ADBI Working Paper Series

Development Trajectories, Emission Profile, and Policy Actions: Singapore

Tilak K. Doshi and
Neil Sebastian D'Souza

No. 424
May 2013

Asian Development Bank Institute

Tilak K. Doshi and Neil Sebastian D'Souza are chief economist & principal fellow and fellow, respectively, at the Energy Studies Institute, National University of Singapore.

This paper was prepared as a background paper for the second workshop of the Asian Development Bank (ADB)/Asian Development Bank Institute (ADBI) Flagship Study, Climate Change and Green Asia.

Suggested citation:

Doshi, T. K. and N. Sebastian D'Souza. 2013. Development Trajectories, Emission Profile, and Policy Actions: Singapore. ADBI Working Paper 424. Tokyo: Asian Development Bank Institute. Available: http://www.adbi.org/working-paper/2013/05/30/5727.emission.profile.policy.actions.singapore/

Please contact the authors for information about this paper.

Email: esitkd@nus.edu.sg

Asian Development Bank Institute
Kasumigaseki Building 8F
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500
Fax: +81-3-3593-5571
URL: www.adbi.org
E-mail: info@adbi.org

Abstract

Singapore is the most industrialized and urbanized country in Southeast Asia and is totally dependent on oil and natural gas imports to satisfy its energy needs. Its national energy policy framework seeks to find a balance between maintaining Singapore's competitiveness, improving energy security, and enhancing environmental sustainability. In this paper, we discuss where Singapore stands with regard to its energy consumption and CO_2 emissions, its energy policies to date, and those that will be implemented in the near future. We use a Singapore Energy-Economy model based on the Long Range Energy Alternatives Planning (LEAP) framework to assess the impact of energy efficiency and conservation policies on Singapore's energy intensity and CO_2 emissions through to 2050. We also discuss the challenges that Singapore will face on account of climate change policies affecting key sectors of its economy. We find that Singapore has achieved much progress over the past four decades. Prudent energy policies and a changing economic structure have led to more efficient use of energy as evidenced by Singapore's declining energy intensity. There is considerable uncertainty as to the evolution of a global agreement on CO_2 emissions reductions and the exact nature of the commitments that countries will be held to. Given Singapore's status as a preeminent shipping center and global oil refining center, CO_2 emissions policies that will affect these industries will impact Singapore's economy if issues of "carbon leakage" are not adequately addressed.

JEL Classification: O53, Q38, Q45, Q48

Contents

1. INTRODUCTION

Singapore is the most industrialized and urbanized country in Southeast Asia, rapidly transitioning from a gross domestic product (GDP) per capita of US$428 in 1960 to US$36,537 in 2009.[1] It is a small country that consists of 63 islands (including the main island, commonly referred to as Singapore Island). Reclamation of land has resulted in the expansion of Singapore's land area to approximately 710.3 km^2 in 2009 from 581.5 km^2 in the 1960s.[2]

Highly urbanized and with an estimated population of 5.08 million in 2009 (which grew by over 3% from 2006 to 2010), Singapore's population density stands at approximately 7,100 persons/km^2, which makes it one of the most densely populated countries in the world.[3] Despite its population and land constraints, Singapore, a vibrant free-market economy, has leveraged its strategic location and has become one of the world's busiest shipping ports, an important petroleum hub, a major supplier of oil and gas equipment in South-East Asia, and an emerging leader in the biomedical industry.[4] With regard to energy, Singapore is totally dependent on oil and natural gas imports to satisfy its energy needs.

Given its unique national circumstances, Singapore's national energy policy framework seeks to find a balance between maintaining Singapore's competitiveness, improving energy security, and enhancing environmental sustainability.[5] In this paper, we use a Singapore Energy-Economy Model based on the Long Range Energy Alternatives Planning (LEAP) framework to assess the impact of energy efficiency and conservation policies on Singapore's energy intensity and CO_2 emissions through to 2050. We then discuss where Singapore stands with regard to its energy consumption and CO_2 emissions and the energy policies that have been implemented thus far or those that will be implemented in the near future. Next, we consider the other environmental policies that Singapore has instituted in order to grow sustainably. Finally, we consider the challenges that Singapore will face on account of climate change policies affecting key sectors of its economy and its key strategies of "greening" its growth trajectory.

