Article

Conceptualizing Niche–Regime Dynamics of Energy Transitions from a Political Economic Perspective: Insights from Community-Led Urban Solar in Seoul

Daphne Ngar-yin Mah 1,2 and Darren Man-wai Cheung 1,2,*

1 Department of Geography, Hong Kong Baptist University, Hong Kong, China; daphnemah@hkbu.edu.hk
2 Asian Energy Studies Centre, Faculty of Social Sciences, Hong Kong Baptist University, Hong Kong, China
* Correspondence: dmcheung@hkbu.edu.hk

Received: 26 March 2020; Accepted: 21 May 2020; Published: 12 June 2020

Abstract: The complex dynamics between technological niches and regime “lock-in” are critical in determining the pace and outcomes of energy transitions. The socio-technical transitions literature has received growing scholarly attention, but it lacks consideration of the broader political and economic contexts. This paper aims to advance understanding of socio-technical transitions by conceptualizing niche–regime dynamics from a political economic perspective, with reference to a case study of solar in Seoul. Based on in-depth face-to-face interviews with 18 key stakeholders, we have three findings. Firstly, the politico-economic contexts have created an embedded environment in which five factors have a clear influence on niche–regime dynamics. Secondly, the politico-economic contexts created conducive conditions for niche developments on the one hand, but, on the other hand, have created inhibitive conditions that have cancelled out the positive forces and reinforced “lock-in”. Thirdly, the processes occur at multi-scalar levels: Community solar niches in Seoul are conditioned by the broader politico-economic contexts at city and national levels. We conclude that sufficient policy attention should be given to the political economy of a national energy system in order to create conducive conditions for community-led niches to realize the full potential that they could offer in energy transitions.

Keywords: niche–regime dynamics; socio-technical energy transitions; community-led urban solar; political economic perspective; lock-in; South Korea

1. Introduction

Low-carbon and energy innovations have proliferated in national and sub-national levels all over the world. Among these initiatives, urban solar photovoltaic (PV) developments in cities such as Seoul, London, and New York City have experienced major progress as solar PV costs continue to decline and policy-makers seek cost-effective post-Fukushima energy strategies. The Solarize NYC program in New York City [1] and the 2022 Solarcity Plan in Seoul [2] are examples showing that solar has become a core element of cities’ sustainability and energy plans.

These recent solar developments have increasingly shown that cities are key sites of transitions [3–6]. An extensive body of energy studies has already found that renewable energy (RE) has the potential to break the lock-in and achieve deep decarbonization targets required to avoid catastrophic climate impacts [7,8]. How and the extent to which these urban solar developments emerge, scale up, diffuse, and compete with traditional fossil fuel/nuclear energy options has, however, remained under-studied.

Transitions studies have grown rapidly in the last decade, shedding light on the complex interplay of socio-technical aspects of energy transitions. Transitions theorists argue that energy transitions can be delivered only if there is a co-evolution of technology, policy, infrastructure, scientific knowledge,
social, and cultural practices in order to foster niche formation and regime destabilization [9]. A major limitation of transitions studies is, however, a lack of consideration of the political dimensions.

Political economy analysis is increasingly utilized by transitions theorists seeking to understand the politico-economic factors of embeddedness situations in transitions (e.g., [10]). Recent developments on the “Yellow Vests Movement” in France [11] and the “Green Growth National Strategy” of South Korea [12] suggest that the broader political and macro-economic contexts can influence energy transitions in both negative and positive ways, and the outcomes cannot be ascertained and require further study.

This study aims to understand and explain the complex interactions between socio-technical energy niche building, scaling up of niche innovation, regime destabilization, and lock-in from a multilevel perspective (MLP) expanded with political economic perspective, utilizing community solar in Seoul as an empirical case. The main research question is: How do the politico-economic contexts of South Korea create conducive and inhibitive conditions for the niche development of urban solar in Seoul? We argue that the Seoul model has made progress only in technological niches with some emerging developments towards market niches, but is far away from initiating regime shifts under the confluence of conducive and inhibitive conditions at the national, city, and community levels.

This case study of urban solar in Seoul is not meant to be representative of all of South Korea. Rather, it is a significant case providing a detailed account of energy transition pathways and mechanisms within the national socioeconomic and political contexts. Seoul has a policy tradition in engaging low-carbon innovations in policy-making, such as the C40 city network and ICLEI Local Governments for Sustainability. Seoul’s mayoral policies on the One Less Nuclear Power Plant Policy (OLNPPP), introduced since 2012, and the associated energy self-reliant village program have given rise to the proliferating community energy niche initiatives. This article, to the best knowledge of the authors, is the first of its kind to analyze community-level niches under a broader politico-economic context at the city and national levels. In addition, Seoul and other leading cities, such as London and New York City, are key “transition arenas” where many national and city governments, communities, business, and local leaders have proactively introduced energy innovations and experimentations. The Korean case is thus significant, as it offers a crucial context to test and refine our theoretical insights. A better understanding of Seoul’s niche development processes in the broader politico-economic context would be of scholarly relevance beyond South Korea.

This paper is structured as follows. Section 2 sets out our theoretical perspectives, which emphasize the importance of understanding the political economic perspectives of socio-technical energy transitions. Our integrated conceptual framework is then presented. Section 3 discusses the methodological approaches that this study adopted. Section 4 presents the case contexts of Seoul urban solar niche developments. Section 5 presents the findings. The last section offers concluding thoughts and policy recommendations.

2. A Theoretical Understanding of the Political Economic Perspective on Energy Transitions

2.1. Understanding Niche–Regime Dynamics in Socio-Technical Energy Transitions

Socio-technical transitions refer to the processes that involve long-term deep structural changes and require the co-evolution of technology, policy, infrastructure, scientific knowledge, and social and cultural practices. [9]. The multilevel perspective (MLP) [13–15], a sub-theme of the socio-technical transitions literature, sheds light on the niche formation and regime destabilization processes across three levels: Niche, regime, and landscape [9]. Niche refers to a protected space at the micro-level, within which radical innovations and learning associated with new technologies, markets, ideas, practices, and policies emerge. Regime refers to patterns of technologically determined behavior shaped by the cognitive routines shared among policy-makers, scientists, engineers, incumbent utilities, vested interests, and energy users [16,17]. Landscape refers to the structural forces in the external environment or at the macro-level, including global trends (e.g., worldviews on climate change,
nuclear risks [18]), political ideologies, societal values, macro-economic patterns, and institutions [10]. The MLP argues that as niches scale-up, diffuse, and accumulate, they can weaken, destabilize, shift, and eventually replace regimes. This niche development process can be conceptualized as a progression from technological niches to market niches and to regime shift [19].

Transitions studies explain and conceptualize the complex niche–regime interactions by introducing the terms “lock-in” and niche development processes. Studies on carbon and nuclear lock-in have attributed the causes of lock-in principally to the dynamics of collective action (societal norms, customs, consumption patterns, and formal regulations through coalition building and networking) and asymmetries of power [20].

In addition, niche building processes can weaken lock-in situations in the presence of particular drivers and contexts [19,21]. However, the linkages between niche processes and the broader contextual environment have remained under-studied. The understanding of complex linkages between carbon/nuclear lock-ins and niche development processes and of the relationships with the broader contextual environment is not well developed [19].

2.2. The Political Economic Perspective on the Niche–Regime Dynamics

Context has been increasingly recognized as an important factor shaping energy transitions. The political economic perspective is increasingly examined to provide a broader, contextualized view of energy socio-technical transitions [22–25]. This sub-theme of transitions studies examines embeddedness formed by the politico-economic factors of a transition site [16,26]. This political economic perspective of energy transitions is thus crucial to provide a better understanding of the conditions in which niches might move to regimes [26].

The political economy analysis of energy transitions gives special attention to national political and socio-economic relationships and positions of actors, where political elites and incumbent utilities in particular may be able to reinforce carbon/nuclear lock-ins [10]. This perspective of regime–niche dynamics tends to focus on the relatively democratic nature of state power, national infrastructure development, political institutions [16], energy access, national capacities for technological innovation, and levels of electricity market reform [16,25,27–29]. However, this perspective lacks an understanding of complex interactions between national and sub-national levels, with a few exceptions [27].

There are three main gaps in the literature. Firstly, most political economy analysis focuses on the “lock-in” or path-dependent mechanisms favoring incumbent fossil/nuclear-based regimes [20,30], overlooking conducive conditions that may favor niche diffusion. Secondly, most analyses focus on the national level, and few capture the dynamics across national and sub-national levels. Some transitions scholars argue that “scales” are critical in understanding complex social processes, which have a certain scale size at a certain level, i.e., an operational scale [31]. Such a scalar perspective has the potential to provide a better understanding of the socio-political interactions of regime and niche actors in energy transitions beyond and below the national level. It is thus relevant to this study, as urban/community solar may well operate on an individual or a community scale, but fail to function well when scaling up to the regime level. The current literature has limited discussion in this important aspect. Thirdly, few studies develop a political economy analysis of energy transitions beyond North America and Europe (except, for example, [25,28]).

