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Low-Carbon Transition of the Power Sector in Southeast Asia:

A Case Analysis on Thailand in the Face of Disruptive Technologies

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Abstract

In understanding the low-carbon transition dynamics of the power sector, this paper draws upon two separate strands of existing literature, namely the mainstream sustainability transition theory — multilevel perspective (MLP) approach — and the canonical disruptive innovation paradigms. It is observed that the former doctrine follows a holistic pattern that maps out general conditions under which transition is to occur, but is overly deterministic and falls short of contemplation on actors themselves; by contrast, the latter is actor-based and investigates locally their responses towards disruptive technologies, but has been mainly applied in the context of business strategy research. In this regard, the particularity of the power sector in Southeast Asian countries, wherein the state-owned power utility falls under the category of both a sociotechnical regime through the lens of MLP approach and technological incumbents through the prism of disruptive innovation paradigm, may link these two literatures together. Acknowledging the sociotechnical nature of technological transformation which is a non-linear process, this article suggests three dimensions to evaluate whether a country's power sector is undergoing low-carbon transition: reconfiguration within the incumbent power regime, business model transformation, and the evolving regime-niche relationship. A case analysis is performed on Thailand against the proposed framework, and it is concluded that the Thai power sector is indeed undergoing a low-carbon transition. However, Thailand's progress may not be similarly discerned in other Southeast Asian countries, which offers a fertile ground for future research on the power sector of those countries and on the possible reasons why they demonstrate different levels of low-carbon transition.

Keywords: Low-carbon transition, disruptive technologies, Sustainability, STI studies, Thailand.

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1. Introduction

In a bid to limit global warming to 1.5°C with the objective of reducing the negative effects of climate change, "global net anthropogenic CO2 emissions [should] decline by about 45% from 2010 levels by 2030" (IPCC 2018: 14). Rapid transition towards a low-carbon economy, especially in Association of Southeast Asian Nations' (ASEAN) countries which are vulnerable to climate change effects, cannot afford to be delayed (Eco- Business Research 2018). Such a transition process, according to the 2018 IPCC Special Report, requires "widespread adoption of new and possibly disruptive technologies and practices and enhanced climate-driven innovation" (Ibid: 24). In this sense, there is no doubt that new low-carbon technologies, e.g. solar photovoltaic, smart grid and electric vehicles, which have been vastly analyzed in mitigation scenarios and modeling studies, are bound to play a pivotal role in modifying or disrupting the business-as-usual (BAU) model of energy generation and production and "enabling transitions to low carbon economies and societies" (Wilson 2018; Urban 2018: 321). In other words, the utilization of new and disruptive low-carbon technologies is a *sine qua non* for low-carbon transition, while a speedy low-carbon transition to timely limit global warming depends on and results from the extent to which these new and disruptive low-carbon technologies are produced, adopted and disseminated across the globe. In brief, sociotechnical transition and technological change are engaged in a symbiotic relationship.

Sustainability transition and technological change have attracted abundant research. On the one hand, the *multilevel perspective* (MLP) approach (Rip & Kemp 1998; Geels & Schot 2007) as the mainstream sustainability transition paradigm elucidates the conditions under which different typologies of transition are likely to take place, by suggesting that the *timing* and *nature* of interaction between landscape, regime and niche may lead to distinct transition pathways. Here, landscape connotes exogenous environment, international institutions and trend; regime englobes shared national policymakers, scientists or stabilized cognitive routines; and niches constitutes ''the micro-level where radical novelties emerge'' (Ibid: 400). However, the MLP is concerned with the holistic process of transition, downplaying the actual role played by actors involved. On the other hand, the canonical literature of disruptive innovation (Christensen 1993; Rosenbloom & Christensen 1997; Gilbert 2005; Henderson 2006; Markides 2006; O'Reilly & Tushman 2007) zooms in on actors, and provides a clear understanding on the micro-level of the "immediate action processes that create short-run developmental patterns" (Poole & Van de Ven in Geels & Schot 2007: 414). Nonetheless, the main preoccupation of this stream of studies with firms and their respective market and organizational strategy tend to de-emphasize socio-institutional and socio-cognitive factors in shaping the technological change process. Given their complementary foci, when these two lines of studies are combined, they may contribute to a clearer comprehension of the ongoing low-carbon transition taking place across the globe.

This paper adopts the position that the low-carbon transition in the broader sociotechnical dimension is influenced by the dynamics of technological change on the micro-level, while the evolution of (micro-)niche low-carbon technology is in turn shaped and conditioned by the larger transition dynamics. Also, it holds the view that a socio-cognitive mechanism plays an essential role in technological transformation, whereby the types of new technologies and innovations are bound to be shaped by the cognitive factors of human society. For the purpose of this paper, *technology,* following the definition by Rip and Kemp (1998: 387), depicts *configurations that work*, so as to eschew "the individualistic bias of a tools concept" and incorporate "large technical systems". Drawing upon these two streams of theories, this paper aims to discern the low-carbon transition dynamics in the power sector by asking how and to what extent the power sector in Southeast Asia is undergoing a low-carbon transition in the face of disruptive low-carbon technologies and what the concrete embodiment of such a transition is. Two following reasons are presented for choosing the power sector as the research object: first, Southeast Asian countries face formidable climate challenges and have pledged in their national policies to augment the share of renewable energy sources in their energy mix as well as increase energy efficiency; second, the profile of state-owned utilities in these nations as lasting dominant power producers reliant on fossil fuels and as *single buyers* controlling the transmission and sometimes the distribution system can in essence be depicted, through the MPL lens, as representatives of the technological *incumbent* on the one hand and, from the disruptive innovation perspective, as part of the domestic sociotechnical *regime* on the other (IAEA 2018). Following this logic, the unique profile of the state electricity authorities in Southeast Asia and their overwhelming weight in the power sector open a ground for analysis of the *incumbent* power *regime*'s low- carbon transition drawing on a combination of the two approaches.

