LEGACIES OF GEOPOLITICAL INSULARITY FOR URBAN ENERGY TRANSITIONS TODAY: ELECTRICITY GENERATION AND USE IN SINGAPORE AND KOTA KINABALU

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ABSTRACT

Low carbon urban transitions are pursued as means to tackle the challenges posed by climate change to urban energy resource flows and services. Research has, so far, been concerned with accounts as to the what, how and why of these low carbon urban transitions, largely omitting how historical legacies in cities' energy policies and practices affect today's transitions. This paper presents evidence from two case studies – Singapore and Kota Kinabalu – to explore how geopolitical isolation shaped their respective energy systems from colonial times, using historical contextualisation to explain the kinds of energy transitions being pursued today. The paper investigates, firstly how, in response to their respective geopolitical status as British dependent territories in Southeast Asia since the 1800s, the two cities strove to make themselves self-sufficient with strongly localised electricity generation networks, building up capacity for energy autarky. The paper, secondly, demonstrates how political and economic integration with Malaysia since the 1960s (Kota Kinabalu 1963, Singapore 1959-1965), and independence (Singapore 1965), initiated a realignment of each city's energy policy, as local generation capacity was questioned, markets opened to competition, regulatory frameworks changed, new consumer aspirations revealed, public participation sought, and power grids became regionalised. Finally, the paper shows for each case how this came to be, what form energy autarky it took, and what impacts historical legacies and concerns for energy security materialised into 'hard-wired' insular power systems and the limitations this poses for transitions today. The paper concludes that energy autarky and energy security are temporally and spatially context-sensitive. Decision-makers, in their pursuit for an energy policy that brings about energy security, environmental sustainability and economic competiveness, should be mindful of such contextual nuances.

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1. INTRODUCTION

Cities are widely viewed as playing a crucial role in energy transitions, today and in the future, with recent research emphasizing the wide variety in urban responses at a time of climate change (Bulkeley et al. 2011; Rutherford and Coutard 2014; Mai and Francesch-Huidobro 2015; Castan-Broto 2017). This diverse picture of urban energy transitions as they are actually happening is opening up a debate as to the different factors shaping these transitions and the challenges that emerge from them for both policy and practice. What is in danger of getting lost in these contemporary narratives is a sense of where these diverse urban responses are coming from and how past policies of energy production and use are influencing low carbon options today and in the future (Moss and Francesch-Huidobro 2016: 225). This paper analyses two cities – Singapore and Kota Kinabalu – to explore the legacies of their past socio-technical energy configurations for today's attempts to realign urban electricity supply systems. The two cities' status as pioneers of the modern electrified city in Southeast Asia and their determination to switch their economies to a low carbon mode of energy demand and supply makes them appropriate candidates for study.

1.1. SINGAPORE – A CITY SEEKING THE RIGHT ENERGY VISION FOR ITS FUTURE

Singapore, an independent island city-state south of peninsular Malaysia, was among the first cities in Southeast Asia to start electric street lighting in **1906** when still a trading port of the *British East India Company* (1819-1826). Electricity has continuously been generated ever since: during the period Singapore was part of the British administer*ed Straits Settlements* (1826-1941), as a Japanese occupied territory (1942-1945), *during British Military Administration* (1945-1946), as a *Crown Colony* (1946-1955), as a *Self-governed State* (1955-1963), while part of the *Federation of Malaysia* (1963-1965), and after independence in 1965 until today (Yeo 1973; Baker 1999; Turnbull 2009).

Through the years, Singapore has experienced significant transformations to its electricity supply system, while constantly aiming at ensuring self-sufficiency and reliability of supply. These transformations include: legislative changes to regulate new energy sources, infrastructure and market mechanisms; physical changes to its fuel mix and to the technology used in its generation power plants; changes to its transmission and distribution networks; transformations to its wholesale and retail markets; institutional changes in ministerial portfolios and public agencies; and low carbon transitions in its supply-side (fuel mix) and demand-side (efficiency) management as well as in its response to the demands of reducing GHG to mitigate climate change (Public Utilities Board 1985, 1988; Koh and Lee 2011; Ng 2012; Doshi and Lin 2016). Since 1995, the power sector has been progressively privatised and commercialised, starting to be liberalised in 2001 opening room for more utility companies to compete. The *Energy Market Authority* is the statutory board under the *Ministry of*

Trade and Industry (MTI) regulating the electricity sector. Table 1 presents a comprehensive summary of the dimensions of Singapore's energy legacies and transitions.

1.2. KOTA KINABALU – A CITY INFLUENCED BY FEDERAL POWER IN ITS QUEST FOR ENERGY SUFFICIENCY

Kota Kinabalu, the capital city of the State of Sabah, East Malaysia (Borneo island), was electrified in **1910** while still a *Protectorate of the United Kingdom* first, from 1888, under the *British North Borneo Company (BNBC)* (Rutter 1922 (ed. 2008): 215), and then from 1946-1963 when its administration was transferred to the *British Crown* to become a *Crown Colony* (Sabah History 1881-1981 n.d.). After merging in 1963 with Malaya (Peninsular), together with the state of Sarawak (East Malaysia, Borneo island) and Singapore island to form the *Federation of Malaysia* to date, its electricity system has not been liberalised and opened for competition but was privatised in 1998 under one vertically-integrated electricity supplier (generation, transmission and distribution).

As with Singapore, Kota Kinabalu has also undertaken and is still aspiring to successfully undertake other legislative, administrative and technological transitions in its supply-side (fuel mix) and demand-side (efficiency) management as well as in reducing GHG to mitigate climate change, largely mandated by national and regional policies. The *Energy Commission Malaysia* (Suruhanjaya Tenaga- West Coast Sabah) is the regulatory agency (economic, technical and safety) for electricity supply and piped gas in the Sabah State. Table 2 offers a summary of the various dimensions of Kota Kinabalu's energy legacies and transitions.

1.3. THE COMPARATIVE STUDY – POWERING THE INSULAR CITY

Beyond their regional significance as electric Southeast Asian cities, Singapore and Kota Kinabalu are distinctive because of their unusual histories of power generation. Being insular, dependent territory cities, they have a long experience of being self-sufficient for their own power supply and having to reconfigure their electricity supply systems around their own municipal territory after landmarked geopolitical changes, namely: Singapore's merger with the Federation of Malaysia in 1963 and subsequent independence in 1965; and Kota Kinabalu's inclusion in the Federation of Malaysia in 1963. Thus, the two cities have had to re-align their electricity systems to take account of the introduction of competition through privatization (Singapore and Kota Kinabalu) and liberalization (Singapore), and the processes of economic and political integration with surrounding regions (ASEAN for both Singapore and Kota Kinabalu). These energy transitions from municipal self-sufficiency to regional integration are accompanied by more familiar policy transformations aimed at reducing carbon emissions, minimising energy use, and increasing energy efficiency through shifts in electricity generation and use, that is, by transiting to a low carbon electricity supply system. The past and present energy histories of these two cities inspire the following research questions, to be addressed in this paper:

- ✓ Firstly, how do these cities strive to render their electricity supply systems to be more **self-sufficient in response to their geopolitical isolation** and to what effect? (Section 3);

- ✓ Secondly, how have the cities been **realigning their electricity supply systems** following independence (Singapore) and merger (Kota Kinabalu) and regionalisation? (Section 4);

- ✓ Thirdly, how far and in what ways are their **past policies/historical legacies of energy autarky framing options for energy transitions** today? How are the **legacies** of territorial integrity, protected markets, supply security, local infrastructure, resource flows and environmentalism **affecting today's transitions**? (Moss and Francesch-Huidobro 2016: 233-234; Section 5);

- ✓ Fourthly, what **lessons** do past policies/historical legacies of energy autarky offer to **future policy formulation in Singapore and Kota Kinabalu** electricity supply sectors? (Section 6).

The paper is conceived not only as a comparative case study of two 'electric cities', but also as a contribution to broader debate on energy self-sufficiency, energy security and urban energy transitions.

In Section 2, we review the urban energy transitions significant research and how it defines energy autarky and energy security. We highlight the multi-disciplinary nature of energy transitions research as well as its diverse epistemological roots. In Section 3, we discuss energy autarky as a response to geopolitical isolation during the colonial period and how building excess capacity allowed the two cities to survive and successfully transition through merger and/or independence. Section 4, analyses energy autarky in the post-colonial period identifying how the two cities have coped with the demands imposed by global, national and regional low carbon trends while retaining a strong obduracy towards autarky as a way to energy security. Section 5, contrasts the Singapore and Kota Kinabalu transitions against six historical legacies – territorial integrity, protected markets, supply security, local infrastructure, resource flows and environmentalism identified by Moss and Francesch-Huidobro 2016 (pp. 233-234) in their study of West Berlin and Hong Kong – to analyse how and why these or other legacies may influence today's low carbon urban transitions. Section 6, highlights the lessons learnt suggesting that historical legacies, while shaping the future paths of urban energy systems, are not totally deterministic and can be overcome by policy innovation that takes account of such legacies. Finally, in Section 7, we draw conclusions on what has worked and what has not in achieving energy autarky together with recommendations for the two cities in pursuing future energy transitions in today's low carbon context.

2. URBAN ENERGY TRANSITIONS –LOOKING BACK TO LOOK AHEAD

2.1. HOW DOES A CITY'S PAST INFLUENCE ITS PRESENT AND ITS FUTURE?

Existing studies on energy transitions are, perhaps inevitably, loaded with normativity. Most studies are grounded on value judgements about the environmental unsustainability of existing energy systems (Castan-Broto 2017), assumptions about the innate benefits of alternative sources of energy and preferences for particular forms of governance, such as decentralised power networks or community energy projects (Geels and Schot 2007; Coutard and Rutherford 2010; Droege 2011; Romero-Lankao and Dodman 2011). Significant contributions on urban energy transitions by human geographers, political scientists and sociologists have helped rectify the powerful normative thrust of energy transitions research (see for example, Bulkeley et al. 2011; Andrews-Speed 2013; Rutherford and Coutard 2014; Mai and Francesch-Huidobro 2015; Table 3). Their interest in how energy transitions develop in particular urban contexts and their epistemological roots in critical and institutional analysis ready these scholars to the problems encountered by, and through, energy transitions in practice.

These studies can, however, be criticised for its contemporary perspective on urban energy transitions, focusing on current attempts to promote low carbon cities and relegating the historical legacies of urban energy systems to introductory contextualisation. This research deficit is met to some extent by researchers of urban environmental history and the history of technology who have explored earlier energy transitions, for instance from wood to coal, from gas to electricity or from municipal to national power utilities (Hughes 1983; Melosi 2000). What is still missing, though, is research straddling these two bodies of literature, i.e. studies capable of explaining how the history of a city's energy system is influencing today's energy transitions.

Building on earlier empirical work on the historical legacies of socio-technical transitions (Moss 2009; Moss and Francesch-Huidobro 2016), this paper documents this research potential by setting out the ongoing energy transitions in Singapore and Kota Kinabalu in the context of their urban energy histories. What makes this attempt particularly attractive is that the two cities have been adapting to a very different kind of transition to their energy systems namely, the in/reintegration of their insular municipal networks into national, regional, and global electricity systems. In Singapore and Kota Kinabalu, processes of infrastructural and market integration such as connecting technical networks, creating new organisational structures, altering existing regulatory regimes and redirecting resource flows are being debated and pursued with different intensity and aims. This offers an excellent opportunity to study processes of reconfiguration of municipal energy networks in a city's recent history, observing which elements change and which do not.

2.2. THE RELATIONSHIP BETWEEN ENERGY AUTARKY AND ENERGY SECURITY

The issues of *energy autarky* and *energy security* in connection with shifting energy geographies echo several strands of recent debate on urban energy transitions. ***Energy autarky*** is conceived most frequently in the normative sense of strategic vision (Müller et al. 2011). According to Müller at al. an energy autarkic region is one that relies on its own energy resources to sustain society in the region (ibid.:5801). They define autarky not simply in terms of self-sufficiency of supply but also regarding the energy source (e.g. renewables from the region, rather than fossil energy imports), the decentralised structure of the energy system, and increased energy efficiency on both the supply and demand side (ibid.: 5802). However, their work does not reflect critically on the assumptions underpinning the connectivity between autarky, renewables and decentralised organisation, nor does it consider potential weaknesses of energy autarky, such as negative impacts on the surrounding region or issues of legitimacy emerging from community initiatives (Hodson and Marvin 2010).

Building autarky into an infrastructure system, such as electricity supply, is one strategy to increase ***energy security*** in cities, and this is the second strand of research of relevance to this paper. In their work on urban ecological security Hodson and Marvin (2010) draw attention to recent trends of cities and their utilities to make their socio-technical networks more resilient to shocks and stresses (see also Medd and Marvin 2005). The emergent strategy of urban ecological security that they identify is about reconfiguring infrastructures to safeguard resource flows and essential services in the face of a growing variety of threats, ranging from impacts of climate change to terrorism and warfare. This work builds on a broader literature concerning the resilient city (Vale and Campanella 2005) within which urban infrastructures are viewed as playing a key role in reducing vulnerabilities in cities increasing their ability to bounce back when challenged by hazards (Graham 2010). Interestingly, for the Singapore and Kota Kinabalu cases, some contributions to this field of study emphasise the importance of building excess capacity into urban infrastructures as a means of withstanding shocks and maintaining functions in situations of stress (Grabher and Stark 1997; Koh and Lim 2010; Amin 2013; Ang, Choong and Ng 2015).

This paper contributes to these two bodies of work by exploring connectivity between ***energy autarky*** and ***energy security*** as components of urban energy transitions (World Business Council for Sustainable Development 2008). Rather than focusing solely on modern day debates on making energy systems more resilient through greater self-sufficiency, we investigate past instances where energy autarky became regarded as a political and technical necessity to secure the continuous and adequate supply of electricity in each of the two cities. We aim to show how this came to be, what form energy autarky took, how this is being reorganized following independence, merger, and regionalisation, and what impacts past policies are having on today's attempts at transition towards a low carbon city.

3. ENERGY AUTARKY AS RESPONSE TO GEOPOLITICAL ISOLATION

3.1 SINGAPORE, FROM BRITISH COLONY TO INDEPENDENT REPUBLIC: AUTARKY AS SURVIVAL, GROWTH, AND LINCHPIN FOR INDEPENDENCE (1819-1965)

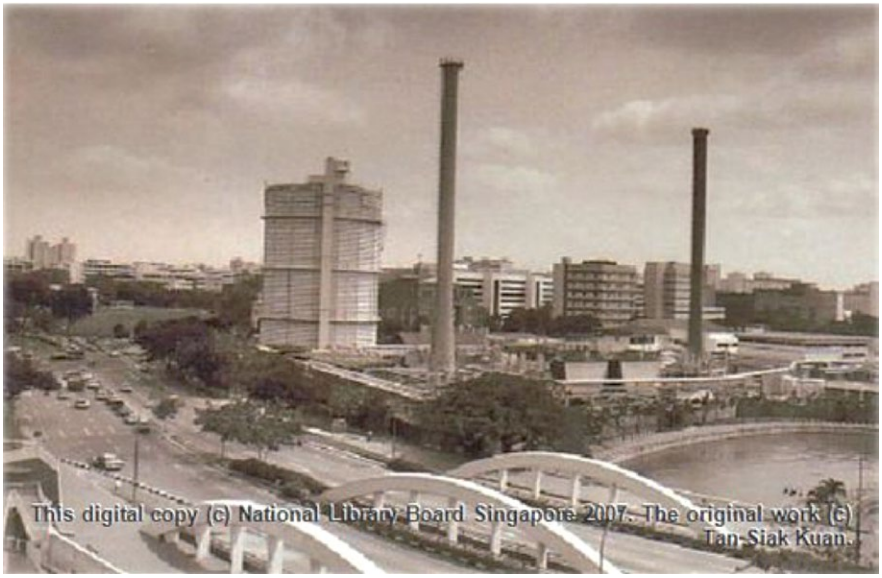
The founding of Singapore in 1819 and the period up to 1905 - the role of gas and steam

When Stamford Raffles, an employee of the *East India Company*, sat foot in Singapore in 1819, he found the island to be an ideal location for the establishment of a strategic trading port on the main route between the Middle East, China, India and Europe - the Malacca Straits (Turnbull 2009; Morgan 2016: 16). By 1826, Singapore, together with Penang and Malacca, formed the *Straits Settlements* under British India rule (Morgan 2016: 16). After reaching an agreement with the island's chieftains, the Sultan of Johor and the Temenggong[1], the island became known for its significant storage and transhipment ability for kerosene and oil bulk cargo owned by *Shell Transport* since 1867 (Turnbull 2009; Doshi 2015: 169; Shell Global 2017). After the *East India Company* folded in 1867, the *Straits Settlements* came under the British Colonial Office, becoming a *Crown Colony* until the Japanese occupation of 1942 (Francesch-Huidobro 2008: 88; Turnbull 2009; Morgan 2016: 16). The day-to-day administration of the city, including the regulation of street lighting and transmission and distribution of electricity supply to commercial, and eventually, residential premises, came under the *Municipal Commission's* purview, since its establishment in 1901.

In 1861, the *Singapore Gas Company*, a private firm, had begun providing piped-gas to power street lighting. The *Kallang Gasworks*, another private investor, had opened the same year at Bugis to tranship Australian coal (the fuel to be gasified into town gas) through the Rochor and Kallang rivers (History SG; Photo 1). Between 1864 and 1897, the *Tanjong Pagar Dock Company*, also a private firm, completed the installation of a marine boiler to generate the steam which powered three engines that supplied electricity to its docks, workshops, wharves and roadways (History SG; Public Utilities Board 1985, 1988; Koh and Lee 2011: 24).

[1] *Malay for chief of public security.*

PHOTO 1. KALLANG GASWORKS

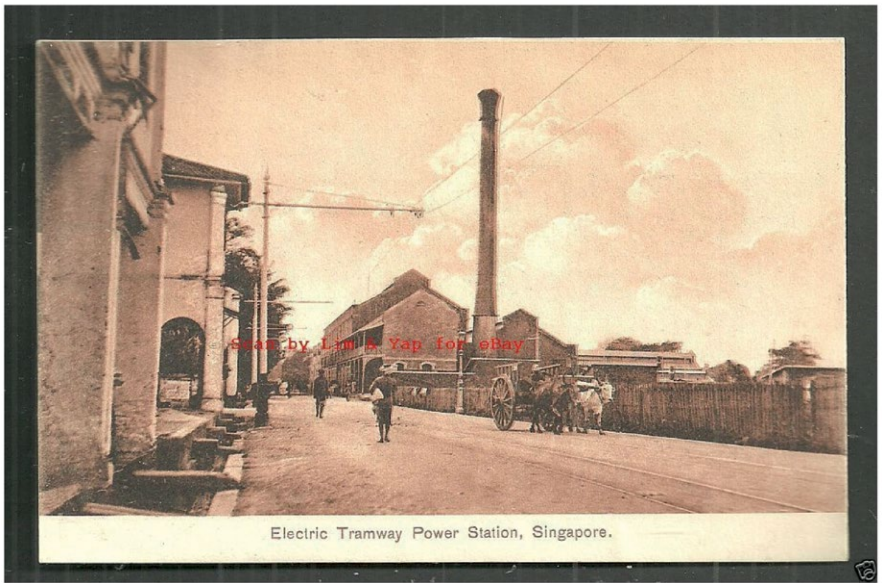


(SOURCE: NATIONAL LIBRARY BOARD, SINGAPORE)

Electricity comes to Singapore in 1906 and the period up to 1945 – availability of supply

In 1906, electricity became more widely available to the Municipality when the first streets lamps lit Raffles Place and North Bridge (Singapore Annual Report 1955: 172). Electricity was sold from 1906 to 1924 as bulk supply to the Municipality by another private company, the *Singapore Electric Tramway Company* from its power station at Mackenzie Road (Koh and Lee 2011: 44-45; Singapore Annual Report 1955: 172; Photo 2).

PHOTO 2. MACKENZIE ELECTRIC TRAMWAY POWER STATION



(SOURCE: NATIONAL ARCHIVES SINGAPORE)

In less than a year since streets were first lit, the number of electricity user accounts increased by 400% (Energy Portal 2016). In 1926, a second power station, *St. James Power Station,* opened in the Pasir Panjang area (West Coast) (ibid.:172; Photo 3).

PHOTO 3. ST JAMES POWER STATION

(SOURCE: FRANCESCH-HUIDOBRO 2017)

By 1928, household electrical appliances were already available for rent by the *Hiring Department* at Orchard Road. In 1928, an *Electricity Department* under the *Municipal Commission* was established and the first traffic lights were located at Empress Place. Other than its functionality, electricity also had positive effects on Singapore's population comfort. For example, Cathay Cinema movie-goers started to enjoy movies in air-conditioned rooms (Energy Portal 2016). The *Electricity Department* and *St. James Power Station* continued regular functions and operations until the Japanese Occupation of Malaya (including Singapore) in World War II (WWII), from 1942 to 1945. Upon occupation, the Japanese established the *Nippon Hassoden Kabushiki Kaisha* or *Nippon Power Supplies Company* as a military-run company that also took over the administrative functions of the *Electricity Department* (Singapore Annual Report 1955: 172-173; Energy Portal 2016).

Post-WWII Singapore – rebuilding the city's electricity between 1946 and 1950

After the Japanese defeat in 1945 and during the short period of Singapore's *British Military Administration* (1945-1946), the *Electricity Department* was restored to civilian management but times were hard. In a circular dated 23 December 1945, the Chief Staff Officer of the

BMA mandated all heads of departments to conserve electricity as consumption had more than doubled since the re-occupation of the city by the British. He stated that *'the Generating Plant at the Electrical Power Station has been run with practically no maintenance for the past 3½ years and the distribution system has been completely neglected and the cables have been damaged in many cases by misuse and by bombing'* (National Archives Singapore, War Office, WO203/4106). Among the measures mandated were: *'switching off fans when leaving the room, using all lights sparingly, not using lights in porches, using no outside lighting whatever, avoid servants using electricity unnecessarily, and being particularly careful in the use of electricity between 1800 and 2300 hours'* (ibid.). Such measures were issued by proclamation giving wide-ranging powers to authorities to forbid certain types of lighting, to fix rations for consumption, and to admonish persons who wasted electricity (National Archives Singapore, War Office, WO203/4106).

