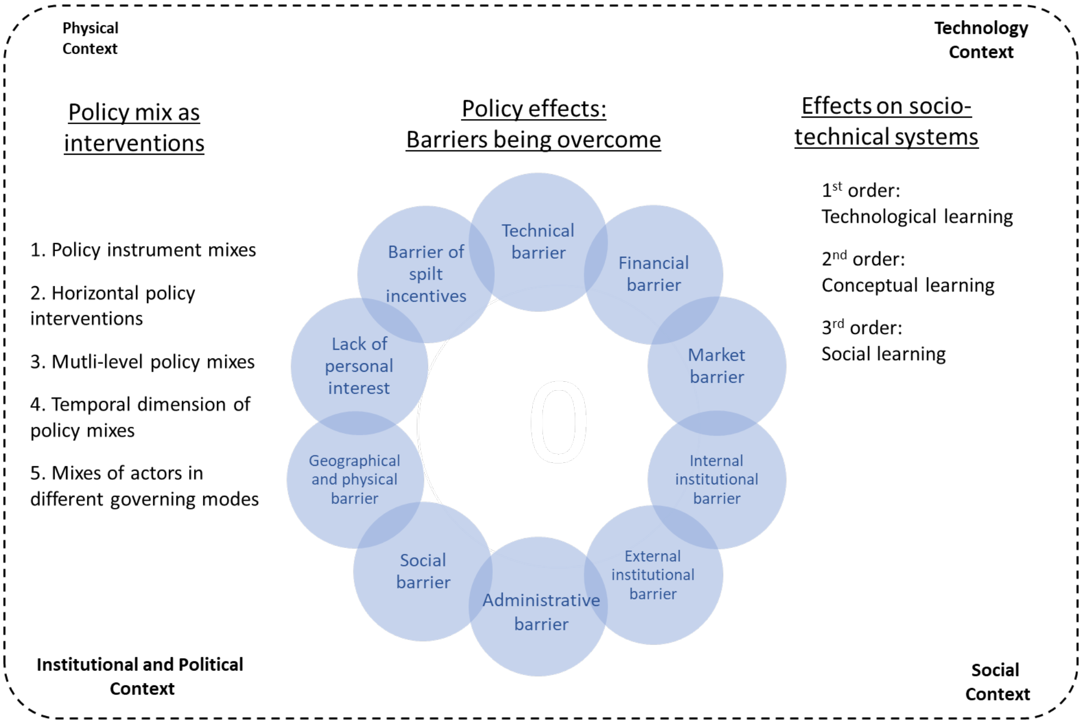

Figure 1. A conceptual framework for a policy-mix approach for energy transitions.

3. Methodology

This paper brings together the concepts of policy mixes and policy learning for guiding our analysis. This is a qualitative, single case study of the new FiT policy in Hong Kong, with a particular reference to the solar developments in two prospective solar communities. When compare with quantitative methodologies, a qualitative case study approach is well suited to examine the policy processes associated with the introduction of the FiT in Hong Kong because this method enables us to examine a phenomenon in greater depth, and is thus able to provide answers to 'how' and 'why questions (Yin, 2014).

In this case study of Hong Kong, two prospective solar communities, FP and HLY, are selected to examine the extent to which FiT could facilitate community solar development. FP and HLY worth study for two reasons. Firstly, the two case communities share several important favourable physical, and socio-economic conditions for large scale solar deployment. FP and HLY are both low density-communities characterised by: (1) semi-detached and garden housing design; (2) tilted rooftops with ceramic tiles and non-competing uses that can maximise sunlight exposure; and (3) relatively flat and widening terrains. Solar assessment results of the two communities, which is part of this larger project, as published elsewhere (Mah et al., 2020), found that the two case communities have rich solar resources. They alone have the potential to contribute to 1/10 of the government estimates of 660 MW of solar that could be realised by 2030. According to our GIS-based solar assessment (Table 5-2)**,** the projected annual solar energy potential of the entire FP community (including all 5,024 households) amounted to 42,138 – 44,424 MWh with an installed capacity of 42.5 MW, and the projected annual solar energy potential of the entire HLY community (including 1,190 households) amounted to 16,926 – 18,093 MWh with an installed capacity of 17.2 MW. To put these estimates into context, 42.5 MW + 17.2 MW = 59.7 MW, which is already equivalent to nearly 10% of the Hong Kong Government's estimate of 660 MW of solar that could be realised by 2030. Apart from the physical features, residents in FP and HLY have relatively high-income levels (Figures 3-1, 3-2 and 3-3). Secondly, based on previous local studies, some residents in these two case communities had expressed interests in installing solar PV on their rooftops before the introduction of the REFiT in late 2018, indicating their communities as potential first-movers responding to the new FiT Scheme (Mah et al., 2018). An overview of FP and HLY are provided in Table 2.

Figures 2a, 2b and 2c: Panoramic view of Fairview Park (FP; top left) and Hong Lok Yuen (HLY; top right); tilted rooftops with ceramic tiles of Hong Lok Yuen (HLY; bottom).
Photo credits: (left) Chun-hei Wong and Bethel High School (2017);[1] (right and bottom) Mondo Ching (2019).

[1] A drone video of Fairview Park: https://drive.google.com/file/d/1NdK4TzAMpo-zkS2aru00rGqTlVuUoPXb/view?usp=sharing (Source: Chun-hei Wong and Bethel High School)

Table 2: An overview of FP and HLY.

Case community	FP	HLY
Year of completion (1st phase)	Late 1970s	Early 1980s
Number of buildings	5,024 semi-detached houses	1,132 garden houses and 58 apartments
Number of Schools	3	1
Developer (Largest landowner)	Fairland Resources Limited (formerly Canada Overseas Development)	Hong Lok Yuen Estates Ltd
Unique geographical features	Adjoining Mai Po Inner Deep Bay Ramsar Site (Wetland of international importance)	Hilly landscape
Median monthly household income (Hong Kong median: HK$25,000)	HK$65,000	HK$121,160
Educational attainment (Highest level attended; % of residents)	Primary and below : 17.5% Secondary : 40.4% Post-secondary : 42.1%	Primary and below : 15.2% Secondary : 38.2% Post-secondary : 46.7%
Estimated solar potentials (assuming all rooftops are equipped with solar panels)[2]	42,138 – 44,424 MWh/year (240,811 m^2 estimated rooftop area; equivalent to annual consumption of about 12,800 – 13,500 3-person households)	16,926 – 18,093 MWh/year (97,544 m^2 estimated rooftop area; equivalent to annual consumption of about 5,100 – 5,500 3-person households)

Sources: Data compiled from the Deed of Mutual Covenant of Fairview Park, Fairview Park Property Management Ltd. (2017), "Hong Lok Yuen" 2011), LandsD (n.d.), and 2016 Population By-census (2016a).

This is a qualitative research that adopts a multi-method approach. In addition to an analysis of the literature and policy documents, we had three major sources of primary data: (1) in-depth semi-structured interviews, (2) stakeholder interviews, and (3) stakeholder workshops. Our heterogenous datasets enable us to examine household responses on community solar development before and after the launch of the FiT Scheme.

(1) Household interviews

We conducted 72 in-depth, semi-structured, face-to-face ex-ante interviews (43 FP and 29 HLY households) between August and September 2018 (before the enforcement of the FiT in October) and 6 ex-post follow-up interviews (2 FP and 4 HLY households) between January and June 2019 to collect supplement information. The full list of household interviewees is provided in Appendix 2a, b, and c, and the number of interviewed solar and non-solar households are provided in Appendix 3. Household interview questions comprised electricity consumption patterns, solar electricity generation information (if applicable), motivations, and perceived barriers to install solar panels. All interviews were conducted face-to-face (except

[2] See Mah et al. (2020) for detailed solar assessment results of FP and HLY.

for three which were conducted by telephone), audio-recorded and transcribed (except a few for which interview notes were taken instead of transcript where audio-recorded as not possible.

(2) Stakeholder interviews
This study conducted 5 in-depth, semi-structured, face-to-face ex-ante stakeholder interviews in August 2018; and 16 ex-post interviews between November 2018 to November 2019 to collect stakeholders' views. Stakeholders were carefully selected informants of Hong Kong FiT policy, comprising representatives from utilities, solar industry, two schools within FP,[3] the district councillor in FP,[4] MO, residents' associations, one NGO, and Heung Yee Kuk (a statutory advisory body for indigenous inhabitants in the New Territories). Stakeholders were invited to share views on the development of the FiT Scheme and the prospects of and barriers to community solar development. Interviews were conducted either face-to-face, by telephone or by emails, audio-recorded (for face-to-face interviews), and supplemented with transcripts or interview notes. The list of stakeholder interviews is provided in Appendix 2c.

(3) Solar community workshops
We conducted two half-day solar community workshops in FP in March 2019 and HLY in June 2019 respectively. The FP workshop was attended by 24 householders and eight stakeholders and the HLY workshop attended by 33 householders and nine stakeholders (Appendix 4).

The two workshops had two main objectives: firstly to understand householders's perceived barriers to solar adoption after the introduction of the FiT, and secondly how their vision, explore the feasibility, pros and cons on different scenarios of community solar development and provide suggestions (the analysis derived from this second part is reported in another publication).