This paper first provides an overview of existing theories concerning sustainability transition and disruptive technologies, respectively, while seeking to find a potential common ground that may link these two separate streams of studies in evaluating the low-carbon transition process. It then moves on to operationalize the key concepts by proposing some instances of the concrete embodiment of low-carbon transition of the power sector. Subsequently, a case study will concentrate on the power sector in Thailand, a progressive case among the ASEAN Member-States (AMS). This study is primarily based on examination on academic literature, think tank and media reports. Meanwhile, seven in-depth semi-structured interviews with Thai government officials, representatives from state utilities, civil society organizations and business groups have contributed to triangulate information. Following that, the paper will discuss the preliminary findings and potential considerations behind those, before drawing conclusion on the transition situation.

2. Theoretical framework: sustainability transition and disruptive innovation

This section aims to conduct a brief review of existing theories with regards to sustainability transition and disruptive technologies. As stated, low-carbon transition in a broader and more global sociotechnical dimension co-evolves in tandem with the technological change on a lower and more local level. It attempts to find an intermediary theoretical ground that enables a renewed interpretation of the power sector's low-carbon transition against the backdrop of the emergence of disruptive low-carbon technologies.

2.1. Multilevel Perspective – Mainstream approach to study sustainability transition

It is useful to first recall the definition of *transition*. As per Grin (2016: 105), transitions can be defined as "profound societal transformations in that they involve changes in both multiple, interacting societal practices and the institutional, structural and discursive structures in which these are embedded". Traditional sustainability transition theory is best exemplified by the multilevel perspective (MLP) approach (Rip & Kemp 1997; Geels & Schot 2007) which contemplates the interaction dynamics between three different levels in shaping the transition process: external *landscape* on the macro level, domestic *regime* on the meso level and domestic *niche* on the micro level. The *timing* and *nature* of the interaction lies at the core of the framing of the MLP approach: first, "[i]f landscape pressure occurs at a time when niche-innovations are *not* yet fully developed, the transition path will be different than when they *are* fully developed" (Geels & Shot 2007: 405); second, whether or not transition takes place also depends on the *reinforcing* or *disruptive* nature of the niche-innovations and the landscape pressure: should innovations reinforce the profile of the existing technology, the regime falls short of incentives to make a change; on the contrary, should they be disruptive, the regime is more likely to undergo a transition (Ibid: 406). As will be explained in the next part, this to a certain degree echoes the concepts of *sustaining* and *disruptive innovations* in the canonical disruptive transformation literature (Christensen *et al.* 2018). To continue, different *timings* of multilevel interaction may result in five distinct transition pathways: *reproduction*, *transformation*, *de-alignment* or *re-alignment*, *substitution* and *reconfiguration*. Figure 1 shows the pathways in detail. Geels and Schot (2007: 413) also note that it is likely that transition follows a particular sequential pattern, but cross-overs may also occur between transition pathways. Apart from the MLP, a more nuanced concept of *niche-regime* was later put forward by Rotmans and Loorbach (2010) to refine the original MLP approach, given that it is the *niche-regime*, an intercalary level between niche and regime, that acts as a key element in the transition process whereby "regime changes gradually result from changes at the niche level" (Grin 2016: 109).

Figure 1: Typologies of transition pathways (Geels & Schot 2007: 54-76)

Reproduction path	If there is no external landscape pressure, then the regime remains dynamically stable and will reproduce itself.
Transformation path	If there is moderate landscape pressure ('disruptive change') at a moment when niche-innovations have *not* yet been sufficiently developed, then regime actors will respond by *modifying the direction* of development paths and innovation activities.
De- / re-alignment path	If landscape change is divergent, large and sudden ('avalanche change'), then increasing regime problems may cause regime actors to lose faith.
Reconfiguration path	Symbiotic innovations, which developed in niches, are initially adopted in the regime to solve local problems.
Substitution path	If there is much landscape pressure ('specific shock', 'avalanche change', 'disruptive change') at a moment when niche-innovations *have* developed sufficiently, the latter will break through and replace the existing regime.

By and large, this mainstream sustainability transition theory sheds light on the understanding of the general circumstances under which a certain type of transition is more likely to occur. It holds explanatory power, valuable for a better comprehension of transition dynamics by incorporating socio-cognitive factors into the evaluation. However, there are two observations that need to be made here with respect to this theoretical framework. First, the underlying thesis that the very *timing* and *nature* of two variables' — niche-innovation and landscape pressure — interaction with the regime may lead to different transition pathways renders secondary the actual *interaction* between actors. Rather than a *local* model that dwells upon the "immediate action process that creates short-term developmental patterns", the MLP is more of a *global* model that "maps the entire transition process […] (and) tends to give less attention to actors" (Poole & Van de Ven in Geels & Schot 2007: 414). Second, it appears that, in Geels and Schot (2007)'s thesis, transition will take place in a deterministic manner so long as the external pressure intervenes on a "right" timing, leaving unanswered the matter of regime *inertia*. Even though Rotmans and Loorbach (2010) touch on *inertia,* they attribute it to the equilibrium in the established system which can be, again, disrupted by pressure. Insightful at it is, it does not explain why some incumbent sociotechnical *regimes* resist to top-down or bottom-up pressure longer than the others. This is to say that internal adjustments or reforms within the regimes sometimes do reflect a certain degree of transition.

2.2. Paradigm of disruptive innovation

The literature revolving around disruptive innovation displays some internal inconsistencies (Christensen *et al.* 2018: 1043), and scholars have continuously questioned the *ex-ante* predictability of this paradigm despite its utility for *ex-post* analysis. Eschewing the discussion of this debate, this section looks at the canonical strand of the disruptive innovation paradigm.

First and foremost, disruptive innovation is defined as "an innovation that helps create a new market and value network, and eventually goes on to disrupt an existing market and value network (over a few years or decades), displacing an earlier technology" (Christensen & Bower in Tayal 2016: 15). Existing scholarship on disruptive innovation shows that technological transformation is closely associated to firms and strategy, e.g. whether and how incumbents of a certain technology respond immediately in market or organizational terms to an emerging innovation. Here, the paramount attention is given to the dynamics between technological incumbents and new entrants, as well as to their respective market strategy, change of organizational structure and business model, among others. In this manner, technological change in this literature (Christensen 1993; Rosenbloom & Christensen 1997; Gilbert 2005; Henderson 2006; Markides 2006; O'Reilly & Tushman 2007) is analyzed in more of a local sense, as opposed to the global model which the aforementioned sustainability transition theories depart from.