2.3. Towards an Integrated Framework

To fill these gaps, we expand the MLP with the political economic perspective by developing an integrated framework to conceptualize the complex and critical politico-economic dynamics in the niche–regime interactional processes (Figure 1). Our framework has several features. Firstly, we specify five main types of critical factors shaped by the politico-economic contexts, influencing the progression from technological niches to market niches and, subsequently, regime shifts under the interactions between state and non-state actors at the landscape, regime, and niche levels. Encompassing the technical, economic and financial, political and institutional, as well as social and cultural dimensions [26,32],
these factors are highlighted in the literature of political economy analysis of socio-technical energy transitions or sustainability studies. These factors are:

(1) **Global trends, political and economic ideologies, and public preferences**: Manifested at the landscape level, political economy of socio-technical transitions can be approached in the domains of “interests”, “institutions”, and “ideas” [33]. This study departs from and contextualizes these domains into **global trends, political and economic ideologies, and public preferences**. The worldview on climate change (global trends, [18]), the Green Growth Vision in South Korea (political and economic ideologies, [18]), and low tariffs, clean air, energy sources, and community energy (public preferences, [34,35]) are some examples;

(2) **Political power structure, policy traditions, and governance approaches**: Referencing the “horizontal understanding of power” and highlighting the dynamics of actors’ engagement with resources, structures, and systems through reinforcive, innovative, and transformative power [36,37], **political power structure, policy traditions, and governance approaches** are proposed in this study to understand such dynamics. Political power structure refers to, e.g., the relatively democratic nature of state power, political and industrial networks (in particular, the nature and intensity of government–industry linkages) [38–40], social networks between governments and civil society [12], and the role of political media (e.g., [29]); policy traditions include the “developmental state” in east Asia [41]; governance approaches refer to, e.g., authoritarian policy-making in China, technocratic policy-making in France [42,43], and participatory approaches in the UK [44], and key governance issues include public trust [12];

(3) **Physical availability of energy resources, national capacities for technological innovation, and national (energy) infrastructure development**: These elements constitute the core building blocks of socio-technical systems transitions [45]. Energy self-reliant rates and power grid networks are some instances [39,46,47];

(4) **Electricity market reforms and market features**: These features determine regime and niche actors’ incentives/disincentives [48] and constitute the social groups from production and functional/user sides of socio-technical systems transitions [48]; and

(5) **Visioning and leadership, and national energy plans and policy frameworks**: Visioning relates to visions of how energy transitions might unfold over time under the political processes, and the role that specific technologies could play in the process [49]; leadership refers to the ability of political and community leaders to articulate a vision and inspire people to act in order to achieve concrete results [50]; energy policy frameworks relate to clear policy objectives, policy frameworks, and specific policies such as RE feed-in tariff (REFIT) policies to guide technological searches [26,51]. Grounded by the theoretical articulation in “transitions management”, the long-term perspective of transitions is embedded in “goals” and “visions” defined in the processes of visioning, leadership, national energy plans, and policy frameworks [52].
objectives, policy frameworks, and specific policies such as RE feed-in tariff (REFIT) policies to guide technological searches [26,51]. Grounded by the theoretical articulation in “transitions management”, the long-term perspective of transitions is embedded in “goals” and “visions” defined in the processes of visioning, leadership, national energy plans, and policy frameworks [52].

Secondly, our framework argues that these regime–niche dynamics can create conducive conditions to foster niche diffusion, but they can also create inhibitive conditions that impede niche diffusion. Our framework predicts that the existence of more conducive conditions would create stronger forces for change to counteract the forces against change. Thirdly, our framework adopts a multi-scalar approach with special attention to the community niches’ conditions under the broader politico-economic contexts at city and national levels.

3. Methodology

Our research questions are: (1) What are the features of Seoul’s urban solar developments as a niche innovation for Korean energy transitions? (2) To what extent does Seoul’s approach to urban solar development weaken, replace, or transform energy regimes? (3) What are the explanatory factors of the observed phenomenon? In particular, how do the politico-economic contexts of South Korea create conducive and inhibitive conditions for the niche development of urban solar in Seoul?

This study is based on desktop studies and 18 in-depth, semi-structured, face-to-face interviews conducted between 2017 and 2019. The interviewees were carefully selected informants or key stakeholders who participated in climate and RE policy-making at the Seoul city and national levels, comprising energy experts, academics, NGOs, community leaders, government committee members, and government officials (Appendix A). To avoid “limitations of interpretivism”—the person-specific and private subjective account of data interpretation that cannot be viably verified or replicated by a third person [53]—we review government archives, academic publications, reports, and news articles to triangulate the interview data and provide additional contextual information.

4. Case Contexts: Energy Challenges and Policy Responses in South Korea and Seoul

South Korea is heavily reliant on energy imports, with a low energy self-reliance rate of 5.3% [54]. The Korean electricity sector is fossil- and nuclear-based. Coal, natural gas, and nuclear contributed 42.0%, 21.6%, and 26.1% of the national electricity generation in 2017 (Table 1 and Figure 2b) [55]. With 24 nuclear reactors and a capacity of 22.5 GW in 2017, Korea ranked as the fifth largest nuclear-producing country in the world [56,57]. Hydroelectricity and RE (including solar, wind,
biofuel, and other RE) contributed the remainder [55]. South Korea’s electricity consumption increased rapidly since the 1990s, with its peak annual growth rate reaching 10% in 2010 before slowing down. Electricity consumption doubled from 239,535 GWh in 2000 to 507,746 GWh in 2017, followed by an increase in CO\textsubscript{2} emissions from 431.9 MtCO\textsubscript{2} in 2000 to 589.17 MtCO\textsubscript{2} in 2016 (Figure 2d).

Seoul, the capital, is home to 21.9% of the national population and accounts for 9.1% of national annual electricity consumption (Data compiled from [54]), yet its electricity self-sufficiency rate was only 3.0% [58]. While Seoul’s electricity generation mainly came from fossil fuels, Seoul’s electricity consumption was mainly met by electricity transmitted from coastal nuclear power plants. The rising electricity demand has heightened the capital’s electricity dependence issue; Seoul’s electricity consumption rose from 41,824 GWh in 2006 to 46,493 GWh in 2016 [56]. These energy challenges have prompted the national and city governments to formulate energy plans and policies for sustainable energy transitions.

### Table 1. Major economic and energy indicators of South Korea and Seoul (2017).

| Indicators                          | South Korea | Seoul       |
|------------------------------------|-------------|-------------|
| Population                         | 51,422,507  | 10,124,579 (19.7%) |
| GDP (current price; billion Won)   | 1,553,948   | 339,796 (21.9%) |
| Final energy consumption (1000 toe)| Coal 33,360 (14.3%) | 83 (0.6%) |
|                                    | Petroleum 117,861 (50.4%) | 6185 (41.3%) |
|                                    | LNG and Towngas 24,053 (10.3%) | 4205 (28.1%) |
|                                    | Electricity 43,666 (18.7%) | 3982 (26.6%) |
|                                    | Heat energy 2441 (1.0%) | 261 (1.7%) |
|                                    | Renewables 12,520 (5.4%) | 275 (1.8%) |
|                                    | Total 233,901 | 14,990 |
| Electricity consumption (GWh)      | 507,746     | 46,298 (9.1%) |
| Electricity production (GWh)       | 568,174     | 954 (0.17%) |
| Electricity generation mix (GWh)   | Coal 238,799 (42.0%) | N/A |
|                                    | Petroleum 8663 (1.5%) | 12 |
|                                    | LNG 122,773 (21.6%) | 347 |
|                                    | Nuclear 148,427 (26.1%) | N/A |
|                                    | Hydro 6995 (1.2%) | 1.2 |
|                                    | Solar 7056 (1.3%) | 106 |
|                                    | Wind 2169 (0.4%) | 0.2 |
|                                    | Ocean 489 (0.1%) | N/A |
|                                    | Bio 7467 (1.3%) | 43 |
|                                    | Waste 23,867 (4.2%) | 118 |
|                                    | New energy 1469 (0.3%) | 327 |
| Monthly average daily solar radiation (kWh/m\textsuperscript{2}) | 4.01 (Relatively high) | 4.65 (Relatively high) |

Sources: Data compiled from [54,59,60].

Korean and Seoul energy policies have experienced major changes after the Fukushima nuclear accident (Table 2). Nuclear energy was formerly a national strategic priority, but the incumbent president Moon Jae-in aimed to phase out nuclear by 2082 [61,62]. Since 2017, the Korean government has introduced energy-saving initiatives while increasing non-hydro RE installed capacity from about 7.6% in 2017 to 20% by 2030. The national Eighth Basic Energy Plan announced in 2017 set RE targets at 58.5 GW in 2030 from 11.3 GW in 2017.

Under the national energy policy framework, the Seoul government has introduced policies to reduce the reliance on nuclear, use more RE, and improve energy efficiency. The One Less Nuclear Power Plant Policy (OLNPPP) introduced in 2011 was the most notable mayoral energy policy, and was aimed to reduce the city’s energy demand by the annual generation capacity of one nuclear power plant (1 GW) by 2014 [63,64].
Korean and Seoul energy policies have experienced major changes after the Fukushima nuclear accident (Table 2). Nuclear energy was formerly a national strategic priority, but the incumbent president Moon Jae-in aimed to phase out nuclear by 2082 [61,62]. Since 2017, the Korean government has introduced energy-saving initiatives while increasing non-hydro renewable energy (RE) installed capacity from about 7.6% in 2017 to 20% by 2030. The national Eighth Basic Energy Plan announced in 2017 set RE targets at 58.5 GW in 2030 from 11.3 GW in 2017.

Under the national energy policy framework, the Seoul government has introduced policies to reduce the reliance on nuclear, use more RE, and improve energy efficiency. The One Less Nuclear Power Plant Policy (OLNPPP) introduced in 2011 was the most notable mayoral energy policy, and was aimed to reduce the city’s energy demand by the annual generation capacity of one nuclear power plant (1 GW) by 2014 [63,64].