The agenda for discussion for the Area Commander's Conference scheduled at 0900 hrs on 28 December 1945 is a revealing account of the state of electricity supply shortly after the war. It lists power stations in operation, including their capacity and the state of their equipment. These were: *St. James Power Station* (maximum load of 16,500 KW); *Alexandra Power Station* (maximum load of 120 KW to supply cold storage plant and water pumps, and a further 120 KW to supply all hospitals and part of the army barracks); *Harbour Board* that had before the War supplied its own power but now had to take 700 to 1,000 KW from the mains; *Changi Power Station* (consuming 275 kVA); *Naval Base*, with a present demand of 700 KW but expecting to be supplied with 1,000 kVA which would require 4,000 gallons of transformer oil, which was not available at the time(ibid.).

In 1946, the *Straits Settlements,* of which Singapore was part before the War, were disbanded, the Malaya Union Scheme was created (to include Singapore) and the Malay sultans transferred sovereignty back to the *British Crown* (Morgan 2016: 17). But by 1948, the Federation of Malaya Agreement was signed transferring sovereignty back to the sultans (Baker 1999: 253).

The governance of Singapore emerges in 1951 - electricity supply and administration in a self-determined city

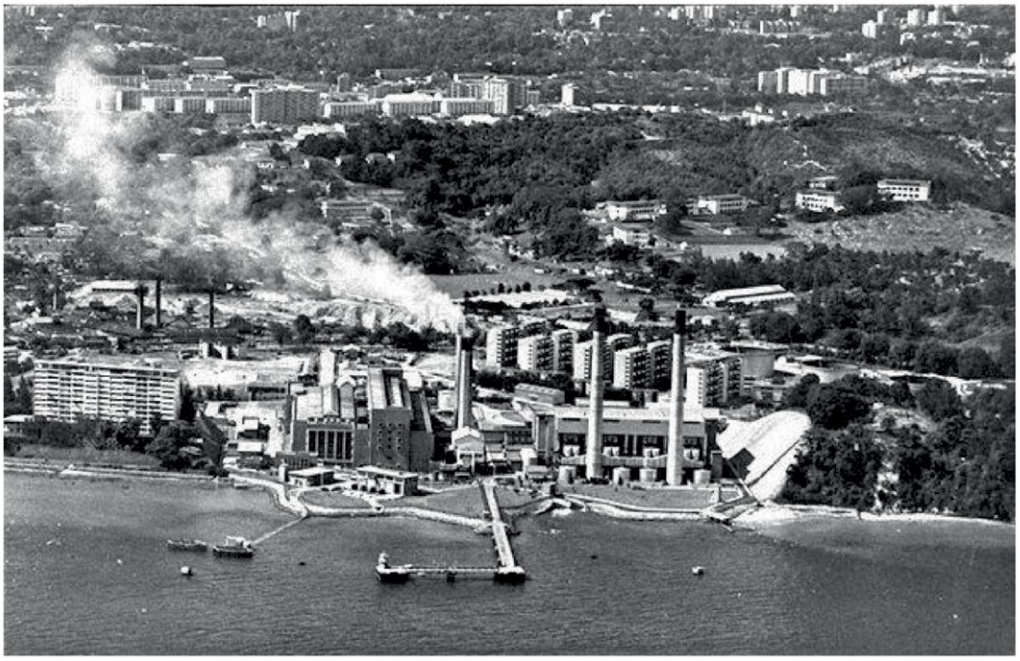
By 1949, a group of four students (one Malay and three Chinese) began to plan the formation of a political party and founded the People's Action Party (PAP) in 1954 with the objective of toppling British colonial rule in Malaya (Baker 1999: 261; Turnbull 2009). In 1958, the British Parliament passed the *State of Singapore Act* converting the city from Colony to a *Self-governing State of Singapore Constitution*[2]. The PAP then became Singapore's ruling party when the city finally achieved self-governance in 1959 and during the period it was

[2] *See also Third Schedule to the Sabah, Sarawak and Singapore State Constitutions Order in Council 1963- signatories Great Britain, Federation of Malaya, Singapore, North Borneo and Sarawak (Morgan 2016: 18).*

included in the *Federation of Malaysia* (from 1963) until Singapore was expelled and became independent in 1965 (Baker 1999: 294; Koh and Lee 2011: 77).

Prior to that, in 1951, Singapore had been granted City status, a City of the *British Commonwealth* (Koh and Lee 2011: 76) and the *City Council of Singapore,* with the mandate to administer electricity, gas, water, street lights, roads and bridges replaced the *Municipal Commission*. The post-war period until 1964, continued to see growth in the electricity supply sector with the commissioning in 1952 of *Pasir Panjang Power Station A* and the installation of 'the first 25,000KW turbo-alternator and boiler' (Singapore Annual Report 1955: 172; Photo 4).

PHOTO 4: PASIR PANJANG POWER STATION



(SOURCE: WIKICOMMONMS).

Supplying electricity becomes a business – the period between 1952 and 1958

Between 1953 and 1955, three more 25,000KW turbo-alternators were added bringing the total installed capacity of the *Pasir Panjang A* station to 100,000 KW. With a peak demand in 1955 of 74,000 KW, these additions provided the city with a comfortable margin of excess capacity. Restrictions on consumption which had become the norm in the immediate post-war period were then removed (Singapore Annual Report 1956: 189). In a letter from IBM World Trade Corporation to the City Electric Engineer of the Electricity Department, Mr G. W. Skelt of IBM advised *'mechanizing your Meter Reading and Billing on an automatic electric basis by introducing IBM All Electrical Accounting Machines to handle meter reading, produce billing documents, and furnish other additional reports, which you may find necessary'* (National Archives Singapore Letter 27th July 1953).

In 1955, the *Electricity Council* of the *City Council*, raised a healthy revenue from the sales of lighting and fans, other domestic use, industrial use, public street lighting in the city area (paid for by the City Council), public street lighting in the rural areas (paid for by the Rural Board), and traffic signals (paid for by the Colonial Government). The total revenue of 1955 amounted to 23,881,067.71 Singapore dollars (ibid.: 173). Revenue from the hiring of ceiling fans, water heaters, cookers and motors by the *City Electricity Department* was 771,084.25 Singapore dollars. The two 5-year street lighting programmes that had been launched after the War had brought a total installed capacity of 7,572 street lamps of which 1,273 were connected by the end of 1955 (ibid.: 173).

A fifth turbo-alternator was added in 1956, bringing the total installed capacity to 125,000 KW, just 25% short of its ultimate planned capacity of 150,000 KW for 1958 (Singapore Annual Report 1956: 188). Yet, an unexpected demand over the peak load period prompted the consideration of additional generation equipment to meet demand. Maximum demand for 1956, was estimated at 83,000 KW, an increase of 7,000 KW from the previous year (ibid.: 189). At the end of 1956, 74,988 consumers were being serviced by the *City Council*, while rural areas were still being supplied by private generators. The total revenue raised in 1956, was 27,413,112 Singapore dollars (ibid.: 190). Hiring of appliances continued to be supplied but ceiling fans were no longer purchased for hire after 31 December 1956. Revenue from hire charges rose to 1,034,982 Singapore dollars (ibid.: 190) that year.

The maximum demand during 1957 was 95,500 KW. Tenders were invited for the purchase, dismantling and removal of the old and obsolete steam power plant at *St. James Power Station*. At the same time, an additional plant (also located at St. James) was commissioned to provide a total installed capacity of 36,000 KW (Singapore Annual Report 1957: 208). That year saw an increase in electricity tariffs and hire charges for appliances, the first since 1949, due to increases in fuel and labour costs. For example, the consumption for domestic lighting and fans in excess of 15 units of electricity per month was charged at 20 Singapore cents for the first 5,000 units and 6 Singapore cents for the next 5,000 units. An additional 3,857 consumers were serviced that year, bringing the total number to 78,845 (ibid.: 209). The total revenue rose to 31,419,039 Singapore dollars, with 1,264,491 Singapore dollars being raised from the hiring of electric appliances (ibid.: 209).

In 1958, 51 new substations were commissioned bringing the total to 444. The number of consumers rose to 86,621. Major changes in *City Council* policy took place, namely *'for commercially administered housing estates, outright payments for the cost of giving supply supersede the previous request for a deposit, refundable when justified by the revenue obtained. Similarly, for commercial enterprises outright payment has been specified in place of a minimum monthly revenue charge for an agreed period'* (Singapore Annual Report 1958: 225). The tariff structure was also revised from that of the previous year (with effect from February 1958). A basic charge of 12 Singapore cents was set for consumption of electricity not exceeding 20 units per month for lighting and fans. Domestic consumers were charged

18 Singapore cents (instead of 20 Singapore cents as per previous year) for the first 5,000 units of electricity per month (with effect from January 1959). All hotels, cinemas and amusement parks were charged a flat rate of 20 Singapore cents per unit of electricity for all consumptions (ibid.: 225).

An important transition that had been taking place since 1956 was the change in fuel mix, both for electricity generation and for cooking and heating. The coal-oil price ratio was shifting steadily in favour of oil and an *'important decision was then taken to discontinue coal/water gas production in favour of oil gasification'* (ibid.: 226). Furthermore, coke[3] production ceased with the discontinuation of coal-gas production, thus, coke had to be imported into the Colony with small consignments received from Shanghai and Sydney.

Expansion of industry and Singapore's economic rise from 1959 to 1960 - electricity and economic development

In 1959, six high thermal, efficient and quick starting machines were installed to replace the steam power plant at *St. James Power Station*. At that time, it was understood to be the largest of its type in the world (Singapore Annual Report 1959: 221). By the end of 1960, the combined generating capacity of *Pasir Panjang A* and *St. James* was projected to reach 188,000 KW. The programme was not only intended to provide consumers with more competitive rates than those in other Southeast Asia jurisdictions but also *'to afford consumers maximum security of supply by the provision of economic reserve of stand-by generating plant'* (ibid.: 221). The maximum load demand of the *City Council* generating plant in 1959 was 113,000 KW (ibid.: 221).

As Singapore became self-governed and throughout the 1960s, it experienced a rapid expansion of its industrial and commercial activities resulting in an increase in the consumption of electricity. Ng Weng Hoong, in his account of fifty years of Singapore's energy economy (1960-2010) posits that, *'Singapore's economic rise was linked to electricity consumption'* (Ng 2012: 110).

Electricity was supplied in July 1960 by 150,000 KW of high pressure steam turbo-alternators, 36,000 KW of free piston gas turbine plant and a 2,000 KW open-cycle gas turbine. In 1960, altogether 188,000 KW generating capacity was available at plants owned and operated by the *City Council*[4] (Singapore Annual Report 1960: 242). Yet, orders were being made for the commissioning of an additional high-pressure steam power station to produce

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3 Coke is obtained from the processing of residue left over by the refining of crude oil. Coke is used as a cost-effective fuel http://education.afpm.org/refining/petroleum-coke/

4 By the end of 1959, Singapore became a self-governing State. The City Council and its Electricity Department were under the State of Singapore, no longer under the Colony of Singapore which had ceased to exit.

an additional 24,000 KW. Thirty three additional substations were also commissioned. An important achievement that year was the completion of the government assisted *Rural Electrification Programme*.

Increases of 14.8% of units sold for lighting and fans, 15.9% for domestic power and 21.68% for industrial power were recorded by the end of 1960. The year ended with a surplus of 7,346,874 Singapore dollars from trading rates. Tariffs were maintained at the 1959 level (ibid.: 244). The capital expenditure of the year, amounting to 9,379,746 Singapore dollars was financed from Revenue (ibid.: 243). In 1961, the Singapore population was 1.7 million and the city's GDP per capita was 1,374 Singapore dollars. Half of the city's 636.6 GWh available electricity was consumed for lighting streets, buildings and public premises.

Electricity supply responds to increased industrial and domestic demand, 1961 to 1962

The maximum peak demand for electrical power in 1961 was 128,500 KW, an increase of 10,000 KW compared to 1960 (available total capacity at the end of 1960 was 188,000 KW). The projected increased generating capacity was estimated at 213,000 KW. The 1961 annual report is the first time in which the fuel consumed is mentioned, namely a consumption of 215,118 tonnes of fuel oil (an average of 0.67 pounds of fuel per KWh) (Singapore Annual Report 1961: 271). Also in that year, 29 additional substations were built and 8,389 new consumers were serviced, an addition of 3,356 from 1960. In comparison with 1960 in which 45 industries applied to be connected to the network, the *Electricity Department* saw 227 applications (ibid.: 272).

At the same time, supplies to six additional industrial estates were being negotiated and approved, anticipating an even further increase in demand. Significant changes were made in the method of supplying electricity and collecting payments from consumers. Commercial estate developers rather than being charged through non-refundable outright payments for the cost of providing electricity supplies were, from 1961, charged on the basis of a deposit that was refundable twice a year for a maximum of 5 years based on the revenue obtained from the sale of electricity. Commercial and industrial companies were charged a minimum monthly payment for a period of 5 years rather than the outright payment that was charged previously. Such changes significantly accelerated the number of applicants to be connected to the network. In 1961, 9,432 new applications were received. Furthermore, despite an increase of 2.75% in the price of fuel, tariffs for 191 remain unchanged. An aggressive expansion of street lighting with roads and avenues previously unlit receiving light also took place in 1961 with 84.69 miles of urban roads and avenues being lit by traffic route lanterns by the end of that year together with 179.11 miles of paths and roads in rural areas also lighted up (ibid.: 273).

By the end of 1962, the site for the new *Pasir Panjang Power Station B* as well as the ordering of equipment, were completed. The new station was planned for an ultimate generation capacity of 240,000 KW. Adjacent to *Pasir Panjang Power Station A*, both facilities shared bunkering, oil storage, workshops and laboratory facilities. In addition, two new open-cycle gas turbo-alternators were ordered for installation at *St. James Power Station.* The maximum peak demand was 138,500 KW while generating capacity had reached 215,500 KW. Of significance was the increase in the distribution network. In 1962 alone, 39 new substations were commissioned, 327,476 yards of cable laid, 1,246 new poles erected, and 489,200 overhead line conductors installed (Singapore Annual Report 1962: 315). A new technology was also used in the distribution network namely, oil-filled cables, connecting the power stations with the major substations as an efficient means to economically distribute large quantities of power (i.e. from *Pasir Panjang A* to Jurong Industrial Area in Boon Lay Rd.). In 1962, a record number of 12,124 new consumers were connected bringing the total number of consumers by the end of 1962 to 118,664. All in all, 212,322 electricity meters were in operation. Industrial demand came mostly from steel mills, facilities owned by the *Shell* oil company, flour mills, motor accessories factories, cement plants, quarries and chemical works. By the end of the year, 33 kampongs had been electrified. Tariffs remained unchanged and street lighting continued to increase reaching a total of 262.5 miles in urban and rural areas (ibid.: 317).

Formation of the Public Utilities Board and its role from 1963 to 1965 - an institutional landmark

In 1963, self-governing Singapore became part of the *Federation of Malaysia* and the *Public Utilities Board* (PUB) was formed on 1st May to take over the functions, assets and liabilities of the *Electricity Department* of the *City Council.* PUB was made responsible for the supply of electricity, water and gas (Koh and Lee 2011: 58; Public Utilities 1985) and was placed under the portfolio of the Prime Minister. The two new open-cycle gas turbo alternators ordered the previous year for *St. James* were commissioned on schedule, increasing capacity by 22,500 KW. 63 new substations were commissioned in contrast with 39 in 1962 and 29 in 1961 (Singapore Annual Report 1963: 329).

The aggressive industrialization policy scheme was reflected in 218 new applications to join the network. The quantity of fuel required to produce power that year amounted to 250,000 tonnes of Bunker C residual fuel (ibid.: 328). In 1963, the *Housing Development Board* (HDB), set up three years previously, (Koh and Lee 2011: 77) intensified its aggressive affordable price housing plans, increasing the supply of electricity to 18,000 new housing units and 100 new kampong roads. Tariffs however remained unchanged. A further aggressive industrialisation programme, put forward by the *Housing Development Board* and the *Economic Development Board*, required a significant increase in electricity supply. The *Shell Company*, that had established itself in the Singapore energy/power sector since 1867, acquired 'pioneer status' in 1962 and was granted a concession of 5-year tax free earnings for

its first refinery at Pulau Bukom (Doshi 2015: 169). The *Rural Electrification Programme* began aiming at bringing the benefits of electric power to the *kampongs* in a strategic manner (Koh and Lee 2011: 77). Singapore had at this juncture built self-sufficiency of electricity supply to support its survival and drive its growth.

In 1964, the PUB was transferred from the *Prime Minister's* portfolio to the *Ministry of Law* (Singapore Yearbook 1964: 267). The construction of *Pasir Panjang Power Station B* was in progress, and expected to be completed by mid-1966 (ibid.: 269). The highest recorded maximum demand rose to 168,000 KW. The distribution network continued to expand. A record number of 83 new substations were commissioned raising the number of total substations serving Singapore to 726. The total number of consumers in 1964 reached 146,474 (ibid.: 270). Tariffs for very large industrial consumers were reduced. For example, *'under Tariff G, large industrial consumers using excess of 1,500,000 units per month could obtain a basic charge per KWh of only 2.70 Singapore cents. Tariff A applied to all consumers for lighting and fans, Tariff B applied to domestic power (for cooking, heating and all appliances except fans), Tariff C applied to lifts, Tariff D for hotel power, Tariff E for commercially operated industrial consumers using more than 400,000 units per month, and Tariff F for commercially operated industrial consumers using more than 1,000,000 units per month'* (ibid.: 270). Lighting of roads and hiring of electrical appliances (fans, water heaters and cookers) continued steadily (ibid.: 272).

By 1965, the demand for electricity *per capita* in the newly established Republic of Singapore was the highest in Southeast Asia (Singapore Yearbook 1965: ch. 21 n. p.). The first phase of *Pasir Panjang B* opened in October 1965. By the end of 1965, the first submarine cable was laid between *Pasir Panjang B* and Pulau Bukom to supply the oil refinery located there. PUB had by then 197,000 registered consumers, an increase of about 27,000 from 1964 (ibid.: n. p.). In the 10th anniversary publication of the *Energy Market Authority* Singapore (2011), Koh and Lee reflected on the fact that for the first three decades after independence (1965-1995), *'electricity is the unsung hero in the history of Singapore's economic success, with its instant availability and reliability'* (ibid.: 83). *'But at the onset of the new Republic, ensuring adequate supply was decisively aiming at 'planning ahead to achieve sufficiency for Singapore's needs'* (ibid.: 84).

As the PUB Chairman from 1978 to 2000, Lee Ek Tieng recalled, *'PUB's work was to always aim to stay ahead of the curve and to build a power station ahead of time'* (ibid.: 84). This is wittingly expressed by Soh Siew Cheong, who joined PUB in 1965 and became Chief Distribution Engineer in the 1980s, *'the reliability of electricity supply was linked to advances in technology and industrialisation. It moved from do you have? to do you have enough? to how reliable are you?* (ibid.: 84; National Archives Singapore Oral Histories Acc. No. 3274/05 CF4: 68). Mr Soh added: *'in the 1960s, the policy was about availability. After 1975, it was about reliability, and after 1985, it was about quality and price'* (quoted in Koh and Lee 2011: 84).

Electrifying the kampongs in the 1960s – don't forget the villages!

All these goals required a total system of generation, transmission and distribution to be of the highest standards. PUB embarked into ensuring this was the case (Ibid.: 84). By 1965 Singapore had only 3 power stations to supply urban areas and relied on *'private generators who installed in a diesel generator, and then put out their wires to supply the residents in the village. And these operators could only supply electricity to light up a few bulbs in each household during the evening. But the services, you know, from these private generators was expensive and generally unreliable. So, you know, when we got independence from Britain, we were on our own. And there were two main challenges, you know, the PUB had to face. One was government's initiative, you know, for industrialisation in Singapore to provide employment. And two, the government also introduced a rural electrification program. And this program…was to improve the standard of living of its people'* (National Archives Singapore Oral Histories Acc. No. 3274/05 CF4: 68-69).

To electrify the kampongs, a two-man PUB team of an engineer and a technician was sent out to the villages to try to draw maps of the location on access tracks and houses, record how many people lived in each house and their activities. They would return and prepare an estimate of cost of supplying electricity to each kampong (ibid.: 70). As available funds were limited, the *Urban Rural Services Committee* chaired by a Member of Parliament was established to study proposals and approved projects. The criterium set to approve projects invariably was that *'total expected revenue return over a five-year period should exceed the total capital cost of the project. This was the viability test. The second criterium was to give priority to projects which had the lowest investment per prospective consumer'* (ibid.: 70). As projects progressed, the criteria were relaxed and even financially non-viable projects were executed as justified by social needs. The programme was finally completed in 1973 (ibid.: 72).

SUMMARY

From the time electricity was first generated in Singapore in 1906 by the private enterprise of *East India Company* agents who were determined to expand and protect Britain's sprawling interests in the Indian subcontinent, Southeast Asia and China, to Singapore's independence in 1965, Singapore strove to render its electricity supply system to be more self-sufficient in response to geopolitical isolation.

The availability of electricity was the constant driver for the city's economic growth and social stability. From providing its people a sense of safety to light up the 'dark' thereby allowing them to establish or participate in industrial development to sustain their living, thus increasing their sense of security in a new, fledgling nation, the availability of electricity supply had the effect of helping Singapore survived through colonial overlords, occupying armies, physical destruction, and powerful federations being formed by neighbouring

nations. Ensuring energy autarky by building excess capacity became the goal for survival, growth, and, was possibly, the linchpin for independence.

Other than the post-WWII years of scarcity and austerity, Singapore's first 100 years of access to electricity supply, coincided with a golden period of cheap and abundant supply of coal and, eventually, oil and of free trade. This made development and sustainable growth possible.