According to this paradigm, it is useful to distinguish *sustaining innovations* from *disruptive innovations* (Christensen 1993; Christensen 1997). Incumbents are more prone to develop *sustaining innovations* that "improve products and services along dimensions of performance" in order to secure their mainstream customers and established markets, than to develop *disruptive innovations* that are initially "*inferior* to incumbent products on accepted performance dimensions, but […] offer a novel mix of attributes that appeal to fringe customer groups, notably those near the bottom of the market" (Christensen *et al.* 2018: 1048). It is posited, in a similarly deterministic manner, that incumbents will decline in the face of disruptive technologies because they prioritize well-defined existing customers over fringe customers, which incentivizes them to focus on *sustaining innovations* and de-incentivizes them from developing *disruptive innovations*. Eventually, incumbents succumb as a result of "attacks by start-ups and the new architectural technologies the entrants employed" (Christensen 1993: 569). This classification echoes the aforementioned Geels and Schot (2007)'s distinction between *reinforcing* and *disruptive* nature of technologies.

On the one hand, this traditional line of disruptive innovation thinking is insightful in that it amounts to the suggestion of a common causal mechanism for disruptions — pursuit of *profitability* that prompts both incumbents and new entrants to move up-market rather than down-market (Christensen *et al.* 2018: 1051). On the other hand, however, it falls short of socio-institutional and socio-cognitive considerations. Various previous case studies on disruptive innovation have demonstrated that "[o]lder firms that initially rejected the new product architecture often found that they were unable to move to the new standard in time and as a result most of the incumbent firms failed or exited the business" (Nair & Ahlstrom 2003: 347). This deterministic so-called *technology cycle model* deemphasizes the institutional, ecological and technical factors that, in other cases, lead to the *coexistence* of technologies during the transformation period (Ibid). In the power sector of many countries, for example, different power generation, transmission and distribution technologies find themselves in an *era of ferment* when they compete, co-exist and co-evolve with one another. Therefore, it is far too early to jump to the prediction on when and which disruptive low-carbon technologies will ultimately displace the electricity incumbents. Moreover, Marx, Gans and Hsu (2014: 3119) using the concept of *dynamic commercialization strategy,* argue that in some cases the "disruptor competes initially and later cooperates" with incumbents.

2.3. Sociotechnical nature of technological transformation

In fact, some authors in both streams of theories converge on one point: that technological transformation is of a *sociotechnical* nature. Recalling the definition of *technology* in the first part not as hard tools but as *configurations that work* (Rip & Kemp 1997), encompassing tangible equipment, intangible skills, knowledge and environment, it is clear that "technologies are embedded interdependently in existing social practices and reflect knowledge of these practices, as well as knowledge of technical principles" (Ockwell & Mallett 2012:10).

Some scholars focusing on disruptive innovations studies have brought the sociotechnical and socio-cognitive dimensions of technological change to the fore. Nair and Ahlstrom (2003) contend that ecological factors, regulatory regimes and assessment criteria of technologies all shape the technological transformation, which could prolong the actual duration of the transition, or, in their words, of the *era of ferment*, and which may inhibit the market from rapidly having a winning technology over the peers. Arguably, it is the environment or contexts in which technologies are embedded that co-shape the technological evolution. Garud and Ahlstrom (1997) argue that before a disruptive technology dominates the market, *assessment* plays a central role in technological choices. Assessment practitioners may not necessarily be *objective*, in that their bias may be derived from "different beliefs about what is technologically feasible and how technologies should be developed" (Ibid: 26). Hence, the perception of what is the *best* is in effect socially constructed and / or politically defined.

Linking sustainability transition studies with disruptive innovations scholarship is the *sociotechnical* nature of technological change, which can shed light upon the analysis of low-carbon transition, especially in the context of developing countries where different forces shape the low-carbon transition process.