4. The Hong Kong context

4.1. Energy mix and the electricity sector in Hong Kong

Hong Kong has been relying heavily on energy imports and fossil fuels (mainly coal and natural gas) in electricity generation. While Hong Kong obtained 99.8% of the primary energy sources by imports in 2015 (C&SD, 2016), coal (48%), natural gas (27%) and nuclear energy (around 25%) were the three major fuels in electricity generation (ENB, 2017). To reduce reliance on fossil fuels, Hong Kong aimed at reducing coal in the fuel mix from 48% in 2015 to 25% by 2050, and increasing natural gas from 27% in 2015 to 50% by 2050 (ENB, 2017). In the latest long-term decarbonisation strategy consultation, the options of importing more nuclear and RE from mainland China to offset the reduction in fossil fuels were opened up for public deliberation (Council for Sustainable Development, 2019). The current centralised electricity systems are run by two privately owned, vertically integrated utilities, China Light and Power (CLP) and Hongkong Electric (HK Electric) which operate as geographical monopolies. The two utilities are are governed by a regulatory framework known as the Scheme of Control Agreements (SCAs) (Mah et al., 2014).

[3] One school in FP and the school in HLY did not accept our interview invitations.
[4] The district councillor in HLY did not respond to our interview invitation.

4.2. Renewable energy policies in Hong Kong

The Hong Kong Government has started to introduce RE initiatives since the early 2000s. In 2002, the Electrical and Mechanical Services Department (EMSD) commissioned a study titled "Study on the Potential Applications of Renewable Energy in Hong Kong" and set one of the first RE targets for Hong Kong (EMSD, 2002). Since then, the Government has launched difference policies, including RE incentive factors under the Scheme of Control Agreements (SCAs; in 2008 and 2018) with the electricity companies (Figure 3).

In October 2018, the Government introduced its first major RE policy, the Hong Kong Government introduced its first major RE policy, the FiT, under the current SCAs with two electricity companies: First with CLP starting from October 2018 and HK Electric starting from January 2019 (HKSAR, 2017). In the Policy Address announced in the same year, the government committed to leading the development of renewable energy by introducing measures for private, public, and school sectors (LegCo, 2018b).

The FiT Scheme in Hong Kong has several design features as follows:

(1) A fixed-priced FiT with high FiT rates: The current FiT rate is between HK$3-5/kWh (USD0.38-0.64/kWh) in Hong Kong, depending on installed capacity; this is one of the highest rates among all former and existing FiT policies in the world.

(2) Gross metering: Hong Kong FiT Scheme adopts gross metering (paid for every unit of generated electricity) instead of net metering (paid for the excess electricity exported to the grid only) (EMSD, 2018c). All RE electricity generated under the FiT Scheme is directly transmitted to the grid rather than for self-consumption by the RE system owners.

(3) Duration of contract until 2033: Under the current SCAs, the FiT contracts between RE producers and utilities will expire in 2033. The maximum contract duration can be up to 15 years depending on the start date of the respective contract.

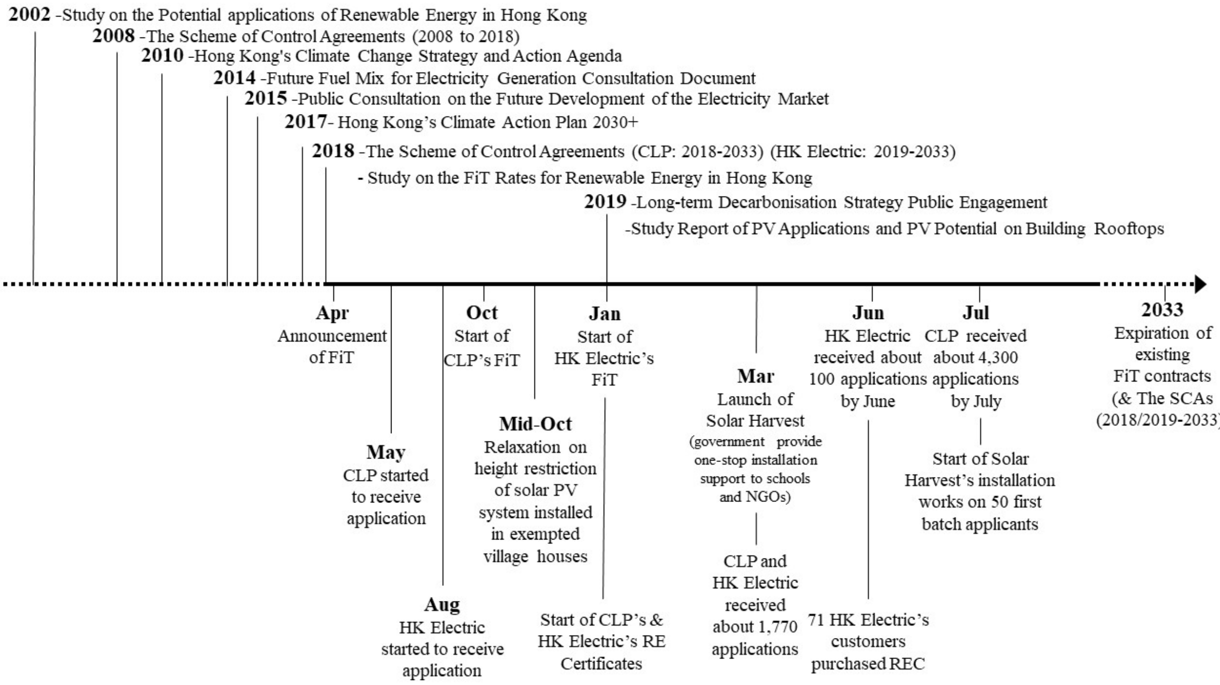

Figure 3: Timeline of the government's RE-related public consultations, studies, SCAs and the FiT Scheme. Sources: Data compiled from Chan (2019) and ENB and EMSD (2019).

4.3.The pre-FiT development of solar power in Hong Kong

In Hong Kong, solar PV has played a minor role in our energy sector. Before the implementation of the FiT Scheme, installed solar PV capacity contributed to about 0.05% of the total installed capacity in Hong Kong with a total installed capacity of no more than 6.29 MW in 2017. For electric generation, solar power has generated about 6,289 MWh of electricity, which is 0.014% of the total electricity use in 2016 (C&SD, 2019a; Meinhardt, 2019). There were approximately 155 solar PV projects in Hong Kong until 2014 (EMSD, 2018a, 2018b). Some of the major local solar projects before the FiT Scheme included a 1 MW solar PV system on Lamma Island, a rooftop solar PV system at the headquarters of the government's EMSD in Kowloon Bay, and the building-integrated PV systems in Wanchai Tower.

Hong Kong does face some major challenges in increasing its solar PV capacity: it is a highly urbanised city with a cityscape of high-rise buildings with limited roof space; costs are still a major concern as the public appears to be highly sensitive to tariff impacts associated with any supportive policies to solar (Lo et al., 2018; Mah et al., 2018). Recent studies suggest that the FiT policy in Hong Kong may be associated with public controversies in at least two areas: (i) how to set the pricing level and finance the subsidies so as to modulate electricity price increases, and (ii) FiT may not be effective if some other major non-cost barriers, including institutional and technical issues, are not addressed (for example, institutional arrangements need to be made to open up access to the grid to small scale energy producers (Mah et al., 2017a; Mah et al., 2017b; Mah et al., 2017c).

5. Findings and discussions

5.1. The FiT Scheme is an effective policy in addressing the economic barriers to renewable deployment, and has stimulated a substantial growth of new solar projects in Hong Kong

The FiT has stimulated *a substantial increase in new solar PV projects in the residential sector*. Before the launch of the FiT Scheme, there were only about 50 on-grid RE systems between 2008 and 2017, including 46 solar PV systems and four wind systems (LegCo, 2018a). Most of the pre-FiT solar projects in Hong Kong were non-residential projects in government buildings and schools with some in commercial buildings (Mah et al., 2018). The first year of the implementation of the FiT has recorded a substantial increase of new solar projects in Hong Kong. CLP and HK Electric have received a total of 5,317 FiT applications (by the end of September 2019), which is approximately 440 new applications per month in the first 12 months of the implementation of the FiT Scheme in Hong Kong. Those approved RE systems, which are mostly small-scale solar PVs, generated a total of 3,750,000 kWh of renewable electricity by the end of September 2019 (LegCo, 2019)(Interview S20)(Table 3).

Table 3: Breakdown of applications of the FiT Scheme and RE Certificates (as at end of September 2019).

	CLP	HK Electric
Overview of Feed-in-Tariff Scheme (FiT)		
Applications received	Over 5,200	110
Applications approved	4,513	73
Average time to process applications	Three weeks	Two weeks
Percentage of customers who have successfully installed RE systems and started receiving FiT	20%	40%
RE purchased (kWh)	About 3,500,000	About 250,000
FiT figures' breakdown by installed capacity		
≤10 kW	3,913	57
>10 kW to ≤200 kW	595	16
>200 kW	5	0
FiT figures' breakdown by building types		
Residential customers	83%	52%
Commercial and industrial customers	8%	24%
Schools	4%	17%
Other customers	5%	7%
Overview of RE Certificates		
Applications Received	143	113
Electricity sold (kWh)	Over 2,500,000	About 900,000[5]

Source: (LegCo, 2019) and Interview S20.

[5] This number includes the renewable energy generated by Lamma Winds project.

The Hong Kong FiT is highly effective in shortening the estimated payback period of solar PV projects, thus overcoming one of the major economic barriers to prospective solar households reported in local studies. Before the implementation of the FiT, the estimated payback period of a rooftop solar PV system of a typical exempted village house would be approximately 35 years in the absence of any governmental subsidies (Mah et al., 2018). After the introduction of FiT, taking into account FiT income, the payback period has been reduced to less than ten years in general (CLP, 2019). Among the interviewed householders who have joined the FiT, none of the estimated payback period of their solar investment is longer than ten years, ranging from three to eight years (Interviews: (H31) (F3, F44, F11, H30)).