![Graph A](image1.png)  
**Figure 2.** Cont.
Figure 2. (a) GDP in South Korea by year (billion Won). (b) Fuel mix for electricity generation in South Korea, 2017. (c) Electricity consumption in South Korea by year (GWh) (d) CO₂ emission in South Korea by year (MtCO₂). Sources: Data compiled from [55,56,65,66].
Table 2. Major energy plans and policies in South Korea and Seoul.

| Year | Energy Plan/Policy | Relevance to Renewable Energy | References |
|------|---------------------|-------------------------------|------------|
| **South Korea** | | | |
| 2012 | National RE policy reform | - National feed-in tariff abolished in 2012  
- Renewable portfolio standards (RPS) began in 2012 as an alternative policy  
- Annual RPS target for RE revised upwardly every year; RPS in 2018 was 6.0% | [67,68] |
| 2014 | Fourth Basic Plan for Technology Development, Application, and Deployment of New and Renewable Energy (2014–2035) | - Increase share of new RE in total energy consumption to 11% by 2035 | [69] |
| 2015 | National Seventh Basic Plan for Long-Term Electricity Supply and Demand (2015–2029) | Generation Mix Outlook:  
- Nuclear: 29% by 2035  
- RE: 4.6% by 2029 | [70] |
| 2017 | National Public Deliberation on Shin-Gori Nuclear Reactors No. 5 and 6 | - Polling results: Resume construction of the Shin-Gori Nuclear Reactors No. 5 and 6 | [71] |
| 2017 | National Eighth Basic Plan for Long-Term Electricity Supply and Demand (2017–2031) | - Fossil-fuel-based power plants expand from 74.2 to 87.4 GW  
- Nuclear capacity decrease from 22.5 to 20.4 GW  
- RE (mainly solar and wind) increase from 11.3 to 58.5 GW between 2017 and 2030 | [66] |
| 2017 | Renewable Energy 3020 Plan | - RE in energy mix from 7% in 2017 to 20% in 2030  
- New RE generation capacity of 48.7 GW | [72] |
| 2018 | Greenhouse gas (GHG) reduction plan (revised) | - Reduce GHG by 315 million tons, or 37% from BAU levels by 2030  
- 32.5% by domestic reduction; 4.5% by international market mechanisms | [73] |
| 2018 | National feed-in tariff | - Provide an amount of 189,175 won/MWh (169 USD/MWh) to photovoltaic (PV) facility of less than 30 kW (100 kW for agriculture-related cooperatives) | [74] |
| **Seoul** | | | |
| Since 2011 | One Less Nuclear Power Plant Policy (OLNPPP)  
Phase 1 (2011–2014)  
Phase 2 (2014–present) | - RE: Seoul-type REFIT (introduced in 2013; national feed-in tariff was abolished in 2012)  
- Energy efficiency  
- Energy demand management | [75] |
| 2017 | 2022 Solarcity Plan | - Solar target: To produce 1 GW of solar energy and ensure one million households in Seoul to equip solar panels by 2022 | [2] |
5. Findings and Discussions: Understanding Seoul’s Solar Niche Innovation from the Political Economic Perspective

5.1. Solar Has Been Supported as a Viable Energy Option in Both the National and Seoul Post-Fukushima Energy Strategies

Solar, alongside energy-saving, has become a public preference as a viable energy alternative in post-Fukushima South Korea, and in Seoul in particular. Several observations of this solar-oriented post-Fukushima energy strategies are important to note:

(1) Solar ranked top among all RE sources in Korea’s energy mix. In 2017, solar contributed 5.83 GW of Korea’s 15.7 GW RE capacity (Figure 3a) and 7056 GWh of electricity (1.3% of national electricity production).

(2) Solar power in Korea has experienced a marked increase in recent years because of falling solar system costs and government policy support. The national solar installed capacity recorded a 70 fold increase from 81 MW in 2007 to 5.8 GW in 2017, with annual growth rates of over 40% in 2012–2015 before slowing to a growth rate of around 25–30% in 2016 and 2017 (Figure 3b).

(3) Seoul’s solar deployment shows a roughly similar pattern to the national picture. Solar installed capacity increased from 6.7 MW in 2005 to 65 MW in 2016, with the highest annual growth of nearly 50% in 2013 (Figure 3c). Solar panels were, however, installed by less than 1% of the city’s 3.6 million households in 2017 [76], providing just 0.23% of Seoul’s electricity needs in 2017 despite Seoul’s ambitious solar target of 1 GW by 2022 (Table 2).

(4) Solar energy is considered the most promising RE source mainly due to its suitability across the country [59]. South Korea is generally exposed to relatively high solar radiation, especially in the southern part of the Korea Peninsula. Seoul has a significant solar resource, with a monthly average daily solar radiation of 4.65 kWh/m² compared to the national average of 4.01 kWh/m² [59]. Approximately 30% of the 187 million m² rooftops at a five-degree tilt in Seoul are also found suitable for solar deployment [77].
Secondly, Seoul's model is empowered by the Seoul government through a series of policy initiatives. The most notable policy is the Energy Self-reliant Village Program introduced in 2012 [64]. The OLNPPP has adopted a citizen-centric approach and has encouraged wide citizen participation in energy transitions (Interviewees 16 and 18). In addition to rooftop solar, mini solar panels, characterized by their small size (usually 1 × 2 m) and capacity (below 1 kW), have also been introduced to the balconies of apartment-type buildings.

Developments in Seoul's niche innovation have been driven by the core values of energy sharing and public participation, a slogan of “Citizens are Energy”. This citizen-centric approach partly explains why Seoul has emphasized the development of solar energy projects, particularly in residential areas. Seoul has become a leader in renewable energy, with a significant portion of its electricity coming from solar sources. This is due to the city's ambitious solar target of 1 GW by 2022.

Figure 3. (a) South Korea renewable energy (RE) installed capacity by year (GW). (b) South Korea solar PV installed capacity and growth rate by year. (c) Seoul solar PV installed capacity and growth rate by year. Sources: Data compiled from [55].
5.2. Seoul’s Model of Niche Innovation: Government-Empowered Community-Led Solar Developments

Urban solar developments have proliferated across Western and Asian countries, but progressed along different pathways. Seoul’s niche innovation with a government-empowered community-led approach for urban solar has two distinctive characteristics.

Firstly, Seoul’s model is community-based and citizen-driven, underpinned by the pre-existing community grassroots environmental movement across Seoul (Interviewee 7b; [50]). In contrast to countries (e.g., the U.S. and China) where solar PV deployment is dominated by the utilities, a relatively high level of household participation is evident in Seoul’s solar developments. Of the 105.01 MW of solar PV installed between 2003 and 2015 in Seoul, private buildings (mainly residential) and micro-PV (also mostly in residential) constituted 31.74 and 17.74 MW, whereas public buildings and schools had 43.04 and 12.49 MW of solar installed, respectively [78].

Secondly, Seoul’s model is empowered by the Seoul government through a series of mayoral policies. The most notable policy is the Energy Self-reliant Village Program introduced under the OLNPPP in 2012 [64]. The OLNPPP has adopted a citizen-centric approach and has a slogan of “Citizens are Energy”. Driven by the core values of energy sharing and public participation, Mayor Park Won-soon introduced this program with the aims of enhancing citizens’ energy awareness and promoting energy-saving and solar PV installations. By mid-2018, a network of some 100 energy self-reliant communities across Seoul have been established (Interviewees 7b and 18).

This citizen-centric approach partly explains why Seoul has emphasized the development of energy self-reliant villages (Interviewee 4) and mini solar panels as a means of enhancing wide citizen participation in energy transitions (Interviewees 16 and 18). In addition to rooftop solar, mini solar panels, characterized by their small size (usually 1 × 2 m) and capacity (below 1 kW), have also been introduced to the balconies of apartment-type buildings.

Community solar in these energy self-reliant villages can be categorized into two main types: Solar in old urban neighborhoods and solar in residential apartment buildings. As a representative of the first type, Sungdaegol began a community energy movement after the Fukushima accident. Apart from energy-saving initiatives to reduce nuclear reliance, Sungdaegol extended the movement to solar PV installation alongside the OLNPPP. Seoul’s citizen-centric approach helped Sungdaegol in establishing its focal Energy Supermarket, in networking academics, solar installers, financial institution, and volunteers to overcome technical, financial, and educational issues from solar installation (Figure 4), and in installing solar PV in some 50 buildings; Sungdaegol’s leader participated in the OLNPPP Implementation Committee and the Citizens’ Committee of the Seoul Energy Corporation (Interviewee 7b; [50,79]).
Shindaebang Hyundai Apartment is a typical apartment-type energy self-reliant village. The resident representatives of the apartment initiated energy-saving campaigns to promote energy-efficient devices and energy-saving habits among residents. Similarly to Sungdaegol, the campaigns extended to promoting mini PVs, and rooftop solar on residential blocks and an apartment kindergarten (Figure 5). Resident representatives were also invited to sit in Seoul Government’s energy committees and participate in energy policy-making (Interviewees 5 and 6).
5.3. An Evaluation of the Niche Formation Process of Urban Solar in Seoul: Solar Niches Are Emerging, but the Magnitude of Energy Socio-Technical Regime Shift Has Been Limited

To what extent, then, is Seoul’s model for urban energy transitions effective? By applying Schot and Geels [19]’s conceptualization of niche development processes, we found that Seoul’s solar technological niches have emerged and shown early signs of development into market niches. However, these niches had only limited impacts on regime shifts. Major outcomes of the niche development processes are illustrated in Table 3.

Technological niches of solar communities have evidently emerged in Seoul. Sungdaegol, for example, has provided protected spaces that allowed solar applications to be tested in local customer environments. The Energy Supermarket, a co-operative shop, has become a meeting place, a platform where group works were organized, and a local store for solar DIY tools (Interviewees 7b and 9; [50]). Flat cables were introduced by a local solar installer to address tenants’ need of mini PV cable connections without drilling holes into walls.

Early signs of the developments of market niches are also evident from Sungdaegol’s technological niches. The recent diffusion of solar rooftops in the local wet market—a defining feature of market niches—demonstrated that market niches supported by user demands existed [19,21]. As a Sungdaegol leader notes,

“At first, only a few stores in the local market installed solar panels. However, as that number grew to 20 and 30, we had a power of scale. Then, those stall owners who didn’t have solar panels installed feared of being isolated. They thought they might lose something by not being part of this new local social trend. In a sense, we made them feel like outsiders. So, without having to do any further persuasion, more and more merchants decided to install solar panels . . . I think about 50% of merchants have installed solar panels right now, and I hope the number will further increase”.