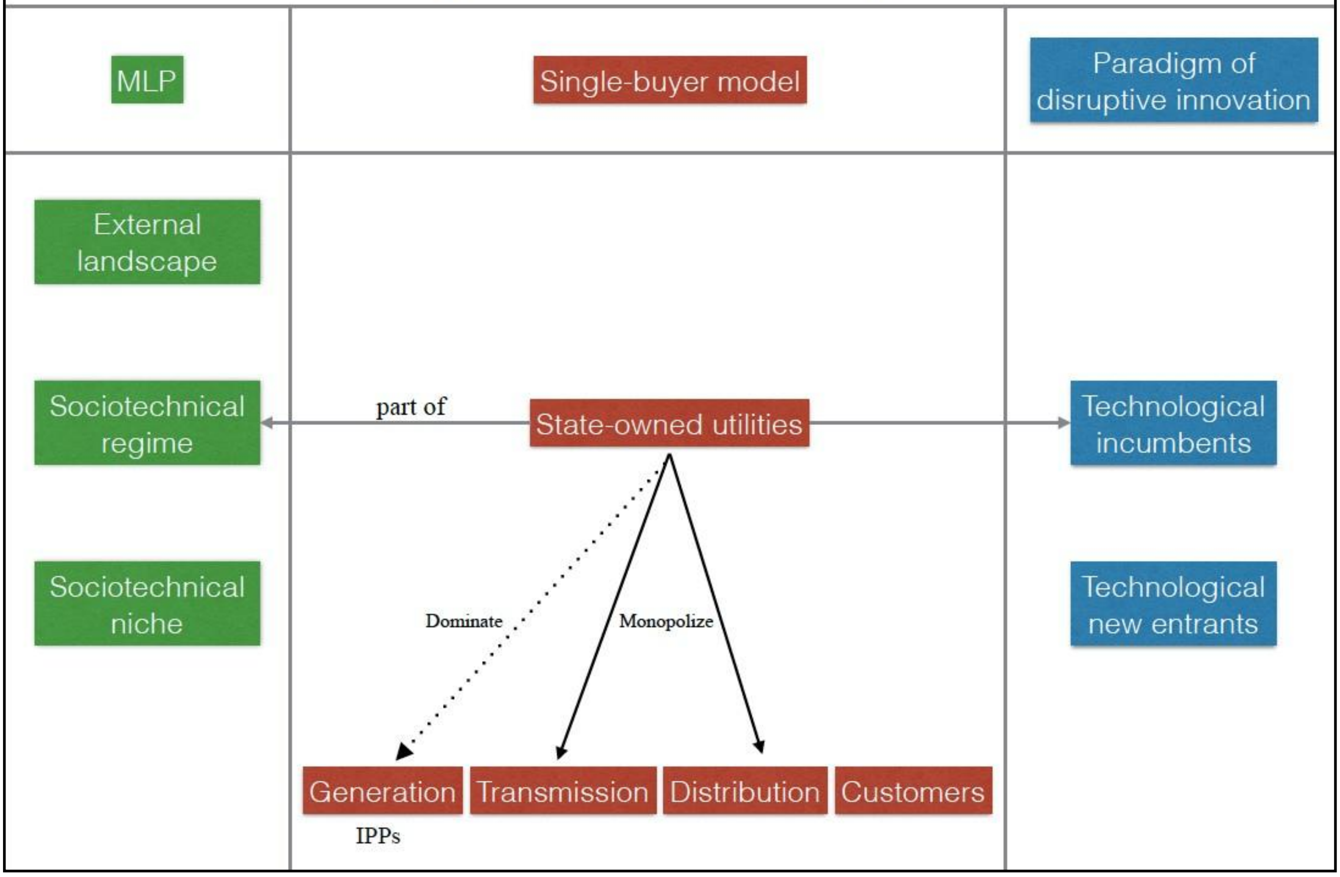
3. Operationalization of concepts: what embodies a low-carbon transition?

The *sociotechnical* nature of technological transformation provides implications for analyzing the electricity sector in a Southeast Asian context wherein state-owned electricity authorities in most ASEAN states not only occupy the biggest share of power generation but also dominate the transmission and / or distribution system due to the application of the *single-buyer model*. In this sense, albeit not monopolistic, state electricity authorities still enjoy a predominant position in every procedure of electricity, which, when interpreted through the disruptive technology lens, makes them the technological incumbent *vis-à-vis* the new entrants with potentially disruptive low-carbon technologies. Also, since they are backed by the government whose legitimacy is partly ascribed to the sound delivery of electricity at a reasonable price to their population, their interests reflect to some extent the governments' position. The Electricity Generating Authorities of Thailand (EGAT), for example, is the largest power producer in Thailand and is solely responsible for power transmission based on the single- buyer model. The Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA), both state-owned utilities, control power distribution in Thailand. Moreover, these utilities have been much involved in the energy strategy and policymaking process. Hence, from the perspective of mainstream transition theory, these state electricity authorities constitute a part of the standing sociotechnical regime *vis-à-vis* external landscape or niche-innovation.

The fact that the technological incumbents of the power sector in these countries are simultaneously embedded in the sociotechnical regime offers three insights. First, it adds to the canonical disruptive innovation paradigms in that the *public* sector can also be a technological incumbent and, when it is the case, it needs to respond to the emergence of disruptive technologies just like any privately-held incumbent would do in other industries. This may include strategies such as the shift of existing business models (Markides 2006), development of ambidexterity (O'Reilly & Tushman 2007) or development of complementary systems (Rosenbloom & Christensen 1994) to stage those disruptive technologies. However, they may fail to change due to *inertia*. Second, because the incumbent power regime is inserted in a broader sociotechnical environment, its transition in response to new technologies is not a mere business matter, but one that is shaped by multiple socio- institutional and socio-cognitive factors. Hence, transition is more than a process whereby a new entrant replaces the incumbent, but one of an evolving complex relationship principally between niche and regime, particularly when the regime is supported by a strong government. Third, during the transition, the gradual growth of niche- innovation does not solely depend on the mechanism proposed in Christensen *et al* (2018) that contend that the pursuit of profitability drives both the incumbent and new entrants up-market. It is also subject to an *enabling environmen*t facilitated by government actions (UNFCCC 2001) and to a favorable external milieu that creates "window of opportunity" for its expansion. In short, the particularity of the power sector in most ASEAN countries may supposedly turn the low-carbon transition into a co-evolution process between the incumbent power regime and disruptive niche-technologies.

Figure 2

Operationalization of concepts



It is observed that, from the multilevel perspective in Geels and Schot (2007) in the traditional transition studies, regimes are portrayed as a *static* entity in which internal adaptation / accommodation or reform does not exist (except in the *reconfiguration* pathway). In this regard, transitions are discerned based on the change of the way how a regime interacts with other two levels. However, as stated above, this paper argues that not only the regime but also the niche are *dynamic* in the sense that the regime can be self-adjusted in response to disruptive niche-innovations while disruptive niche-innovations may be in need of resources from within the regime to scale up. To sum up, change *in* the incumbent regime, in addition to change *of* the incumbent regime, embodies transition as well.

To operationalize this conception, several propositions are presented that may suggest concrete embodiments of transition. First, a reconfiguration within the incumbent regime involving disruptive low-carbon technologies may contribute to the bridging of transition.