2. THE LEAP MODEL

In order to determine the energy growth trajectories we develop an energy-economy model of Singapore in LEAP. Here we give a brief overview of the model. A flow chart tracking the conversion of primary fuels to electricity or refined products for final demand is illustrated in Figure 1. Coal use is included in the chart even though its role is insignificant in Singapore, as it is recorded (at a minimal usage) in the International Energy Agency's (IEA) energy balance table for Singapore.[6] We have also included solar power as a source for electricity generation

---

[1] Department of Statistics Singapore, accessed at http://www.singstat.gov.sg/stats/themes/economy/hist/gdp.html#top.

[2] With continuing land reclamation, land area in Singapore might increase by about another 100 km^2 by 2030 as posited by Housing and Development Board (HDB), Jurong Town Corporation (JTC), and PSA Corporation, which are the principal land reclamation agencies. This is, however, dependent on two considerations: the increasing costs of further reclamations (due to reclamation projects moving further offshore) and the need to pursue Singapore's maritime objectives.

[3] Department of Statistics Singapore, accessed at http://www.singstat.gov.sg/stats/keyind.html.

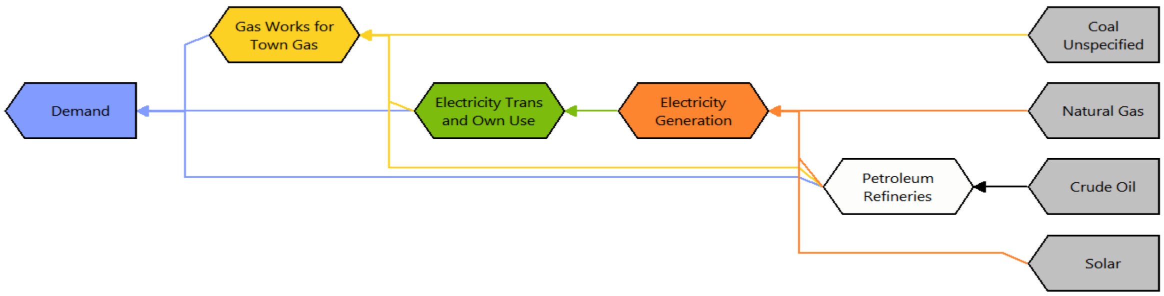
[4] Asia Pacific Energy Research Center 2009.

[5] Ministry of Trade and Industry Singapore 2007.

[6] International Energy Agency 2009.

despite its current marginal status to allow for the possibility of some level of penetration of solar power into Singapore's fuel mix in the long run. [7]