3.2 KOTA KINABALU, FROM BRITISH SETTLEMENT TO MERGER WITH THE FEDERATION OF MALAYSIA: AUTARKY AS SURVIVAL AND AS THE TRUMP CARD FOR UNION WITH MALAYSIA? (1877-1963)

Api Api and Jesselton from 1877 and the period up to 1910 – steam locomotives as electricity engines

Kota Kinabalu[5] , today the capital of the State of Sabah, was locally known when first settled by British businessman Alfred Dent in 1877 as Api Api[6] (Holdsworth and Munn 2012: 123; State of Sabah Annual Report 1963: 214). In 1878, Baron von Overbeck, consul of the Austro-Hungarian Empire in Hong Kong and also a Hong Kong agent of the British firm *Dent Brothers* in Shanghai, had entered into a partnership with Alfred Dent to exploit concessions in Sabah. He was not only granted land by the Sultan of Brunei (owner of the conceded land) but also made Maharajah of Sabah and Raja of Gaya[7] and Sandakan.[8] All in all, Overbeck was granted 30,000 square miles of land and 850 miles of coastline. Having parted with Alfred Dent, Overbeck and his associates formed the *British North Borneo Company* (BNBC) in 1879 seeking a suitable location with a natural harbor close to the newly built steam engine of the *North Borneo Railway* (ibid.).

Electricity was first supplied to Sabah by the *North Borneo Railway* and it was to be essential to the success of these private enterprises and the territories they governed. As it was the case with the *East India Company* that administered the trading port of Singapore, the BNBC not only concerned itself with trading matters but also with governing the territory, including the administration of utilities that supported its development (Rutter 1922 (2008 ed.): 146). The BNBC was incorporated by Royal Charter in 1881 (Miller 1914: 118-119- 2007 ed.; Rutter 1922 (2008 ed.): 119; State of Sabah Annual Report 1963: 214; Holdsworth and Munn 2012: 103-104; 348). Sabah was then renamed *British North Borneo* and Api Api renamed Jesselton in 1899 after Charles Jessel, BNBC's then vice president.

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5 *Kota Kinabalu means 'Chinese window' in Malay.*

6 *Api Api means 'Blazing' in Malay.*

7 *Gaya is the island opposite Api Api (South China Sea).*

8 *Sandakan (Sulu Sea), then capital of North Borneo, means 'the place that was pawned' in Malay.*

Supplying electricity between 1910 and 1945 – double whammy: ice and light!

Electricity arrived to Jesselton in 1910 by the private *North Borneo Railway* company but it was not until 1915 that electricity became widely available when the *Jesselton Ice & Power Co., Ltd* also a private firm, begun to provide electric light and ice *via 'two gas generators coupled to electric generators which supply the whole of the power required…with the available voltage supply of the switch board being 230 volts continuous current distributed at radius of a mile of the power station, and up to 4 miles through the use of motor alternators that convert direct current into alternating current from 230 volts to 2,000 volts'* (British North Borneo Herald 1916: 72; Tenaga Nasional https://www.tnb.com.my/about-tnb/history).

In 1917, the *British North Borneo Herald* reported the minutes of the Annual General Meeting of the company indicating that its electric branch had done quite well. Nevertheless, a rise in prices of all supplies resulted in *'higher prices at which we have to sell, doubtlessly curtailing demand for electricity installations and fittings'* (BNB Herald 1917: 91). The BNBH also published the Directors' Fourth Report to Shareholders in its 1 July 1918 and 1919 issues (p. 124 and 135, respectively) showing that there was an increase in revenue from the power plant *'due to steady increase in the demand for electric energy. Extensions have been made to new consumers'* (ibid. 124).

In 1922, utility-scale supply was finally provided to the city by the *Jesselton Ice & Power Co., Ltd* under the oversight of the *Electricity Advisory Board* that bought the company in 1949 (North Borneo Electricity Board Annual Report 1957: 3). During the Japanese occupation of North Borneo and of Jesselton, which the Japanese renamed Api Api from 9th January 1942, electricity supply services were taken over by the *Nippon Hasso-don Co.* as it had been the case all over Malaya (National Archives Singapore: War Office File WO 203/4490: 116)[9].

Bankrupt and unable to rebuild Jesselton, the *British North Borneo Company* gave the administration of British North Borneo in 1945 to the *British Crown* that first administered Jesselton as a *British Military Administration.* From 1946 onwards and after establishing the first Executive and Legislative Councils in 1950, the British Crown continued to govern the city until September 1963 (State of Sabah Annual Report 1963: 216).[10] Almost twenty years later, in 1963, British North Borneo, Sarawak, Singapore, and the Federation of Malaya

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[9] *Jesselton was a trading center for rubber, rattan, honey and wax and so it remained until the Japanese occupation of 1942. The town was destroyed at the end of WWII by Allied forces in 1945.*

[10] *Peninsular Malaysia, but not North Borneo and Sarawak, had been independent since 1957. A Federation of Malaya was inaugurated as early as 1948 including nine peninsular states and the three Straits Settlements of Singapore, Penang and Malacca, but not North Borneo, Sarawak or Brunei.*

(peninsula) formed the Federation of Malaysia, British North Borneo was renamed Sabah and Jesselton changed its name to Kota Kinabalu in 1967, eventually acquiring city status in 2000 (State of Sabah Annual Report 1963: 215; Rutter 1922 (2008 ed.): 126).

Post WWII electricity supply in Jesselton between 1946 and 1956 – private and public enterprise for reconstruction

In the post-war years, particularly after the establishment of the *Crown Colony* and the transfer of its capital from Sandakan in the east coast to Jesselton in the west coast in 1947, serious attempts were made to rebuild infrastructure, refuel the economy, and power the city and the State through exploration of coal resources. Memoranda of exchange on the subject issued by the Special Commission in South East Asia, Singapore, dated 10th September 1947, recorded the analysis of coal samples by expert adviser Mr. Heywood, who suggested the quality was such as to justify the reopening of the Selimpopon mine, formerly owned by the Cowie Harbour Coal Com., Ltd. that had closed 16 years earlier (National Archives Singapore, Memo Ref: E/600/A/47).

Then from 1957, after the closure of the private *Jesselton Power & Ice Co., Ltd*, electricity was supplied by different generating sets some of which were property of the municipality via the *North Borneo Electric Board* (NBEB)[11] while others were private power stations such as the *Sandakan Light & Power Company (1922) Ltd* (installed capacity 2,250 KW by steam and diesel) (Colony of North Borneo Annual Report 1957: 116-117; State of Sabah Annual Report 1963: 214).

The Annual Reports of the Colony of North Borneo's electricity entries of 1948, 1957, 1959 and 1963 (Sabah State Archives accessed 28 Mar 2017), as well as the *North Borneo Electricity Board* (NBEB) Annual Reports' entries of 1957, 1958, 1962 and 1963 (Sabah State Archives accessed 28 March 2017), provide other important insights into electricity transitions prior to North Borneo's merger with Malaysia.

Already in 1948, *'negotiations were being undertaken with the Jesselton Ice & Power Co., Ltd with a view of terminating their concession, whereby they supplied Jesselton with its electricity and ice'* (Annual Report of the Colony of North Borneo 1948: 47). Damages incurred by their plant during the War and uncertainty about the future urban planning of Jesselton, had discouraged its owners from repairing the existing equipment and after the municipality bought it in 1949, there were plans to replace it altogether. With a planned increased output of 397 KW, in contrast with the previous output of 128 KW which only allowed the use of electric lights from 6 to 11 pm, electricity was finally available for 24-hours in 1953 (NBEC Annual Report 1957: 5).

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[11] *NBEB supplied Jesselton and its hinterland, Penampang, as well as the offshore island of Labuan.*

Also in 1949, the *Electricity Supply Act* (national) had been enacted (Ansari 2011: 198) and the *Central Electricity Board (CEB)* (national) formed to administer electricity generation, transmission, and distribution (Tang & Tan 2013: 298). Nevertheless, these boards had no jurisdiction over North Borneo as it was still a Crown Colony. CEB was renamed in 1965 the *National Electricity Board* (NEB) with Sabah having its state equivalent as the *Sabah Electricity Board* (Sabah Electricity Supply: Industry Outlook 2014: 8).

In 1950, while all major towns in North Borneo were still to be rebuilt Electricity Ordinance n. 10 of 1950 (Cap. 40 in 1957) was enacted to license large and small providers (ibid. 6). Also, in the absence of expert advice, it was decided that *'the Public Works Department should be responsible for the provision of electricity, and should order modern plants and erect the necessary buildings'* (ibid. 6). Loans, possibly from the *International Bank of Reconstruction and Development*, were not available until 1953, thus, costs were shouldered by government. A new 1,485 KW station was installed and put to use in Jesselton in 1954 doubling its capacity by 1956 (ibid. 6).

This excess capacity allowed a revision downwards of tariffs to encourage the commercial and industrial use of electricity beyond lighting. It was also in 1954, that an *Electricity Advisory Board* was established to *'advise the Government and the Director of Public Works on all aspects of the operation of [public] electrical installations in the Colony….and on the possibility to remove the responsibility for the electrical undertakings from the Public Works Department to an appropriate statutory body'* (ibid. 7).

Another piece of legislation was enacted in 1956 (Section 33 of Ordinance 27) to second staff of the *Electricity Branch* of the *Public Works Department* to the NBEB and determine their conditions of service to be as competitive as those they had previously enjoyed. This additional cost plus sending two board members to Australia for training under the Colombo Plan[12] added to financial and personnel shortages (ibid. 10).

A difficult period of transition from 1957 to 1962 – crises, excess capacity, low demand, new fuel sources

By the time the *North Borneo Electricity Board* (NBEB) was established in 1957 to replace the *Electricity Advisory Board*, the total installed capacity available to Jesselton was 1,485 KW increasing by the end of 1958 to 2,235 KW to provide electricity to 1,681 consumers (Colony of North Borneo Annual Report 1957: 116: NBEB Annual Report 1957: 8; NBEC 1957: 13). In its remit, the goal of building capacity to *'promote and encourage the generation of energy with a view to promote the economic development of the Colony'* was clearly

[12] *Established in Sri Lanka in 1950 by the Commonwealth Conference of Ministers to provide foreign aid and technical assistance to Southeast Asian countries.*

spelled out (ibid. 9). Nevertheless, the NBEB experienced a poor business environment due to low demand, despite a growth in the number of consumers to 2,461 (ibid. 3). *'Consumption is low given the conservative habits of consumers who have no previous experience in the use of electricity for other purposes other than lighting, refrigerators, fans and small hand irons'* (ibid. 2).

Although, a transition by industrial consumers from other sources of power to electricity had not yet occurred, the NBEB was conscious that if they wanted to keep prices competitive, electricity at off-peaks hours had to be made available (ibid.2). Moreover, there were compounding factors affecting the NBEB profitability, namely, higher freight charges resulting from the Suez crisis, increase of bank rates in the United Kingdom (UK), and capital investment in new offices. All these drove the NBEB to pass costs to consumers who saw an increase of a temporary 15% surcharge on all tariffs (ibid. 3). New public and civic buildings served by the Jesselton power plants included Queen Elizabeth Hospital, Central Government Offices, and the new Public Works Department (ibid. 13). Eventually, smaller sub-stations were built. For example, an 11 KV station near Queen Elizabeth Hospital that provided power to the new Jesselton water supply pumping station (ibid. 14; see also load duration curve and tariffs for Jesselton in NBEC Annual Report 1957: Appendix I and III).

In 1959, the NBEB continued *'to encourage additional consumption during the off-peak load periods and increase usage of electrical appliances and machinery, making a number of tariff reductions'* (Colony of North Borneo Annual Report 1959: 126). That year, no major shutdowns and blackouts took place with the exception of the Jesselton Power Station that experienced a major breakdown of the 12SV set in August due to faulty pistons: *'prompt action by the engine-room staff averted a serious failure and the effect was not reflected to the consumers'* (ibid. 126). In 1959, the number of consumers in Jesselton rose from 1,916 to 2,180.

By 1962, the NBEB had ventured into setting out the principles governing its financial policy and things began to look brighter. Of significance, was its commitment to *'financing at least 40% of its development programme, including provision for depreciation and other reserves from revenue'* (NBEB 1962: 2). Its annual report of 1962 presented its overall growth (not only Jesselton) from a 2,217 KW installed capacity in 1957 to 11,184 KW in 1962 (ibid.:3). Consumers during the same period had risen from 2,461 to 8,887 (ibid.: 3). The value of dividends increased to 5% in 1962.

By the end of 1962, Jesselton was the largest North Borneo load centre with 4,250 KW capacity and 12.05 million units of electricity sold (Sabah History 1881-1981 n. d.: 242). Such steady growth, prompted the Board to look into new ventures such as the feasibility of hydropower and, with the advice of Australian experts, the linking of the Tuaran Station to the Jesselton network together with the support for the increasing demand for air-conditioning (ibid.: 4 & 5–32, December 1962, graph load curve of Jesselton).

Ongoing negotiations to have North Borneo incorporated to the Federation of Malaysia, further prompted the Board to seriously consider developing hydropower foreseeing *that 'there will be even more buildings in the town center including multi-storey office and hotel buildings, most of which will be fully air-conditioned'* (ibid.: 8). By then, Jesselton was becoming a popular tourist centre. Underground cables were being laid to tourist landmarks like Australia Place and overhead lines were connecting Likas Plain to the Community Centre.

PHOTO 5: AUSTRALIAN PLACE

(SOURCE: ARKIB NEGERI SABAH).

Formation of the Sabah Electricity Board – the period between 1963 and 1965

As the *Colony of North Borneo* joined the *Federation of Malaysia* to form one independent country in August 1963, North Borneo became the State of Sabah and Jesselton was renamed Kota Kinabalu (National Library Board Singapore).

The rainy season, roughly from December to March, was especially severe that year. On 10th December 1963, the *Jesselton Power Station* was flooded for the first time in its history and a landslide in the hill behind it (Observatory Hill next to Atkinson Clock Tower) caused serious damage to one of its cooling towers (Sabah Electricity Board Annual Report 1963: 5; Sabah State Annual Report 1963: 216).

PHOTO 6: ATKINSON CLOCK TOWER SESB SUBSTATION

(SOURCE: FRANCESCH-HUIDOBRO 2017).

Despite these setbacks, the new Board kept busy coping with an increase of 22% of consumption over that of 1962 (Sabah Electricity Board Annual Report 1963: 5). A new 1,500 KW diesel engine generating set was installed. A report produced by experts surveying the hydro-electric potential, indicated that that there was *'considerable suitable water power in the State for the generation of electricity ranging from small schemes of 250 KW output in the interior up to over 250,000 KW on the Padas River, South of Kota Kinabalu'* (State of Sabah Annual Report 1963: 147). A suitable site was located in the Papar/Labak area. The first trainee on an electrical engineering 4-year course, was sent to study at the Singapore Polytechnic (ibid.: 147).

In 1965, the *North Borneo Electricity Board* was renamed the *Sabah Electricity Board* with most of its incumbent members remaining *in situ*. Maximum demand and consumers continued to increase with the former rising to 3,000 KW and the latter increasing to 3,698 customers (Sabah Electricity Board Annual Report 1963: 5). The use of air-conditioning continued to rise having become a common feature of new commercial buildings.

SUMMARY

From the time it was first generated in 1910 by the private interests of the *North Borneo Railway* company and the *Jesselton Ice & Power Co Ltd* until North Borneo's inclusion in the *Federation of Malaysia* in 1963, the availability of electricity supply was viewed as the essential driver for economic growth and people's well-being.

Although Jesselton strove to pull together the efforts of private and public enterprise to render its electricity supply system self-sufficient in response to geopolitical isolation, the system was fraught from its inception with unreliable supply and low demand despite efforts to build enough capacity. Jesselton's access to the otherwise abundant local fuels (coal and hydro), building the generation, transmission and distribution infrastructure and, most importantly, maintaining it in difficult terrain and under challenging climatic conditions were constant challenges.

Even as overcapacity of supply was built, changes in people's behaviour towards using more electricity and maintaining its infrastructure did not occur. This was compounded by the slow pace in transiting from less energy intensive industries (agriculture and mining) to more energy intensive ones (industry and services) which did not keep pace with other British territories in Asia like Hong Kong and Singapore.

Both these factors had rendered the electricity Jeselton's supply system unsustainable. The economies of the initial private generators and those of the state-run companies that followed had consistently been in bad shape. Nevertheless, abundant reserves of fuels such as coal and hydro and a self-sufficient electricity supply infrastructure that was in place in the 60s kept Jesselton (and North Borneo) afloat through colonial times and through the destruction caused by WWII making it a welcomed candidate to join the Federation of Malaysia in 1963.[13]

4. FROM AUTARKY TO REINTEGRATING INFRASTRUCTURE IN RESPONSE TO INDEPENDENCE (SINGAPORE), MERGER (KOTA KINABALU), REGIONALIZATION AND THE LOW CARBON ECONOMY (1963/65-2017)

4.1 SINGAPORE, FROM AUTARKY AS SURVIVAL AND GROWTH TO AN INTERNATIONAL ENERGY MARKET AND LOW CARBON HUB, SECURITY REMAINING CONSTANT, 1965-2017

Singapore post- independence and the period up to 1975 – adequacy and self-sufficiency of supply as goal

The first two decades of Singapore as an independent nation saw significant transitions in the electricity supply sector. Having reached the goal of availability by building excess capacity, the next transition was fundamentally geared towards the adequacy and self-sufficiency of supply in order to enhance energy security, essential to national security at such critical juncture of nation-building. Thus, energy security was enhanced through the passing

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[13] *See also Cobbold Commission Report on formation of Malaysia*
http://seeds.theborneopost.com/2014/09/16/the-cobbold-commission-giving-people-a-voice/

of new legislation, the building of new infrastructure, and the uptake of new generation, transmission & distribution technologies. These transitions were translated in practical terms by providing access to electricity to as many as possible and supporting rapid industrialization. On a first instance, the opening of the *Pasir Panjang Power Station B* in 1965, symbolised a return of power to the people (literally and metaphorically) reinforced with the arrival of electricity to the villages, where most people lived, through the *Rural Electrification Programme* (1963-1973).

With the help of a 30 million Singapore dollar loan from the *World Bank* and the *International Bank of Reconstruction and Development*, the construction of the *Jurong Power Station* using the latest technology was open to business in 1970 (Singapore Yearbook 1964: ch. 21 n. p; Koh and Lee 2011: 84; Straits Times 7 Aug 1970). Lee Ek Tieng, who spent 21 years working at PUB in the capacity of Board member and Chairman sheds light on how new technologies and equipment were chosen: *'PUB found that, by far, the most competitive lot of people were the Japanese and as a result you'd notice that most of our power stations from the 1970s are Japanese. All the tenders were approved by PUB board. It never had to go to any ministers. It was quite transparent'* (National Archives Singapore Oral Histories Acc. No. 2832/08 Reel 6: 62).

In 1969, the *Electricity Department* of the *Public Utilities Board,* tapped into additional sources of electricity by connecting undersea cables to the Exxon Mobil oil refinery of Pulau Ayer Chawan, Jurong Island (Koh and Lee 2011: 95). From the 1970s onwards, Singapore begun to be recognised as a crude oil and refined product hub and trading centre (Energy Portal 2016; Doshi 2015: 170). Between 1971 and 1972, demand increased by more than 20%, prompting the installation of two 20,000 KW (20 MW) outdoor gas turbines at Senoko in 1972 even before the *Senoko Power Station* was completed (Koh and Lee 2011: 87; National Archives Singapore Oral Histories ACc. No. 2832/08 Reel 6: 60). As Lee Ek Tieng says:*'in deciding on new infrastructure our projection was always based on a five-year rolling plan, we never think of 20 years because you would never know how rapid development would be. The five-year rolling plan was essentially based on MIT (Ministry of Trade and Industry) way of projection or GDP growth…customers cannot wait for electricity, electricity supply must wait for customers'* (ibid.: 61).

Providing power to meet demands in the 1970s and 1980s – overcapacity, engineering and training

Soh Siew Chong, who had joined PUB in 1965 and spent more than 40 years engaged with electricity supply projects, reflects on the challenges of the early 70s*: 'by then, PUB had to face two more challenges. This time the new challenge was how to provide adequate power to existing customers. And secondly, how to provide supply to a sharp increase in the number of new customers. To meet such phenomenal load growth, the power system needed new power stations and an extensive reinforcement program to increase the capacity of the*

transmission and the distribution network' (National Archives Singapore Oral Histories Acc. No. 3274/05 CF4: 74).

As skilled manpower was limited and with a very strong union movement in support of daily-rated workers employed by PUB to do the trenching work prior to laying underground cables, new contractual arrangements were drawn. Instead of having PUB do all the supply and delivery work, *'a supply, delivery and installation'* contract was put in place. This allowed PUB to contract out the *'supply, delivery and installation of switch gears, transformers, low tension boards and overground distribution boxes thereby relieving PUB of manpower needs'* (ibid.: 74).

Other strategic decisions that allowed PUB to reduce manpower and save costs were the replacement of oil-filled cables that required regular checks to ensure the oil was dry, with hermetically-sealed transformers that required no maintenance at all (ibid.: 77) and the standardisation of ratings of its transformers and cables. Transformers were reduced to 2 sizes only (1,000 KVA and 500 KVA). Cables were reduced to just one single size, 300 mm sq (millimetres square) (ibid.: 77).

All these decisions had the positive effect of meeting customer needs without increasing manpower requirements. Of significance was the deliberate decision to keep overcapacity in the generation infrastructure. As Mr. Soh said: *'in this way, most of the customers could expand their production capacities without losing precious time to apply and wait for PUB to upgrade their supply'* (ibid.: 78). This greatly contributed to continuous rapid industrialisation and economic growth.

In 1975, new legislation such as the *Electricity Supply Regulations* was enacted to provide for the regulation of supply. In 1977, the *Senoko Power Station* opened achieving a full capacity of 1,610 MW in 1983. This greatly alleviated pressure on supply. By then, the old plants of *St. James* and *Pasir Panjang A & B*, had become 'standby generators'. All three were eventually decommissioned in 1983 (ibid.: 87).

In 1979, all electric cables started to go underground to protect them from inclement weather and to offer more aesthetic scenery to the city (National Archives Singapore Oral Histories Acc.No. 2832/08 Reel 6: 61). In the same year, plans were drawn up to build a new power plant in Pulau Seraya. In addition, digital systems entered the management of the electricity sector with the computerization by the *Public Utilities Board* of its energy management system (at Ayer Rajah Substation) (Koh and Lee 2011: 111).

Having ensured availability of supply in the period before independence, the period up to the late 1980s was characterised by adequacy and self-sufficiency in order to enhance energy security. These were essential to national security in the first two decades of nation-building for Singapore and were achieved through the enactment of new legislation, the

building of new infrastructure to the latest available standards, the uptake of new technologies and the exploration and tapping on new fuel sources.