This may include, *inter alia*, the introduction of *ambidexterity* or *hybrid offerings*. On the one hand, *ambidexterity* is defined as the ability to "exploit existing assets and positions in a profit producing way and simultaneously to explore new technologies and markets; to configure and reconfigure organizational resources to capture existing as well as new opportunities" (O'Reilly & Tushman 2007: 9). To contextualize, the incumbent power regime could be regarded as undergoing a low-carbon transition should it embark on exploiting current technological pattern while concomitantly exploring disruptive low-carbon technologies. This suggests that organizational flexibility is required to prevent core capabilities from hardening into core rigidities (Leonard-Barton 1992). This also suggests that, in this scenario, both the incumbent power regime and the disruptive niche-innovation co-evolve due to their interdependent relationship. On the other hand, *hybrid offerings* are the combination of features of "an emerging innovation […] with existing offerings to create something novel", thereby creating an "interim step between competing generations" (Christensen *et al.* 2016: 1063). In this scenario, *power system flexibility* is one of the instances that reflect this concept. However, both *ambidexterity* and *hybrid offerings* are positive responses by the incumbent which opts for *adopting* disruptive low-carbon technologies. It could also otherwise respond "by investing in their existing business to make the traditional way of competing even more competitive relative to the new way of competing", or even by counter-attacking the disruptors (Markides, 2006). Certainly, the last scenario will *not* be seen as an embodiment of transition.

Second, in the face of challenges brought about by disruptive low-carbon technologies that may significantly improve the renewable energy capacity, the transformation of incumbent power regime's *business model* which is able to accommodate these technologies can be viewed as an embodiment of transition (Bryant *et al.* 2018). This is insightful in that an incumbent power regime's response involves not only simple exploration / adoption of disruptive technologies but also reinvigoration of their traditional yet eroding *centralized* operating model into something new (Tayal 2016). The core rationale behind this *centralized* and *vertically-integrated* model is that "electricity should be treated as a 'public good'", leading the power sector to most commonly become a natural monopoly (Ibid: 14). Against the backdrop of the "convergence of several factors across technology, economics, public policy", and of the upheaval of solar photovoltaic (PV) and distributed generation, the established business model is under increasing scrutiny (Ibid.). This, however, does not mean that a thorough business model shift has to occur so that transition is embodied, because after all "disruption is a process and not an event" (Christensen & Raynor in Markides 2006). Rather, insofar as the incumbent power regime starts to get *aware* of or to debate about the necessity of making adaptions to their old business model, or to the extent that pilot projects with innovative business model led by or with the participation with the incumbent power regime are in place (often in collaboration with the niche), then the low-carbon transition of the power sector is embodied. These debates and discussion entail a certain degree of cognitive transition within the regime from sticking to the business-as-usual model to thinking about other possibilities; and the pilot projects with the participation with the incumbent regime demonstrate the experimentalism and shows the regime's willingness to explore.

Third, drawing upon the MLP approach and related to the first point, low-carbon transition is embodied in the evolving relationship between the regime and disruptive niche-innovations. But here, the emphasis is laid more on the actors themselves. Since low-carbon technologies are still immature niche-innovations in most developing countries, their replacement of the incumbent regime will not take place until they are full-fledged. Before the actual substitution takes place, the incumbent power regime may, aside from adopting (or not) them into their existing business by developing *ambidexterity*, choose to act from the outside, either by adopting a hedging strategy that allows various new technologies to *benevolently* compete for the market with each other, or by exploring *sustaining innovations* (e.g. clean coal, ultra-supercritical boiler) to arrest the potential erosion of their traditional line, which may lead to a low(er)-carbon economy, or even by actively investing in research and development (R&D) in order to take the lead in this transition process. Any of these scenarios embodies transition to a low-carbon economy, in the sense that either the development of disruptive low-carbon technologies is consented by the regime or existing technology has been ameliorated to reduce CO_2 emission as a response to the challenges from the disruptors. The result derived from the *benignity* of this evolving relationship is therefore the catalysis of low-carbon transition. On the contrary, should the regime hinder the development of niche-innovation or create hurdles for the implementation of policies conducive to disruptive low-carbon technologies with the motive to maintain their business-as-usual model and industry scale to the detriment of the environment, then the *predatory* feature of the incumbent power regime renders the relationship antagonistic, engendering hardship for the low-carbon transition process.

The operationalization of the transition concept in the context of the electricity sector provides renewed insights for future analysis. Hereinafter, the power sector in Thailand will be under scrutiny.

4. Case Analysis of the Power Sector in Thailand

This section selects Thailand as the case to be assessed against the framework proposed above, namely the internal reconfiguration of the incumbent power regime, the transformation of business models as well as the evolution of the regime-niche relationship. It seeks to present core elements to contextualize the discussions, instead of portraying comprehensively this country's energy sector.

In the post-Paris era, Thailand seeks in its intended nationally-determined contribution (INDC) to reduce greenhouse gas emissions by 20-25% from the projected BAU level by 2030. Successful delivery of this ambition should be supported by a sound low-carbon transition in the power sector, adjustment of the existing business model and a benign evolution of the niche-regime relationship. Low-carbon transition is even more pertinent against the backdrop of rapid depletion of domestic energy reserves, the preponderance of gas in its energy mix as well as a prospective growing energy demand (IRENA 2017).

4.1. Reconfiguration within the incumbent power regime

The incumbent power regime in Thailand mainly involves Electricity Generating Authority of Thailand which accounts for 40% of the country's electricity generation and which dominates 100% of the transmission, and Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA), which engage in the electricity distribution across the country. Overall, these SOEs hold paramount influence *vis-à-vis* independent power producers (IPPs) and small power producers (SPPs).

The incumbent power sector has been undergoing substantial transformation, especially since Thailand's ratification of the Paris Agreement. In response to global climate imperatives and the exigencies in the Thailand Integrated Energy Blueprint (TIEB)[1], reconfiguration within EGAT has been observed. Ten EGAT projects based on renewable energy are expected to operate or have already been operating in the period of 2016-2020, among which two are from non-hydro sources (EGAT 2015). By the time of writing, around seven power plants operated by EGAT are dedicated to electricity generation from hybrid or non-hydro non-fossil fuel sources, including solar, wind, geothermal, etc. It is noteworthy that the Thap Sake Solar Power Plant inaugurated in 2017 is the "is the only power plant in Thailand which combines 4 technologies in electricity generation by solar cells" (EGAT 2018: 8). Although the establishment of EGAT's first renewable power plant can be traced back to 1986 when the Klong Chong Klum Solar Power was built, the fact that more renewable power plants have been constructed along decades only demonstrates that EGAT has been in the course of developing *ambidexterity* - *exploiting* while *exploring* at the same time (O'Reilly & Tushman 2007). It also unveils that, apart from safeguarding *energy security*, EGAT has been intentionally reconfiguring its organizational resources to invest in disruptive low-carbon technologies that may end up deranging its BAU model.