Based on data derived from our semi-structured household interviews, most interviewed households perceived the FiT as an effective policy that could motivate them to install solar PV systems. About 55% and 63% of the interviewees in FP and HLY regarded FiT as effective in terms of motivating them to consider installing solar PV systems. Many stated that the FiT is an effective policy that can provide financial returns that cover their upfront costs, regarding the FiT as "the last push" needed for interested households to take action. This finding is consistent with data derived from stakeholder interviews.

5.2. Policy impacts of the Hong Kong FiT-related policy mixes were limited

Since the launch of the FiT Scheme in October 2018, the Hong Kong Government has subsequently implemented a number of complementary policies to support the development of renewable energy, indicating the use of policy mixes by the Hong Kong government. These complementary policies centered around the FiT include: the relaxation of the height limit for RE system installation on village houses, introduced in late 2018,[6] and the Solar Harvest Scheme – an initiative introduced in February 2019 that provides a one-stop service solar support scheme for subsidised schools and welfare NGOs.[7] A key question to be answer is: what are the effects of these mix dynamics of across policy instrument types on policy outcome in the form of renewable technology diffusions?

Our study found that the *FiT Scheme has not yet caused solar energy to become a mainstream form of energy* in Hong Kong. The total RE purchased by the two power companies under the FiT Scheme amounted to approximately 3,750,000 kWh as of the end of September, 2019 (3,500,000 from CLP; 250,000 from HK Electric) (Table 5-1), which is equivalent to approximately 0.0085% of the total electricity consumption in Hong Kong.[8] In our two case communities, solar householders are also low in number. As of November 2019, the numbers of solar applications in FY was only 41 households – a minute of 0.8% of the 5,024 households. About 20 applications in HLY represent approximately 2% of the 1,132 households there.

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[6] In order to encourage village houses to install RE system, the height limit for installing RE system has been relaxed from 1.5 metres from the roof level to 2.5 metres since late 2018 (EMSD, 2019a; LandsD, 2018). The exempted village houses in Hong Kong are regulated of maximum 3-storeys with total height not exceeding 27 feet (8.23 metres).

[7] In February 2019, Hong Kong Government announced the "Solar Harvest" Scheme to subsidise and assist schools and welfare NGOs to install small-scale solar photovoltaic (PV) system. The Scheme will conduct feasibility study of solar PV installation and system design, fully subsidise the installation costs of system under 10 kW and provide technical assistance to applicants. The applicants are urged to use the FiT income to finance RE system maintenance and repairing costs (EMSD, 2019b).

[8] 1% electricity consumption in Hong Kong is equivalent to approximately 440 million kWh (ENB, 2017).

New solar PV projects concentrated in pockets of sub-sets of the residential, school, and government sectors. Most of the new residential solar projects are in village houses, which can benefit from a relaxation of the height limit of solar system installations. *New solar projects in other residential areas, such as our two case communities, are however few* in number. The FiT and the Solar Harvest Scheme have led to a *surge of solar schools* in Hong Kong. The Solar Harvest Scheme has received approximately 210 applications in the first two rounds of applications, which closed in early April and at the end of May 2019 respectively. Approximately 50 of these applications have been approved with FiT. The FiT Scheme has received *modest responses from the business sector* (S15). *The RE Certificate Scheme* has received *lukewarm responses* from the market. Some companies were motivated to buy the RE certificates to fulfil their corporate social responsibility. But generally RE certificates as a market instrument to finance the FiT was ineffective due to its lack of attractiveness and competition of similar products from other regions to the private sector (S15).

5.3. The FiT was insufficient to address the multi-facet barriers faced by interested households

Despite the fact that the FiT was widely welcomed by the interviewed householders and workshop participants, there remained several major barriers to solar deployment in the two case communities. These include: technical, financial (economic), market, institutional (internal), institutional (external), administrative, and social barriers (Figure 4; Table 4a-d). Their views on the major barriers are illustrated as follows:

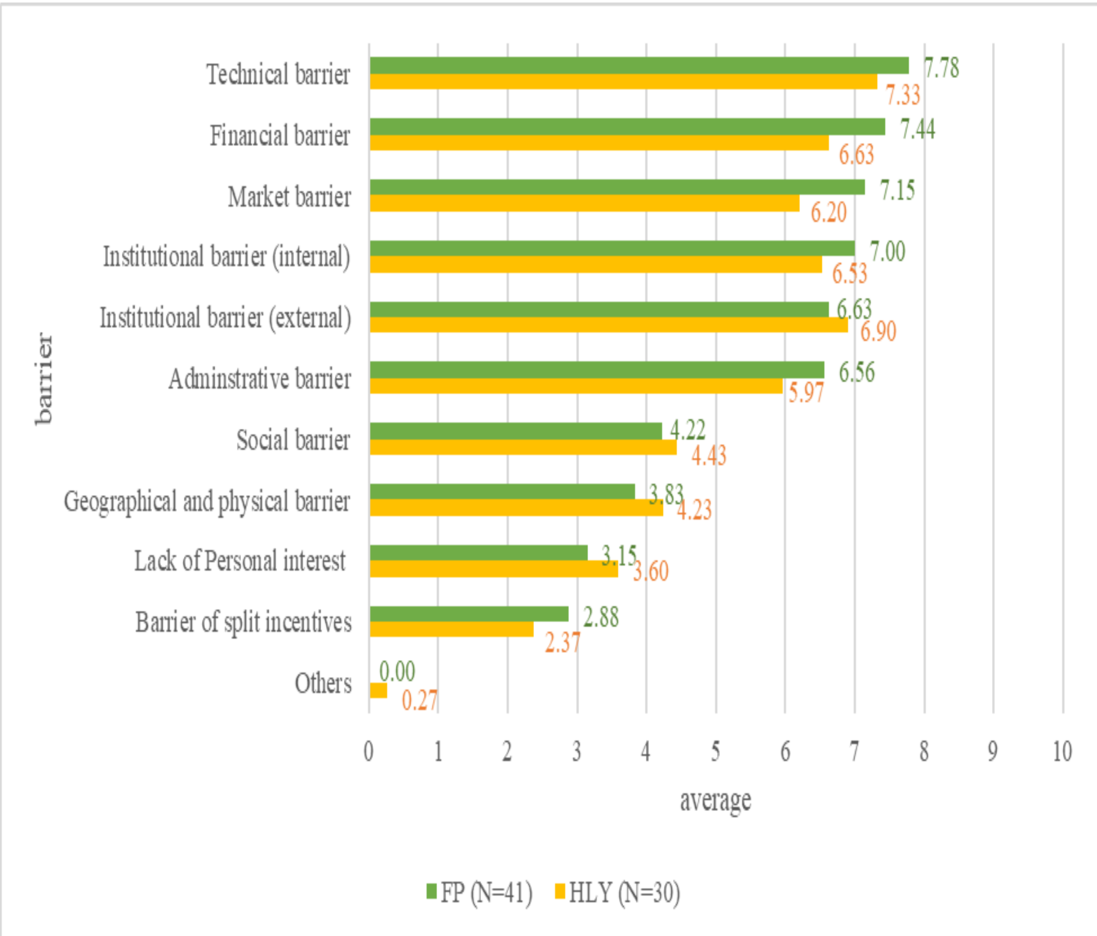

Figure 4: Perceived barriers from FP (n=41) and HLY (n=30) interviewees.

(1) ***Technical barriers.*** Technical barriers, such as water seepage and concerns regarding house structure, were highlighted by both case communities. Houses in FP were ageing and had water seepage issues even without solar PV installation (F40). Households were concerned about the time-consuming process involved in installation and the complicated maintenance process, not only "how" but also "who" could deal with the maintenance beyond the warranty (F35; H15). HLY households expressed concerns regarding scaffolding and the removal of roofing tiles during maintenance (H7; H8). Some were concerned about the ability of the PV panels to withstand typhoons. The efficiency and lifespan of current solar PV system were also questioned by the households. Other concerns included health issues arising from radiation and the potential fire hazard.

(2) ***Financial (economic) barriers***. In the absence of direct subsidies provided by the government, the FiT cannot fully address households' concerns over high upfront costs of solar PV systems. According to households and solar installers we interviewed (F3; S16), the upfront costs of residential solar PV systems ranged from HK$100,000 to 200,000 in FY, and from HK$300,000 to HK$500,000 in HLY (S17). Even with the introduction of the FiT, some interviewed households note that the payback period was generally too long for households. Interviewees also concerned about the additional costs for maintenance and repair (F26; F29; H24).

(3) ***Market barriers.*** A lack of market information, standardisation, accreditation of products, and insurance systems added to the market obstacles in both case communities. Some households reported that they could hardly find reliable contractors (H29; WF2). Some noted that they had encountered solar contractors who varied greatly in terms of the level of professionalism, including some who overstated the efficiency of PV systems, and some who were unfamiliar with the installation requirements imposed by MO and CLP (F5). Some worried that solar companies may not be able to deliver after-services when needed or may even close down (F21; F32; H13; WF3).