Figure 1: Singapore's Energy System in the LEAP Model

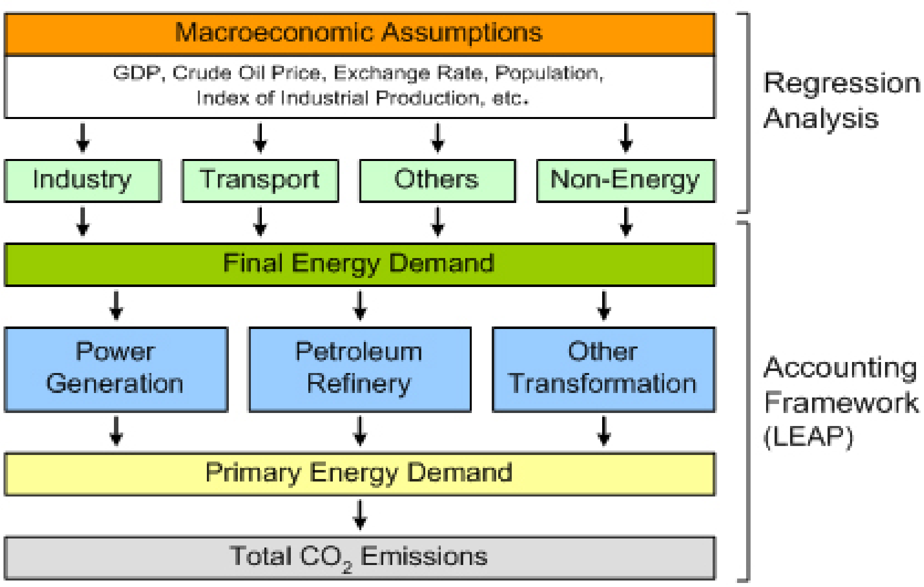


LEAP = Long Range Energy Alternatives Planning.

Source: Singapore Energy-Economy Model in LEAP.

The model projects final energy demands based on exogenous assumptions of economic growth, population growth, etc., and it calculates the corresponding primary energy demand as illustrated in Figure 2. Correlations among energy use and macroeconomic parameters are derived by time series regression analysis of historical data. Total final energy (TFE) demand covers energy demands in four end-use sectors—industry, transport, others, and non-energy use. The "others" sector includes residential, commercial, public services, and agriculture sectors. The "non-energy use" sector covers the consumption of petroleum products as raw materials, such as the use of naphtha as feedstock in the petrochemical industry and the use of lubricants in automobiles. In the model, Singapore's GDP is projected to grow at 3.5% per annum from 2007 to 2030 and its population at 0.8% per annum over the same period.

Figure 2: Structure of Singapore Energy-Economy-Model



LEAP = Long Range Energy Alternatives Planning.

Source: Singapore Energy-Economy Model in LEAP.

---

[7] *ESI Bulletin 2009.* 2(2). Development of renewable energy in Singapore*.*

3. SCENARIOS

Two scenarios were developed to assess the energy use trajectories in light of energy efficiency and conservation policies in Singapore. The "Business As Usual" (BAU) scenario projects energy use and CO_2 emissions taking into consideration energy policies implemented up until end-2010, while the "Alternative Policy Scenario" (APS) projects energy use and CO_2 emissions in a case where there is higher uptake of energy efficiency and conservation policies. In this case, demand management policies are assumed to be more effective, as human behavior is more "elastic" or responsive to such policies.

Table 1 summarizes assumptions in these two scenarios. We compare the two scenarios with a baseline scenario (BAS), which projects the hypothetical energy use and CO_2 emissions given the implementation of energy efficiency policies up until end-2007. In 2007, the overall thermal efficiency of gas-fired power plants was 41%. According to International Energy Agency (IEA), the average thermal efficiency of combined cycle gas turbine (CCGT) generators was 57% and that of conventional power plants was 41.1%.[8] We assume that both the BAU and APS scenarios will see improvements in the efficiencies of gas and thermal power plants. By 2030, gas-fired turbines attain 45% efficiency, while thermal power plants will have attained an efficiency of approximately 41%. Further improvements in the following decade are assumed to occur whereby by 2050, gas-fired turbines attain 49% efficiency, while thermal power plants attain an efficiency of approximately 42%. In both scenarios, the share of electricity contributed by solar power reaches 5% by 2050.

Another assumption is that gasoline consumption is linearly proportional to Singapore's car population. The Land Transport Authority (LTA) has capped the growth rate of vehicles at 1.5% from 2009 to 2011. Thereafter, we assume that the annual growth rate is as per historical levels. In a nutshell, gasoline use grows by 2.2% in BAS and by 1.9% in both BAU and APS. For diesel, the annual growth rate is assumed to be 3% from 2009 to 2050. In both scenarios, diesel use grows by 2.8% per annum.

[8] International Energy Agency 2010.