(Interviewee 10)

Additionally, in 2018, Sungdaegol started to develop an energy trading scheme among local residents, providing support for emerging market niches (Interviewee 7a).

Our case study, however, revealed that the niche development processes have very limited impact on regime shifts with major limitations in the following important aspects:

i. Fossil fuel/nuclear “lock-in” prevails in Seoul’s electricity sector. Solar is still a minor energy source in Seoul, representing merely 0.23% of Seoul’s electricity consumption in 2017. Solar households represented a tiny segment of Seoul. As of June 2017, 34,000 households were equipped with solar panels, equivalent to less than 1% of 3.6 million households [76].

ii. There is limited co-evolution of regulatory structures. KEPCO, the state-owned monopolistic utility that owns 92% of the nation’s total electricity generation capacity, has remained as a key regime actor for centralized fossil fuels and nuclear generation (Interviewees 4, 7b, 15, [28]).

iii. There is limited co-evolution of user practices. Although some residents in Seoul were attracted by the financial benefits of solar PV and its low up-front cost (as low as 70,000 KRW (approximately 63 USD) as of January 2019), they might be unwilling to pay for the replacement costs of inverters (170,000 KRW (approximately 152 USD)). Some householders in Sungdaegol have already idled or resold their solar systems in the second-hand markets to avoid paying the replacement costs though the systems were used for only several years. Despite the fact that the official figure of such cases is not available to the authors, at least some early solar adopters had an evidently low level of awareness of the need for system maintenance and low attachment to their solar systems (Interviewee 7b).
### Table 3. Political and economic contexts and the key factors affecting niche–regime dynamics in the case of Seoul’s community solar.

| Factors Affecting Niche-Regime Dynamics | Administrative Levels | Conducive Conditions | Inhibitive Conditions | Outcomes |
|----------------------------------------|-----------------------|----------------------|----------------------|----------|
| 1. Global trends, political and economic ideologies, and public preferences | National              | ■ Widespread public awareness of air pollution and nuclear risks since the Fukushima accident  
■ Clean, hi-tech energy industries as potential economic driver | ■ Public’s prime concerns over energy reliability and affordability tend to resist RE  
■ Developmental State—orientation towards nuclear power  
■ KEPCO goes global: Potential global nuclear market perceived by incumbent KEPCO | ■ Anti-nuclear atmosphere formed at all levels following the power outage in 2011 and nuclear scandals from 2012-2014  
■ Nuclear policies sustained until the incumbent presidency; nuclear still constituted 26.1% in electricity mix in 2017 |
| City                                   | Prioritizes social consideration in nuclear policy-making of the OLNPPP | NA | NA | |
| Community (since the Fukushima accident) | National              | ■ Power structure: Social networks of solar community  
■ Governance approach: Increasingly opening up | ■ Strong policy traditions of top-down, technocratic policy-making styles  
■ “Nuclear village”—pro-nuclear policy coalition | ■ Policy traditions and nuclear regime largely remained unchanged and energy initiatives mostly used a bottom-up approach  
■ Gradual nuclear phase-out policy |
|                                          | City                  | ■ Power structure: Institutionalization of policy networks that span downwardly from Seoul to energy self-reliant communities, horizontally to other provinces, and upwardly with global leading cities through the C40 Network  
■ Governance approach: Mayor Park: Opening up, engaging, citizen-centric | ■ Can be influenced by national energy policy framework | ■ Cities started to ally with Seoul to launch similar energy policy initiatives since 2015 |
|                                          | Community             | ■ Governance: Concepts of self-governing, energy self-reliance instilled by the Energy Self-Reliant Village Program; an emphasis on the co-production of technical solutions for solar householders  
■ Governance: Business model innovations involving new market actors, e.g., community-scale energy trading scheme under a new energy cooperative; locally grown credit unions providing solar loans | NA | ■ Networking between energy stakeholders and policy-makers in communities and Seoul since the beginning of the Energy Self-Reliant Village Program |
### Table 3. Cont.

| Factors Affecting Niche–Regime Dynamics | Administrative Levels | Conductive Conditions | Inhibitive Conditions | Outcomes |
|----------------------------------------|-----------------------|-----------------------|----------------------|----------|
| 3. Physical availability of energy resources, national technological innovation systems, and national (energy) infrastructure development | National              | Very low energy self-reliant rate | Moderate solar resources | Pursued nuclear technological development (past) and Developed RE policies such as RPS for utilities (2012) and REFIT (2018) to promote solar to enhance self-reliance |
|                                          | City                  | Very low energy self-reliant rate | Moderate solar resources | Energy-saving and solar (e.g., mini-PV) initiated partly owing to the geographical conditions and solar resources available to enhance self-reliance under the OLNPPP |
|                                          | Community             | Very low energy self-reliant rate | Moderate solar resources | KEPCO continued its plan to develop different electricity sources, including nuclear and solar; local energy initiatives had little impact on KEPCO to revise its development plan at present |
| 4. Electricity market reforms and market features | National              | Partial electricity market reforms: Opening up of the electricity market sends out market signals | Partial electricity market reforms: Incumbent KEPCO retains dominating role in the electricity market; new entrants limited in number and influence; limited competition and very weak forces for regime changes | KEPCO continued its plan to develop different electricity sources, including nuclear and solar; local energy initiatives had little impact on KEPCO to revise its development plan at present |
|                                          | City                  | Progressive Seoul-type REFIT—strong market signals | Excessive subsidies to solar householders | New energy initiatives continued to develop with limited impacts; minimal impacts to influence electricity market reforms |
|                                          | Community             | Locally grown credit unions prioritizing social responsibility over profit maximization; providing solar loans and supporting market niches of community solar | Weak financial establishments because of a lack of market demand for solar loans | National level: More ambitious solar and RE targets (e.g., Renewable Energy 3020 Plan) were proposed with the determination to phase out nuclear since the incumbent presidency |
| 5. Visioning and leadership, and policy framework | National              | Then-President Lee Myung-bak: introduced the National Green Growth Strategy in 2008 | NA | Latest mayoral energy policies (e.g., 2022 Solarcity Plan) gained support through alignment of interests with communities since the OLNPPP |
|                                          | City                  | Mayor Park Won-soon: introduced the OLNPPP and the Seoul-type REFIT | NA | Local community leader has limited policy impacts |
|                                          | Community             | Kim Soyoung: Initiated self-reliant energy movement in Sungdaegol in 2011 | NA | Existing politico-economic contexts nurtured grassroots leadership in energy movements |

Source: Authors; NA: Data are not available from this case study.
5.4. The Conducive Conditions for Niche Formation: From a Political Economic Perspective

By applying our framework into the case of Seoul, we found that the politico-economic contexts of South Korea have conducive conditions for various niche-formation processes. The contexts have, however, also become the root of some inhibitive conditions impeding solar niche diffusion. The linkages and interactions between contexts, conducive and inhibitive conditions, and the outcomes in terms of the niche–regime dynamics are summarized in Table 3. Four key conducive conditions are discussed as follows.

5.4.1. Public Preferences for RE Introduced a Major Change in the Landscape

Historically, Koreans supported the fossil- and nuclear-based energy systems mainly because they provided low tariffs and a reliable supply. However, after the Fukushima accident in 2011, because of public concerns over severe fine dust pollution, nuclear risks, and the associated public health issues, the public began to look beyond just the economic issues (Interviewees 7b, 14, 15).

It is in the post-Fukushima context that RE as a viable energy alternative has become much more widely supported by the public in South Korea (Interviewees 7b, 14, 15). In addition, the aspiration of community energy self-reliance has grown in South Korea and in Seoul in particular, and this explains the wider support for RE and decentralized energy systems (Interviewee 15).

5.4.2. The Alignment of the National Green Growth Strategy and the Development Plans of Hi-Tech RE Clusters

The alignment of the Korean government’s macro-economic policy—the Green Growth Strategy [12] and its industrial policies—to support hi-tech energy industries has created a reinforcing effect fostering solar development. While the solar manufacturing industries are not located in Seoul, RE clusters have been set up in a number of regions across South Korea. These regions include Chungcheongnam-do and Chungcheongbuk-do (Cheongju-Cheonan-Sejong), Jeollanam-do (Gwangju), Jeollaabuk-do (Jeonju), Busan and Gyeongsangnam-do, Gyeongsangbuk-do (Daegu-Ulsan), and Jeju [80].

The national technological innovation capacity in PV has been gradually built up in recent years, closing the gap between advanced countries [80]. Currently, PV and wind power accounts for 34% of the new and RE industry’s deployment, 74% of investment, 80% of sales, and 97% of exports [80]. Enhancing competitiveness in the global solar market has become a national strategy. A major initiative is the plan to establish the Chungbuk Innovation City as an outpost to promote the nation’s PV industry [80].

5.4.3. Political Openness Enables a Bottom-Up Citizen-Centric Approach to Urban Solar in Seoul

The conventional top-down approach in energy strategies has been seen as a root problem causing central–local policy incoherence and the low level of community involvement in South Korea [81]. This was until 2008; when the Lee Myung-bak Administration set up the Prime-Ministerial Green Growth Committee, the Korean policy-making systems started opening up [12]. In more recent years, the Moon Jae-in Administration, which assumed office in May 2017, has provided increasing opportunities for NGOs to be invited to offer inputs to energy policy-making (Interviewee 16).