(4) ***Institutional barriers.*** Institutional barriers were found to be a critical factor affecting householders' decisions in regard to installing solar PV systems. Institutional barriers came from both internal and external sources associated with solar application and permitting procedures. Internally, MO were perceived by many interviewees and workshop participants as playing a passive, if not restrictive and inhibitive, role in regulating the installation of residential solar PV in the case communities. In FP, it took some eight months for residents to convince the MO to relax a condition stated in the MO's solar application form, which originally set a limit of the permitted rooftop solar panel area to only $4m^2$; this was regarded by some interested householders as a decision made by the MO out of ignorance of the solar technology (F3). Many interviewed householders perceived the MO as having authority over individual households to approve or reject a solar PV installation application with little justification (F8; F21; F32). Many interviewed households in FP and HLY also expressed their concerns that their solar PV installations would be deemed as illegal structure by the MOs.

Externally, utilities' permitting procedures were perceived to exert external institutional barriers. While the reported average FiT application processing time for CLP and HK Electric was about three weeks and two weeks respectively (LegCo, 2019), uncertainty over the time needed to make a successful application of grid connection was a significant factor in deterring interested householders from installing solar PV. Householders raised concerns over the lack of transparency and consistency in the permitting procedures, resulting in widespread uncertainty among prospective solar householders in our two case communities.

Interviewed householders raised the following specific concerns: (i) unexpected additional requests in system upgrades; (ii) case-by-case inspections (in some cases, utility and the solar installer would carry out more than 10 inspections); and (iii) case-by-case capacity reduction requests from the utilities contributed to the lengthy permission process. First, interviewed householders perceived that there to be a lack of transparency in utilities' inspection of technical issues such as system designs and household grid connection conditions. Our interviewees reported that the inspection could vary from two weeks to over four and a half months. Often, the utilities required solar household applicants to spend several additional months changing from single-phase to three-phase installation.[9] Second, some householders perceived that there to be a lack of consistency in utilities' inspection processes. One solar household interviewee mentioned that the utility staff members examined and inspected her solar PV installation as many as ten times before permitting the FiT contract (WH1). In addition, while utilities state that proposed projects need to fulfil technical and safety requirements (LegCo, 2019), some householders complained that the utility appeared to be arbitrarily "force" applicants to scale down their proposed installed capacity in order to obtain permission (WF3; WH5). This lack of transparency and inconsistency complicated and lengthened the application time and constituted a significant barrier to prospective solar households.

(5) ***Other barriers:*** Other concerns perceived by households included the social barrier of neighbours' complaints about solar PV panel reflection (F4; F40; H10). In HLY, potential aesthetic impacts of solar panels appeared to be a major concern. Many residents in HLY emphasised that some 1,000 rooftops covered by red ceramic tiles had contributed to a unique landscape that was highly valued by many residents; they were concerned that solar panels would spoil this valuable landscape (S12; WH3). A lack of personal interests in environmental action was also perceived as a barrier among the two case communities. Split incentives and *geographical and physical constraints* were barely mentioned by the households, due to the fact that most interviewees owned their own properties and the two case communities had prospective solar resources.

[9] Utilities' guidelines of customers' single-phase and three-phase installations: https://www.clp.com.hk/en/customer-service-site/open-and-close-account-site/meter-installation-guideline-site/Documents/GuideToSupplyMetering_(v8)_Eng_Final.pdf. In some cases, households are advised to change from single-phase to three-phase installation to ensure grid stability.

Table 4a: *Technical* barriers perceived by FP and HLY interviewees.

Technical Barriers	FP	HLY	Other stakeholders
Technical barriers:			
(a) Concern on water seepage and water proofing	- Risk of water seepage caused by installation [F1; F3; F9; F10; F13; F14; F16; F18; F19; F32; F40]	- Risk of water seepage caused by installation [H2; H3; H6; H13; H18; H19; S14] - Technical difficulties in simulating water seepage resistibility on tilted roof under heavy rain condition [WH2]	- Concern on water seepage by residents [S11]
(b) Concern on structural loading on roof	- Concern on the weakening of structural support with additional loading [F18; F40; F3; F12; F14; F22; F24; F26; F36; F40; F43]	- Concern on the weakening of structure with additional loading [H6; H7; H12; H13; H21; H22]	- Concern on the weakening of structure with additional loading [S11]
(c) Unknown in equipment efficiency and lifespan	- Uncertainty on the efficiency and lifespan of products [WF1] - Concern on substantial energy loss during transmission e.g. transformer required by utility companies as a safety measure had led to energy loss [F44]	- Uncertainty on the efficiency of products [H5; H3; H23; H24] - Perception that the current technology was of low efficiency [H20]	- Uncertainty on the lifespan of products [S15]
(d) Complexity in installation	- Perceived difficulty and lengthy process for installing solar PV system [F22; F12; F42] - Lack of understanding about the installation requirement [F25; F26]	- Perceived difficulty and lengthy process for installing solar PV system [H2; H14; H21; H27] - Lack of understanding about the installation requirement [H21]	/
(e) Complexity in maintenance	- Lack of understanding on the maintenance requirement [F6; F14; F35; WF3]	- Warranty was too short [H2] - Concern on the need for scaffolding, or damage of rooftop during maintenance [H6; H7; H8] - Lack of access or contact for technicians to maintain the system [H10; H15; H19; H28]	/
(f) Unknown in ability to withstand typhoon	- Risk of typhoon lead to concerns on: (1) destruction that may require additional repair [F3; F9; F23; F26; F28] (2) the legal responsibility on destruction [F27; WF2]	- Risk of typhoon lead to concern on: (1) destruction that may require additional repair [H13; WH1] (2) the legal responsibility on destruction [H18; H19]	- Increased risk of typhoon due to the relaxation of height limit for solar PV installation in exempted village houses [S8, S11]
(g) Degradation of current power supply quality	- Interruption or instability of electricity supply [F2; F28]	- Potential damage on the current electricity facilities [H19; H21]	/
(h) Concern on reflection	- Cause of nuisance from reflection [F4]	- Cause of nuisance from reflection [H10]	- Cause of nuisance from reflection [S11]
(i) Concern on radiation	- Health concern on the harmful radiation emitted from panel [F12; WF2]	/	/
(j) Concern on fire hazard	- Risk of fire hazard [F14; F28]	/	/
(k) Lack of waste treatment for solar panels	- Problem of waste pollution and lack of recycling system for abandoned solar panels [F20]	- Problem of waste pollution and lack of recycling system for abandoned solar panels [H28; WH2; WH4]	- Increase of solar panel waste due to the rapid technological improvement of panels' quality and lifespan [S1]

Table 4b: *Financial (economic) and market barriers* perceived by FP and HLY interviewees.

Financial and Market Barriers	FP	HLY	Other stakeholders
Financial (economic) barriers:			
(a) High upfront cost	- Quotation reached about $150,000 generally; acceptable cost was under $100,000	- Quotation might be up to $200,000; considered the installation as economically ineffective [H29]	/
(b) Long payback period	- 10 years was too long; expected payback in 5-6 years. - Possibility of moving out before getting the payback.	- 10 years was too long; expected payback in 3-5 years [H28] - Possibility of moving out before getting the payback.	/
(c) Uncertainty in maintenance and repair	- Concern on: (1) the frequency for maintenance or repair [F29] (2) the costs for maintenance and repair [F18; F39] (3) the additional costs to unknown risk (e.g. typhoon) [F26]	- Concern on the substantial costs [H2; H8; H22] - Unknown in maintenance and repair costs [H24]	/
(d) Lack of subsidies	- Lack of subsidies to support installation or maintenance [F6; F1]	- Lack of subsidies to support installation or maintenance [H12; H20]	/
Market barriers:			
(a) Lack of market information	- Lack of network or access to find contractors [F14; F16; F33] - Lack of contractors in the market [F19; F26; WF2]	- Lack of experienced professional technicians in market [H29; WH1] - Lack of time to search for contractors [H2] - Irresponsive contractors for enquiry [H2]	/
(b) Lack of standards	- Lack of standards for comparison [F18; F23; F25; F28] - Lack of proven track records of contactors [F3]	- Lack of proven track records of contactors [H16; H20]	- Variation of contractors' credibility in the bloom of contractors in market after the launch of FiT [S13] - Lack of expert knowledge to identify trustworthy contractors by the residents [S1]
(c) Immaturity of local market	- Unfamiliar with utilities' requirement of the contactors [F5] - Lack of credibility of contractors (e.g. some may exaggerate the system efficiency [F14]) [F41; F24; F14; WF3] - Concern on the close down of contractor firm [F21; F28; F30; F32; F3; WF2; WF3] - Pendency due to the expectation on product development and improvement in the near future [F27; F34; WF2]	- Lack of references or information about the quality of contractors [H4] - Lack of credibility of contractors [H31] - Lack of experience and knowledge to install solar panels of the contractors [H31] - Concern on the close down of contractor firm [H13; WH2]	- Huge variation of quotation given by contractors [S10] - Failure in keeping promise and meeting the installation standard of contractors [S13] - Lack of supervision of product quality at the importing stage [S1]
(d) Lack of insurance system	- Uncertainty on the availability of home insurance to cover the solar PV systems and the amount of additional insurance costs [F25; F21; F22]	- Uncertainty on the availability of home insurance to cover the solar PV systems [H22]	/
(e) Delay of financial sector – irresponsive to new market needs	/	/	- Excessively high entrance barriers for new market players to get loans [S8]
(f) Delay of innovation on product technology and market in Hong Kong	/	- Risk of typhoon and lack of new technology and construction method to withstand bad weather conditions [H31] - Absence of local market supply for some parts for solar PV system installation [H31]	/
(g) Delay of energy market reformation	/	/	- Levelised cost of solar energy too high while the cost of energy tariff from utility company low; not attractive to people to transit to solar energy. [S8]

Table 4c: *Institutional* barriers perceived by FP and HLY interviewees.