In juxtaposition to its investment in disruptive low-carbon technologies, coupled with domestic opposition against the further construction of coal-fired power plants, EGAT is also pushing several *sustaining innovations* on power generation. Combined-cycle gas turbines fueled by natural gas have become EGAT's favored technology, due to its domestic availability and imports from Myanmar (Middleton 2016). Furthermore, clean coal technology with the usage of ultra-supercritical boilers is applied to some of the power plants based on fossil fuels. In this regard, the introduction of *sustaining*

[1] TIEB covers five separate but interconnected energy plans, namely natural gas, oil, energy efficiency, the power sector and alternative energy sources.

innovations themselves reflect a *lower*-carbon transition. When interpreted through the disruptive innovations paradigm, *sustaining innovations* are in place with the aim to cushion the disruptive effects unleashed by the disruptors while enabling the technological incumbents to adopt a hedging strategy.

The development of EGAT's *ambidexterity* is also reflected by the change of its internal organizational structure. In 2017 the structure "was reengineered with the addition of the line of command for Deputy Governor - Renewable and New Energy", who becomes one of EGAT's fifteen deputy executives team (EGAT 2018: 8). More importantly, according to O'Reilly and Tushman (2007: 33), it is of significance for the incumbent to construct an "overarching vision and values [that] permit employees from the legacy and new business to forge a common identity, even as they pursue different business strategies". Interpreted through this prism, the introduction of a novel vision of "Innovate Power Solutions for A Better Life" in EGAT in 2017, and the establishment of new values and cultures known as SPEED - "Sense of Belonging, Performance, Excellence, Ethic and Integrity, Enthusiasm for Innovation, Devotion to Society" - may make sense among employees from different departments of working together towards a shared goal. Moreover, *disruptive technology* was for the first time codified in EGAT's Annual Report in 2017.

Low-carbon transition within the incumbent power regime can also be evidenced by the launch of *hybrid responses*. This is deemed by some pundits as an effective response strategy since recombinations of their existing products with (disruptive) innovations serve as 'stepping stones' that allow incumbents to improve their existing technology while learning and adapting to an uncertain new technology" (Furr & Snow in Christensen *et al.*: 1064). In the cases of the Khlong Chong Klum Solar Power Plant and the Lamtakong Jolabha Vadhana Power Plant, both run by EGAT, solar or wind solutions are being explored in combination with hydropower. In addition, within the time span between 2018 and 2021, floating solar panels that will be implemented in four different reservoirs in Thailand are expected to be gradually commercialized (EGAT 2017: 8). According to interviews conducted with EGAT, the rationale for fostering this hybrid capacity lies in the strategy to ensure *power system flexibility* in the light of the intermittency of power generation from renewable sources, e.g. solar and wind, given that power storage is still relatively costly.

To summarize, EGAT's efforts to develop *ambidexterity* and to adopt *hybrid* offerings as well as the organizational reconfiguration bolstered by a brand-new vision that links different departments empirically demonstrate that a low-carbon transition is embodied in the Thai incumbent power regime. In other words, change *in* the regime is underway.

4.2. Business model transformation

As stated above, low-carbon transition calls for a new business model that can accommodate or be adapted to the characteristics of these disruptive low-carbon technologies, "given their ability to reduce electricity use and demand" from the utilities (Tayal 2016). The current business model in the Thai power sector is the so-called *enhanced single-buyer* (ESB) model following a vertically-integrated pattern with increasing participation of the private sector, e.g. the IPPs, SPPs and VSPP (Very Small Power Producers), in the power generation process. However, the partial privatization of the state-owned utility EGAT since 1980 is by no means a new story (Middleton 2016). What has been changing is the increasing debate within the Thai incumbent power regime around not only privatization but also power decentralization against the backdrop of technological advancement of rooftop solar panels in residential areas as well as peer-to-peer (P2P) technology.

The debate about a decentralization of the utility was confirmed by the interviewed policymakers in the Thai government, who were much aware about the *prosumer* trend and its associated disruptiveness on the BAU model. A *prosumer* model in effect provides the customers with "the prospect of green, local, self-produced electricity, whilst seeking to maximize customers' ability to utilize their own (owned/leased) self-generation assets" (Bryant *et al.* 2018: 1039). The deployment of "P2P trading software and distributed generation control processes […] in order to allow for the development of 'Virtual Power Plants (VPPs)" features centrally in this operating model. In this spirit, interviewees contended that the emergence of technologies exemplified by the *rooftop solar PV cells* was unleashing a decentralizing effect on the existing business model, which has driven them to revise their Power Development Plan (PDP), Alternative Energy Development Plan (AEDP) and the Gas Plan. More significantly, despite far from being a leitmotif, there is an emerging discussion within the incumbent power sector with regards to the *public good* nature of electricity. This embryonic debate may add to the power decentralization dynamic.

Some empirically enlightening cases with regards to the transformation of the business model are noteworthy here as a result of this emerging debate. First, a P2P renewable energy trading pilot project is being implemented in the capital of Thailand. Partnered with Thai Metropolitan Electricity Authority (MEA), an Australian blockchain company — Power Ledger — and a Thai RE enterprise have been tasked with this P2P trial in Bangkok with a total capacity of 635 kW in solar energy since August 2018 for the duration of two years (Hong 2019). This shows that the Thai incumbent power regime is working jointly with the private sector and is creating a niche / incubator for the development of disruptive technologies, by which the incumbent *learns* and *understands* the new technologies which are in turn shaped by the local sociotechnical circumstances. This also echoes the concept of *sustainability enclave* which is a "territory subject to the coproduction of knowledge and governance arrangements performed in a sustainable and socially just manner" (Gururani & Vandergeest 2014: 349). Second, the newly amended PDP in 2018 mandates the EGAT and the Provincial Electricity Authority (PEA) to build a smart grid in the Eastern Economic Corridor (EEC), which may contribute to the integration of RE into the system (Ibid.).