Upgrading of Singapore's electricity supply between 1987 and 1995 – reliability, the new target

The years up to 1995, saw technical, infrastructural, and institutional landmark developments in the electricity sector such as the mandatory fitting of high sensitivity residual electricity circuit breakers for all new homes (safety), the training of adequate manpower to meet the requirements of the electrical industry (Straits Times 26 Jan 1978), the opening of the *Pulau Seraya Offshore Power Station* (three 250MW steam plants) in 1988 and the fitting of an undersea cable to bring power from Seraya to the main island (Fig 1 p. 13).

All these transitions were geared towards *'enhancing quality and safety of supply, and of anticipating needs before they were felt'* (Koh and Lee 2011: 89). Supply availability had been resolved in the 1960s, adequacy had been ensured from the mid-70s to mid-80s, reliability was the next frontier to be conquered from the mid-80s together with quality and competitive price (see National Archives Singapore Acc. No. 3274/05 CF4: 78).

With the industrial sector having shifted by the mid-1980s from *'a labour-intensive, low-value added and low technology manufacturing industry, into a high-value added, high technology industry (such as computer disk drives, petroleum refinery, chemicals, silicon wafers, integrated circuit fabrications, pharmaceuticals, etc)…they had one thing in common; they were very dependent on computer-controlled manufacturing systems. They could not even tolerate a voltage dip! And such systems required a very high…a highly-reliable supply (of power)*' (ibid.: 79).

This required a decisive technological shift towards *'advanced telecommunications and control technologies'* (ibid.: 79). Thus, power control systems acquired in the 70s were replaced by advanced computerised energy management systems to manage generation. The transmission and distribution were set to standards that *'no customer should experience any interruption of supply in the event of a failure of any feeder in the network'* (ibid.: 79). For this, PUB engineers developed a 'flower network' (ibid.: 80). The installation of a brand new 22 KV network to replace the entire city's distribution system was accomplished in five years. Despite this, interruptions were not preventable due to weakness in the substation switchboards. To ameliorate this, expensive (60,000 Singapore dollars each) but reliable gas-insulated switch gears were installed in the new 22 KV network that were humidity and dust-proof, suitable for Singapore's tropical weather conditions (ibid.: 82). Other improvements were made to the circuit breakers, switchgear panels and high voltage cables.

While these upgrades improved reliability of supply in the industrial and commercial sectors, *'residential customers were still affected by failures of fuses, or cutouts (as we called them)'*

(ibid.: 82). These were then replaced by miniature circuit breakers which could be reset by customers themselves. A replacement drive of 500,000 pieces was undertaken.

Recorded in Oral Histories, an employee said: *'Results were spectacular, in a sense. In 1987, the number of complaints of supply interruption per month reached a height of 780 of a total of 620,000 customer accounts. As of February 1993, the number of complaints was reduced to 256 per month, with a customer account population of 820,000 accounts. These worked out to be an impressive figure of about one supply interruption per day, per 100,000 customers. This figure is among the best in the world. Also, the average supply interruption time was reduced to 145 minutes per year. This figure has steadily decreased over the years, to only 15 minutes in a year in 1991, among the best in the world's utility supply'*. (ibid.: 83-84).

Corporatization of PUB in 1995 and events up to 2000 - the start of market discipline: security, sustainability and prices

In 1995, the *Public Utilities Board* (electricity & gas services) was corporatized to introduce market values and competition to these services. This was considered the 'big switch' (Ng 2012: 113; National Archives Singapore Acc. No. 3274/05 CF4: 113). With the opening of the market, the principles of security and sustainability that had inspired the electricity pioneers were complemented by *'the push factor of high costs of investment in capacity to meet higher demand, and partly by the pull factor of achieving lower tariffs by introducing competition'* (National Archives Singapore Acc. No. 3274/05 CF4: 118).

A reliable, secure system at competitive prices was put in place in substitution for a PUB vertically integrated, managed and regulated sector (Ng 2012: 113). In the same year, *Tuas Power Ltd* was established to take over from PUB in the development of the *Tuas Power Station* (Koh and Lee 2011: 89) which opened in 1999 and in 2005 reached a total generation capacity of 2,670MW (ibid.: 89).

Taking over from PUB's portfolio the electricity and piped-gas generation, transmission and distribution assets, *Singapore Power Ltd (SP Power)* was established in 1995 as a government-owned corporation under Temasek Holdings, an investment company with a wide-ranging portfolio of industries (i.e. financial services, real estate, telecommunications, energy, etc). PUB, nevertheless, retained its regulatory role over electricity supply (Chang 2007: 404; Ng 2012: 113).

In 1996, PUB issued *Service Standards for Public Licensees* of electricity to monitor the performance of new players. In 1998, *Singapore Power Grid Ltd*, the transmission & distribution outlet, started the *Singapore Electricity Pool* ('the Pool') as a *'wholesale electricity market to facilitate competitive bidding among generation companies'* (Koh and Lee 2011: 122; Ng 2012: 113). The Pool sets the rules, mediates disputes and controls budgets. It

began to operate in April 1998 with *Power Senoko Ltd, Power Seraya Ltd and Tuas Power Ltd* as the generation companies, and with *Power Supply Ltd* as the only retailer, initially.

This transition brought the breaking of the electricity industry into three sectors (Koh and Lee 2011: 122). Best practices were at the same time being learned overseas on how to review the electricity market framework, thus PHB Consultants of New Zealand, were retained to undertake the review. Their main recommendation was *'the breakup of the Temasek Holdings-owned Singapore Power, and the retention of the grid by Singapore Power as a monopoly regulated by government'* (ibid.: 123). The Asian financial crisis of 1997 then brought challenging times to the sector.

Other significant transitions were happening. The year 2000, saw the announcement by the *Ministry of Trade and Industry* (MTI) of further liberalisation of the electricity and gas industries and its deregulation. The unions were concerned about job losses in the process of privatization, corporatization and restructuring of PUB but managed to navigate the opposition to this transition in the believe it was for the *'greater good of the nation'* (ibid.: 127).

Liberalising Singapore's electricity market from 2001 to 2004

Through the new PUB Act, PUB ceased its regulatory function over electricity with the establishment in 2001 of the *Energy Market Authority* (EMA) to oversee liberalization that allowed 250 Commercial & Industrial consumers with a demand above 2MW to choose supplier. EMA was formed from merging PUB's regulatory role in energy matters and the power system operation of *Power Grid Ltd*.
As one interview puts it: *'In 2001, we created a new government mechanism, EMA, and now we have a liberalised market where we have different players from the generators to the retailers, the system operator and the grid operator. The motivator was to see whether we could get some efficiency gains from introducing more market discipline and pass on some of the savings to the consumer. If you compare it to a situation in which you only have a government entity doing the supply and only one type of tariffs, and, as it is the case today, another where you have different kinds of packages from the most simple type of just being connected to the grid to others which include green features such as solar or added services such as demand side energy efficiency, I think from the perspective of the market has become more exciting and hopefully benefits consumers in the long run'* (Interview 4, March 2017).

But at the time EMA was established, its full mandate was not made definitive. *'The role of the regulator has to evolve from one of regulating monopolies to that of regulating competitive markets'* (Koh and Lee 2011: 128). In 2001, the *Singapore Electricity Pool* was replaced by the *Energy Market Company (EMC)*. Incorporated in the same year, it took over the operation and administration of the electricity market in 1 April 2001 (ibid.: 129). At the same time, *SP Power* divested the domestic electricity generation to *Temasek Holdings Private Ltd* (2001) retaining only the Transmission & Distribution and market support functions

(Ng 2012: 116). In 2003, EMA divided the market into contestable (industrial and commercial) and non-contestable (residential) (ibid.: 117).

A significant shift also happened in the fuel mix. Natural gas became *'10% cheaper than electricity generated using oil'* (ibid.: 129). Thus, in 2001, *Sembcorp Cogen* started importing gas from Indonesia for the generation companies and industrial consumers. Singapore had been importing natural gas from Malaysia since 1992 for the exclusive use of power generation in the *Senoko Power Station*. New deals followed. These were challenging due to the absence of staff expertise and the difficulty of *'working out the market restructuring ahead of time to suit a new regulatory framework'* (ibid.: 131). It took from 2000 to 2008 to develop and implement a regulatory framework for the new gas market (ibid.: 132).

As one interviewee explained: *'when we started our liberalisation in 2001, our fuel mix was 70% fuel oil. This meant that the carbon content emitted from its burning in very inefficient plants was much higher than natural gas. Today, it is a totally different scenario, 95% of our electricity is provided by natural gas. And this has been accelerated by the market process. The government way of planning was to allow the power plants to fully depreciate and go to the end of their life-span before investing in new ones. But after we introduced market discipline, investors saw that it is cheaper to invest in new plants and when to invest using their own money with the most up to date technologies. What we see is that the carbon emitted 30 years compared to today is quite dramatically reduced'* (Interview 4, March 2017).

2003 saw the establishment of the *National Energy Market Singapore* (NEMS) to allow prices to reflect supply and demand fundamentals (Chang 2007; Doshi 2015: 170; Energy Portal 2016). By December 2003, the *'authorized electricity generation capacity in Singapore was 11,640 MW while the (actual) installed capacity was 8,919 MW. The system peak demand was 5,139 MW recorded on 23 May 2003…which implies a huge excess capacity (authorized installed capacity includes current installed capacity and capacity yet to be commissioned'* (Chang 2007: 405 and footnote 4). Moreover, *'huge excess capacity underlies that the power generation market in Singapore might be highly competitive as generation companies are chasing a smaller share of residual demand under vesting contracts though concentration measures suggest otherwise'* (Chang 2007: 406).

Thus, during the period from 1987 to 2004, the Singapore's electricity supply sector experienced further transitions. Power was available, its supply was adequate and the system had been made self-sufficient prior to 1987. The reliability and security of the system at competitive prices was the next frontier conquered. This was achieved through the corporatization of agencies such as PUB which introduced market rules to the system, as well as through the liberalization and deregulation of the sector.

Moving towards further liberalisation between 2005 and 2011

In 2006, 75% of total electricity demand opened to retail (Energy for Growth: National Energy Policy 2007; Doshi 2015: 170), accompanied by a period of rapid changes in the public policy electricity sector. These are reflected in the establishing by EMA of the *Energy Policy Group (EPG)* that coordinates energy-related matters in the remits of 5 ministries and 6 agencies (Doshi 2015: 168), the launching in 2008 of the *Singapore Intl Energy Week* with the theme "Powering Cities for Future", and the publication by the *Inter-Ministerial Committee on Sustainable Development* of the *Sustainable Singapore Blueprint* (2008) that includes proposals for the optimisation of energy resources. Moreover, in 2008, Temasek sold its entire stakes in Tuas, Senoko and Seraya Power to a private sector consortium (Ng 2012: 118- Fig. 5.1 structure of Singapore's electricity industry).

In 2009, EMA introduced the pegging of the fuel cost component of electricity tariffs to average fuel oil prices in the previous quarter (Koh and Lee 2011: 143). 2010, saw the establishment of the *Singapore District Cooling* system at Mariana Bay and, most significantly, the recognition in a report published by the *Economic Strategies Committee*, that *'Singapore's energy resilience and sustainable growth was facing challenges of rising global demand, volatile prices, climate change and security concerns'* (Ng 2012: 218). The *Economic Strategies Committee* (Subcommittee on Energy Resilience and Sustainable Growth) of EMA recommended energy security and environmental protection as incentive to balance the energy portfolio (ibid.: 165).

The first Electric Vehicles (EV) charging stations opened in 2011, and EMA and the *Economic Development Board* (EDB) started to co-chair the *R&D Energy Innovation and Programme Office* with the *National Research Foundation* (NRF) thus establishing the energy resilience and sustainable growth programme with focus on cost competition, energy efficiency, carbon emissions reduction, and increase of energy options. By 2009, Singapore's population had risen five-fold to 5 million, its GDP per capita was up to 53,100 Singapore dollars (3,764% higher than in 1961) but electricity consumption was up to 37,974 GWh (5,871% higher than in 1961) (Ng 2012: 111-112).

Singapore's energy strategies from 2012 to the present – markets, fuels, efficiency, RE, and cooperation

The opening in 2013 of the first LNG terminal in Jurong Island (back up), and the lowering in 2014 of the demand threshold for Commercial & Industrial consumers to choose supplier so that a larger number become contestable, were two milestones in Singapore's modern electricity development. In 2014, during the 7th Singapore Intl Energy Week, EMA announced S$20 million Energy Training Fund.

Besides these landmark developments, a close look at the policy remit and objectives the *Energy Policy Group (EPG)* has set for itself since its establishment in 2006, demonstrate not only its mandate of national energy policy and sectoral policy with the power sector policy focusing on issues of energy efficiency, climate change and regional and international cooperation, but also its policy objectives namely economic competitiveness, enhancement of the energy sector (technological, infrastructural, financial, and human) and protecting the environment.

Since 2007, the *Energy Policy Group (EPG)* has been promoting five energy strategies: (1) competitive markets (get the prices right); (2) diversify sources (under the golden age of gas); (3) energy efficiency (identify barriers, market and government failure); (4) develop the energy industry for power generation (specially PVs); and (5) invest in R & D and training (there are about 5,000 power sectors professionals today). We discuss these.

1) Competitive markets. This strategy was spelled in *the Ministry of Trade and Industry's* (MTI) National Energy Policy- Energy for Growth plan. A free-market approach to the economy is Singapore's cornerstone in general and of its energy policy, in particular. Oil refining, trading and retailing and domestic electricity and gas have been open for competition for 75% of consumers since 2006. The future direction is to create an Electricity Vending System (EVS) for households and small consumers to enable full contestability (as it is the case with telephone service providers) projected by 2018. Singapore does not subsidize electricity from the public budget as it believes subsidies mask the real cost of electricity and diminish energy efficiency (in countries like Malaysia electricity subsidies amount to 1-2 % of total GDP) (Doshi 2015: 170: Koh and Lee 2011: 150). In a turn from the business as usual scenario, the decision was made in 2017 to price carbon by introducing taxes in 2019 the rationale being: ' *there are different ways to reduce emissions…but the most economically efficient and fair way to reduce greenhouse gas emissions is to set a carbon tax, so that emitters will take the necessary* actions' (Budget 2017 C.7; Francesch-Huidobro 2017b).

A field interviewee commenting on the market strategy said: *'In Singapore we have an electricity market where generators bid every half an hour, there is a demand cut off and a price set every half an hour. That means that that is the price the generators get. On the supply side, suppliers buy electricity from the wholesale market and they sell it to the end consumers, so the price for the contestable sector is a market-driven price. Then there is another sector, which we are going to open up very soon which is the non-contestable sector, mainly households. Today, they are buying directly from SP Power and the tariff they are being charged is set by the regulator. By 2018, the non-contestable sector will be opened for competition so that people can choose service providers or stay with SP Power. So SP Power will cease to be the monopoly to run the transmission and distribution and they will just be the regulator entity (of Transmission & Distribution) which means their revenues and profits will be regulated'* (Interview 4, March 2017).

2) Diversification of fuel mix. Variety for certainty and safety is Singapore's approach to fuel mix. Diversification brings security which, in turn, helps avoid risk and increases resilience. Since independence in 1965, oil-stock levels (crude and refined) worth of 90 days of net demand have been maintained (these are also required by the International Energy Agency (IEA). After the oil crisis of 1973, the Singapore government became more aware of the need to keep a national stockpile of crude oil. While this ended in 1983, EMA today requires all private energy companies to maintain a 45-day back up onsite and 45-day offsite which would be equivalent to a 7-day worth of stored capacity (Doshi 2015: 180; Koh and Lee 2011: 151 & 152). Currently, Singapore's available storage capacity is equivalent to 300 days of supply so that Singapore's dependence on oil is mitigated by large storage capacity with government having the first right to access (although the oil is privately owned).

In addition, the government has built an underground storage facility, the Jurong Rock Caverns (130 m below sea level) for crude, condensate, naphtha, and gas oil with a capacity of 1.5 million m^3. The overall storage capacity is 20 million m^3. Plans are also underway to build very large floating structures (VLFS) to store oil and petrochemicals. Offshore, more storage facilities have been secured in nearby locations such as Johor (Malaysia) and Batam (Indonesia), and the overall capacity surpasses the Amsterdam-Rotterdam-Antwerp (ARA) oil region in Europe.

But the significant development in the change of the fuel mix is the uptake of gas to counteract the volatility in oil producing places in the Middle East, Nigeria and Venezuela. In the 1970s, Singapore secured the imports and storage of oil as the city was totally oil-dependent, but from 1992, Singapore has been importing natural gas (NG) via four pipelines (Malaysia and Indonesia) through five contracts (two with Malaysia and three with Indonesia) (see Doshi 2015: 183, Table 5.3; Koh and Lee 2011: 153).

By 2010, 78% of electricity was generated by natural gas but this arrangement has become increasingly insecure. Gas production in Malaysia and Indonesia is declining with no new explorations being exploited and the domestic demand in these countries is increasing rapidly. Contracts that are expiring between 2015 and 2023 are not being renewed. Thus, in 2013, the city's first liquefied natural gas (LNG) terminal started operations. At the capital cost of 1.7 billion Singapore dollars (Doshi 2015: 184) the plant aims to gasify up to 3.5 million tonnes of LNG a year (Mtpa) by 2018 and up to 6-11 Mtpa when the four tanks are in full operation. *BG Singapore Gas Management* has obtained the exclusive right through a competitive bid to import and sell up to 3 Mtpa of LNG by 2023 (ibid.: 184). *Singapore LNG Corporation* (SLNGC) is, on the other hand, the 270,000 m^3 terminal operator as well as owning QMax-Qatari LNG Carriers.

'*There is a potential for Singapore to turn into an LNG trading hub (for export rather than local consumption)*' (Interview 1 & 4). The city is already offering concessionary tax rates of 5% of LNG trading income and can, for example, barge LNG to nearby locations that are

not served by the electricity grid or by gas pipelines. In these remote locations, LNG can replace expensive diesel fuel power plants and LPG fuelled households. These short haul deliveries (out to 1,500 nautical miles or sailing 3-4 days) offer an attractive market niche (Doshi 2015: 186).

In 2013, Temasek invested globally in LNG trading, exploration, storage, processing and shipping through starting a joint venture with *BW Group* to acquire, manage and charter LNG carriers. Out of Temasek's total portfolio of 198 billion Singapore dollars (2012), 6% has been invested in energy related holdings. Thus, Singapore's objective of energy security depends on oil price shock impacts, fuel mix, LNG hub ambition, general role of government and of government linked companies (GLCs) in the energy sector (an issue of concern despite the general trend of privatization) and investment in energy infrastructure (ibid.: 204).

3) Energy efficiency. This can take the form of subsidies, mandatory standards, labelling and information provisions (Doshi 2015: 205; Doshi and Lin 2016: 49-62; Francesch-Huidobro 2017c). In the Singapore power sector, the uptake of energy efficiency measures has taken the form of: a competitive electricity market that has returned an increased efficiency from 38% to 44% from 2000 to 2006 attributed to an increase of natural gas from 19% to 78% during the same period; the uptake of co-generation (electricity + heat) and tri-generation (electricity + heat+ chilled water) that has also optimised the use of electricity through the E^2PO Singapore initiative (Doshi 2015: 215); and conducting energy audits to spot where the inefficiencies are (ibid.: 216) with the audits being facilitated by the Energy Efficiency Improvement Assistance Scheme (EIAS).

The question is whether Singapore is energy efficient as the lack of fuel subsidies means that the cost of imported fuels is passed to end consumers. So where is the incentive to improve? The barriers identified in the sector are: lack of motivation by senior management; absence of energy audits; few energy service companies (ESCOs); little financial capital investment in new technology; a general resistance to change; and inability to show a convincing cost benefit analysis (CBA) of energy efficient investments (Interview 1, 3 & 4; Doshi 2015: 226; Doshi and Lin 2016: 55-59; Francesch-Huidobro 2017c).

4) Development of solar photovoltaics (PVs) and investment in R&D These developments are driven by high fuel costs and global climate change concerns. However, Singapore does not fund any Feed-in Tariffs (FITs) for renewable providers or provide any policy incentives. On the other hand, the city is heavily investing in R&D projects (Doshi 2015: 227 & 228). For example, solar PVs, fuel cells and biomass technologies are within the remit of projects funded by the *National Research Foundation* (NRF) that has allocated 170 million Singapore dollars for R&D in clean technology. The *A*STAR* (Agency for Science, Technology and Research (dedicated buildings in College Rd, NUS Kent Ridge) is conducting research on smart grids.

Other agencies investing in energy-related R&D are the *Ministry for Trade and Industry* (MTI), the *Ministry of Water Resources & Environment* (MWRE), and *National Environment Agency* (NEA) and the *Economic Development Board* (EDB) that has invested 17 million Singapore dollars to test solar PVs. New energy research academic institutes have also been established like the NUS Solar Research Institute (2008) and the NTU Energy Research Institute (2010) (Doshi 2015: 229-230). The total Transmission & Development expenditure in 2011 was 2.2% of GDP (similar to Germany's). The *National Climate Change Secretariat* (NCCS) has furthermore published a report on solar PVs focusing on 'grid parity' (cost of renewable energy (RE) for electricity equals or is cheaper than retail electricity price and cost parity is equal to the traditional cost of electricity (fuelled by fossil fuels) (ibid.: 231). The NCCS is studying the correlation between carbon emissions and the use of solar PVs (ibid.: 235) as well.

As one interviewee put it: *'the drive to increase the proportion of RE in our fuel mix comes, on the one hand, the commitments we made in COP21 to undertake a 36% reduction from 2005 levels by 2020, and on the other hand, energy security in the face of uncertainty in the price of fossil fuels. Thus, we are committed to go up to 1000 MW from the 100 MW of today. But we have to bear in mind that we cannot have intermittent supply given the fact that we have quite a bit of cloud cover in Singapore. So, we rely on technologies that may allow the storage of solar power'* (Interview 3, March 2017).