In Seoul, although the national RE policy framework regulates and influences solar energy developments, the mayor of Seoul, Park Won-soon, has shown his leadership in opening up policy-making and governance systems. The formulation process of the OLNPPP was distinguished by its inclusive approach—many local stakeholders, including local community leaders and NGOs, were invited to offer policy inputs through rounds of consultations and various committee groups. This inclusive approach was found to be effective in gaining substantial local support, and, thus, implementation capacity, to deliver the Energy Self-reliant Village Program (Interviewee 16).
Political leadership of Mayor Park also played an important role in the solar niche diffusion process by introducing the OLNPPP. Different from traditional preoccupations with economic and carbon-reduction benefits, Park emphasized and prioritized social concerns in Seoul’s energy policy-making. He brought Seoul citizens’ attention to the inequity issue of transmitting nuclear electricity through rural parts of South Korea. In this sense, Park’s political leadership and his OLNPPP created spaces for RE to gain public support. In addition, even though the national government abandoned the national REFIT policy in 2012, Mayor Park decided to introduce his Seoul-type REFIT policy in 2013. The REFIT and direct subsidies provided strong economic incentives for solar installation in Seoul (Interviewees 1, 4, 7a).

5.4.4. Vertical and Horizontal Networks

Alongside the energy community network formed by some 100 energy self-efficient villages across South Korea, Mayor Park appointed the Sungdaegol solar community leader, Kim Soyoung, a co-chair of the energy self-reliant villages network, to two important policy committees for the Seoul government. This government-empowered network has allowed Kim to act as a spanning actor for bridging the social and political networks and between community and city levels. Additionally, the community-grown network has, though less directly, extended further upwards to the national level—through the Joint Declaration of Regional Energy Conversion signed between Seoul and three other provinces [82]—as well as to the global level—through the C40 network of global city mayors [83].

5.5. The Inhibitive Conditions for Niche Formation: From a Political Economic Perspective

5.5.1. The “Developmental State” as the Dominant Economic Ideology Has Reinforced a Technological Lock-In Towards Nuclear

South Korea’s economy has been characterized by its “developmental state” model, which continues to impact the economy and reinforce the lock-ins towards fossil fuels and nuclear energy. Introduced by Chalmers Johnson in the 1980s, the concept of the developmental state refers to a state that prioritizes and directs economic growth, productivity, and technological competitiveness with state intervention under an elite economic bureaucracy [84–87]. Striving for economic development after the Korean War, South Korea has been widely regarded as a developmental state in the literature [41,87,88].

Korea’s “developmental state” model favored scientifically and technologically driven economic growth. Nuclear was first pursued as a tool of national development and economic growth under President Park Chung-hee’s administration in the 1960s and 1970s [41,88]. Unlike the US nuclear position of being a “responsible regulator” imposing effective containment, South Korea cultivated a national imagination of nuclear as the “atom of development” through a logic of self-reliance [89]. With this ideology and nuclear being viewed as an irreplaceable, affordable, and essential energy source [90], nuclear has gradually been embedded into the Korean political economy as an integrated part of economic development with support from subsequent conservative governments. In recent years, responding to the post-Fukushima power outages in mid-September 2011, the Korean government proposed expanding generation capacity with new coal and nuclear power plants [91]. The political support for nuclear has been reduced since 2017, when the incumbent Moon’s administration introduced a nuclear phase-out policy to close all of the nuclear reactors when their lifetimes are over [62].

This developmental state ideology has also cultivated a pro-nuclear approach under a national imagination of wealth creation through developments in science and technology (i.e., technological developmentalism) [41]. Vested interests in nuclear were thus developed among conservatives and nuclear power interests [28,88,92]. The “nuclear village”, a term used to describe networks of institutions, utilities, contractors, academics, and scientists favoring nuclear technologies in Japan and other places [93], also exists in South Korea. KEPCO, the political media, conservationists, and other nuclear stakeholders resisted the Moon Administration’s nuclear phase-out policy. They argued that phasing out nuclear would lead to tariff increases, dampen the nuclear industry, and damage nuclear
technology exports (Interviewees 7b, 15, 16, and 17). KEPCO, through its subsidiary, the Korea Hydro and Nuclear Power (KHNP), owned 22.53 GW of nuclear capacity and announced plans for entering the global nuclear market. KEPCO thus has a vested interest in resisting RE [41].

The OLNPPP, on the other hand, can be seen as a policy response of the Seoul government to counteract the nuclear lock-in. Since the Seoul government and citizens could not directly influence the national nuclear decision and, yet, nuclear constituted the main electricity source for Seoul, the Mayor, inspired by the post-Fukushima citizens’ energy-saving initiatives, launched the energy campaign and drew a linkage from Seoul’s energy-saving to having “one less nuclear power plant”. The mayoral policies could be attributed to the national nuclear situation and the existing nuclear vested interests.

5.5.2. Incomplete Electricity Market Reforms and Regulatory Incompetence

Electricity market reforms in South Korea officially started in 2001 with the aim of improving efficiency and privatizing the state-owned vertically integrated monopoly KEPCO [18,94]. The reforms were, however, halted in 2004 due to political resistance [18,94]. A recent attempt to break the stalemate was made in August 2016 by the Park Geun-hye Administration, which announced it would continue the reforms [95]. However, to date, only the generation sector is open to market competition, while the transmission, distribution, and retail sectors have all remained monopolized. These partial electricity market reforms have created barriers to solar niche developments in Seoul in at least two important ways.

The first barrier relates to the disincentives of KEPCO to change. KEPCO has remained a state-owned monopoly controlling the transmission, distribution, and retail systems. As a dominating incumbent, KEPCO faces limited forces for change from its customers, who have literally no choice of their electricity suppliers (Interviewees 7b, 15, and 17). Although there is an emerging force for change from the commercial end-users for RE, the force is too weak to force KEPCO to change. Several Korean conglomerates, such as SK hynix and Naver, have set 100% RE targets for their datacenters, with Samsung recently making a similar commitment [96]. A solar community leader notes that solar niches would be able to cause regime shifts only when these bottom-up forces for change from end-users become strong enough. That leader notes that:

“When this kind of change takes place with more companies and in more places, KEPCO will have no choice but to respond.”

(Interviewee 7b, a community leader of the Sungdaegol solar community)

The second barrier relates to regulatory incompetence in dealing with increasingly market-based energy systems. While market competition has already been introduced to the generation sector, KEPCO’s subsidiaries still dominate the sector with about 69% of the total capacity of South Korea, though the number of non-KEPCO-affiliated power producers recorded exponential growth to more than 3500 by December 2019 [97]. Some niche actors and academics thought that complete market reforms were essential to open up transmission and distribution segments under such a context. The reforms would create a conducive market environment for new RE suppliers and business models to develop. In Sungdaegol, for example, some local residents were keen to set up a solar energy trading system through which they can act as middle-men. There exist market niches, but there is, however, a lack of regulatory clarity for regulating new business models of a similar nature, nor are there sufficient regulations for local initiators in supplying electricity (Interviewee 7b). Regulatory clarity and competence need to be improved to develop effective rules to regulate energy trading of various forms, such as trading between people, between buildings, and between buildings and people (Interviewee 15).

The third barrier relates to the incompetence in regulating electricity prices. Tariff reforms are essential in order to create a more favorable market environment for RE to make a business case (Interviewees 14, 15, and 17). Electricity prices have been modulated at low levels by the Korean
governments. Koreans are, therefore, generally accustomed to low electricity prices and would oppose tariff increases (Interviewee 17).

5.5.3. Swinging between Excessive Government Intervention and Inadequate State Action in Governing Solar Niche Developments

Governments have an important role to play in creating favorable price signals and market conditions for niches development [51]. In Seoul, direct subsidies have effectively scaled up solar deployment by cutting upfront costs. This policy has, however, revealed two major limitations. Firstly, the government has relied too much on direct subsidies to increase new solar installations. Direct subsidies to solar have been raised several times in recent years to incentivize potential solar householders. In 2018, a mini-sized PV purchaser had to pay only 60,000 KRW (54 USD) of the full price of 570,000 KRW (510 USD) in contrast to paying 350,000 KRW (315 USD) a few years ago (Interviewee 7b). It has become a concern that the government subsidies have become excessive in ways that have made people accustomed to subsidies. In Sungdaegol, there are reported cases where PV householders were reluctant to pay 170,000 KRW (152 USD) to replace old inverters, as the costs cannot be covered by the subsidies, and their entire solar systems were left unused or even demolished (Interviewee 7b).

Additionally, the subsidies are perceived as excessive, as they have undermined market formation in the solar industry. Credit unions that provide solar loans exist in Seoul as new niche market actors. These locally grown financial institutions have, however, met with limited market demand, as solar householders have good access to heavy subsidies and most of them do not need to apply for solar loans (Interviewees 7b and 11). There are also concerns that public spending could have been allocated to long-term research and development investments in improving efficiency of solar panels rather than focusing on subsidies (Interviewee 11).

In short, there are multiple reasons for the reliance of favorable and perceived excessive subsidies to promote solar at the community level in Seoul. Some of these reasons include:

1. The policy target of the OLNPPP has focused on increasing decentralized solar installed capacity rather than centralized solar electricity generation in order to promote niche development through a citizen-centric and community-led approach [58];
2. Fewer policy priorities have been given by the Seoul government on grid enhancement to take up more RE from mini-PVs (Interviewee 7b). Under the partial electricity market reforms in South Korea, the national government provided insufficient incentives for the utilities to enhance grid capacity, nor did the Seoul government have the authority to provide such incentives; and
3. Seoul-type REFIT could only be offered to limited sizable solar PV projects instead of covering mini-PV projects under the existing grid infrastructure.

These contextual factors contributed to the conducive and prohibitive conditions in the niche developments in Seoul, and partly explained why the development could not be scaled up to regime shift. Although these factors might not be directly attributed to the outcome of the subsidy policy, these factors limited the potential of using REFIT to promote community solar in Seoul. As such, subsidies and other incentive programs, such as eco-mileage, were utilized to incentivize citizens’ engagement under the existing politico-economic contexts.