The domestic debate within the incumbent power regime and the willingness demonstrated by Thai policymakers to transform the current business model has led to policy amendments that foster *decentralization* and to an evolving operating model that is more aligned to the adoption of disruptive low-carbon technologies. Hence, the low-carbon transition of the Thai power sector's business model is materializing.

4.3. Evolving relationship between the regime and the niche

A presumption is made here that a benign relationship between the sociotechnical regime and the niche with potential disruptive innovations should not be taken for granted. In the power sector, due to *vested interests* or the privilege given to *regular practices*, the incumbent regime does not always necessarily respond to environmental imperatives in a benevolent manner and, instead, it may remain lukewarm to the urgency to change or even choose to obstruct the low-carbon transition process. According to Grin (2016: 111), "niche practices may face inertia as the regime tends to 'draw' them back into their regular practices, and does not offer proper rules and resources". This entails minimal support for the niche development, "while actors resisting those niche practices may be better served by the regime" (Ibid).

As the IRENA report states (2017: 21), the Government of Thailand "has long recognised the importance of alternative, especially renewable, energy sources, but also realised that there was a need to introduce programmes in support of renewable energy development and deployment". As a result, multiple supporting measures have been launched, varying from adder programme and feed-in tariffs (FITs) to tax exemptions (Ibid). Among them, the FIT regime in Thailand merits a particular note. By definition, feed-in tariff is a policy that supports "the development of new renewable energy projects by offering long-term purchase agreements for the sale of RE electricity" (ACE & CREEI 2018: 4). This *power purchase agreement* (PPA) "provides a specified price for every kilowatt-hour (kWh) of electricity generated" (Ibid). As these disruptive low-carbon technologies based on renewable energy are still relatively immature in the technical sense, and because RE power generation shows intermittency, the PPA signed with RE power plants traditionally follows the pattern of a non-firm contract, freeing independent power producers (IPPs) from the obligation to provide a certain amount of power to the state-owned electricity authorities (Asian Power 2017). Interestingly, in 2017 Thailand's Energy Regulatory Commission (ERC) promulgated a competitive bidding scheme which ruled that the feed-in tariff could only be applied by those small power producers (SPPs) and very small power producers (VSPPs) with firm capacity or semi-firm capacity, with the latter referring to the ability to generate a certain amount of electricity during *peak* hours (ACE & CREEI 2018; IRENA 2017). This entails that the government is orienting the niche and encouraging it to develop *hybrid* capacity to (partially) resolve the intermittency problem when it comes to power generation.

This policy shift has implications for the interpretation of the evolving regime and niche relationship in Thailand. As stated above, in order to ensure the *power system flexibility*, the incumbent power regime, EGAT, is proactively exploring hybridized energy sources and is seeking to apply ICT technologies to the grid. These approaches principally involve demand-side management techniques and reflect the effects on the incumbents by the new entrants in the sense that the former adjusts *responsively* its strategy *vis-à-vis* new challenges. Nevertheless, through the lens of the *sociotechnical* nature of technological transformation, the regime and the niche are engaged in a symbiotic relationship. By providing financial incentives only to IPPs with (semi-)firm capacity through competitive bidding, the incumbent power regime in Thailand displays its awareness of local circumstances where the whole grid transformation necessitates a long duration of time, and is shaping the course of RE development by cultivating benign competition from the supply side so as to enhance the performance of these technologies. Policy change reflects thus co-evolutionary dynamics of low-carbon transition.

Also noteworthy, among others, is the establishment of EGAT Learning Centers in a number of EGAT-owned RE power plants. The one affiliated to the Pha Bong Solar Power Plant, for example, aims to diffuse knowledge on smart grid, smart city and RE technologies to the general public in the form of multimedia exhibition. Other learning centers are designed to guide visitors to view the solar cell panels or to display technologies such as wind power and pumped-storage. The efforts derived from the Thai incumbent power regime *per se* to raise public knowledge of disruptive low-carbon technologies and to nurture environmentally friendly consumer behavior highlight the fact that the low-carbon transition is being promoted on the grassroot level, pointing to a benevolent relationship between the power regime and the niche. Again, such efforts should not be taken as a given and its extent varies from country to country.

Recalling the definition of *technology* in this paper as configurations that work, *knowledge* and *expertise* are no less important than the tangible equipments. Capacity-building is carried out and supported by the Thai government in various forms. This includes the incorporation of energy efficiency into the curriculum of the current education system; provision of funds to incentivize university students to undertake research on RE technologies, energy efficiency and energy management; and support for short-run HR development and oversea technical visits (APERC 2017). Besides endeavors on capacity-building at universities, the Department of Alternative Energy Development and Efficiency (DEDE) is pushing for the personnel training for those who want to be "registered as responsible persons for energy" (Ibid: 7). Furthermore, the ENCON Fund serves as one of the financial arms to provide grants or subsidies for both public and private sectors in the realm of renewable energy, research and development, human resource development and education (Ibid). In this regard, support from the sociotechnical regime for this emerging niche that carries with it disruptive low-carbon technologies, knowledge and expertise portray a relatively cooperative relationship between the regime and the niche.

What is more, in the newly-amended Power Development Plan, which at the time of writing still awaits the final approval from the Cabinet, the target for the non-hydro renewable energy share in the total energy mix is reported to be raised from 20% to 30% by 2036 (Hong 2019). This progressive policy shift entails bigger efforts from the regime to further transform the BAU and to incorporate even more disruptive low-carbon technologies into the current power system.

By and large, a benign regime-niche relationship is discerned in the Thai power sector, which however may not be equally notable in some other AMS, either due to the vested interests in the BAU model or because of other priorities.