5) International and regional cooperation. To ensure energy security and, given its dependency on others, Singapore has promoted the establishment of an ASEAN Power Grid (APG) announced in 1997, which at the moment has taken the form of bilateral rather than multilateral connections (Doshi 20-15: 247 & 252). This includes: the building of a trans-ASEAN Gas Pipeline (TAGP) (Sovacool 2009: 2357) (although the necessity for this mega infrastructure has been questioned as LNG technology becomes available); the securing of shipping lanes in the Straits of Malacca (60% of China's, 90% of Japan's, 80% of Korea's imported oil passes through the Straits); and supporting the ASEAN Vision 2020 that promotes an integrated energy (electricity, gas and water) (Andrews-Speed 2016).

Indeed, an interviewee, explained: *'in 2013, the relevant ASEAN ministers decided that they were going to set up the LTMS (Laos, Thailand, Malaysia and Singapore) consortium, whereby Singapore would agree to buy a small amount of hydroelectricity from Laos. Now, I and a colleague in Thailand went to a meeting in 2014 where one of the Thais presented what they and Malaysia were looking at namely, transmission charges and then she and I looked at each other and said 'this is a non-starter because basically the intermediate states just want to run past intermediate rates by which time the price in Singapore was going to be unattainable'. Then you come back to Singapore and you realize that they have an internal market here and even if a foreign institution wanted to enter this market, they would have to bid in, so the minister (whoever he was) who was involved in this decision, did not appear to understand the full implications of committing Singapore to such arrangement. They would have to agree for Singapore to allow the power to come in at a certain price, in which*

case the local generation companies in Singapore would be remarkably upset, because they have been fighting to get in (a competitive market) and here you are bringing in a foreigner who is basically subsidized by a fixed price and they will lose out or you have to say to the LTMS, fine, welcome!' (Interviewee 4, March 2017).

In 2014 and 2015, the LTMS became very low key. But as the same interviewee explained, *'I put together a one and half day event here in Singapore. We invited a Nordic philosopher, and it was just after the latest ASEAN energy officials meeting that I realize that LTMS was not going anywhere…The ASEAN energy officials were keen for an alternative solution. So, suddenly, our meeting instead of a low-level thing became the place to be. So, in November 2015 we had this meeting, and everybody from the ASEAN electricity side came. And at the end this was taken forward and the next year May (2016) when we took part in the formal meeting of ASEAN energy consultative committee and we did a workshop in Jakarta for officials, then we realized that the agenda had gone back up to the senior officials and came down again to the HAPUA - Heads of ASEAN Power Utilities Authorities which is the energy utilities organization. They told us to do a feasibility study and follow this up. This is what we are doing now (my colleague from Thailand and I) and in a months' time there will be a meeting in Jakarta (April 2017). There is a special Taskforce assigned to this that includes International consultants and IEA, and WB to say right, what's the plan and who is going to pay for the feasibility study. Now throughout this integration initiative in the last four years, Singapore has been a thorn in our side. They never went to any of the meetings they were invited to. Brunei did not come either. Then once I was called and told to keep up with the academic work but not to meddle with politics, don't contact us, we will contact you (called by EMA). Anyway, we did invite them but they did not come. The representative from EMA (Jonathan Goh) no longer objected in the end because Singapore is, at the moment, the ASEAN sub-sector secretariat of energy policy and planning'* (Interview 4 March 2017).

SUMMARY

The past 12 years have seen decisive transitions in the electricity supply sector in Singapore to realign its system following independence and, to a certain extent, regionalisation and the quest for a low carbon economy. Increased market competitiveness, diversification of the fuel mix, fostering energy efficiency, the development of a solar PV industry and investment in R&D and cooperation were reinforced by the development of a comprehensive public policy on energy that, as Ng (2012: 219) puts it, is not without challenges.

Besides the October 2007 *National Energy Policy's* five goals spelt out earlier, the policy is described in the *Sustainable Development Report* (April 2009). The Report fosters developing the economy with fewer resources. Another government document, *the Smart Energy Economy* (February 2010), acknowledges that Singapore will *'remain a price-taker on world markets and that the island is at the mercy of the increases of sea-level brought about by climate change to vulnerable low-lying islands'* (Ng 2012: 219).

However, as Ng (2012: 219) also posits: *'the three documents do not spell out the core values or a vision for the nation's future in a world characterised by fierce competition, conflict, scarcity, resource nationalism, population growth, inflation and environmental, ethical and climate challenges'.* With oil production reaching its peak, the nuclear solution put on hold for now and the technical and policy barriers still slowing a full rolling out of EVs and smart grids, a Plan B seems necessary.

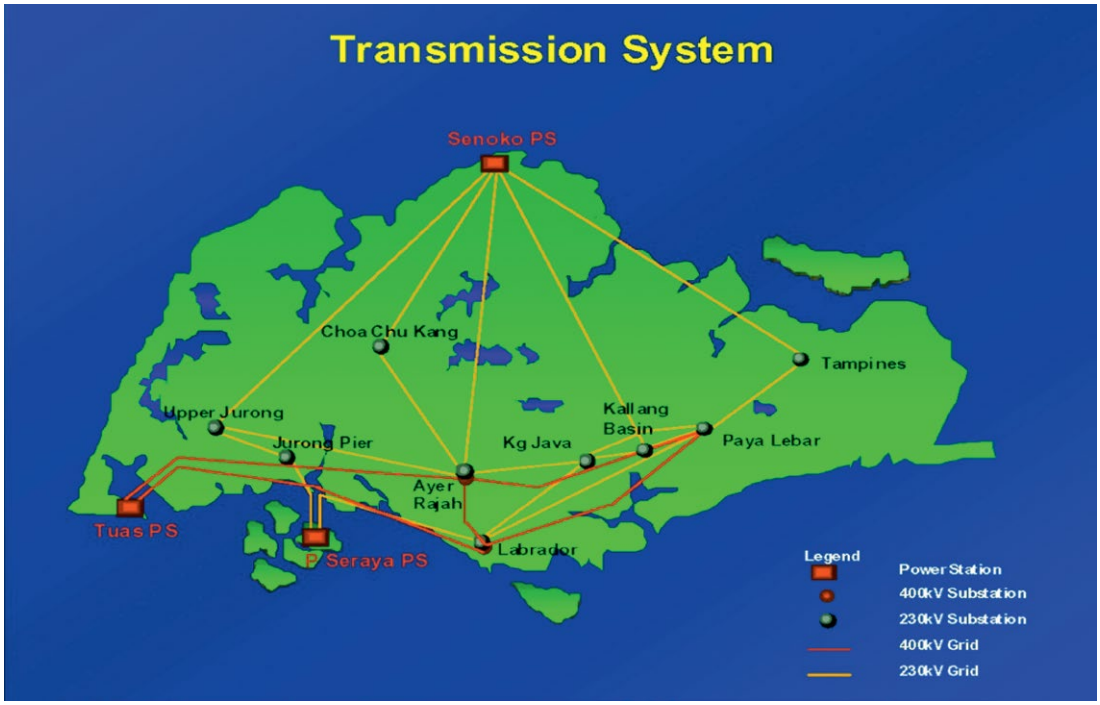
As we write, the questions being asked regarding energy are whether prices will rise; what sort of global climate change regime will be in place after 2020; and what will be the new technologies (Chatham House Seminar 8 June 2017).

While Singapore will continue applying economic principles to influence corporate and consumer behaviour, for example, deploying carbon taxes, and retain competition in energy markets, the role of the state will continue to be essential in ensuring diversification of supply to minimise supply scarcity and demand fuel reserves, and in supporting the development of alternative technologies such as the use of smart grids (Interview 1 and 2, February 2017). For this the *Sustainable Singapore Blueprint 2015: 51*, spells out Singapore's commitments to low carbon transitions.

On 5th June 2017, UN World Environment Day, the *Singapore Public Sector Sustainability Plan 2017-2020* was launched indicating the public sector's awareness about Singapore's vulnerability to the effects of climate change and its commitment to reduce emissions intensity by 36% from 2005 levels.

Under the *SolarNova programme*, Singapore has aggregated the demand for solar power across various agencies, lowering the cost, and making it more convenient to deploy. By 2020, 5,500 solar panels will be installed in HDB blocks and increase the 126 megawatt peak (MWP) to 350 MWP. Post-2020, there is a commitment to have in place 1 gigawatt peak (GWP) or 15% of electricity demand (Prime Minister Office Speeches 5 June 2017). On par with the launching of the plan, the private sector *Sustainability Energy Association of Singapore* (SEAS) and *City Development Ltd*, has designed and built the Singapore *Sustainability Academy* to engage global and local experts in knowledge transfer and training (ibid.). Singapore's long-term survival seems to depend on using resources wisely and when possible to reduce consumption as there are limits to unrelenting growth in times of peak oil.

FIG 1. SINGAPORE'S POWER GRID



(SOURCE: SINGAPORE POWERGRID)

4.2 KOTA KINABALU, FROM AUTARKY AS SURVIVAL AND AS THE TRUMP CARD FOR ACCESSION TO MALAYSIA TO THE WOWS OF AN ENERGY-INSECURE SABAH STATE (1963-2017)

For Kota Kinabalu's electricity supply system, merger with Malaysia and the subsequent establishment of the Sabah Electricity Board, meant that the realignment of the city's system was intrinsically linked to that of the Sabah State following its ebbs and flows. Thus, the following discussion largely deals with developments in Sabah.

Electricity supply by the Sabah Electricity Board between 1963 and 1989

In the years following merger with the *Federation of Malaysia*, the Sabah State continued to see growth in electricity demand. In 1965, consumers of the *Sabah Electric Board (SEB)* plants had risen to 13,512 customers. By 1970 there were 25,086 people tapping into the SEB grid with units of electricity consumed also doubling in 1970 to 87.9 MWh. The total additional capacity provided to Kota Kinabalu was 6 MW (History of Sabah n.d: 271)

In 1979, the *National Energy Policy* (supply, utilization, and environment) was formulated in response to the 1973 and 1979 oil crises (Koh and Lim 2010: 4720; Sovacool and Drupady 2011: 7246). In 1981, the *Four-Fuel Diversification* strategy was promulgated to promote non-fuel oil based fuels such as natural gas, hydropower, and coal throughout the country.

This precipitated a transition from oil and coal to a mix that included natural gas and hydropower (Jaffar et al 2003: 1061). In 1980, natural gas rose from 1.2% in 1980 to 71.1%. These national policies applied to all states including Sabah.

In the 1980s, the *National Grid*, had been extended to the whole of Peninsular Malaysia (Sabah was not included in these plans) and was also interconnected to the transmission network of the *Electricity Generating Authority of Thailand* (EGAT) through a 117 MVA, 132 KV Single Circuit Line now upgraded to a high voltage DC (HVCD) line. The *National Grid* was also connected to *Singapore Power Limited (SP)* through a capacity of 250 MVA-230 KV transmission line and submarine cables. These connections were the precursors of what was foreseen to one day become the ASEAN grid (Tenaga Nasional).

As reported in the Public Utilities entry of 1980 (Sabah History, 1881-1981), the total installed capacity for Sabah for that year was 166.4 MW, more than double the 1975 figure (Sabah History 1881-1981 n. d: 340). Finally, the time for hydropower had come in 1980 when, *'the most important single project ever undertaken in Sabah was probably the Tenom-Pangi Hydroelectric power scheme which was started in 1978. The first phase was completed in 1983 adding 44 MW to provide electricity to load centres from Beaufort to Kota Kinabalu'* (ibid.: 341). The second phase providing an additional 110 MW to the grid was completed with the damming of the small town of Sook (ibid.: 341). The *Rural Electrification* scheme had started by then, aimed at providing electricity to the *kampongs*. This mean electricity for 2,366 households as a starting point by means of mini or micro-hydro, a realistic goal given the mountainous and riparian terrain especially around the West Cost of Sabah (ibid.: 341).

The Sabah grid (West Coast Grid) came into operation at the end of 1989. The Kota Kinabalu substation, Tanjung Aru Power Station and Inanam substation were connected to the West Coast Grid via a 66 KV sub-station system (Stations Statistics for the Year Ended 1989: 12). The total installed capacity in Kota Kinabalu in 1987 was 94,470 KW but by 1990 it was 77,460 KW (Stations Statistics Year Ended 1987: 20; 1990: 21). This lowered capacity was due to operational and maintenance deficiencies that continue to grip the Sabah electricity infrastructure until today (see Sabah Electricity Supply Outlook 2015: 55).

Privatization of Sabah's electricity supply in 1990 and the period to 2014

In 1990, a new *Electricity Supply Act* [Act 447] (national) replaced the legislation of 1949 to *'provide for the regulation of the electricity supply industry, the supply of electricity at reasonable prices, the licensing and control of electrical installations, plants and equipment with regards to people's safety and the efficient use of electricity'* (Ansari 2011: 198).
In an attempt towards privatization, in 1990, the private but wholly-owned government corporation *Tenaga Nasional Berhad (TNB)* was established to replace the public *National Elec-*

*tricity Board (NEB)***.** The objectives of privatization were: *'to relieve the administrative and financial burden of the Government, to improve the effectiveness and quality of the public services, to encourage the spread of private entrepreneurship in the public sector, and last but not least, to contribute to the attainment of the goals set for the New Economic Policy (NEP)'* (Tenaga Nasional Berhad).

These policies were extended to the states and on 1st September 1998, the *Sabah Electricity Board* was privatized becoming *Sabah Electricity Sdn Bhd (SESB),* an 80% owned subsidiary of *Tenaga Nasional Berhad (TNB)* and 20% owned by the State Government of Sabah. *SESB* is a vertically integrated company providing generation, transmission and distribution in the State of Sabah and the Federal Territory of Labuan (Sabah Electricity Supply: Industry Outlook 2014).

In its statement pledge, the company commits *'to develop the electricity infrastructure including the implementation of the Rural Electrification Program'* (ibid.). Its area of distribution is 74,000 sqkm. As of December 2014, its total number of customers was 533,243 of which 83% (442,516) were domestic clients but only contribute to 32.2% of KWh demand and sales. The total installed capacity of the Sabah Grid excluding that provided by Independent Power Providers (IPPs) is 448.7 MW and the maximum demand is 830 MW (as of December 2012). The voltage along the grid varied from 66KV, to 132KV and 275 KV. As of December 2014, the total length of transmission circuit was 2,440.81 km. The forecast demand is of about 7.7% increase.

Electricity is supplied via the *Sabah Grid*, an integrated system linked up since 2007 by a 247 km cable interconnecting the West and East Coast Grids (275KV). The Sabah Grid only serves the State of Sabah (see Figure 1) as it is not interconnected to other national, Borneo Island (Sarawak state, Brunei Kingdom, Kalimantan state) or interregional grids (ASEAN). Electricity is supplied from power plants located within the Sabah state (Figure 2; Sabah Electricity Supply Industry Outlook 2014: 22; Koh and Lim 2010: 4720).

Electricity reliability and alternative energy options for Sabah

Since the 1990s, Sabah has experienced a series of blackouts, especially in its East Coast. For example, in 2014, there were 22,739 scheduled and unscheduled interruptions of which 3,317 were due to overload and 1,368 to no supply. This is an average of 1,849 interruptions per month (see Performance and Statistical Information on Electricity Supply in Malaysia 2014, pp. 42-52, 84, 86 for Sabah) which compare with the average monthly interruptions at 1,759 in 2009 (Koh and Lim 2010: 4721; see also Electricity Supply Statistics).

SESB continues to express concern over the reliability of power supply in the East Coast region. In 2009, a proposal was presented to build a coal-fired plant of 300 MW installed

capacity although its function in enhancing adequate and reliable generation capacity was questioned due to the fact that Malaysia (including Sabah) heavily relied on coal imports from Australia, Indonesia, China and South Africa.

Malaysia's environmental performance targets (the goal is to cut down GHG emissions intensity by 35% by 2020 from 2005 levels) would also not be met. Alternative options based on technical, economic and GHG emissions assessment are being discussed. These include solar PV, biomass, hydropower supplied from Bakun dam in Sarawak, a second east-west interconnection, wind and tidal power. The preliminary conclusions are that hydropower, biomass (palm oil waste), and the hydro supply from the Bakum dam are realistic options that would match the 300 MW installed capacity proposed for the coal-powered plant without the negative effects of GHG emissions (Koh and Lim 2010: 4721-4728; Malaysia Energy Statistics Handbook 2015: 80).

The turn of the century saw additional transitions. In 2001, the Electri*city Supply Act 2nd Amendment* [Act 610] was enacted to amend the 1990 national legislation and establish the *Malaysia Energy Commission* (see Ansari 2011: 198 for list of changes). Also in 2001, the *Fifth-Fuel Diversification* national policy was announced to promote more renewable energy sources to the fuel-mix (Sovacool & Drupady 2011: 7244, 7246; Tang and Tan 2013). The national *Small Renewable Energy Power (SREP) Program* was also advanced in 2001 to establish 500 MW generating capacity by biomass, biogas, municipal solid waste, solar PVs, and mini-hydroelectric (2001-2005) (ibid.: 2011). The *SREP* was extended up to 2010. All these national policy programmes have been passed down to the state level including Sabah via mirror State legislation and regional agencies (Energy Commission Pamphlet 2013: 12).

The national economic and technical regulatory energy functions have been in existence since 2002, namely: the *Malaysia Energy Commission (Suruhanjaya Tenaga)* (Malaysia Energy Information Hub; the Energy Commission Pamphlet 2013; and the Ministry of Energy, Green Technology and Water (Kettha) Energy Commission Act 2001 [Act 610]).

Policy-making over electricity supply, energy efficiency and renewable energy is, on the other hand, the purview of the *Ministry of Energy, Green Technology and Water* (formerly known as *Ministry of Energy, Water and Communications*) that started operations in 2009 (Sovacool and Drupady 2011: 7246). Rural electricity supply policy is part of the *Ministry of Rural Development* portfolio (Ministry of Energy, Green Technology and Water).

The Chairman and Commission members are accountable to the Minister in charge of energy. The regulatory roles and functions of the Commission are executed by various departments and units namely: electricity supply and market regulation; energy management and industry development; enforcement and regional coordination; electrical safety and regulation; gas safety and supply regulation; corporate services); and nine Regional Offices with the remit of certification and enforcement and investigation and prevention (Energy Com-

mission Pamphlet 2013). These offices regulate the utilities, the Independent Power Providers (IPPs) and co-generators as well as the distributors. The Malaysia Energy Commission has representatives in the regional offices, including Sabah.

Sabah's electricity supply from 2014 onwards – looking back to move ahead

The latest review (2014) of the Sabah electricity supply industry and the outlook for 2015, as well as views from our field informants, reflect the historical challenges posed by Sabah's quest for self-sufficiency and autarky as a means to security and economic growth. The challenges presented by the re-alignment of its system after merger with Malaysia while remaining an insular State of the Federation are still lack of adequate and reliable generation capacity, weak transmission and distribution network and operational unsustainability. These continue to define the Sabah electricity supply system and that of Kota Kinabalu in the past 3 years.

In 2014, a tariff hike was announced at 34.52 sen/KWh to align it with that of Peninsular Malaysia that was set at 38.53 sen/KWh in order to make *SESB* financially viable. *SESB* has had to rethink its strategy to meet its huge debt that limits its ability to finance new projects and maintain existing networks. On 17th January 2014, the system experienced a total collapse for ten hours which affected 400,000 *SESB* customers; and several high-impact interruptions through the year caused by plant and fuel operational stability highlight the need for system maintenance.

Apart from speeding up new projects approved in the 10th Malaysian Plan to meet the demand for dependable (not installed) capacity that stood at 1,497 MW, with 27% of that capacity owned by *SESB* and the balance by IPPs, *SESB* has looked into improving the reliability of protection equipment, system defense, etc. in acknowledgement of the need to look beyond the infrastructure by strengthening the operation and maintenance culture. A diversified fuel mix should also help make the system more robust. While gas continues to be the main source of fuel at 76% of the fuel mix, diesel stands at 15%, hydro at 6% and biomass at 3%. With a recently sluggish economic growth in the State standing at 3.3% GDP (Malaysia GDP 6.6%), generation and sales growth stood only at 4.0% and 2.5% respectively, the lowest growth since the West and East were interconnected in 2007 (Sabah Electricity Supply Industry Outlook 2015: 38).

As of 31 December 2014, maximum demand in Sabah was at 908 MW, a mere increase of 41 MW from 2013 (ibid.: 12). The peak load reached 946 MW in 2015 while dependable capacity was expected to stand at 1,324 MW giving the system a wide margin for eventualities even when subject to tripping in large units (ibid.: 44). Projections are that, by 2020, peak demand MW will stand at 1,238 MW (ibid.: 27). A key study by the *Ministry of Energy, Water and Green Technology* together with the *MyPOWER Corporation*, entitled the 'Strategy Development and Implementation Plan for Sabah Electric Supply Industry' (SESI) proposes new governance initiatives (ibid.: 45) the effect of which cannot be ascertained yet.

Electricity supply differences between the East Coast and West Coast of Sabah

While plans are also being made to increase future potential of hydro-electricity as well as interconnections of Sabah-Sarawak-Brunei, Sabah-North Kalimantan (Indonesia), Sabah-Philippines (Mindanao or Palawan) as well as the Trans-Sabah Gas Pipeline, it is believed that the 'work in progress status of the electricity supply industry in Sabah requires concerted efforts from all relevant parties (ibid.: 55)'.

One interviewee from *Sabah Electricity Sdn Bhd (SESB)* explained that traditionally the East and West Coast of Sabah were two separate systems. As the East Coast (Sandakan) has no gas resources, they depend on local generation by diesel plants. The West Coast (where Kota Kinabalu is located) was originally reliant on diesel but made a shift as oil prices rose and gas exploration off the West Coast increased. Then, there was a rapid switch to gas for generation subsidized by the government.