5.6. Understanding the Niche–Regime Dynamics across National, City, and Community Levels

To sum up, our case study shows that political and economic contexts have created an embedded environment for five critical factors that have been influencing the niche–regime dynamics of Seoul’s urban solar developments (Table 3). The current political and governance systems in South Korea have strengths in aligning the national macro-economic policy with the industrial development policy of hi-tech new energy clusters, political openness that enables community engagement, and building extensive social and political networks, both horizontally and vertically. The current systems, however, lack sufficient forces for change, in part because of the “development state” ideology, the existence
of incomplete electricity market reforms, and the lack of strategic roles of the state in governing the sustainable growth of technological niches.

Our scalar perspective that emphasizes niche–regime dynamics across national, city, and community levels also sheds light on the complexities involved. Our case study demonstrated that the politico-economic context affects niche diffusion in both positive and negative ways at the national, city, and community levels. We found that in some indicative areas of our framework, there exists a delicate relationship across the national, city, and community levels. For example, in relation to the first factor: Global trends, ideologies, and public preference, the widespread public awareness of nuclear risks at the national level, the prioritization of social considerations in nuclear policy-making in Seoul, and the citizen movement at the community level have reinforced each other across different administrative levels. A set of illustrative examples is summarized in Table 3.

6. Conclusions and Policy Implications

By integrating political economy and socio-technical energy transitions theories, this paper seeks to contribute novel insights to the energy literature. Utilizing a case study of the urban solar community in Seoul, this paper underscores the importance of politico-economic contexts in creating embedded conditions that define the opportunities and constraints of niche development processes. Our empirical analysis demonstrates the complex interactions in energy transitions and contributes to the literature in three important ways.

Firstly, we characterized Seoul’s model of niche developments as a government-empowered community-led solar approach. This finding enriches the understanding of the variety of transition pathways growing rapidly worldwide (see, for example, [98–100]). Indeed, Seoul’s approach to engaging communities and citizens in urban solar is atypical compared with initiatives in other global cities. London, for example, focuses on solar deployment in low-income social housing supported by a robust social enterprise sector [101]. Singapore, on the other hand, relies on market forces and central tendering processes coordinated by the government to promote solar in social housing [102]. This case study of Seoul can therefore enrich the literature by providing a crucial context for comparative studies and explaining the resulting varieties in transition pathways and outcomes.

Secondly, we conceptualized the mechanisms of niche–regime interactions and provided greater clarity to complex socio-technical transitions processes. A growing body of energy transitions studies argues that transitions involve long, complex, and uncertain processes that take place at various geographical levels [9]. Our study makes a contribution to the literature by specifying five factors that are shaped by political and economic contexts, and which, in turn, affect niche–regime dynamics. Global trends and public preferences, political power structure and governance approaches, physical availability of energy sources, electricity market reforms, and visioning and leadership have impacted the niche development process in significant ways, as we discussed.

We also argued that the politico-economic contexts are a double-edged sword, creating critical conducive conditions for niches’ growth and diffusion, yet major inhibitive conditions that constrain niche developments and reinforce carbon/nuclear “lock-ins”. Our assessment of Seoul’s niche development argues that the Seoul model has made progress in technological niches with some emerging developments towards market niches, but is far from initiating regime shifts. Our analysis suggests that the outcomes of energy transitions depend on an array of factors, as well as complex interactions between forces for and against change. In Seoul, the forces against change have counteracted the forces for change, subsequently resulting in limits in transitions progress. Our case study has shown that political economy analysis of energy transitions is significant in offering a better understanding about the conditions conducive to or impeding more effective governance. Our conceptualization allows us to make predictions on the governing capacity of energy transitions; the more conducive conditions exist, the more likely that there are effective energy transitions.

Thirdly, the multi-scalar perspective in this case study highlights the multiple and often conflicting trends, values, preferences, and governing approaches of different actors with regard
to niche development and regime change. Niches are shaped not only at the local level, but also by politico-economic factors at the city and national levels. Our case study confirms the multi-scalar research that states local sustainability decisions and actions are seldom entirely local, but are conditioned by the values, priorities, and policies of state and non-state actors on various geographic and administrative scales [103]. We also confirm the literature that states a scale-sensitive governance system is needed for energy transitions to respond to inter-scalar political interactions [31].

Our findings have various policy implications. We shed more light on what conditions are promoting and impeding niche development, and where these conditions are (at which spatial scales—national, city, or community). Three policy recommendations can be derived from our findings. Firstly, governments can apply our framework to critically evaluate whether the current energy systems and the associated governance and political systems are well equipped to enable the desired energy transitions. Policies and governance strategies should then focus on reinforcing the conducive conditions or positive drivers for change that exist, and on addressing the inhibitive conditions. Secondly, governments need to give sufficient attention to “operational” strengths and limits of various scales of transitions. In the case study, the community in Sungdaegol acts as a niche testbed, but this testbed has been conditioned by the broader contexts at Seoul’s city and national levels. In some important aspects, Sungdaegol has made good progress in technological niche developments. However, the “developmental state” ideologies and incomplete electricity market reforms, for example, have constrained the further development of market niches. Our multi-scalar research approach suggests that governments must focus on leveraging existing or potentially complementary or reinforcing effects across the three administrative levels. Thirdly, our findings reveal the difficulties for governments to assume new roles in energy transitions. The strong solar policies, particularly in the form of direct subsidies introduced by Seoul’s mayor, may present a problem of excessive government intervention, as the government has overlooked its role in building markets for a sustainable solar industry. There is, for example, minimal demand for loans. Governments need to be responsive enough to assume new roles and retreat from some. Energy transitions are context-dependent. This case study of Seoul has limitations in generalizability. However, it is important to note that our conceptualization of niche–regime interactional mechanisms is not exclusive to the Korean context, and can be applied to energy transitions research in other national contexts. In relation to future research directions, a comparative study of a number of case cities with diverse national institutional contexts would test the generalizability of the framework. Furthermore, this may assist in identifying cities where the environment is more conducive to niche development and which might therefore be more likely to deliver energy transitions towards sustainability.

Author Contributions: Conceptualization, D.N.-y.M.; methodology, D.N.-y.M.; formal analysis, D.N.-y.M. and D.M.-w.C.; investigation, D.N.-y.M. and D.M.-w.C.; resources, D.N.-y.M. and D.M.-w.C.; data curation, D.N.-y.M. and D.M.-w.C.; writing—original draft preparation, D.N.-y.M. and D.M.-w.C.; writing—review and editing, D.N.-y.M. and D.M.-w.C.; project administration, D.N.-y.M. and D.M.-w.C.; funding acquisition, D.N.-y.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Hong Kong Research Grants Council, University Grants Committee’s General Research Fund, grant number 12602717, and Hong Kong Baptist University’s Faculty Research Grant, grant number FRG2/17-18/096.

Acknowledgments: The authors sincerely thank the academic editor and two anonymous reviewers for providing valuable comments for revising this manuscript, as well as the interviewees for providing valuable information for this study.

Conflicts of Interest: The authors declare no conflict of interest.
Appendix A. List of Interviewees

All of the interviewees agreed to be interviewed anonymously and were indicated by numbers. All interviews were semi-structured and conducted face-to-face. Some interviews were useful to inform the authors, but might not be referenced in the main content.

| Codes of Interviewees | Interviewees Background | Dates of Interviews | Duration of Interviews (Approximately) |
|-----------------------|-------------------------|---------------------|----------------------------------------|
| 1.                    | An associate research fellow of the Korea Energy Economics Institute | 22 November 2017 | 1 h 30 min |
| 2. and 3.             | A senior researcher and a senior manager of the Economy and Management Research Institute, KEPCO | 23 November 2017 | 1 h (group interview) |
| 4.                    | An assistant professor of the Department of Urban Administration, University of Seoul | 23 November 2017 | 2 h |
| 5.                    | A chairman of resident representatives of a residential property in Dongjak-gu, Seoul | 24 November 2017 | 30 min |
| 6.                    | An administration manager of a residential property in Dongjak-gu, Seoul | 24 November 2017 | 30 min |
| 7a.                   | Sungdaegol community representative A in Dongjak-gu, Seoul | 25 November 2017 | 2 h |
| 7b.                   | Same interview as 7a | 9 July 2018 | 2 h 30 min |
| 8.                    | Sungdaegol community representative B in Dongjak-gu, Seoul | 9 July 2018 | 2 h |
| 9.                    | Sungdaegol community representative C in Dongjak-gu, Seoul | 9 July 2018 | 1 h (group interview) |
| 10.                   | Sungdaegol merchants’ federation representative; community representative D in Dongjak-gu, Seoul | 9 July 2018 | 1 h (group interview) |
| 11.                   | A director of a credit union in Dongjak-gu, Seoul | 9 July 2018 | 30 min |
| 12.                   | Chairman and President of a credit union in Dongjak-gu, Seoul | 9 July 2018 | 45 min |
| 13.                   | Representative of a solar company in Seoul | 9 July 2018 | 45 min |
| 14.                   | An assistant professor of the Corporate Course for Climate Change, Sejong University; Academic member A of the Implementation Committee, One Less Nuclear Power Plant | 10 July 2018 | 1 h 45 min |
| 15.                   | A professor of the Graduate School of Environmental Studies, Seoul National University; Academic member B of the Implementation Committee, One Less Nuclear Power Plant | 10 July 2018 | 1 h 15 min |
| 16.                   | A director of the Korea Federation for Environmental Movements | 10 July 2018 | 1 h 15 min |
| 17.                   | A researcher of the Institute of Green Transition, South Korea; Also a member of the Presidential Committee on Green Growth | 11 July 2018 | 40 min |
| 18.                   | A government official of the Green Energy Division, Seoul Metropolitan Government | 12 December 2019 | 1 h |
References