Institutional barriers (internal):			
(a) Restrictions on open space	- Bureaucratic obstacles e.g. car park could be a good site for a community solar project, but required "discretion" to be exercised by the Lands Department	- Lack of suitable open space [S12]	- Might require change in use from the Government for alternative use of open space [S9]
(b) Ambiguous regulations and guidelines from MO	- MO was passive in promote solar [F1; F6; F7; F8; F13; F20; F27] - Lack of standard from MO to justify decisions for approving/rejecting installation [F8; F21; F22; F28] - Complexity in application procedure [F32] - Strict regulations on illegal structures [F12; F35; F41; F43] - Irresponsive attitude of MO to the households' demand [WF1]	- Complication in DMC issue – required further clarification if the installation would change the appearance of roof (e.g. orange in colour) [H2; H17; H19; H29; WH1; WH4] - Lack of promotion and support from MO [H7; H10; WH1] - Expectation of disapproval by MO [H13; H16; H23; H24]	- Requirement of legal clarification on the DMC issue [S12]
Institutional barriers (external):			
(a) Lack of certainty and transparency in the permitting procedures from utility companies	- High uncertainty in the permitting procedures: (1) uncertainty in the purchase amount of RE electricity from utility companies (case-by-case without justification) [WF3] (2) uncertainty in CLP grid constraint and capacity [WF1] (3) uncertainty in the processing time required for application - Sluggish responses from CLP [F3; F6; WF3] [10]	- High uncertainty in permitting procedures: (1) uncertainty in the purchase amount of RE electricity from utility companies (case-by-case without justification) [H8; WH1] (2) uncertainty in CLP grid constraint and capacity to cater the need of community [H30; WH5] (3) uncertainty in the processing time required for application with limited staffs responsible for meter installation in the region [WH1] - Lack of justification for approval or rejection [WH5] - Problem in single phrase or three phrase electric power in the community [WH5]	- Uncertainty in the purchase amount of RE electricity from utility companies [S13] - Lack of justification for approval or rejection of the applied installation capacity [S8] - Slow responses for application [S8; S13]
(b) Uncertainty in illegal structure regulations	- Uncertainty if the installation will violate the illegal structure regulations [F2; F9; F21; F22; F23; F25; F27; F31; F36; F37; F38; F39] [11]	- Uncertainty if the installation will violate the illegal structure regulations [H2; H10; H11; H12; H13; H15; H22; H23; H26; H27] - Avoidance for troubles of discovering their illegal structures during installation [H31]	/
(c) Uncertainty in panel specification and installation standards	- Lack of standard on the specification and installation requirement of solar PV system [F2; F19; F22; F32; F38; F39]	- Lack of standard on the specification and installation requirement of solar PV system [H10]	/
(d) Lack of uniform regulations from different Government departments	- Example of potential community project in Shan Pui River: Lengthy application procedures to get concession of various government departments	- Complication on passing regulations from different departments (e.g. building regulations, fire regulations) [H3; H9; H25; WH1; H31]	- Complexity of bureaucracy [S9]
(e) Insufficiency of long-term sustainability plan in Hong Kong	- Lack of enabling sustainability target [F26; F35] - Uncertainty in the sustainability of FiT after 15 years (when SCAs expired) [F10; F14; F18; F30]	- Lack of enabling sustainability target [H10]	- Lack of Government promotion or sustainability target [S13]
(f) Monopolistic nature of the electricity market	/	/	- Concern on the fair judgement of approved installation capacity as utility also setup a subsidiary as a solar installer [S8]

[10] Some governments set up a renewable facilitation office to streamline application procedures.

[11] If alterations and additions to the existing building structure are involved to support the additional system components, prior approval and consent from the Building Authority under the Building Ordinance and Lands Department are required (EMSD, 2019c).

Table 4d: *Administrative, social and other barriers* perceived by FP and HLY interviewees.

Administrative barriers:			
(a) Lack of step-by-step guidance for FiT	- Confusion on: (1) application procedures [F8; F27; F39] (2) application time [F21; F41]	- Complexity in application [H9; H11; H20] - Confusion on: (1) application procedures [H23; H24] (2) application time [H2; H11; H14; H21; WH5] (3) application fee [H9]	/
(b) Uncertainty in the FiT contract	- Uncertainty in the sustainability of high FiT rate in the coming 15 years [F18; F22; F41; WF2] - Perception of 15-year FiT contract as too short [F30]	- Uncertainty in the sustainability of high FiT rate in the coming 15 years [H14; H24; H28] - Perception of 15-year FiT contract as too short [H11]	- Uncertainty in the continuity of FiT and its ability to influence the general public [S10]
Social barriers:			
(a) Complaints from neighbourhood	- Complaints on reflection [F4; F40] - Complaints on poor aesthetic [F20]	- Complaints on reflection [H10; H20] - Complaints on poor aesthetic [H14; H20] - Opposition out of cultural beliefs of dark coloured PV panel as unpropitious [WH3]	- Needs in balancing the view of solar and non-solar households [S12] - Growing complaining culture [S12] - Complaints on the aesthetic value and violation of DMC by some residents [S11]
(b) Lack of examples in the community	- Lack of proven cases of installation for peer learning [F9; F12; F19; F22]	- Lack of proven cases of installation for peer learning [H9; S12]	/
(c) Concern on privacy issue	/	- Risk of more outside workers coming into the community (especially with celebrities living in the community) [H10; S12]	/
Geographical and space constraint :			
/	/	/	/
Lack of Personal interest			
(a) Lack of motives to care about the environment	- Low priority for environmental action [F1; F14; F19; F39; F41]	- Low priority for environmental action [H16; H20; H26]	- Perceived minimal positive externality of installing solar PV to the environment and no responsibility to take green action [S10]
Split incentives:			
(a) Uncertainty in the continuity of investment and return of system as a tenant	/	- Possibility of moving out if owners did not renew the lease [H21]	/
Others:			
(a) Concern on aesthetic value	/	-Visual impacts of rooftop solar PV panels [WH3; WH5]	/

5.4. Evaluating Hong Kong's FiT policy: Insights from the perspectives of policy mixes and policy learning

The FiT policy was introduced in Hong Kong is the first major renewable policy ever introduced in this city, and as one of the most generous FiT system even at the global standards. Our case study found that the FiT was an effective policy in stimulating growth of new solar projects in Hong Kong, but the policy effects have been limited in a few specific sub-sectors, i.e. villages houses with rooftop spaces (rather that those with tile-roofs), and public schools in the educational sector. We found that solar PV has not yet been scaled up at the community and city levels. Our detailed study of the two prospective solar communities has shown that even though the two communities have very rich solar resources, prospective solar householders were confronted by multiple barriers, including financial, market, internal and external institutional barriers. The FiT policy has remained insufficient to address these barriers. How, then, can we make sense out of these observations?

By applying our integrated framework in this case study, we provide a critical evaluation of the impacts of the FiT policy in Hong Kong, and reflect on the explanations for the persistence of a wide range of barriers to solar adoption even the FiT policy is introduced.

5.4.1. Policy mixes that combined types of policy instruments made some, but limited progress in promoting solar adoption

Our framework suggests that policy mixes can occur in at least five forms. A combination of different types of policy instruments is one of the key dimensions. It is evident that the Hong Kong government has adopted a set of policy instruments to support the development of renewable energy. While the FiT itself is a typical economic instrument, a renewable certification (REC) system, a typical example of market-based instrument, has been introduced alongside the FiT. The REC is administrated by the two power companies through which the public purchase RE certificates at USD$.43 per 100 kWh to support renewable generation. The revenue from the sales of RE certificates is used to cover the additional costs borne by the two power companies in procurement of solar electricity.

In addition, since the launch of the FiT Scheme in October 2018, the Hong Kong Government has subsequently implemented a number of complementary policies to support RE development, most notably the relaxation of the height limit for renewable system installation on village houses, introduced in late 2018,[12] along with the Solar Harvest Scheme – an initiative introduced in February 2019 that provides a one-stop service solar support scheme for subsidised schools and welfare NGOs.[13] While the height relaxation is a typical example of a command-and-control measure, the Solar Harvest Scheme itself is a mix of economic measures (subsidies) and informational measures (as the Government provides a one-stop service for interested schools.

[12] In order to encourage village houses to install RE system, the height limit for installing RE system has been relaxed from 1.5 metres from the roof level to 2.5 metres since late 2018 (EMSD, 2019a; LandsD, 2018). The exempted village houses in Hong Kong are regulated of maximum 3-storeys with total height not exceeding 27 feet (8.23 metres).

[13] In February 2019, Hong Kong Government announced the "Solar Harvest" Scheme to subsidise and assist schools and welfare NGOs to install small-scale solar photovoltaic (PV) system. The Scheme will conduct feasibility study of solar PV installation and system design, fully subsidise the installation costs of system under 10 kW and provide technical assistance to applicants. The applicants are urged to use the FiT income to finance RE system maintenance and repairing costs (EMSD, 2019b).

As such, it is evident that policy mixes in terms of policy instrument types have been deployed by the Hong Kong government. The government has introduced economic incentives (the FiT); market-based policy (the REC); economic subsidies (to schools and NGOs; Solar Harvest Scheme); and command-and-control administrative measure (height relaxation for solar system installations in village houses) to promote solar uptake and RE development. It is also evident that horizontal policy mixes exist to a certain extent. The complementary measures of height relaxation applicable to exempted village houses and the Solar Harvest programme provide evidence of a mix of policies across policy domains of energy, housing and education. It is however important to note that there was indiscernible evidence of the deployment of the three other forms of policy mixes, the multi-level policy mixes, temporal dimensions of policy mixes, and the mixes of actors in different governing modes.