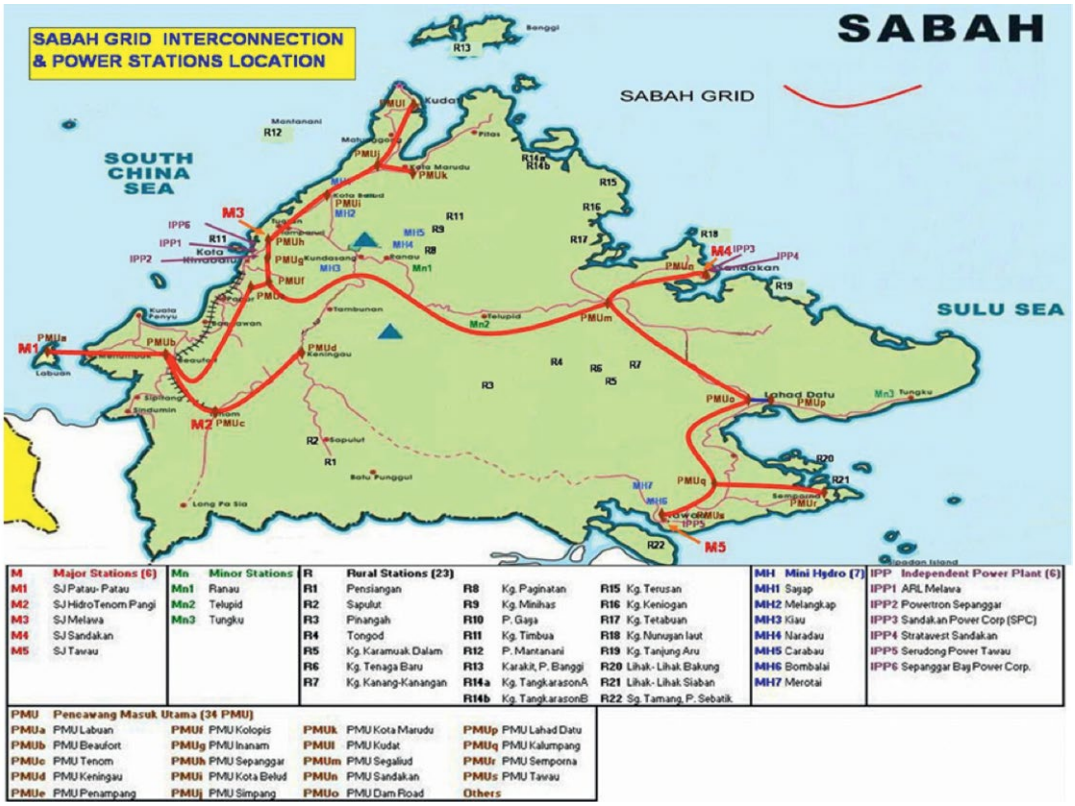
An important development was the interconnection of the West grid to supply power to the East grid, nevertheless this is not *'strong enough' despite the fact that supply far exceeds demand in the West Coast but electricity cannot be successfully transmitted to the East Coast'* (Interview 6th April 2017). As mentioned above, another compounding factor that is making the power sector financially unviable in Sabah is the fact that in the last 2 years, demand has been stagnant at about 900 MW owing to a financial stagnation that has seen factories closing and palm oil prices plummet (Interviews 6th April 2017).

In interviews carried out with a former member of the *Energy Commission* (West Coast Sabah), the current Regional Director of the *Energy Commission* (West Coast Sabah), the Deputy Chief Executive from the *Sabah Energy Corporation* and a senior manager from the Planning Division (Transmission & Distribution) of *Sabah Electricity*, these geopolitical challenges were highlighted.

One interviewee explained: *'from 1986 to 1992, the thrust was the privatization of the electricity supply system. Sabah Electricity was the property of the state government. It was the same for Sarawak Electricity. The Energy Commission had no say in its operations. But we couldn't manage our finances and went into a 3 billion ringgit debt with the federal government. Then this tension between federal and state politics has been a constant. There is distrust. And we have had brown outs, particularly in Sandakan (East Coast of Sabah), not as much in Kota Kinabalu, and people just thought it was part of life…But we went ahead with studies on the possibility of privatization (Ernst & Young was a consultant to the federal government). By 1995 with changes in political parties, the relationship between the federal and state governments had improved. But we are very far off from Peninsular Malaysia and we are worst off, thank Sarawak because at least there they got LNG that Petronas extracts which is a huge source of revenue to the federal government so they cannot so easily bully Sarawak, but in Sabah we use combined oil-gas to generate electricity'* (Interview 5, April 2017).

Another interviewee mentioned that *'the reason why electricity supply is lagging behind in Sabah after privatization in 1998 is due to the politics. We have been revising the need for new/projected infrastructure since 2007 and we have been pumping 2.1 to 2.5 billion Malaysian ringgit (RM), but it is because of the politics….and our relationship with the federal government'* (ibid.).

FIG 2. SABAH GRID



(SOURCE: SABAH ELECTRICITY SDN BHD CORPORATE PROFILE)

SUMMARY

The post-colonial period in Kota Kinabalu and its state of Sabah is characterized by a realignment of its electricity system following merger with the Federation of Malaysia. This realignment is manifested in growth in demand, the formulation of decisive energy policy following national strategies, fuel diversification and the uptake of significant hydropower projects, the creation of the Sabah grid, and the privatization of transmission and distribution providers. While these developments forebode well, the reality is that the system suffers from frequent blackouts despite the fact that, particularly since the 2008 financial crisis, demand was stagnant.

5. LEGACIES OF LOCAL AUTARKY AND REGIONAL/NATIONAL ALIGNMENT/ REALIGNMENT FOR ENERGY TRANSITIONS TODAY

Having addressed in the previous two sections the first two questions of how each of the two cities developed their own forms of energy autarky in response to their geopolitical isolation, and how they are currently realigning their electricity systems to fit conditions of post-independence and merger, we now turn to the third research question and consider how these historical legacies are framing options for energy transitions today.

The purpose of this section, in conceptual terms, is about considering the degree to which current developments in the two cities can be considered path dependent. Path dependence is a process by which future choices are restricted by development trajectories of the past (North 1990), for instance when policy legacies constrain current policy options (Kay 2005). The concept has been widely applied to explain the obduracy of socio-technical systems (e.g. Melosi 2000), but has been criticised for being far less able to explain change (Hay 2002; Kay 2005) or the effects of disruptive events. This differentiation is important to the following interpretation of continuity, contingency and change in Singapore and Kota Kinabalu post-independence, post-merger within the demands imposed by low carbon economy narratives and policies.

Looking across the two cases, the first observation to make is that the experiences of energy autarky made during and after periods of geopolitical isolation do not fit into straightforward categories of isolation versus integration. The energy directions pursued by each city may have been influenced by the desire to seek security in autarky of electricity generation, but they were never completely independent of the exogenous forces, as the reliance on external fuel sources and more recently, global and federal demands and grid connections to the region show. Equally, political independence and merger in the two cases did not cause the legacies of energy autarky to lose their relevance overnight. They continue to influence current policies and practices of energy provision and use in Singapore and Kota Kinabalu; not in an overpowering way, but in a more subtle and selective manner. This fact guides us to analyse, in this section, the extent to which these historical legacies are framing today's urban energy systems.

5.1. TERRITORIAL INTEGRITY

During their corresponding periods of geopolitical isolation, the two cities developed autarky of electricity generation and supply as means to defend their territorial integrity and remain relevant to the colonial overlords. The vulnerability of Singapore's power supply after its departure from the Federation of Malaysia in 1965 and its subsequently becoming independent was the incentive for redesigning its electricity system around the geography of an isolated city with new local power stations covering for the loss of imported electricity from Malaysia with the exception of a 'back up' connection with the neighbouring State of Johor. Singa-

pore's history of territorial protection – as a response to forced separation – is today largely insignificant in the independent city-state.

In Kota Kinabalu, by contrast, the legacy of territorial integrity built-up by the British to protect their North Borneo settlement remains a key issue today in terms of relations with the federal state in West Malaysia embodied by the ' fattening cow' approach its administrative capital Putrajaya takes towards Sabah in particular and the rest of East Malaysia in general. Ongoing debates on closer cooperation with the state of Kalimantan (Indonesia-Borneo) and with ASEAN over Kota Kinabalu's future electricity supply are powerfully framed by fears of Kota Kinabalu losing yet more of its ability to pursue its own policy agenda and ensure security of supply.

5.2. PROTECTED MARKETS

The local power utilities, initially the realm of private entrepreneurs in Singapore and Kota Kinabalu, were instrumental in maintaining territorial integrity by providing reliable energy services and as such they were protected from competition and allowed to operate market monopolies. This was, of course, the norm in many countries prior to liberalisation from the 1980s onwards, but the separation of Singapore from Malaysia's national grid after independence and the self-dependence this cultivated could have made the transition to a liberalised electricity market in the mid-1990s especially hard, as it was the case in many cities around the world. Nevertheless, Singapore weathered this transition by always being ahead of the curve, strategically keeping excess capacity and taking up new technologies in the city's new generation, transmission and distribution infrastructure to remain competitive.

In Kota Kinabalu, the inclusion of the State of Sabah in the Federation of Malaysia in 1963 and the dependence on energy subsidies from the national government while having to be self-sufficient in designing and operating its generation, transmission and distribution infrastructure, has resulted in Kota Kinabalu's electricity system remaining at the margins and the mercy of national politics and seriously challenged in its ability to bring it on par with that of West Malaysia. As a city, Kota Kinabalu's energy security and autarky has become dependent on the operation of *SESB* and its performance, which to date has given rise to limited optimism.

5.3. SUPPLY SECURITY

Securing electricity supplies at all times and, often, under challenging circumstances was the guiding principle of energy policy in the two cities during their geopolitical isolation. To allow for potential disruption of service – whether owing to political upheaval or delays in accessing fuel sources – very large capacities for generation were built up in each city, in the shape of multiple power stations, substations and grid extensions. It is interesting to note that, with the exception of the period of Japanese occupation and post-WWII years, neither city seriously pursued the option of minimising electricity consumption and thereby

reducing the need to expand capacity. It is likely that the availability of international aid and other mechanisms to finance this strategy of network expansion encouraged the growth. The legacy of supply security in the two cities is continued reliance on the logic of build-and-supply to the detriment of demand-side management. Establishing energy efficiency on the policy agenda is, for this reason, proving difficult in Singapore and Kota Kinabalu although Singapore has strategically shifted towards putting energy efficiency at the cornerstone of its energy strategy (Francesch-Huidobro 2017c).

5.4. LOCAL INFRASTRUCTURE

The construction of enough power stations within its own territory was a particular challenge in the two cities. Particularly in Singapore, competing claims on land for residential and commercial purposes caused urban plants to be replaced by ones at increasingly peripheral locations. This in turn involved extensive investment in transmission and distribution networks and customer service provision. This is a positive transition that is best served by a liberalised market where competition obtains the most efficient and cost-effective solutions. In the case of Singapore, constraints have been turned into opportunities.

In Kota Kinabalu, the problem lay rather in how to deal with the legacy of its derelict urban power stations in a re-integrated energy market. Despite the practice of having the private sector running the electricity supply, with only one player, namely *SESB*, there has been a deterioration of maintenance as well as service quality. The blackouts are an indication of how the market is not working in Kota Kinabalu even though there is an abundance of potential energy resources.

5.5. RESOURCE FLOWS

Energy autarky in Singapore and Kota Kinabalu was always only limited to electricity generation, transmission and distribution as the two cities were dependent almost entirely on fuel imports to run the power stations. It is interesting to observe a gradual process of diversification of fuel sources over the years – also largely for geopolitical reasons – in particular in Singapore.

Originally the two cities were heavily reliant on coal to fire their power stations. This was supplemented by oil until the oil crisis of 1973, after which there was a gradual shift towards natural gas, and increasingly to LNG from all over the world, most significantly in Singapore. This heavy dependence on fossil fuels for generating local electricity is today creating difficulties for the two cities to achieve the ambitious CO_2 reduction targets they have set themselves or ones that have been set for them. Pressure to deliver on climate mitigation goals is pressuring city governments to reduce local generation and import more electricity. This practice is criticised by environmental groups for concealing the fact that the CO_2 emissions are merely being produced elsewhere.

Kota Kinabalu has a golden opportunity to leverage on the renewable resources being exploited in Sabah state. However, without the intelligence of a smart grid it is not possible to see where the source of fuel is coming from, whether from a coal-fired power station or renewable sources like hydropower. This is one advantage that the city has over Singapore's island situation. In terms of energy resilience, Kota Kinabalu is likely to be in better health than Singapore.

5.6. ENVIRONMENTALISM

Singapore and Kota Kinabalu have a strong tradition of local environmentalist movements and initiatives, more so in Kota Kinabalu than in Singapore, arising partly in opposition to the dominant energy strategy of their governments and utilities. The diverse cultures of the two cities - Singapore a cosmopolitan urban hub branded as a garden city, and Kota Kinabalu an affordable natural and cultural tourism destination – are, for different reasons, attracting young people interested in alternative, unconventional lifestyles and a more open and sustainable society. These protagonists of sustainable forms of energy provision and use range from environmental non-governmental organisations campaigning for more effective climate protection measures (i.e. World Wide Fund for Nature Clean Energy Kota Kinabalu) to 'eco-preneurs' marketing energy-saving technologies or services (i.e. Wilson Ang of the Global Compact Network Singapore). They all play a crucial role in ensuring that the energy transition policies of their respective cities are not exclusively the 'sandbox' of the political and business elites. In the two cities, the obduracy of a fossil-based, supply-oriented energy policy has engendered strong environmentalist opposition as a major force for change that is beginning to pay off.

SUMMARY

Amongst these different legacies we can detect some degree of path dependence, but only with respect to certain dimensions of the socio-technical transitions in the electricity supply system. Areas where self-reinforcing mechanisms from the past are impacting future options include Singapore's political culture of territorial integrity in relation to its surrounding neighbouring Indonesia and Malaysia, the dependency West Malaysia has on the State of Sabah when it comes to energy sources, the security-driven logic of build-and-supply in the two cities and their dependence on fossil-fuel generating capacity.

But introducing market forces through liberalization and privatization for Singapore and Kota Kinabalu are chartering a different future. For Singapore, getting the best price of electricity for the market has engendered efficiency and cost-effectiveness; but progress comes with a cost and future investment has to be made on ageing infrastructure and new infrastructure (like a smart grid). This is where the players must come up with innovative ways to finance the schemes and still make a profit after investment. Kota Kinabalu, on the other hand, has one major player to contend with namely *SESB*, where the challenge is to

make this corporation accountable to its stakeholders in the delivery of reliable and affordable electricity. Notwithstanding the political influence of the Federal government, the opportunity to revamp the old system and embark on an ambitious green energy programme is immense. And so is the case with the national GHG reduction goals, the sustainability aspirations for the country and the overall quality of life in the city and the nation.

6. LESSONS THAT PAST POLICY AND HISTORICAL LEGACIES OF ENERGY AUTARKY BRING TO FUTURE POLICY FORMULATION IN SINGAPORE AND KOTA KINABALU ELECTRICITY SUPPLY SECTOR

6.1. CONNECTING THE PAST TO THE PRESENT

Studying how insular cities are powered to ensure the resilience of their infrastructure in the face of spatial and temporal changes is a theme of historical and intellectual importance. Recording the developments of two cities' electricity sectors as well as critically analyzing how past developments affect present and future changes, is the aim of this paper. The legacies of past energy autarky and security for current urban energy transitions in Singapore and Kota Kinabalu provide a snapshot of how Southeast Asian cities are going about energy policymaking and market design to weather present and future challenges so as to continue to boost their developmental capacity and ultimate survival.

The important point to note is that both cities pursued autarky for common reasons namely, meeting current needs, relevance to international and regional influences, and future proofing. Meeting current needs is a reflection of the historical development of the two cities. Singapore has built excess capacity and a reliable supply that has served the city's rapid economic growth. As stated earlier in this paper, Kota Kinabalu on the other hand has been unable to shift from less energy intensive industries (agriculture and mining) to more energy intensive ones (industry and services) due to the difficulty in building the right infrastructure and maintaining it.

Between 1987 and 2004, the challenge for Singapore was to ensure that its supply was reliable and secure at the right price. Through the corporatization of agencies such as PUB, market rules were introduced to the system, as well as through the liberalization and deregulation of the sector. By contrast, stagnant demand in East Malaysia meant that Kota Kinabalu actually regressed in performance with frequent blackouts in spite of formulation of energy policy, fuel diversification through the uptake of significant hydropower projects, the creation of the Sabah grid, and the privatization of transmission and distribution providers. The telling factor has been the presence or absence of vision and focus. It would seem that after the ravages of WWII, both cities underwent a process of rebuilding but the differences in history made one more assertive about its future than the other.

6.2. FUTURE-PROOFING

Today and looking to the future, both cities sit at the nexus of the ASEAN economies. However, each has adopted a different role. For example, Kota Kinabalu is a key part of Brunei, Indonesia, Malaysia and Philippines East Asia Growth Area (BIMP-EAGA) in which the city aims to be a focal point for regional partnerships between private and public sector initiatives. ASEAN's vision in the future is to be a union of countries, much like the European Union, where jobs will be borderless and tariffs non-existent between the member states. The reality is that this vision is too ambitious given the political and territorial squabbles between the nations. Singapore on the other hand has embraced a bigger picture of international importance and has elevated its position to be one that draws in talent and investment to keep its relevance on the global arena. Investment in urban development, smart technology, education, and knowledge industries has made Singapore one of the most competitive cities in the world in terms of GDP and liveability.

Future-proofing both cities will entail climate change adaptation and social and economic resilience. In terms of climate vulnerability, Singapore faces more to lose being an island city-state with exposed shorelines. Kota Kinabalu as an inland city within an island state is more prone to drought and conversely flooding as hydrological cycles take on erratic patterns due to climate change. From an energy perspective this means protecting critical infrastructure like transmission and distribution grids but at the same time weaning the cities off fossil fuel dependence and towards more sustainable energy sources like renewables as well as embarking on energy efficiency.

Economic resilience will depend on the exposure of the cities' capital markets and trade flows to economic patterns. At a more basic level, this resilience will also depend on how the resources of each city are provided. In Singapore's case, the city is dependent on supply chains while Kota Kinabalu has a large hinterland with much natural reserve that can be tapped. The health of the economy will affect the wellbeing of the society. Singapore's citizens have undergone many shifts from the older 'pioneers' of the city state to its current youth. The city needs to align with the modern innovative industries of Internet of Things (IoT), data analytics and artificial intelligence (AI) and look at jobs for professionals that may not have been invented yet. Kota Kinabalu on the other hand is burdened with socio-political and, to a degree, religious circumstances that have made the city underachieving in its potential.

So to bring the dialogue to the present, where has each city gotten to in its respective energy supply?

The telling fact is that each system suits the type of economy the city represents. Singapore has had to embark on an ambitious energy expansion to meet the needs of a modern advanced city, while Kota Kinabalu remains a second-tier city despite its aspirations in

industrial parks. This may change in time if ASEAN becomes better organised. A further factor to consider is the growing influence of China which may well determine in the future where the strategic regional importance of these two cities lies from the viewpoint of a global superpower.

Future investment in electricity supply will further be affected by maintenance of existing infrastructure, new infrastructure and choices of fuel. With ageing infrastructure, the economic decision rests in whether electricity to currently served communities should remain unchanged or upgraded. This is also a matter of land planning as it may be uneconomic to serve an isolated community or on the other hand if urban development becomes a matter of vertical living then investment in transmission and distribution facilities – old and new – becomes relevant. Ultimately, both cities should be looking at smart technology like smart grids which are able to combine the benefits of renewable energy, energy storage, a robust electricity retail market and energy efficiency.

Like many utility industries, the electricity sector will be subject to the vagaries of socio-political and cultural factors. Singapore to an extent has managed to contain societal disruptions although there is a burgeoning discontent between the old and young, the middle class and the growing imports of professional talent and the city's residents and the immigrant working population and, to a degree, the urban poor and the wealthy. Kota Kinabalu faces challenges of a different nature due to its relationship with Western Malaysia which has disadvantaged Sabah's natives as well as forged an uneasy relationship between the predominantly Christian residents and the Muslim governing powers. Both cities in this regard will have to fashion a way that addresses these tensions and maintain a reliable supply of electricity to power the city.

In 2015, the UN produced the Sustainable Development Goals (SDGs) as guidelines for sustainable development to the year 2030. These goals associated with 169 targets set the framework for cities as well as countries and are all interlinked. Pursuing a low carbon future (Goal 13) is thus incisive and beneficial. As sustainability did not really emerge as any sort of global or national agenda until 1987 under the Brundtland report, both cities are gradually interpreting the implications for their respective situations. Singapore is a member of Resilient Cities 100 (100RC) and C40 networks, which gives it a platform and benchmark on how it will achieve its goals. Kota Kinabalu as part of Malaysia is committed to the 11th National Plan which embodies the country's commitment to lowering carbon levels by 35% by 2030 based on 2005 levels. Both directions are correct and commendable. The question arises as how the electricity industry will be aligned to meet the goals of sustainability. Obviously, a shift towards cleaner energy (Goal 7) is relevant but there are other interlinked goals like Jobs (Goal 8), Innovation (Goal 9), Cities (Goal 10) and Responsible Consumption (Goal 11) come into play.

6.3. SUSTAINABILITY AND ENERGY POLICY

In summary, what connects the past to the present and the future? The part played by legacies was reviewed in the last section and this illustrates that path dependence is pertinent to the development of the two cities. But can this be extrapolated to the future? What we feel that path dependence allows is an enriching experience of how to respond to future challenges and opportunities. The big question in Asia is the role if regional superpowers like China. Which city is best suited to work with China's strategy for regional dominance?

Both cities surprisingly have their own advantages in making this happen using their own brands of energy autarky. Singapore can lead in technology development, given its advanced intellectual capital, while Kota Kinabalu has a rich reserve of natural resources that would benefit China along with its ASEAN neighbours. The other challenges are resilience and quality of life, which both hold significant implications for energy supply and security. Both cities need to develop trajectories towards energy efficiency and how to create new paradigms of efficient and low carbon societies without compromising the quality of life. Each should incorporate sustainable visions of their cities and communities; and their governments paying heed to the precepts of the SDGs is not a bad thing in this respect.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. THE FOUR QUESTIONS

We have attempted to answer four questions through an analysis of past and present energy histories of Singapore and Kota Kinabalu:

- ✓ How do these cities strive to render their electricity supply systems more self-sufficient in response to their geopolitical **isolation** and to what effect?
- ✓ How have these cities been realigning their electricity supply systems following **independence** (Singapore) and **merger** (Kota Kinabalu) and regionalisation?
- ✓ How far and in what ways are their **past policies/historical legacies of energy autarky framing options for energy transitions** today? How are the legacies of territorial integrity, protected markets, supply security, local infrastructure, resource flows and environmentalism **affecting today's transitions**?
- ✓ What **lessons** do past policies/historical legacies of energy autarky offer to future policy formulation in **Singapore and Kota Kinabalu** electricity supply sector?