1. **Solarize NYC**: NYC Solar Partnership: New York, NY, USA, 2019.
2. Chung, E. Gov’t announces plan to take Seoul solar. Korea JoongAng Daily, 22 November 2017.
3. Almirall, E.; Wareham, J.; Ratti, C.; Conesa, P.; Bria, F.; Gaviria, A.; Edmondson, A. Smart Cities at the Crossroads: New tensions in city transformation. *Calif. Manag. Rev.* 2016, 59, 141–152. [CrossRef]
4. Jacobson, M.Z.; Cameron, M.; Hennessy, E.M.; Petkov, I.; Meyer, C.B.; Gambhir, T.K.; Maki, A.T.; Pfeiffer, K.; Clonts, H.; McEvoy, A.; et al. 100% clean and renewable Wind, Water, and Sunlight (WWS) all-sector energy roadmaps for 53 towns and cities in North America. *Sustain. Cities Soc.* 2018, 42, 22–37. [CrossRef]
5. Rohracher, H.; Späth, P. The Interplay of Urban Energy Policy and Socio-technical Transitions: The Eco-cities of Graz and Freiburg in Retrospect. *Urban Stud.* 2013, 51, 1415–1431. [CrossRef]
6. Wolfram, M. Cities shaping grassroots niches for sustainability transitions: Conceptual reflections and an exploratory case study. *J. Clean. Prod.* 2018, 173, 11–23. [CrossRef]
7. IEA. *World Energy Outlook 2018*; International Energy Agency: Paris, France, 2018.
8. IPCC. *Special Report: Global Warming of 1.5 °C*; IPCC: Geneva, Switzerland, 2018.
9. Geels, F.W. The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environ. Innov. Soc.* 2011, 1, 24–40. [CrossRef]
10. Newell, P.; Phillips, J. Neoliberal energy transitions in the South: Kenyan experiences. *Geoforum* 2016, 74, 39–48. [CrossRef]
11. Tian, D.; Ying, Q.; Han, B. Xinhu Headlines: “Yellow vest” movement points to a troubled France. *Xinhuanews*, 16 December 2018.
12. Heo, I. The Political Economy of Policy Gridlock in South Korea: The Case of the Lee Myung-bak Government’s Green Growth Policy. *Polit. Policy* 2013, 41, 509–535. [CrossRef]
13. Geels, F.W. Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Res. Policy* 2002, 31, 1257–1274. [CrossRef]
14. Genus, A.; Coles, A.-M. Rethinking the multi-level perspective of technological transitions. *Res. Policy* 2008, 37, 1436–1445. [CrossRef]
15. Smith, A.; Voß, J.-P.; Grin, J. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Res. Policy* 2010, 39, 435–448. [CrossRef]
16. Baker, L.; Burton, J. The politics of procurement and the low-carbon transition in South Africa. In *Handbook of the International Political Economy of Energy and Natural Resources*; Edward Elgar Publishing: Cheltenham, UK, 2018; pp. 91–106.
17. Geels, F.W.; Schot, J. Typology of sociotechnical transition pathways. *Res. Policy* 2007, 36, 399–417. [CrossRef]
18. Mah, D.N.-Y.; Van Der Vleuten, J.M.; Ip, J.C.-M.; Hills, P. Governing the transition of socio-technical systems: A case study of the development of smart grids in Korea. *Energy Policy* 2012, 45, 133–141. [CrossRef]
19. Schot, J.; Geels, F.W. Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. *Technol. Anal. Strat. Manag.* 2008, 20, 537–554. [CrossRef]
20. Klitkou, A.; Bolwig, S.; Hansen, T.; Wessberg, N. The role of lock-in mechanisms in transition processes: The case of energy for road transport. *Environ. Innov. Soc. Transit.* 2015, 16, 22–37. [CrossRef]
21. Harborne, P.; Hendry, C.; Brown, J. The Development and Diffusion of Radical Technological Innovation: The Role of Bus Demonstration Projects in Commercializing Fuel Cell Technology. *Technol. Anal. Strat. Manag.* 2007, 19, 167–188. [CrossRef]
22. Arent, D.; Arndt, C.; Miller, M.; Tarp, F.; Zinaman, O. (Eds.) *The Political Economy of Clean Energy Transitions*; WIDER Studies in Development Economics; Oxford University Press: Oxford, UK, 2017.
23. Inderberg, T.H.J.; Tews, K.; Turner, B. Is there a Prosumer Pathway? Exploring household solar energy development in Germany, Norway, and the United Kingdom. *Energy Res. Soc. Sci.* 2018, 42, 258–269. [CrossRef]
24. Kucharski, J.B.; Unesaki, H. An institutional analysis of the Japanese energy transition. *Environ. Innov. Soc. Transit.* 2018, 29, 126–143. [CrossRef]
25. Mori, A. Socio-technical and political economy perspectives in the Chinese energy transition. *Energy Res. Soc. Sci.* 2018, 35, 28–36. [CrossRef]
26. Baker, L.; Newell, P.; Phillips, J. The Political Economy of Energy Transitions: The Case of South Africa. *New Polit. Econ.* 2014, 19, 791–818. [CrossRef]
27. Strunz, S.; Gawel, E.; Lehmann, P. The political economy of renewable energy policies in Germany and the EU. *Util. Policy* 2016, 42, 33–41. [CrossRef]
28. Tsai, C.-M. The Political Economy of Restructuring the Electricity Sector in South Korea. *Issues Stud.* 2016, 52, 1650004. [CrossRef]
29. Valentine, S.V.; Sovacool, B.K. The socio-political economy of nuclear power development in Japan and South Korea. *Energy Policy* 2010, 38, 7971–7979. [CrossRef]
30. Unruh, G.C. Escaping carbon lock-in. *Energy Policy* 2002, 30, 317–325. [CrossRef]
31. Padt, F.; Arts, B. (Eds.) Concepts of scale. In *Scale-Sensitive Governance of the Environment*; Wiley Blackwell: Chichester, UK; Hoboken, NJ, USA, 2014; pp. 1–26.
32. Sovacool, B.K. The political economy of energy poverty: A review of key challenges. *Energy Sustain. Dev.* 2012, 16, 272–282. [CrossRef]
33. Meadwocroft, J. Engaging with the politics of sustainability transitions. *Environ. Innov. Soc. Transf.* 2011, 1, 70–75. [CrossRef]
34. Greenberg, M. Energy sources, public policy, and public preferences: Analysis of US national and site-specific data. *Energy Policy* 2009, 37, 3242–3249. [CrossRef]
35. Petersen, J.-P. The application of municipal renewable energy policies at community level in Denmark: A taxonomy of implementation challenges. *Sustain. Cities Soc.* 2018, 38, 205–218. [CrossRef]
36. Avelino, F. Power in Sustainability Transitions: Analysing power and (dis)empowerment in transformative change towards sustainability. *Environ. Policy Gov.* 2017, 27, 505–520. [CrossRef]
37. Saculsan, P.G.; Mori, A. Why Developing Countries Go through an Unsustainable Energy Transition Pathway? The Case of the Philippines from a Political Economic Perspective. *J. Sustain. Res.* 2020, 2, 200012. [CrossRef]
38. Kostka, G.; Hobbs, W. Embedded Interests and the Managerial Local State: The political economy of methanol fuel-switching in China. *J. Contemp. China* 2013, 22, 204–218. [CrossRef]
39. Lundvall, B.-A. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*; Pinter Publishers: London, UK, 1992.
40. Mah, D.N.-Y.; Hills, P. Collaborative Governance for Technological Innovation: A Comparative Case Study of Wind Energy in Xingjiang, Shanghai, and Guangdong. *Environ. Plan. C Gov. Policy* 2014, 32, 509–529. [CrossRef]
41. Kim, E.-S. Sociotechnical Imaginaries and the Globalization of Converging Technology Policy: Technological Developmentalism in South Korea. *Sci. Cult.* 2017, 27, 175–197. [CrossRef]
42. Grübler, A. The costs of the French nuclear scale-up: A case of negative learning by doing. *Energy Policy* 2010, 38, 5174–5188. [CrossRef]
43. Hadjilambrinos, C. Understanding technology choice in electricity industries: A comparative study of France and Denmark. *Energy Policy* 2000, 28, 1111–1126. [CrossRef]
44. Geels, F.W. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Res. Policy* 2004, 33, 897–920. [CrossRef]
45. Heiskanen, E.; Matschoss, K. Understanding the uneven diffusion of building-scale renewable energy systems: A review of household, local and country level factors in diverse European countries. *Renew. Sustain. Energy Rev.* 2017, 75, 580–591. [CrossRef]
46. Schweizer, P.-J.; Renn, O.; Kück, W.; Bovet, J.; Benighaus, C.; Scheel, O.; Schröter, R. Public participation for infrastructure planning in the context of the German “Energiewende”. *Util. Policy* 2016, 43, 206–209. [CrossRef]
47. Byrne, J.; Mun, Y.-M. Rethinking reform in the electricity sector: Power liberalisation or energy transformation? In *Electricity Reform: Social and Environmental Challenges*; Wamukonya, N., Ed.; UNEP-RISØ Centre: Roskilde, Denmark, 2003; pp. 49–76.
48. Torvanger, A.; Meadowcroft, J. The political economy of technology support: Making decisions about carbon capture and storage and low carbon energy technologies. *Glob. Environ. Chang.* 2011, 21, 303–312. [CrossRef]
49. Mah, D.N.-Y. Community solar energy initiatives in urban energy transitions: A comparative study of Foshan, China and Seoul, South Korea. *Energy Res. Soc. Sci.* 2019, 50, 129–142. [CrossRef]
50. Quitzow, R. Dynamics of a policy-driven market: The co-evolution of technological innovation systems for solar photovoltaics in China and Germany. *Environ. Innov. Soc. Transf.* 2015, 17, 126–148. [CrossRef]