5.4.2. Policy learning

To what extent and how policy learning took place and influenced the efficacy of the renewable energy policies in Hong Kong? Reflecting Glasbergen's (1996) distinction between technical, conceptual, and social forms of learning, our case study of the FiT policy in Hong Kong showed that the policy makers in Hong Kong can attain technical forms of policy learning, but with limited forms of conceptual or social learning being pursued.

Based on the indicators showed in Table 5, it is evident that Hong Kong attained technical learning, and was able to progress to conceptual learning, but faced major constrains in advancing further to social learning.

Our study shows that *technical learning* was evident. Incremental changes in policy instruments and regulations were seen during the implementation of the FiT and other complementary measures, including the height relaxation of solar systems on exempted village houses indicates that there was technocratic search for policy instruments to address some economic and technical barriers to solar PV adoption in Hong Kong. The FiT effectively shortened the estimated payback period of household solar PV systems to less than 10 years, and has clearly raised our interviewed householders' interests in installing solar. The height relaxation promotes solar PV adoption in exempted village houses which might not otherwise be deployed as village houseowners would have preserved rooftop spaces for other uses such as air-drying laundry. However, many other remaining issues confronting prospective solar householders have remained unresolved by the FiT. There was limited evidence that problem definitions were carefully reviewed and redefined. In addition, exemptions for other potential solar PV applications in community settings, e.g. solar canopies in car parks have not been introduced. More harmonised regulations and supplementary rules are needed.

There is some, but rather limited evidence on the existence on *conceptual learning* during the implementation of the FiT in Hong Kong. The current FiT-oriented renewable policy has major limitation of lacking an explicit renewable target to guide the developments of renewable and to ensure policy sustainability. The government's Hong Kong Climate Action Plan 2030+ released in January 2017 only stated that Hong Kong had about 3-4% of realisable RE potential from wind, solar and waste-to-energy exploitable between 2017 and 2030, and 1-1.5% of Hong Kong's electricity consumption could be powered by solar (ENB, 2017). This government estimate is equivalent to about 440 – 660 million kWh which requires an installed capacity of about 440 – 660 MW of solar PV systems to generate.[14]

In a recent Legislative Council's document, the government states that in consideration of many technical and financial challenges regarding the scaling up RE deployment and the way in which there is limited local experience on FiT, "it is not yet appropriate to specify a target of RE (including that for solar energy) in the fuel mix for electricity generation at this stage" (LegCo, 2019).

Interviewees from households and utilities however converged on the concern of FiT policy sustainability in the absence of explicit target. Target was considered essential to lead strategic plan and actions for energy transition, which in return will help sustain FiT (F26, H10). Utility interviewee suggested that the absence of explicit RE target could not provide justification to households or even government itself to commit to RE development and energy transition in Hong Kong (S15).

Major rules and regulations governing the utilities (under the SCAs) and solar industry (such as performance recognition scheme) were not adjusted or introduced. The current SCAs ensure utilities to have an annual permitted return of 8% but only a small incentive to promote RE (extra permitted return for RE is capped at 0.055% per annum if all the RE performance is reached; HKSAR et al., 2018; LegCo, 2018a). There was no regulation on the utilities in handling FiT application, leading to uncertain and prolonged application processing time. There was little evidence in regulating the solar industry concerning solar installers' integrity and quality (H32). Overall, comprehensive adjustment on rules were needed in conceptual learning but currently missing.

In terms of social learning, there was some, but rather limited evidence of this advanced form of policy learning as social interactions with the policies have remained limited. The REC system and the Solar Harvest programmes were in fact important government initiatives on engaging the wider public in solar adoption: The REC system has been introduced to engage corporates as well as citizens who do not have rooftops to take part in the development of renewable energy. The Solar Harvest Scheme, on the other hand, is a government initiative on engaging the school sector in renewable development. However, the effects of the REC and Solar Harvest have been constrained to a large extent. The REC system as a market instrument has been widely perceived by industrial practitioners as ineffective to attract corporate subscribers due to its lack of attractiveness and competition of similar products from other regions to the private sector. Lukewarm resp□onses were also received from the general public in Hong Kong (Interview S20). Social interactions with the school sector have been limited so far as the hardware installation of solar PV systems has not yet been supported by educational toolkits which could fully capitalize the educational values of those solar PV systems in schools.

[14] We assume 1 MW of solar PV systems could generate 1 million kWh of solar electricity annually.

Table 5. An evaluation of the Hong Kong FiT from a policy learning perspective.

Areas of change	Indicators	Assessment	Illustrative examples
1st order: Technical learning	▪ A technocratic search for more effective forms of intervention/ policy instruments, but no adjustment of problem definition or policy objectives; ▪ Incremental changes (more harmonized regulations, more supplementary rules (Fiorino, 2001; Glasbergen, 1996)	◐	- Incremental regulatory changes: Relaxation of height for solar PV system installation on exempted village houses. But exemptions for other potential solar PV applications in community settings, e.g. solar canopies in car parks have not been introduced. More harmonised regulations and supplementary rules are needed.
2nd order: Conceptual learning (rules)	▪ Problem definitions are debated, policy objectives are redefined and strategies are adjusted ▪ More radical changes with more far-reaching impacts	◔	- No renewable energy target is set in Hong Kong, indicating there is a lack of strategic plan and political determination of the government to lead energy transition - No regulation on the utilities in handling FiT application, leading to uncertain and prolonged application processing time - No regulations or authentication on industry's quality resulted in mistrust - The sustainability of the policy is subjected to the SCAs. Households concerned that the policy may fade out after the end of current SCAs as utilities were perceived with no motive to continue the scheme
3rd order: Social learning	▪ Policy-making is based on social interactions, emphasising social contexts and social forces in shaping the policy process ▪ *The promotion of collective responsibility* for policy implementation	◔	- Market instrument presents with renewable energy certificates available to citizens but not popular - Solar schools under the Solar Harvest systems are not yet supported by educational tools which could have better capitalise the educational and social values of such solar PV systems in schools
	●: Strong evidence in policy learning ◐: Moderate evidence in policy learning ◔: Some, but rather limited evidence in policy learning ○: Indiscernible evidence in policy learning		

(Fiorino, 2001; Glasbergen, 1996; Gouldson et al., 2008; Mah & Hills, 2014)

6. Conclusions

This study examined the effectiveness of FiT from the perspectives of policy mixes and policy learning, with a particular reference to the developments of two prospective solar communities in Hong Kong. We contributed to the policy aspects of the energy transition literature by providing detailed insights into how relying on the FiT as the key single policy instrument has resulted in major constraints to address the multi-faceted barriers confronting prospective solar householders in the two case communities. We contributed to the literature in three important ways.

Firstly, by applying an integrated framework that integrates the concepts of policy mixes and policy learning, this study offered a systematic analysis on the multiple dimensions of policy mixes and how this understanding of the breath of policy mixes can explain the limitations of the FiT policy. Our case study of Hong Kong demonstrated that policy learning did exist in certain forms, but the limits of the deployment of policy mixes has constrained progression from technical learning to more advanced forms of policy learning, which subsequently resulted in the lack of effective policy interventions that are needed to overcome the barriers to solar deployment. We thus enriched the evaluative aspects of the emerging literature on policy mixes in the context of energy transitions (Rogge & Reichardt, 2016; Schmidt & Sewerin, 2018).

Secondly, this study contributed to a better understanding of the conditions under which policy learning may progress. Our integrated framework guided us to specify that learning has been constraints under three critical conditions. These include: (i) a lack of policy coherence between the national and city renewable energy targets: while the Chinese national government has set a **15%** renewable target (with an installed capacity of 680 GW) by 2020 and a **20% target** by 2030 (NDRC, 2016), the Hong Kong government has yet to set an explicit renewable goal; (ii) weaknesses in horizontal policy mixes, in particular in areas where institutional changes (for example, in the Scheme of Control Agreements) are needed; and (iii) a lack of conscious policy intervention to build synergies across multi-stakeholder efforts - as our case demonstrated that actors from the residential sector, business sector, and school sector have their own mechanisms to engage in solar deployment but their potentials, capabilities and resources are not linked up to create aggregate impacts. Our study thus contribute to the governance theme of the energy transition studies that focuses on conceptualising the enabling conditions and mechanisms of building governing capacity for energy transitions (Lange et al., 2018; Vogelsang-Coombs & Miller, 1999).

Our findings reflect the specific features of Hong Kong and of the two case communities selected. But we argue that these are important observations that are highly relevant to the broader debates on the policy dimensions of socio-technical energy transitions. Our findings can be generalized to at least some extent to other leading cities in Asia such as Seoul and Tokyo which shares some similarities in addressing energy challenges in terms of for example the uncertainties associated with electricity market reforms, and the tensions between national and city policy dynamics (Mah, 2020; Tsai, 2016).

Our findings suggest that we need to reflect on how city government could handle the need for policy learning for the development of effective renewable energy policy mixes. Three policy recommendations can be derived as follows:

Firstly, city governments need to give sufficient attention to the importance of target setting to provide guidance for urban solar developments. Whilst the Hong Kong Government does not currently have a RE (including solar) target. In our study, interviewees from households and other stakeholder groups converged on the concerns about FiT policy sustainability in the absence of explicit targets. Targets were considered essential to leading strategic plans and actions in terms of an energy transition, which in return would help sustain policy continuity.