In response to the first question, we explained the means by which Singapore and Kota Kinabalu made their electricity supply systems autarkic in response to geopolitical isolation.

Unable to rely on a national or regional power grids, both cities responded by building up and sustaining their own power generation capacity capable of meeting all electricity needs, with substantial reserves to cover for emergencies.

Energy security – in the sense of securing supply at all times – was their priority concern; creating energy autarky through capacity expansion was the strategic response. With the exception of the Japanese occupation and post-war years when austerity was mandated to reduce electricity consumption, within this powerful supply-driven logic there was otherwise no attempt to curb demand.

Energy efficiency was only advanced much later from the 1990s onwards under pressure from global, regional and national norms of the low carbon economy and only if it made economic sense. Nevertheless, the strategy of energy security through autarky proved effective in both cities but with different levels of success. While power services were never subject to significant interruption in Singapore throughout the years of isolation as a British colony and standards of service and safety were high as technology advanced, Kota Kinabalu's power infrastructure and services were from the onset challenged by climatic and behavioural factors while isolated as a dependent territory, this despite having direct access to abundant resource flows (coal and hydro) at all times.

In response to second question, we demonstrated how each city has been realigning its electricity supply system since merger and independence in 1963 and 1965 (Singapore), and merger in 1963 (Kota Kinabalu).

Singapore, even during its brief existence within the Federation of Malaysia (1963-1965), while remaining dependent on the regional and global markets for its resource flows, it retained the autarky of its supply infrastructure, including its generation, transmission and distribution. The city continued to build generating capacity within while opening itself to some dependency by liberalising the sector and bringing in market discipline. Yet, the strong regulatory regime under EMA leadership meant that not a speck of autarky and excess capacity was surrendered despite liberalisation. However, the past 10 years have seen intense debate about the future viability of energy autarky for a small city-state like Singapore. Economists recommend *'a continue monitoring of oil supply to ascertain if prices are rightly reflective of the actual situation and that markets can remain competitive and thus sustainable'* (Ng 2012: 241). They propose to do an energy return on energy investment test (EROEI) on all development projects on which Singapore relies upon to boost its economy (theme parks, casinos, etc). If the energy produced by these projects is higher than that invested, all is good. If the price of fuel is up, ultimately energy produced will be higher than that invested (Ng 2012: 241); but if the prices of fuel are down, the autarkic energy system will be rendered unsustainable sooner or later (ibid.: 245). Not only energy security issues, but also climate mitigation interests are being included in arguments to increase the degree of bilateral and multilateral connectivity and lessen autarky, thus, shifting to importing

more electricity (via a transgas ASEAN pipeline, ASEAN power grid), thereby, reducing the need for local generation in power stations driven by fossil fuels. Nevertheless, progress in this respect has been very slow and Singapore has, ultimately, resorted to tapping on global LNG resources and regasification in its very expensive LNG terminal.

In Kota Kinabalu, energy autarky is retained both in its resource flows and infrastructure. While the logic of building excess capacity, established during the colonial period, was retained after merger, Kota Kinabalu is not benefitting from this logic as it finds itself having to share resource flows (oil, coal and gas) with peninsular Malaysia that treats the island of Boneo and the states of Sabah and Sarawak as *'resource-rich brothers but with modest tastes'* who should be proud to contribute a big portion of their resources to the nation. The paradox that has resulted from this (sharing resources out and consuming little) is that with an increasingly stagnant local demand, the utilities are not financially viable and thus have no means to keep the numerous power plants and transmission & distribution substations in good working order, this despite abundant resources flows that, as mentioned, peninsular Malaysia continuous to demand from.

Turning to the third question, we reflected on how historical legacies of local energy systems are framing urban responses to climate change and energy security today. Looking at the experiences of the two cities and based on Moss and Francesch-Huidobro (2016) research, we categorised the findings in terms of six different, but interdependent, legacies of energy autarky relating to territorial integrity, protected markets, supply security, local infrastructure, resource flows and environmentalism. These categories helped reveal and interpret some of the principal differences, but also similarities, between the two cities' current situations.

In Singapore, the most influential factors from its history of isolation and subsequent independence was the dominant supply-oriented logic of the original power utility (PUB) and of SPower and EMA (regulator) that followed after the market opened in the 2000s. One can also count the city's active research community within and outside government as driving many innovative low-carbon projects.

In Kota Kinabalu, similar pressure for more sustainable energy systems is revealing severe structural weaknesses behind its long-standing strategy of energy autarky. If the city wants to meet its own targets to reduce greenhouse gases, it will need to reduce electricity generation from its coal- and oil-fired power stations substantially and find alternative sources of electricity from hydro or renewable sources. Given Kota Kinabalu's physical geography, this will mean greater dependence on a pan-Borneo cooperation, for example, with the state of Kalimantan (Borneo Indonesia), raising new issues of geopolitical and energy security. The post-colonisation towards independence and merger trajectories do not fit straightforward into simple categories of path dependence on the one hand or temporal and spatial contingency on the other. Parts of their electricity systems reveal a high degree of path dependence, whilst others do not.

The fourth question suggested the idea that past developments can affect present and future changes. The legacies of past energy security and autarky for current urban energy transitions in Singapore and Kota Kinabalu show how Southeast Asian cities are going about energy policy-making and market design to address future challenges so as to continue to boost developmental capacity and ultimate survival.

One should be cautious about generalising from the experience of two Southeast Asian cases. The value of studying Singapore and Kota Kinabalu, as it was the case when studying the impact of energy legacies in West Berlin and Hong Kong (Moss and Francech-Huidobro 2016) rests not in any Asian model they may depict, but in what their unusual histories can tell about urban energy transitions that is absent or less visible in other cities with more conventional trajectories.

In terms of *energy autarky* and *energy security* the stories of Singapore and Kota Kinabalu make very clear that these concepts have not always been interpreted in the ways they are today and that their meanings can be very different in particular spatial and/or temporal contexts.

The *energy autarky* pursued in Singapore during isolation and independence and in Kota Kinabalu during isolation and merger did not follow today's prescriptive understanding of a city aspiring voluntarily to local self-sufficiency based on renewable sources, low demand and citizen participation. For these two cities autarky was, rather, imposed upon them by geopolitical circumstances and involved securing electricity supply *without* having to change practices of consumption, technologies of generation or governance structures until very recently. The two cases of Singapore and Kota Kinabalu suggest that autarky can be a geopolitical requirement and a mode of energy security, but also a limit on future energy options and an inefficient use of energy resources.

Similarly, *energy security* can mean different things at different times and in different places. Both Singapore and Kota Kinabalu have to come to terms with rapidly shifting meanings of energy security. What was once principally about protecting their energy systems from colonial overlords and hostile neighbouring states today includes many concerns ranging from climate protection and ecological security to fuel availability and sheer survival.

7.2. RECOMMENDATIONS

This paper has argued that historical legacies are important to understanding urban energy transitions. Here, it is not enough to acknowledge that history matters. We need to reveal *how* history matters, for instance in the ways in which some components of an urban energy regime remain obdurate, some disappear or are discarded, whilst others adapt to shifting contexts or emerge in the wake of contingent events.

The processes by which these socio-technical components, be it electricity, water, waste etc get realigned are often not straightforward. Although strongly influenced by the past, they are not determined by it. This suggests research and policy analysis in the direction of more empirical studies of socio-technical legacies, revealing the dynamics and continuities of these complex systems and their components (sources, technological, management, governance, geographical, social etc.).

Finally, this analysis also draws the reader to refrain from taking too biased a view on cities when analysing urban energy transitions. The energy histories of Singapore and Kota Kinabalu cannot be studied as an urban phenomenon alone. As it was the case with West Berlin and Hong Kong (and possibly it is the case with other similarly divided or isolated cities), their pursuit of energy autarky was in direct response to their geopolitical situation. The realignment today is equally influenced by their relations with their federal states, hinterlands and surrounding territories. We need to continue exploring the multiple ways in which urban energy transitions are shaped by, and themselves shape international, regional, and national developments.

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REVIEWER NOTES:

Dr Thomas S.K. Tang, former Managing Director of the Kuala Lumpur Centre for Sustainable Innovation:

'I reviewed Dr. Francesch's manuscript on the legacies of geopolitical insularity for urban transitions today: electricity generation and use in Singapore and Kota Kinabalu and I found it to be an insightful discourse of how an understanding of a city's history and past challenges to its power supply effectively shape its current policies in this area. In the course of sustainable development, cities must find ingenuous ways to survive and be resilient for the future - energy security and autarky is key to this. Dr. Francesch's work on the historical development of Singapore and Kota Kinabalu reveals how geo-political factors have played an important role in how electricity and power have been organised and are organising in these two cities, both of whom have followed diametrically different paths and who are now shaping up for a future that is carbon-challenged as well as politically charged. Asia is at a dynamic nexus of many issues around cleaner and better electricity and this research could not have been better timed' (23rd Nov 2017).

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Directors report to shareholders of Jesselton Ice and Power Company Ltd (2 pages) (hardcopy)

French Map of Peninsular Malaysia, Sumatra, Borneo, Celebes [colour photocopy]

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North Borneo Electricity Board Revenues of Account, 1958, (1 page) (hardcopy)

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Map State of North Borneo (East and West Coast Residencies) [no date]

Sabah State Library

Operation Statistics for Each Undertaking Lembaga Letrik Sabah, 1986 (1 page)

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Stations Statistics, 1990 (1 page)

APPENDIX 1 - DATA COLLECTION AND FIELD INTERVIEWS (19 MAR - 3 APRIL 2017)

Note: *The study was conducted by making extensive use of archival material accessed on-site during an extended stay in Singapore and Kota Kinabalu in March-April 2017. Open-ended field interviews were also conducted with relevant public and private sector stakeholders of the electricity supply sector of Singapore and Kota Kinabalu and with analysts abreast of past, present and future developments. All in all, 7 interview sessions were conducted with 11 individuals. With the exception of interview 5, all other interviews were recorded and transcribed.*

IDENTIFIER	INTERVIEWER	DATE
Interview 1 (individual)	Principal Fellow & Head, Energy Economics Division, ESI, Singapore	Face to face, 17 Feb 2017
Interview 2 (individual)	Research Associate, Energy Economics Division, ESI, Singapore	Email, 16 Mar 2017
Interview 3 (group)	• Director, Policy & Planning Department, EMA, Singapore • Senior Analyst, Policy & Planning Department, EMA, Singapore	Face to face, 23 Mar 2017
Interview 4 (individual)	Senior Principal Fellow, Energy Security Division, ESI, Singapore	Face to face 24 Mar 2017
Interview 5 (individual)	Director, Centre for Liveable Cities, Singapore	Face to face 23 Mar 2017
Interview 6 (group)	• Regional Director, West Coast Sabah, Energy Commission, Kota Kinabalu • Director, Planning Division, T&D Power Grid, Sabah Electricity, Kota Kinabalu • Deputy Chief Executive Officer (Gas Supply), Sabah Energy Corporation, Kota Kinabalu	Face to face 27 Mar 2017
Interview 7 (group)	• General Manager, Generation, Sabah Electricity, Kota Kinabalu • Director, Planning Division, T&D Power Grid, Sabah Electricity, Kota Kinabalu	Face to face 31 Mar 2017

APPENDIX 2 - LIST OF TABLES, PHOTOS, FIGURES

Table 1 - Singapore's Energy Legacies and Transitions (electricity):

Legislative; Historical-geopolitical; Sources & Transformation (fuels & power plants); Infrastructure (generation, transmission & distribution network); Market (wholesale & retail); Institutional (Ministries & Agencies), Low carbon transitions (Supply side- fuel mix, Demand side- efficiency; climate mitigation – GHG reduction). (Sources: Singapore Statutes Online; History SG http://eresources.nlb.gov.sg/history; Singapore Power; Energy Market Authority; Ministry of Trade & Industry; National Energy Market Report 2007; Singapore Energy Statistics 2015; Climate Action Plan 2016; Public Utilities Board; Singapore LNG Corporation; National Library Board Infopedia; Chang 2007; Doshi 2015; Koh & Lee 2011; Morgan 2016; Turnbull 2005).

DIMENSIONS	LEGACIES & TRANSITIONS
Legislative (common law jurisdiction)	*Electricity Act* (ch 89A) (2002) source-plant-grid - C&I retailers-market support service licensee (MSSL)- household consumers *Energy Conservation Act* (ch 92C) (2012, 2014, enhanced 2017). Singapore Statutes Online
Historical-Geopolitical	***Colonial Port City (1819-1945)*** **1819-1905 (trading port)** 1819 Stamford Raffles founds the Singapore trading port under the administration of the East India Company (National Library Board 1826 British administration of The Straits Settlements (SS) comprising Singapore, Penang and Malacca is established (ending 1946) (Morgan 2016: 16) 1861 *Singapore Gas Company* established (piped gas to light streets; private) & *Kallang Gasworks* opens (at Bugis, transhipment of coal from Australia through Rochor and Kallang rivers, private) 1867 The Straits Settlements become a Crown Colony with a Governor, Legislative Council and Supreme Court (Morgan 2016: 16) 1890s storage and transhipment of kerosene, oil bulk cargo (Doshi 2015: 169) 1901 *Municipal Commission* established (renamed *City Council of Singapore* 1951) **1906- 1924 (Colonial Port City/Singapore Municipality/City Council & Rural Board)** 1906 first electric street lighting (Raffles Place, North Bridge); *Singapore Electric Tramway Company* power station (Mackenzie Rd) offers bulk electricity supply to Municipality who sells it to consumers (electricity generated to drive the trams could be used to supply electricity to the town) 1907 there are 132 electricity accounts (up by 400%) **1924-1944 (Colonial Port City/Singapore Municipality/City Council & Rural Board/ British administration of the Straits Settlements (SS) comprising Singapore, Penang and Malacca from 1826 to 1946).** 1924 *St James Power Station* starts construction at West Coast 1928 *Electricity Department* established (under the *Municipal Commission*). *Hiring*

Department of Electricity Department, Orchard Rd offers household appliances for rent

1930 First electric traffic lights at Empress Place

1939 Cathay Cinema is air conditioned

1943-1945 WWII, Japanese Occupation, Nippon Hassoden Kabushiki Kaisha or *Nippon Power Supplies Company* takes over electricity supply

Political Change (1945-1964)

1945-1958 (Political Change/ British Military Administration Singapore & Malaya (under Mountbatten, Aug 1945-April 1946); End of Straits Settlements (1 April 1946); Singapore a separate Crown Colony 1946-1958

1945 British Military Administration restores and returns *Electricity Department* (under *Municipal Commission*) to civilians (Koh & Lee 2011: 76-77)

1946 The Straits Settlements are disbanded. Singapore becomes a separate Crown Colony (Morgan 2016: 17)

1948 First Singapore Constitution (Crown Colony). The Progressive Party wins most elected seats in the Legislative Council (Morgan 2016: 17)

1951 City Status granted, a City of the British Commonwealth (Brighter Koh & Lee 2011: 76). *City Council of Singapore* is established with a remit on electricity, gas, water, street lights, roads and bridges; it replaces *Municipal Commission*

1952 *Pasir Panjang Power Station A* commissioned

1957 first fully elected *City Council*

1958 The British Parliament passes the State of Singapore Act converting the city from Colony to a self-governing state State-of-Singapore Constitution. The post of Governor is abolished and the office of Head of State established (Yusof bin Ishak 1st HoS) (Morgan 2016: 18)

1959-1964 (Singapore Self-governing 1959-1963; Merger with Malaya to form the Federation of Malaysia 1963-1964)

1959 Declared Self-governing State (internal self-rule) PAP forms Cabinet (Bighter Koh & Lee 2011: 77)

1960-1961 Formation of the Housing Development Board & Economic Development Board and industrialisation programme (requires electricity) (Brighter Koh & Lee 2011: 77)

1961 Shell granted pioneer status, 5-year tax free first refinery Pulau Bukom (Doshi 2015: 169)

1963 *Rural Electrification Programme* begins (Brighter Koh & Lee 2011: 77)

1 May 1963 *Public Utilities Board* (water, gas and electricity) established taking over utilities operation from the City Council [ZK Fiuczek, foreigner, in charge of electricity section (1963-69). Generators bought from Japan (Russian generators used to overheat)].

1963 Merger with Malaysia to form Federation of Malaysia, State of Singapore Constitution Adopted (Third Schedule to the Sabah, Sarawak and Singapore (State Constitutions) Order in Council 1963 (signatories: GB, Federation of Malaya, Singapore, North Borneo (Sabah), Sarawak)

Nation and Global City (1965-present)

1965-1974 (Independence, Republic of Singapore, City-State onwards)

1965 Independence (9th August). The Malaysian Parliament transferred all legislative and executive powers from the Federal government to the Singapore government. Constitution of the State of Singapore 1963 (Morgan 2016: 19). Amendments of 1969 and others subsequently.

1965 'Power to the People' Opening of *Pasir Panjang Power Station B* by Lee Kuan Yew (PM) rapid industrialisation.

1966 PUB was getting loans from the World Bank and the International Bank of Reconstruction and Development. $30 mill loan for *the Jurong Power station* (CEO of PUB got to be approved by WB).

1969 *Electricity Department* (of PUB) lays undersea cables *from* Pasir Panjang B Power Station to the oil refinery in Pulau Ayer Chawan.

1973 *Rural Electrification Programme* ends (1963-1973).

1970 *Jurong Power station* opens (Koh & Lee 2011: 110).

1970s Singapore recognised as crude oil and refined product hub and trading centre (Doshi 2015: 170)

1975-1984

1975 enacting of several regulations such as Electricity Supply Regulations and Electricity Regulations (Koh & Lee 2011: 111)

1977 *Senoko Power station* opens (Koh & Lee 2011: 111) full capacity in 1983 1,610MW

1979 Cables go underground (manual mapping of land!); *Public Utilities Board* computerizes energy management system (Ayer Rajah substation)

Supervisory Control Acquisition System (SCADA) for remote control of power networks introduced (Koh & Lee 2011: 111)

1983 St James and Pasir Panjang A power station decommissioned (ibid. 111)

1985-1994

1985 high sensitivity residual electricity circuit breakers mandatory for all new homes (safety) (ibid. 111)

1988 *Pulau Seraya offshore power station* opens (three 250 MW steam plants), undersea cable fitted

1995-2004

1995 *Public Utilities Board*: electricity & gas services are corporatized (introducing market competition) (ibid. 111)

1995 *Tuas Power Pte Ltd* formed

1995 *Singapore Power Ltd (SP)* established: govt-owned under Tamasek Holdings, vertically integrated monopoly, takes over from PUB (electricity & piped gas - generation, transmission and distribution). **PUB retains regulatory role** (Chang 2007: 404)

1996 PUB issues Service Standards for Public Licensees (Koh & Lee 2011: 142)

1998 PowerGrid Ltd tarts the Singapore Electricity Pool (ibid.)

2000 MTI announces further liberalisation of the electricity and gas industries (ibid. 143).

2001 *Energy Market Authority* (EMA) established to oversee liberalization **takes over regulatory role from PUB**; 250 Commercial & Industrial consumers (demand above 2MW) able to choose electricity supplier

2001-2003 *Energy Market Company Pte Ltd* and *National Electricity Market Singapore* (NEMS) established to take over the operation and administration of the electricity market. Allows prices to reflect supply and demand fundamentals (Chang 2007: 403, 405; National Energy Policy Report 2007; Doshi 2015: 170)

2005-2017

2006 75% total electricity demand open for competition (Doshi 2015: 170; Koh & Lee 2011: 143) but not the retail, household

2006 establishment of the *Energy Policy Group (EPG)* 5 ministries + 6 agencies (Doshi 2015: 168)

2008 EMA launches Singapore Intl Energy Week "Powering Cities for Future"

2008 Inter-ministerial Committee on Sustainable Development initiates *Sustainable Blueprint* (includes optimisation of energy resources)

2009 EMA introduces the pegging of fuel cost component of electricity tariffs to average fuel oil prices in the previous quarter (Koh & Lee 2011: 143)

2010 *Singapore District Cooling* system starts: Marina Bay

2010 Economic Strategies Committee (Subcommittee on Energy Resilience and Sustainable Growth) recommends energy security and environmental concerns as incentive to balance energy portfolio (Koh & Lee 2011: 165)

2011 EV charging stations

2011 EMA and EDB co-chair the R&D Energy Innovation and Programme Office

2011 EMA and National Research Foundation energy resilience and sustainable growth programme (cost competition, energy efficiency, reduce carbon emissions, increase energy options)

2013 ground breaking for the first *LNG terminal* in Jurong Island (back up). Establishment of the Singapore *LNG Corporation (SLNG).* Commercial operations start in 7 May 2013

2014 LNG terminal official opening at SG$1.7 billion

2014 EMA lowers demand threshold for Commercial & Industrial consumers to choose supplier (contestable)

2014 7th Singapore Intl Energy Week. Announcement of S$20 million Energy Training Fund

February 2017 Budget announcement of deploying of carbon taxes

13th April 2017 LNG truck loading facility ready for operations at LNG Jurong Island 'The facility allows small quantities of LNG to be transported overland to just about any location where it may be needed. This may include industrial plants that could use natural gas for furnaces and burners but are not connected to the gas pipeline network, and locations in the port from where LNG may be delivered to ships for use as fuel' (SLNG).