4.4. Limitations

Notwithstanding encouraging advancements, Thailand remains a net gas importer. The new PDP scales up power generation based on natural gas accounts for 53% of the overall power generation (Piggot *et al*. 2019; Rujivanarom 2018). Environmental activists have also voiced concerns that fossil fuels and other harmful energy sources, such as hydropower, "would not only hinder progress on achieving the Paris Agreement's goal for stabilising climate change, […] (but) would jeopardise sustainable-energy development and 'environmental justice'" (Rujivanarom 2018: para. 3). Interviewees in international organizations based in Thailand transmitted the idea that Laos and Cambodia, as Thailand's hydropower trading partners, are concerned about Thailand's low-carbon transition, since electricity export brings revenues to these two countries. Furthermore, as per a report issued by the Stockholm Environment Institute, the Thai government falls short of strategies to cope with socioeconomic problems engendered by the technological transformation, e.g. the disappearance of extraction roles for the workforce in depleting energy fields, the difficulty for households to adapt to shift of energy sources or prices, etc (Piggot *et al*. 2019). It concludes that "[t]he first signs of a transition in Thailand are emerging, yet there are few indications that plans are being put in place to ensure it is a just and equitable transition" (Ibid: 7).

5. Discussion

Since Thailand's ratification of the Paris Agreement, the trajectory of its power sector towards a low-carbon economy has been notable. First, the incumbent power regime is undergoing substantial change evidenced by the development of *ambidexterity* on a continuous basis, the exploration of low-carbon technologies for power generation and *hybrid* capacity in several power plants, and the creation of new departments for organizational oversight. Hence, this behavioral and structural change *in* the incumbent power regime implies a dynamic low- carbon transition process. Second, open debate in the incumbent power regime leads to the gradual transformation of the operating model, by virtue of the inclusion of disruptive ICT technologies into the state- owned grid system that may contribute to the power *decentralization* drawn on the *prosumer* model and that may disrupt the existing *vertically-integrated* pattern or even eventually the *single-buyer* paradigm. Pilot projects implemented jointly by the incumbent power regime and technological forerunners permit the former to better comprehend the disruptive technologies and shape its development direction on the one hand and the latter to adjust their products and services to the local circumstances on the other. Therefore, this low-carbon transition process implies a coproduction dynamic (Jasanoff 2007). Third, the Thai incumbent power regime, ranging from the pervasive SOEs to the electricity regulatory authorities, is gradually taking more initiative to interact and cooperate with niche-innovations and, more significantly, is proactively disseminating knowledge and expertise regarding RE and EE across universities and the general public. Its endeavors to promote low-carbon technology, which also englobes intangible knowledge and know-how, both from the supply-side and from the demand-side, as well as its cooperation with the niche reflect to a large extent a benign evolving relationship between the regime and the niche. Despite some limitations, judging from these three dimensions above, a low- carbon transition of the Thai power sector is arguably underway.

It is also interesting to see that the current transition process in the Thai power sector embodies a social construction pattern in that a forum was provided by the government wherein "different constituencies can come together to discuss and debate their different points of view", be they *sustaining* or *disruptive* innovations, which would "enhance the possibility that the most appropriate technology evolves over time" (Garud & Ahlstrom 1997: 45-46).

What conditions the low-carbon transition in the Thai power sector? And why is the transition more salient in Thailand than in some other AMS? Although it is not the intention of this paper to dig into the conditioning factors, several of them can be tentatively pointed out based on existing literature. Institutionally speaking, it is important to count on (1) the presence of visionary national leaders committed to climate actions and their interaction with international environment bodies (Geels & Schot 2007), (2) inter-institutional collaboration whereby all national ministries, SOEs and local municipalities work for the same goal, and (3) a strong and vocal civil society that acts as an external factor pushing the transition process (Middleton 2016). The second element was reiterated by interviewees in other AMS where fieldwork was carried out that some state-owned electricity authorities have been obstructing the implementation of measures to attain their country's INDCs, thereby impeding the low-carbon transition process. In socioeconomic terms, factors conducive to a low-carbon transition in the power sector include (1) the maturity of niche-innovation which can be reflected by their price/ performance level from the supply side, (2) people's affordability of electricity against the backdrop of disruptive low-carbon technologies from the demand side, and (3) the availability of (external) actors to foster transition processes either in the form of investment or by providing technical support. From a socio-cognitive point of view, it is essential that (1) the consumer behavior becomes more environmentally-friendly and people's awareness, especially those who reside in remote areas, on environmental issues is elevated, and that (2) local communities are proactively working with the sociotechnical niche. The proposition of the aforementioned conditioning factors warrants further research, ideally in a comparative manner, to dwell upon the circumstances under which a country's power sector is more prone to a low-carbon transition. At the time of writing, a parallel study with a focus on Indonesian power sector is underway.

When it comes to the influence from the most salient regional actor in Southeast Asia — the ASEAN, it has been revealed by almost all interviewees not only in Thailand but also in other AMS that, in the power sector, its role in fostering low-carbon transition is not notable. Due to the paramount national interests that each AMS holds, and because of the varying development situation across the AMS, national governments are still the main loci of (in)actions.

6. Concluding Remarks

Drawing upon the multilevel perspective (MLP) approach as the mainstream sustainability transition theory as well as the disruptive innovation paradigm, this article sought to shed light on the low-carbon transition of the power sector in Thailand in the face of disruptive low-carbon technologies. The two strands of literature are complementary when it comes to understanding the low-carbon transition of the power sector. Acknowledging that the incumbent power regime is a *dynamic* rather than a static entity, and in recognition of the *sociotechnical* nature of technological transformation whereby technology and society co-evolve in a non-linear pattern, this article has exposed concrete instances of a low-carbon transition of the power sector and examines specifically the case of Thailand. It has shown that the Thai power sector is undergoing a low-carbon transition in that the incumbent power regime explores disruptive low-carbon technologies, seeks to transform the extant operating

model and cooperatively engages with the niche developments. Overall, this paper contributes to the existing transition studies by combining it with the STI doctrines to comprehend low-carbon transition dynamics. The transition progress being made in the Thai power sector, however, may not be similarly discerned in other AMS where there is a lack of debate over power decentralization and where a less benign regime-niche relationship is present. Hence, future analysis on other AMS is warranted.

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