52. Meadowcroft, J. Environmental political economy, technological transitions and the state. *New Polit. Econ.* 2005, 10, 479–498. [CrossRef]
53. Miles, M.B.; Huberman, A.M. *Qualitative Data Analysis: An Expanded Sourcebook*, 2nd ed.; Huberman, A.M., Ed.; Sage Publications: Thousand Oaks, CA, USA, 1994.
54. KEI. *2017 Energy Info Korea*; Korea Energy Economics Institute: Ulsan, Korea, 2017.
55. KEI. *2018 Yearbook of Energy Statistics*; Korea Energy Economics Institute: Ulsan, Korea, 2018.
56. KEI. *2018 Yearbook of Regional Energy Statistics*; Korea Energy Economics Institute: Ulsan, Korea, 2018.
57. WNA. *World Nuclear Performance Report 2018*; World Nuclear Association: London, UK, 2018.
58. Dong, J.I.; Jeong, E.T. New Renewable Energy: One Less Nuclear Power Plant. 2018. Available online: https://seoulsolution.kr/print/3363 (accessed on 27 November 2018).
59. Alsharif, M.H.; Kim, J.; Kim, J.H. Opportunities and Challenges of Solar and Wind Energy in South Korea: A Review. *Sustainability* 2018, 10, 1822. [CrossRef]
60. Seoul Metropolitan Government. *Seoul Statistical Yearbook 2018*; Seoul Metropolitan Government: Seoul, Korea, 2018.
61. Shin, J.-H. Korea to continue to go nuclear-free despite Taiwan’s pro-nuclear move. *The Korea Herald*, 26 November 2018.
62. WNA. *Nuclear Power in South Korea*; World Nuclear Association: London, UK, 2018; Available online: http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea.aspx (accessed on 9 November 2018).
63. Joo, Y.-M. *Megacity Seoul: Urbanization and the Development of Modern South Korea*; Routledge: London, UK, 2018.
64. Kim, H. A Community Energy Transition Model for Urban Areas: The Energy Self-Reliant Village Program in Seoul, Korea. *Sustainability 2017*, 9, 1260. [CrossRef]
65. IEA. IEA Atlas of Energy. Available online: http://energyatlas.iea.org/ (accessed on 23 January 2019).
66. MOTIE. *The 8th Basic Plan for Long-term Electricity Supply and Demand (2017–2031)*; The Ministry of Trade, Industry and Energy (MOTIE): Sejong, Korea, 2017.
67. Korea Energy Agency. Feed-in Tariffs for New and Renewable Energy. 2015. Available online: http://www.energy.or.kr/renew_eng/new/renewable.aspx (accessed on 4 April 2018).
68. Korea Energy Agency. Renewable Portfolio Standards (RPS). 2015. Available online: http://www.energy.or.kr/renew_eng/new/standards.aspx (accessed on 11 June 2018).
69. MOTIE. Promotion of New and Renewable Energy. 2014. Available online: http://english.motie.go.kr/en/tp/alltopics/bbs/bbsView.do?bbs_cd_n=3&bbs_seq_n=19# (accessed on 29 November 2018).
70. MOTIE. *The 7th Basic Plan for Long-Term Electricity Supply and Demand (2015–2029)*; The Ministry of Trade, Industry and Energy (MOTIE): Sejong, Korea, 2016.
71. The Public Deliberation Committee on Shin-Gori Nuclear Reactors No. 5 & 6. *Results of Participatory Surveys for Public Deliberation on Shin-Gori Nuclear Reactors No. 5 & 6*; The Public Deliberation Committee on Shin-Gori Nuclear Reactors No. 5 & 6: Seoul, Korea, 2017.
72. Choi, H.-Y. South Korean government releases draft of plans to increase renewable energy use. *Hankyoreh*, 26 December 2017.
73. Lee, C. Seoul announces 32.5 percent domestic greenhouse gas reduction goal. *The Korea Herald*, 24 July 2018.
74. MOTIE. Full-Scale Implementation of FIT System for Small-Scale Solar Power Generation Companies. 2018. Available online: http://www.motie.go.kr/motie/ne/presse/press2/bbs/bbsView.do?bbs_cd_n=81&cate_n=1&bbs_seq_n=160642 (accessed on 9 November 2018).
75. Lee, T. Translocal Relations & Climate Change in Asia. 2017. Available online: https://www.youtube.com/watch?time_continue=2&v=EFvNOWkBvYQ&feature=emb_logo (accessed on 26 March 2020).
76. Kim, D.-S. Seoul City to expand support for installation of solar panels at homes. *The Korea Herald*, 14 August 2017.
77. Byrne, J.; Taminiau, J.; Kurgdelashvili, L.; Kim, K.N. A review of the solar city concept and methods to assess rooftop solar electric potential, with an illustrative application to the city of Seoul. *Renew. Sustain. Energy Rev.* 2015, 41, 830–844. [CrossRef]
78. Yun, S.-J. Seoul’s Energy Transition Experiment: One Less Nuclear Power Plant Initiative. In *IEA Renewable Energy Working Party “Scaling-Up Renewables through Decentralised Energy Solutions”*; International Energy Agency: Paris, France, 2017.
79. Lee, J.-S.; Kim, J.W. The Factors of Local Energy Transition in the Seoul Metropolitan Government: The Case of Mini-PV Plants. *Sustainability* 2017, 9, 386. [CrossRef]
80. Invest Korea. *Investment Opportunities in Korea: New & Renewable Energy*; Invest Korea: Seoul, Korea, 2017.
81. Lee, J.S.; Kim, J.-W. South Korea’s urban green energy strategies: Policy framework and local responses under the green growth. *Cities* 2016, 54, 20–27. [CrossRef]
82. Seoul Metropolitan Government. Joint Declaration of Regional Energy Conversion (Text in Korean). 2015. Available online: https://opengov.seoul.go.kr/press/6756934 (accessed on 4 April 2018).
83. C40 Cities Climate Leadership Group. The Power of C40 Cities. 2019. Available online: https://www.c40.org/cities (accessed on 30 January 2019).
84. Johnson, C. *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925–1975*; Stanford University Press: Stanford, CA, USA, 1982.
85. Önis, Z.; Amsden, A.H.; Deyo, F.C.; Johnson, C.; Wade, R. The Logic of the Developmental State. *Comp. Polit.* 1991, 24, 109. [CrossRef]
86. Caldentey, E.P. The Concept and Evolution of the Developmental State. *Int. J. Polit. Econ.* 2008, 37, 27–53. [CrossRef]
87. Chu, Y.-W. *The Asian Developmental State: Reexaminations and New Departures*; Palgrave Macmillan: Basingstoke, UK, 2016.
88. Chung, J.B.; Kim, E.-S. Public perception of energy transition in Korea: Nuclear power, climate change, and party preference. *Energy Policy* 2018, 116, 137–144. [CrossRef]
89. Jasanoﬀ, S.; Kim, S.-H. Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea. *Minerva* 2009, 47, 119–146. [CrossRef]
90. Hong, S.; Brook, B.W. A nuclear- to-gas transition in South Korea: Is it environmentally friendly or economically viable? *Energy Policy* 2018, 112, 67–73. [CrossRef]
91. Kim, K.; Cho, Y. Estimation of power outage costs in the industrial sector of South Korea. *Energy Policy* 2017, 101, 236–245. [CrossRef]
92. Yoon, J.-H.; Sim, K.-H. Why is South Korea’s renewable energy policy failing? A qualitative evaluation. *Energy Policy* 2015, 86, 369–379. [CrossRef]
93. Green, J. Japan’s nuclear scandals and the Fukushima Disaster. 1 March 2012. Available online: http://archive.foe.org.au/sites/default/files/FUKUSHIMA_BRIEFING_MARCH_2012_0.pdf (accessed on 12 November 2018).
94. Kim, S.; Kim, Y.; Shin, J.S. The Korean electricity market: Stuck in transition. In *Evolution of Global Electricity Markets*; Sioshansi, F.P., Ed.; Academic Press: Boston, MA, USA, 2013; pp. 679–713.
95. Kim, S.-Y.; Mathews, J.A. Korea’s Greening Strategy: The role of smart microgrids. *Asia-Paciﬁc J.* 2016, 14, 4987.
96. Shin, J.-H. Korean tech giants under pressure to go renewable. *The Korea Herald*, 4 November 2018.
97. KPX. KPX Membership Status. 2019. Available online: http://www.kpx.or.kr/www/contents.do?key=55 (accessed on 23 April 2020).
98. Laes, E.; Gorissen, L.; Nevens, F. A Comparison of Energy Transition Governance in Germany, The Netherlands and the United Kingdom. *Sustainability* 2014, 6, 1129–1152. [CrossRef]
99. Mah, D.N.-Y.; Wu, Y.-Y.; Hills, P.R. Explaining the role of incumbent utilities in sustainable energy transitions: A case study of the smart grid development in China. *Energy Policy* 2017, 109, 794–806. [CrossRef]
100. Rizzo, A. Managing the energy transition in a tourism-driven economy: The case of Malta. *Sustain. Cities Soc.* 2017, 33, 126–133. [CrossRef]
101. Fuller, S.; Bulkeley, H. Creating a low carbon zone in Brixton, London, UK. In *An Urban Politics of Climate Change: Experimentation and the Governing of Socio-Technical Transitions*; Bulkeley, H.A., Broto, V.C., Edwards, G.A.S., Eds.; Routledge: Abingdon, UK, 2014; pp. 199–218.
102. HDB. *HDB Calls First and Largest Solar Leasing Tender on Behalf of Multiple Agencies under EDB’s Solarnova Programme*; Housing & Development Board: Singapore, 2015.

103. Tilt, B. The Political Ecology of Pollution Enforcement in China: A Case from Sichuan’s Rural Industrial Sector. *China Q.* 2007, 192, 915–932. [CrossRef]