Sources (fuels) & Transformation (power plants types/electricity supply)

SOURCES (2014):

- 95% Piped natural gas (NG) from Malaysia and Indonesia (shift to Liquefied Natural Gas (LNG) imported from across the world. Terminal opened 2013 in Jurong Island. See *Pavilion Energy Co* (Tamasek Portfolio) and *Pavilion Gas* (supplier, shipper, retailer)
- 5% Coal/peat, crude oil, petroleum and products 5%
- 15 MW peak solar installed capacity (e.g: 200 four room HDB flat requirements) as of 2014 but 'Solar Nova' plans up to 5% by 2020
- waste-to-energy (3% residual)

Plants' Systems burning oil and natural gas for electricity:

- Steam turbine 32%
- Combined cycle gas turbine 62%
- Open cycle gas turbine 4%
- Incineration 2%

Infrastructure: Power Generation System/Firms (public & private)

PUBLIC (GOVERNMENT-OWNED CORPORATION):
www.singaporepower.com.sg
- Ownership, transmission & distribution: *Singapore Power (SP Power:* energy utility company*;* owns, operates electricity and gas transmission and distribution business; owns operates underground distribution cooling system, Marina Bay new business district);
SP PowerAssets (owns the electricity transmission and distribution networks), *SP PowerGrid* (manages and maintain SP transmission and distribution networks), *PowerGas* (owns the gas transmission and distribution networks which include two onshore receiving facilities for natural gas from Sumatra and Malaysia, and approximately 3,400 km of underground gas pipelines and associated facilities), *Singapore District Cooling* (provides district cooling services to developments at the Marina Bay New Business District) – starting 2010
- Market Support Services Licensee (MSSL, only one): *SP Services Ltd* (application for utilities supply, billing, etc)

PRIVATE:
Fourteen generation licensed companies with individual threshold generation capacity (MW):
Senoko Energy 3,300
PowerSeraya 3,100
Tuas Power Generation 2,670
SembCorp Cogen 785
Island Power Company 800
Keppel Merlimau Cogen 1,400
ExxonMobil Asia Pacific 220
National Environment Agency 179.8 **(public)**
Shell Eastern Petroleum 60
Senoko Waste-to-Energy 55.4
Keppel Seghers
Tuas Wasteto-Energy Plant 24
Total 12,330 MW
Generation Licensees (as of 21 Feb 2017) (generate electricity for injection into the power grid. They offer to generate various quantities of electricity at their associated prices. All offers are then pooled in the wholesale market to match the demand for electricity).
Active generators are: Sembcorp Cogen Pte Ltd, National Environment Agency, Keppel Merlimau Cogen Pte Ltd, Senoko Waste-To-Energy Pte Ltd (in its capacity as Trustee of Senoko Trust),Tuas Power Generation Pte Ltd, Senoko Energy Pte Ltd, Shell Eastern Petroleum Pte Ltd, Keppel Seghers Tuas Waste-To-Energy Plant Pte Ltd (in its capacity as Trustee of Tuas DBOO Trust), ExxonMobil Asia Pacific Pte Ltd, PacificLight Power Pte Ltd, YTL PowerSeraya Pte Ltd, Tuaspring Pte Ltd, TP Utilities Pte Ltd, Singapore Refining Company Pte Ltd.
(ref: Energy Market Authority 2010: Introduction to the National Electricity Market Singapore: appendix 2 figure 10, p. 16-2 & 3)
Full retail competition aimed for 2018
- Natural Gas (for electricity) (importers, transporters, shippers and 7 retailers (i.e. *City Gas Pte Ltd, Green Energy Supply Pte Ltd*, etc)

Infrastructure Power Network System

***Power System Operator (PSO)*:** controls the dispatch of generation facilities, co-ordinates outages and power system emergency planning and directs the operation of the high-voltage transmission system.
The system operates on a frequency of 50 Hz, and consists of the following infrastructure:
- High voltage transmission system (HVTS) comprising a network of 400kV, 230kV and 66kV substations interconnected by underground cables. There are 101 substations: 3 of 400kV, 15 of 230kV and 83 of 66kV, served by 6,106 km of underground cables.
- Low voltage transmission (or distribution) system (LVTS) comprising a network of 22kV and 6.6kV substations interconnected by underground cables. There are 319 22/6.6kV substations, 4,566 22kV and 5,062 6.6kV substations, served by 15,710 km of underground cables.
Network losses for 2009 were reported to be 2.79%.

The Market (consumers, EMC, NEMS, PSO, market participants)

Wholesale Market (traders)

Retail Market (licensees)

Energy Market Company Pte Ltd operates Singapore's wholesale electricity market (rulemaking, compliance and dispute resolution). Connects those who make electricity (generators, transmission and distribution) and those who use it.

***National Electricity Market Singapore* (NEMS)** established and opened for trading . Allows prices to reflect supply and demand fundamentals (Chang 2007: 403, 405; National Energy Policy Report 2007; Doshi 2015: 170)

***Market players*:**
Consumers (classified as being either contestable or non-contestable depending on their level of electricity usage. Contestable consumers may choose to purchase electricity from a retailer or directly from the wholesale market or indirectly from the wholesale market through SP Services. Non-contestable consumers are supplied by SP Services; EMA, EMC, Power System Operator (PSO); Market Participants: generation licensees (private and public), wholesale market traders (private & public) and retail electricity licensees (private).

Wholesale Market Traders (companies, other than generators or retailers, that are licensed by the EMA to trade in the wholesale electricity market).

The current **wholesale market traders** are: Diamond Energy Managers Pte Ltd, Pfizer Asia Pacific Pte Ltd, MSD International GmbH (Singapore Branch), Banyan Utilities Pte Ltd, Green Power Asia Pte Ltd, Singapore LNG Corporation Pte Ltd, Glaxo Wellcome Manufacturing Pte Ltd - GlaxoSmithKline Biologicals, ECO Special Waste Management Pte Ltd, Red Dot Power Pte Ltd , CGNPC Solar-Biofuel Power (Singapore) Pte Ltd, Sunseap Leasing Pte Ltd, LYS Genco Beta Pte Ltd, Solar C&I Holdings Pte Ltd, Singapore District Cooling Pte Ltd, Nanyang Technological University, GreenSync Holdings Pte Ltd, Sun Electric Energy Assets, Air Liquide Singapore Private Limited.
Retail Electricity Licensees (retailers that sell electricity to contestable consumers are licensed by the EMA. Retailers that are registered as market participants purchase electricity directly from the wholesale market).
Active retailers are: Keppel Electric Pte Ltd, Sembcorp Power Pte Ltd, Senoko Energy Supply Pte Ltd, Seraya Energy Pte Ltd, Tuas Power Supply Pte Ltd, Diamond Energy Merchants Pte Ltd, PacificLight Energy Pte Ltd, Hyflux Energy Pte Ltd, Red Dot Power Pte Ltd, Buri Energy Pte Ltd, Sun Electric Power Pte Ltd, Sunseap Energy Pte Ltd, Best Electricity Supply Pte Ltd, I Switch Pte Ltd, Charis Electric Pte Ltd, Environmental Solutions (Asia) Pte Ltd.

89 % are domestic consumers but only consume 19% of electricity
1% are manufacturing consumers consuming 36% of electricity
10% are other industries but consume 45%

Institutional: Ministries & Agencies (public)

- *Ministry of Trade & Industry* (MIT)
- *Economic Development Board* (statutory board under MTI) Energy: related to oil (refining capacity, storage, liberalisation of electricity market). Clean Energy (EDB).
- Regulator: *Energy Market Authority (EMA)* under the Ministry of Trade and Industry (mandates objectives for *SP Power*); statutory board under the Ministry of Trade and Industry. Goals: ensure a reliable and secure energy supply, promote effective competition in the energy market and develop a dynamic energy sector in Singapore. Through our work, EMA seeks to forge a progressive energy landscape for sustained growth.
- Market Operator: *Energy Market Company Pte Ltd (EMC)* operates wholesale Singapore elect market
- Power System Operator (grid operator): *PSO* (maintain, forecast, coordinate, emergencies)
- Other Market Operators (transmission, generation and retail licensees) below

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Low Carbon Fuel Mix (supply side) Energy Efficiency (demand side), Mitigation GHG

Supply-side:

- From piped gas to electricity by Tramway Company, to oil. From Oil to Natural Gas and LNG
- to RE: 'In 2014, the Singapore government announced its commitment to have 350 MWp of solar energy by 2020, which is about 5 per cent of the projected 2020 peak electricity demand'. SolarNova programme and PVs floating systems in reservoirs

Demand-side:

Energy Efficiency Measures (2011 labelling, green buildings 80% by 2030, 2013 energy conservation)

Climate Mitigation:

- *Climate Action Plan 2016* Take Action Today (ch. 3 Reducing Carbon Emissions in Power Generation, p. 27-31); 2012 43% of GHG emissions from electricity generation).
- Measures of *Climate Action Plan* 2016 (power sector):
- fuel switch fuel oil to NG reduced Grid Emission Factor (GEF or CO_2 per unit of electricity) 0.4313 kg/CO_2/KWh (global average is 0.536 kg/CO_2/KWh
- efficient power generation technologies (Combined Cycle Gas Turbine, co and tri) **EMA oversees**
- - increase RE plus storage + smartgrids: 2015 60MWp (aims at 350 MWp by 2020) 'Solar Nova' strategy with OUB installing on waterworks/reservoirs- Building & Construction Authority, Energy Market Authority, Economic Development Board, National Environment Agency oversee
- Waste-to-Energy (from incinerators) about 2.5%
- Feasibility study on onshore nuclear return no-feasibility results

- R& D investment

Table 2 - Kota Kinabalu's Energy Legacies and Transitions (electricity):

Legislative; Historical-geopolitical; Sources & Transformation (fuels & power plants); Infrastructure (generation, transmission & distribution network); Market (wholesale & retail); Institutional (Ministries & Agencies), Low carbon transitions (Supply side- fuel mix, Demand side- efficiency; climate mitigation – GHG reduction). (Sources: Ansari 2011; Sabah Electricity Supply Industry Outlook 2014; Energy Commission http://www.st.gov.my/index.php/en/; History SG; Sabah Museum http://www.museum.sabah.gov.my/?q=content/our-history; History of Sabah https://www.sabah.com/v/history/; State of Sabah Annual Report 1963; Sovacool & Drupady 2011a&b; McNish, Kammen & Gutierrez 2010; Holdsworth & Munn 2012; Rutter 1922; National Energy (Tenaga Nasional) https://www.tnb.com.my/about-tnb/history)

DIMENSIONS	LEGACIES & TRANSITIONS
Legislation (national and Sabah State) (common law jurisdiction)	1949 *Electricity Supply Act* (national) enacted (Ansari 2011: 198) to provide for the regulation of the electricity supply industry, the supply of electricity at reasonable prices, the licensing of any electrical installation, the control of any electrical installation, plants and equipment with respect to matters relating to the safety of persons and the efficient use of electricity and for purposes connected therewith. 1999 *Electricity Act Supply 1st Amendment* 2001 *Electricity Act Supply 2nd Amendment* 2001 *Energy Commission Act* to provide for the establishment of the *Energy Commission* with powers to regulate the energy supply activities in Malaysia and to enforce the energy supply laws and for matters connected therewith. 2010 *Energy Commission Amendment Act* 2011 *Sabah and Labuan Grid Code* 'guidelines, criteria and procedures to permit the equitable management of the electricity sector in Sabah and Labuan, particularly in Grid operation and management, taking into account a wide range of operational conditions likely to be encountered under both normal and exceptional circumstances' (Sabah Electricity Outlook 2014: 14; Fig 6). 2015 *Electricity Supply (Amendment Act) 2015 [A1501]*
Historical-Geopolitical	***Colonial Times (1846-1945)*** 1846 first British settlement in North Borneo. John Brook made Governor General of Labuan (off KK) by Sultan of Brunei (State of Sabah Annual Report 1963: 214-215) 1865 The Sultan of Brunei cedes the West Coast of Sabah to the American Trading Company (Torrey) (ibid.) 1875 concessions formerly given to the American Trading Company are acquired by Baron von Overbeck (Austrian-Hungarian Empire Consul General in HK) (ibid.; Holdsworth & Munn 2012: 348-349) 1877 Baron Overbeck secures backing of Alfred Dent formerly with Dent Bros. in Shanghai and HK w the Sultan of Brunei and Pengiran Temenggong ceding possessions in Sabah to Baron von Overbeck and Alfred Dent. (State of Sabah Annual Report 1963: 214; Rutter 1922 (ed. of 2008): 119) 1877 Api Api (later to be named Jesselton and Kota Kinabalu) settled by the British 1878 Baron von Overbeck granted land and ruling power over Sabah and Gaya at GBP1,000 (Rutter 1922: 121)

1881 Overbeck and associates establish *British North Borneo Chartered Company* (BNBC) to trade in rubber, rattan, honey and wax. Incorporated by Royal Charter and authorised to acquire cessions from the British North Borneo Provisional Association (State of Sabah Annual Report 1963: 214). Formal takeover 1882.

1888 Sabah becomes a British Protectorate (ibid. 215)

1899 Api Api renamed Jesselton (after Mr Jessel, executive of the BNCB), Sabah renamed British North Borneo

1894 first power generator for mining in Rawang (Selangor- Peninsular Malaysia) installed -national, private. First Malaysian street lights lit (gas) in Selangor- Peninsular Malaysia

1895 Kuala Lumpur (Peninsula) railway station lit- Peninsula

1900 first power station opens in Raub, Selangor- Peninsula (by *Raub Australian Gold Mining Company*)- national, private (TNB history)

1905 Railway extended to Jesselton and Tenom (North Borneo)

1906 First export of coal from Silimpopon mines (North Borneo)

1910 electricity first arrives in Jesselton (North Boneo) (TNB History)

1922 utility-scale electricity starts to be provided by the *Jesselton Ice & Power Company Ltd* – private. The *North Borneo Electric Board* is established (see Rutter 1922: 147 'at the present moment the position of the Chartered Company is stronger than it has ever been before. Its new line of action will be watched closely by all who have the country's interests at heart. There is still much to be done. The coast needs better lighting….')

1942 Japanese occupation of British North Borneo

1945 Destruction of Jesselton by Allied forces at end of WWII

Political Change (1946-1962)

1946 Transfer of administration of British North Borneo from BNBC to the British Crown

1946 End of British Military Administration. North Borneo (including Labuan) becomes a Crown Colony. Malayan Union formed (State of Sabah Annual Report 1963: 216);

1946 *Electricity Department* established- national (TNB History)

1948 Federation of Malaya inaugurated (9 Peninsular Malay states + Straits Settlements of Singapore, Penang and Malacca)

1949 *Electricity Supply Act* enacted -national (Ansari)

1949 *Central Electricity Board* established- electricity nationalised (takes ownership of 34 private power stations, a generation capacity of 39.88 MW, 45,495 consumers, and 2,466 staff- exclusively foreign engineers) (TNB History)

1954-1957 training of local engineers at the *British Electricity Authority* (UK) (TNB History)

1955 919 million kilowatt hour (kWh) electricity sold (Tang & Tan 1013: 298)- national

31 Aug 1957 Independence of Federation of Malaya (but not North Borneo until 1963 under Federation of Malaysia)
1958 the proposal for the Closer Association between Sabah, Sarawak and Brunei was mooted

Merger, Nation Building, Regionalisation (1963- present)

1963 establishment of the Federation of Malaysia
1963 North Borneo ceases to be a Crown Colony and becomes the State of Sabah within the Independent Federation of Malaysia. Jesselton renamed Kota Kinabalu, [British] North Borneo renamed Sabah

1965 *Central Electricity Board* (CEB) renamed *National Electricity Board* (NEB) – national (Tang & Tan 2013: 298)

1965 *National Grid* project advanced (generation, transmission, distribution and consumption) - national. [The National Grid is interconnected to the transmission network of the **Electricity Generating Authority of Thailand** (EGAT) through a 117 MVA, 132 kV Single Circuit Line, which has since been upgraded to a HVCD line. The Grid is connected to **Singapore Power Limited (SP)** through a capacity of 250 MVA – 230 kV transmission lines and submarine cables. These significant connections provided us the first evidence of rudimentary ASEAN grid on the map] (TNB History)

1979 *National Energy Policy* promulgated – national

1981 *Four-Fuel Diversification* policy promulgated (transition of oil substitution to oil, natural gas, hydropower, and coal) (Jaffar et al 2003: 1061; i.e.: natural gas from 1.2% 1980 to 71.1%. 2005: NG 70%, oil 5%. 2007: 28% coal; expected to continue to grow till 2035 (Tang & Tan 2013: 298).

1984 *National Electricity Board* installed capacity more than doubled to 1,379.2 MW exceeding peak demand. Its consumer base numbered 1,965,162 with revenue of approximately RM2.2 billion and fixed assets close to RM5.5 billion, as well as 24,882 staff (TNB History)

1984 *Lektric Sabah Act* [Act 278] *Sabah Electric Board* was renamed as the *Lembaga Lektric Sabah* (LLS)

1989 21,889 million kWh sold (Tang & Tan 2013: 298) -national

1990 *Electricity Supply Act 1st Amendment* (of 1949)- national

1990 *National Energy Corporation* (*Tenaga Nasional Berhad)* established to replace the *National Electricity Board (NEB)* – national, **privatization** (largest in Southeast Asia, supplies peninsular Malaysia and Sabah too)

1998 the *Sabah Electricity Board* established in 1984, was privatized becoming *Sabah Electricity Sdn Bhd* **(SESB private, limited) (supply, transmission, distribution)**

2001 Electri*city Supply Act 2nd Amendment* –national

2001 *Fifth-Fuel Diversification* policy promulgated to promote more RE (Sovacool & Drupady 2011: 7244, 7246).

2001 *Small Renewable Energy Power (SREP) Program* advanced to establish 500 MW of biomass, biogas, municipal solid waste, solar PVs, and mini-hydroelectric (2001-2005); extended till 2010- national

2002 *Malaysia Energy Commission* established- national

2007 89,000 million kWh sold (Tang & Tan 2013: 298)

2009 *Ministry of Energy, Green Technology and Water* established- national

2014 & 2015 Sabah Electricity Supply Industry Outlook (see notes below)

Sources (fuel mix) & Transformation (types of power plants) (Electricity Supply) Sabah & KK

Sources (fuel mix):
-Natural gas reserves: 67% (GWh) East Coast of Peninsular Malaysia (for domestic consumption); Sarawak (for LNG exports)
MFO (marine fuel oi) & diesel: 21% (GWh)
Biomass: 4%
Hydro: 8%
Transformation (plants)- combined cycle, diesel, hydro:
See list of **30 power plants in Sabah** (Sabah Electricity Supply Industry Outlook 2014: Table 4, pp. 20-21)

Infrastructure (power generation system/ firms) Sabah & KK

See list of 30 power plants/owners/year commissioned/retirement date in (Sabah Electricity Supply Industry Outlook 2014: Table 4, pp. 20-21 & 2015)

Infrastructure (power network system)	See electricity coverage in Sabah 2013 Ref. Fig 4 p. 11 Sabah Electricity Supply Industry Outlook 2014 & 2015
The Retail Market	None
Institutional/ Ministries & Agencies (public) Ref. Fig 5 p. 13 Sabah Electricity Supply Industry Outlook 2014	*Cabinet* (oversees the industry) -**national** *Ministry of Energy, Green Technology and Water* (facilities and regulates the growth of electricity supply industry; approves electricity tariffs/ licenses issuance; coordinates implementation of energy policies)- **national** *Economic Planning Unit, Prime Minister's Department* (overall planning and formulation of macro-economic policies; approves gas tariffs and gas supply license issuance)- **national** PETRONAS *State Economic Planning Unit* – **state** *(*policy and strategy for socio-economic development) *Public Private Partnership Unit* (legislate public-private cooperation partnership policies and strategies; Plan, administer, control and evaluate the implementation of PPP programmes) *Energy Commission (Suruhanjaya Tenaga)* – consumer relations-**national/ regional offices** (2002) *Malaysia Green Technology Corporation* - Electricity and Pipe Gas Utilities; TNB (national), SESB (Sabah), IPP's**- national** *Sustainable Energy Development Authority* - Generation, Transmission, Distribution; Other Licensees- **national**
Low Carbon Transitions (fuel mix (supply side), energy efficiency (demand side), GHG mitigation)	Sovacool & Drupady 2011a: 7249-7252 on technical, economic & financial, political & institutional obstacles to **RE** transitions. Did interviews 2010-2011 (none in Kota Kinabalu or Sabah state) Sovacool & Drupady 2011b. Innovation in the Malaysian **Waste-to-Energy** Sector: Applications with Global Potential. [Sabah Municipal Solid- Waste (1,174 tonnes per day collected, 20 operating dumping sites, 1 closed dumping site). [Sabah Palm Oil Mills 30]. Potential for investment in waste-to-energy in countries with tropical climates. *Clean Energy Options for Sabah* (McNish, Kammen & Gutierrez 2010)

Table 3 - Transitions Research: urban energy transitions (electricity):

(Sources: Rutherford & Coutard 2014; Moss & Francesch-Huidobro 2016)

STRAND OF RESEARCH	FOCUS	REPRESENTATIVE RESEARCH	ENERGY	URBAN	TRANSITIONS
Cities with large socio-technical systems (electricity generation, T&D)	Supply-side: large, centralized infrastructure systems **(i.e. Singapore/ Kota Kinabalu electricity)**	Hughes (1983); Summerton (1994); Coutard (1999)	Infrastructure deployment and management	Territories & administrative units (city-states, capital cities of federal states; special administrative regions, etc) within national infrastructure systems **(i.e. Singapore/ Kota Kinabalu, Hong Kong, Macau)**	Changes to socio-technical component of systems overtime (historical legacies of electricity, water, waste systems)
Urban consequences of policy reforms	Political economies: 'splintering urbanism' outcome of neoliberal reform	Guy et al. (1997); Graham & Marvin (2011); Erdogdu (2014); Moss & Francesch-Huidobro (2016)	Sector subject to reforms of privatization, liberalization, etc **(i.e. Singapore, Kota Kinabalu electricity)**	'Multiplex', multi-actor urbanism, socio-spatial differentiation within and between cities	Shifts from public to private management, from monopoly to market, sectoral unbundling, resulting urban change (fragmentation) **(HK/ Singapore/ Kota Kinabalu electricity)**
Low carbon transitions in cities	Urban governing/ politics of carbon	Bulkeley et al. (2011); Hodson & Marvin (2009b); Jonas et al. (2011); Mai & Francesch-Huidobro (2012; 2014, 2015); Andrews-Speed (2012)	Energy infrastructure as an instrument of low carbon policy **China, (HK, Shenzhen, Guangzhou, Macau); Kota Kinabalu**	Cities as urban policy actors within multilevel climate governance regimes	Socio-technical changes (electricity transitions) through which low carbon is rolled out
Community energy, post-oil communities	Local energy systems and communities constructed around low carbon energy development and lifestyles	Walker et al. (2007); North et al. (2010); Bailey et al. (2010)	Energy as a tool for local autonomy, development of alternatives (Singapore, KK, Macau, HK)	Bottom-up collective organizations	Local, inclusive, democratic socio-technical change

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