Secondly, city governments need to deploy an intelligent mix of policy instruments beyond the FiT to effectively address the multiple barriers faced by prospective solar householders. Feed-in tariffs have been found as one of the most effectively RE policies but their actual implementation and policy effects often varies in different context. In Hong Kong, we found that the FiT was effective, but only to a limited extent. Many prospective solar householders in our two case communities have adopted a wait-and-see attitude as their multiple barriers have remained largely unresolved. Together these barriers are stalling progress on solar deployment in these prospective solar communities. The government therefore needs to give closer attention to policy mixes and a comprehensive, rather than the choice of a single "most effective" policy instrument as this probably does not exist because of the complexity of steering energy transitions through policy. It is important for the government to use the combinations of policy instruments, mobilise different stakeholders, and to consolidate synergies to improve policy effectiveness.

Thirdly, city governments need to redefine the roles of incumbent utilities in order to enable cities to utilise community solar as a viable resource to meet decarbonisation targets. Our case study of Hong Kong suggests two key areas that worth particular attention are: (i) reconsidering the roles of incumbent utilities as the primary agents for solar deployment; and (ii) revamping regulatory frameworks to ensure utilities are incentivised to develop new business models which could better accommodate large-scale uptake of decentralised energy sources.

This study has some limitations which represent potentially fruitful areas for future research. Our study provides initial insights into how policy mixes can create conducive conditions for the advancement of policy learning from technical to conceptual and social learning. But it remains unclear to what extent and how policy makers can be competent to develop and deploy a coordinated policy mix as a means to improve policy processes and outcomes. Future research that examines the changing roles of city governments in how city governments in response to the growing need for policy learning in the context of energy transitions.

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Appendix 1: Solar Profiles in Major Cities in the World

	London (UK)	**Munich (Germany)**	**Berlin (Germany)**	**New York City(US)**	**Sydney (Australia)**	**Kyoto (Japan)**	**Tokyo (Japan)**	**Seoul (South Korea)**	**Foshan (China)**	**Hong Kong**	**New Taipei**
Population by city (2016)	8,799,000	1,543,000	3,671,000	8,538,000	4,824,000	1,475,000	13,636,000	9,806,000	7,463,000	7,336,600	3,979,208
Global rank of GDP by country (2017)	5th	4th	4th	1st	13th	3rd	3rd	12th	2nd	2nd (HK: 33rd)	22nd
GDP by country (2017; in billion US$)	2,622	3,677	3,677	19,390	1,323	4,872	4,872	1,531	12,238	12,238	591
GDP (City) (in billion US$)	592 (2016)	121 (2016)	149 (2016)	657 (2016)	306 (2017)	97 (2015)	946 (2016)	298 (2016)	121 (2016)	318 (2016)	118 (2016)
National level socio-economic and political features	Central government can dictate local governance activities	Local states have the right of “self-government”	Local states have the right of “self-government”	Democratic country and states retain certain level of sovereignty	Democratic country similar to the UK system	Democratic country; Post-Fukushima energy landscape	Democratic country; Post-Fukushima energy landscape	Democratic country that has a long history of military dictatorship	Centralised, authoritarian country	Democratic legislative system under the sovereignty of China	Democratic legislative system
Global rank of GHG emissions by country (2014)	17th (494 $MtCO_2e$)	10th (817 $MtCO_2e$)	10th (817 $MtCO_2e$)	2nd (6,319 $MtCO_2e$)	16th (523 $MtCO_2e$)	8th (1,322 $MtCO_2e$)	8th (1,322 $MtCO_2e$)	13th (632 $MtCO_2e$)	1st (11,601 $MtCO_2e$)	1st (11,601 $MtCO_2e$)	31st (286 $MtCO_2e$)
Electricity markets	Liberalised	Liberalised	Liberalised	Liberalised	Liberalised	Deregulating	Deregulating	Deregulating	Deregulating	Regulated	Partly Liberalised
Solar targets by city	2 GW by 2050	100% renewable energy by 2025	Solar power cover 25% of electricity supply (assumed by 2030)	1,000 MW by 2030	30% renewable energy by 2030	475 GWh from residential solar PV by 2020	1.3 GW by 2030	1 GW by 2022	1.5 GW by 2020	N.A.	50 MW by 2024
No. of residential solar PV prosumers by country	755,000 (2015)	1,396,000 (2015)	1,396,000 (2015)	1,300,000 (2016)	1,937,000 (2018)	2,053,000 (2016)	2,053,000 (2016)	34,000 (Seoul only, 2017)	464,758 (2017)	N.A.	N.A.
Solar installation capacity by city	116.9 MW (2017)	59.1 MW (2017)	76 MW (2015) 106 MW (2018)	96 MW (2016)	12 MW (2018; City of Sydney District)	136 MW (June 2019)	540 MW (June 2019)	73 MW (2016)	13.64 MW (2018; Chencheng Disrtrict)	6.29 MW (2017)	760 kW (2016)
Solar community engagement approaches/ City Solar Initiatives (selected examples)	• Neighbourhood solar cooperative • Solar empowerment zone • Renewable energy provider	• Solar urban planning as the government tool	• NGO-led energy cooperatives	• Solar empowerment zone • Microgrid energy trading platform • Solar partnership between	• National policy support under Mandatory Renewable Energy Target • Pilot p2p energy trading platform	• Government initiated and developer-driven prosumer development integrated with smart homes • Keihanna new city as site for	• Government initiated and developer-driven prosumer development integrated with smart homes	• Grassroots prosumers’ communities promoted by city government • Community coupon scheme for energy trading	• Entrepreneurial cooperation in prosumer development facilitated by local government • Urban village as base for solar community	• One of the highest Feed-in tariff policies around the world Renewable energy certificates	• Government “Solar Community” with subsidies • Private solar investment platforms (e.g. Finmart, Sunnyfounder) • Successful experience on

	exchange platform			government and university		solar prosumers • Government-led Keihanna Science city as a demonstration project for smart solar prosumers		between prosumers and consumers • WATTMALL, a community-based energy trading market (a social enterprise)	• Multi-level feed-in subsidies make economic senses for solar households • Integrity Management System for solar PV industry		“Participatory Budgeting for Power Saving” in New Taipei
Tentative case communities	Case community 1: Brixton, London	Case community 1: Freiham Nord Munich	Case community 1: Fuldastraße 26-30 and Ossastraße 30-33 (BürgerEnergie Berlin)	Case community 1: Parkchester, Bronx (Altus Bronx Community Solar Farm)	Case community 1: Inner West Community Energy	Case Community 1: Seikadai (精華台; government-led high income smart solar community demonstration) Case Community 2: Hikaridai (光台; residential-commercial mix of solar houses and solar shops)	Case community 1: Tama Empower	Case Community 1: Sungdaegol (Local P2P energy trading platform; active energy co-operatives promoting solar prosumption Case Community 2: Sindaebang Hillstate Apartment (Apartment-type Energy Self-Reliant Village)	Case Community 1: Luonan Village (Strong leadership through Village Committee) Case Community 2: Dengxi Village (Market driven)	Case Community 1: Fairview Park (5,000 flats high income low-rise housing estate with rich solar resources) Case Community 2: Rhythm Garden (Apartment-type solar community with some 900 panels under strong leadership of Management Office and active residential participation)	Case Community 1: Fengjingcuifeng Community (峰景翠峰社區; Old apartment-type smart solar prosumers community) Case Community 2: Banqiao Fuzhou Social Housing (板橋浮洲合宜住宅; New apartment-type eco-community with rooftop solar)

Sources:
London (Department for Business. Energy & Industrial Strategy, 2018; Ferris, 2017; Fuller & Bulkeley, 2014; London Datastore, 2019; Mayor of London, 2018)
Munich (CITIVAS, 2017; City of Munich, 2019; City of Munich Department of Labor and Economic Development, 2019; Lobaccaro et al., 2019; MunichNOW News, 2016)
Berlin (Agency for Renewable Energies, n.d.; BürgerEnergie Berlin, 2019; Senate Department for the Environment Transport and Climate Protection, n.d.; Senate Department for Urban Development and Housing, 2016; Statistics Berlin Brandenburg, 2018; Transport and Climate Protection Public Relations, 2019a, 2019b)
New York City (Bureau of Economic Analysis, 2019; Li et al., 2018; NYC, 2016; Office for National Statistics, 2019; Sisson, 2019)
Sydney (Australian Bureau of Statistics, 2017; Australian Government, 2018; City of Sydney, 2017; Derksma, 2018; Inner West Community Energy, 2019; SGS Economics and Planning, 2018)
Kyoto (Energy Policy Division of Environment Bureau, 2015; Kyoto City Official Website, 2019; Kyoto City Statistical Analysis, 2019; Masukawa, 2018)
Tokyo (Environmental Policy Section General Affairs Division, 2018; Furuya, 2017; Tokyo Metropolitan Government, 2017)
Seoul (Chung, 2017; Kim, 2017a; Korean Energy Economics Institute, 2017; Seoul Open Data Plaza, 2019; Statistic Korea, 2017)
Foshan (Chancheng Development Planning and Bureau of Statistics, 2019; Chinese Energy Net, 2018; Foshan City Bureau of Statistics, 2018; Foshan Industry and Information Technology Bureau, 2017; Office of Foshan People's Government, 2014)
Hong Kong (2016 Population By-census, 2016b; C&SD, 2019b; Meinhardt, 2019)
New Taipei (Department of Civil Affairs New Taipei City Government, 2019; Department of Civil Affairs Taipei City Government, 2016; Directorate-General of Budget Accounting and Statistics Executive Yuan, 2017; Economic Development Department, 2016, 2019; Lai, 2019; Lam, 2019; Secretariat Taipei City Government, 2019; Taiwan Environmental Protection Administration, 2017)
Others (Agency for Natural Resources and Energy, n.d.; European Commission, 2017; Federal and State Statistical Offices, 2019; National Statistics, 2019; World Bank, 2018; World Resources Institute, 2017)

Appendix 2: List of interviews

All the interviewees agreed to be interviewed anonymously and all interviews were indicated by numbers. The semi-structure interviews were conducted in both face-to-face and telephone format. Some of the interviews were useful to provide insights to the authors but might not be referenced in the main content. The order of the interviews is arranged in chronological order of interview date.

Appendix 2a: A list of household interviews in Fairview Park

Code of interview	Number of interviewee(s)	Format of interview (F: Face-to-face; T: Telephone)	Date of interview	Duration of interview (approximately)
F1	2	F	23 Aug 2018	1 hour 30 minutes
F2	1	F	23 Aug 2018	1 hour 30 minutes
F3#	2	F	23 Aug 2018	1 hour 30 minutes
F4	1	F	25 Aug 2018	1 hour
F5	1	F	27 Aug 2018	45 minutes
F6	1	F	28 Aug 2018	1 hour 45 minutes
F7	1	F	2 Sep 2018	45 minutes
F8	1	F	8 Sep 2018	45 minutes
F9	1	F	8 Sep 2018	1 hour 30 minutes
F10	1	F	8 Sep 2018	45 minutes
F11	1	F	10 Sep 2018	45 minutes
F12	1	F	10 Sep 2018	30 minutes
F13	1	F	10 Sep 2018	30 minutes
F14	1	F	12 Sep 2018	1 hour 15 minutes
F15	1	F	15 Sep 2018	30 minutes
F16	1	F	15 Sep 2018	45 minutes
F17	1	F	15 Sep 2018	45 minutes
F18	1	F	15 Sep 2018	45 minutes
F19	1	F	20 Sep 2018	1 hour 45 minutes
F20	1	F	21 Sep 2018	1 hour
F21	1	F	22 Sep 2018	1 hour 30 minutes
F22	1	F	22 Sep 2018	1 hour
F23	1	F	22 Sep 2018	1 hour
F24	1	F	22 Sep 2018	1 hour 30 minutes
F25	1	F	22 Sep 2018	1 hour
F26	1	F	22 Sep 2018	45 minutes
F27	1	F	23 Sep 2018	45 minutes
F28	1	F	23 Sep 2018	1 hour
F29	1	F	23 Sep 2018	1 hour
F30	1	F	27 Sep 2018	1 hour 15 minutes
F31	1	F	27 Sep 2018	45 minutes
F32	1	F	27 Sep 2018	45 minutes
F33	1	F	29 Sep 2018	1 hour 30 minutes
F34	1	F	29 Sep 2018	45 minutes
F35	1	F	29 Sep 2018	45 minutes
F36	1	F	29 Sep 2018	1 hour
F37	1	F	29 Sep 2018	1 hour 15 minutes
F38	1	F	29 Sep 2018	45 minutes
F39	1	F	29 Sep 2018	45 minutes
F40	1	F	30 Sep 2018	45 minutes

F41	2	F	30 Sep 2018	1 hour
F42	1	F	30 Sep 2018	45 minutes
F43	1	F	30 Sep 2018	1 hour 15 minutes
F44#	2 *same interviewees as in interview F3	F	23 Jan 2019	45 minutes
F45#	1	F	7 Apr 2019	1 hour

Appendix 2b: A list of household interviews in Hong Lok Yuen

Code of interview	Number of interviewee(s)	Format of interview (F: Face-to-face; T: Telephone)	Date of interview	Duration of interview (approximately)
H1	1	F	25 Aug 2018	30 minutes
H2	1	F	30 Aug 2018	1 hour
H3	1	F	30 Aug 2018	45 minutes
H4	1	F	31 Aug 2018	30 minutes
H5	1	F	31 Aug 2018	45 minutes
H6	1	F	1 Sep 2018	1 hour 15 minutes
H7	1	F	1 Sep 2018	1 hour 15 minutes
H8	1	F	1 Sep 2018	1 hour
H9	1	F	1 Sep 2018	1 hour
H10	1	F	5 Sep 2018	1 hour 30 minutes
H11	1	F	5 Sep 2018	1 hour
H12	1	F	8 Sep 2018	45 minutes
H13	1	F	8 Sep 2018	30 minutes
H14	1	F	8 Sep 2018	1 hour
H15	1	F	9 Sep 2018	45 minutes
H16	1	F	9 Sep 2018	1 hour
H17	1	F	9 Sep 2018	1 hour
H18	1	F	9 Sep 2018	1 hour
H19	1	F	10 Sep 2018	45 minutes
H20	1	F	10 Sep 2018	1 hour 15 minutes
H21	1	F	10 Sep 2018	45 minutes
H22	1	F	15 Sep 2018	1 hour
H23	1	F	15 Sep 2018	45 minutes
H24	1	F	22 Sep 2018	1 hour
H25	1	F	22 Sep 2018	1 hour 30 minutes
H26	1	F	23 Sep 2018	1 hour
H27	1	F	29 Sep 2018	30 minutes
H28	1	F	30 Sep 2018	1 hour 15 minutes
H29	1	F	30 Sep 2018	1 hour
H30	1 *same interviewee as in interview H10	T	28 Jan 2019	45 minutes
H31#	1 – household & 2 – solar contractors	F	6 May 2019	45 minutes
H32#	1	T	23 May 2019	30 minutes
H33#	2	F	22 June 2019	1 hour

#Households installed **solar PV system** before or during the study period.

Appendix 2c: A list of interviews with stakeholders

Codes of interview	Descriptions	Format of interview (F: Face-to-face; T: Telephone; E: Email Converation)	Date of interview	Duration of interview (approximately)
S1	A general manager of a utility company	F	21 Aug 2018	50 minutes
S2	An assistant of a district councilor in Yuen Long	F	23 Aug 2018	1 hour
S3	A principal of a non-solar school in Fairview Park	F	27 Aug 2018	1 hour
S4	A teacher of a non-solar school in Fairview Park	F	28 Aug 2018	1 hour 30 minutes
S5	An assistant general secretary of an NGO	F	30 Aug 2018	1 hour
S6	A director of a solar PV contractor company	T	27 Nov 2018	30 minutes
S7	A manager of a property management company	F	3 Dec 2018	30 minutes
S8	A managing director of a solar contractor company	F	11 Jan 2019	1 hour 30 minutes
S9	A manager of property management company in Fairview Park	T	16 Jan 2019	30 minutes
S10	A district councilor of Yuen Long	F	23 Jan 2019	1 hour 30 minutes
S11	A chairman of an Owners' Association in Hong Lok Yuen	T	21 Feb 2019	50 minutes
S12	A manager of property management company in Hong Lok Yuen	F	15 Apr 2019	1 hour 15 minutes
	A staff of property management company in Hong Lok Yuen			
S13	A member of Heung Yee Kuk	F	3 May 2019	1 hour
S14	A chairman of a solar PV contactor and distributor	F	6 May 2019	1 hour 30 minutes
	A project director of a solar PV contactor and distributor			
S15	A general manager of a utility company *same interviewee as in interview S1	T	2 Aug 2019	2 hours 30 minutes

S16	A project manager of a solar PV contractor company	T	20 Nov 2019	30 minutes
S17	A chairman of a solar PV contactor and distributor *same interviewee as in interview S14	T	21 Nov 2019	30 minutes
S18	A Planning Manager of a Utility Company	E	25 Nov 2019	N.A.
S19	A manager of property management company in Fairview Park	E	26 Nov 2019	N.A.
S20	A general manager of a utility company *same interviewee as in interview S1	E	28 Nov 2019	N.A.
S21	A manager of property management company in Hong Lok Yuen *same interviewee as in interview S12	T	28 Nov 2019	15 minutes

Appendix 3: An overview of the interviewed households in FP and HLY.

Case community	FP	HLY
Number of interviewed *non-solar* households	42	29
Number of interviewed *sola*r households	2	3

Note: One FP and one HLY households were interviewed twice.

Appendix 4: A list of sessions of the two community workshops.

All the workshop participants agreed to join discussion anonymously. Their discussion were numbered and arranged according to the workshop sessions. Some of the discussion were useful to provide insights to the authors but might not be referenced in the main content.

Codes of sessions	Descriptions	Date of sessions	Duration of sessions (approximately)
WF1	Fairview Park Solar Community Workshop - Small Group A Discussion	23 Mar 2019	1 hour
WF2	Fairview Park Solar Community Workshop - Small Group B Discussion		1 hour
WF3	Fairview Park Solar Community Workshop - Small Group C Discussion		1 hour
WF4	Fairview Park Solar Community Workshop - Plenary Discussion		1 hour 15 minutes
WH1	Hong Lok Yuen Solar Community Workshop - Small Group A Discussion	1 Jun 2019	1 hour
WH2	Hong Lok Yuen Solar Community Workshop - Small Group B Discussion		1 hour
WH3	Hong Lok Yuen Solar Community Workshop - Small Group C Discussion		1 hour
WH4	Hong Lok Yuen Solar Community Workshop - Small Group D Discussion		1 hour
WH5	Hong Lok Yuen Solar Community Workshop - Plenary Discussion		1 hour