Table 1: Assumptions in the BAS, BAU, and APS Scenarios

Sector	Energy Policies	Policy Interpretation and Quantification	Assumptions in BAS Scenario	Assumptions in BAU Scenario	Assumptions in APS Scenario
Power generation	Competitive electricity market	With reference to IEA's report on projected costs of generating electricity, the average thermal efficiency of CCGT generators reviewed is 57% and that of conventional power plants is 41.1%. There were a few OCGT generators in Singapore in 2007 and the overall thermal efficiency of gas fired power plants was 41% in 2007. We assume existing OCGT power plants are replaced by CCGT generators and all new gas fired power plants commissioned from 2007 to 2030 are CCGT generators. We also assume more efficient fuel oil-fired power plants are commissioned to meet the electricity demand in that period. Quantitatively, the overall efficiency of gas-fired power will increase gradually and reach 45% in 2030 and 49% in 2050. The overall thermal efficiency of fuel oil fired power plants will increase marginally and achieve 41% in 2030 and 42% in 2050.	Efficiency of gas-fired power plant remains at 41% Efficiency of thermal power plant remains constant at 39%.	Efficiency of gas-fired power plant increases from 41% in 2007 to 45% in 2030 and to 49% in 2050. Efficiency of thermal power plant increases from 39% in 2007 to 41% in 2030 and to 42% in 2050.	
	Promotion of renewable energies	We assume distributed building integrated solar photovoltaic (BIPV) systems will be deployed in Singapore. Because of solar PV's intermittency, we cap the share of solar PV in electricity generation at 5%. The share of solar PV in electricity generation increases gradually from 0% in 2007 to 5% in 2030 and this share is maintained until 2050.	No renewable energy.	Solar PV's share grows to 5% in 2030 and this share is maintained until 2050.	
Transport	VQS	Vehicle fuel consumption is equal to the product of car population, annual mileage and average fuel efficiency of cars. We assume the annual mileage and car fuel efficiency are steady. Thus, gasoline consumption is linearly proportional to the car population. According the IEA's energy use data, the use of gasoline in Singapore in 2008 was 1.2% less than that in 2007. Quantitatively, the annual growth rate of gasoline use in 2008 is -1.2%. From 2009 to 2011, the annual growth rate is 1.5%, aligning with the COE quota. From 2012 to 2050, the annual grow rate is 2.2%, back to the baseline level.	Gasoline use grows at a CAGR of 2.2%.	Gasoline use grows at a CAGR of 1.9% in 2007–2050.	
	VQS	The use of diesel in 2008 is also 1.2% less than the 2007 level. In addition to diesel car population, we assume the annual mileage will increase but a lower growth rate than that in the BL scenario. Quantitatively, the annual growth rate of diesel use in 2008 is -1.2%. From 2009 to 2050, the annual growth rate is assumed to be 3%.	Diesel use grows at a CAGR of 3%.	Diesel use grows at a CAGR of 2.8% in 2007–2050.	
Residential	Energy Labeling Scheme "10% Energy Challenge" campaign	The energy labeling scheme promotes adoption of fuel efficiency appliances. The 10% Energy Challenge Partners also offer energy efficient appliances with periodic discounts. We assume the electricity saving potential is 2.5–7.5% from the baseline from 2010 to 2050.	Electricity use grows at a CAGR of 3.4%.	2.5% reduction of electricity use from the baseline's in 2050.	7.5% reduction of electricity use from the baseline's in 2050.

Sector	Energy Policies	Policy Interpretation and Quantification	Assumptions in BAS Scenario	Assumptions in BAU Scenario	Assumptions in APS Scenario
Commercial	BCA Green Mark Scheme	In 2001, the Green Energy Management (GEM) at Grand Hyatt Singapore demonstrated a reduction of 60% in electricity consumption. We assume the energy saving potentials increase from 0% in 2010 to 10% and 20% in 2030 (from the baseline) and to 15% and 25% in 2050 (from the baseline) in the two scenarios.	Electricity use grows at a CAGR of 2.7%.	10% reduction of electricity use from the baseline's in 2030. 15% reduction of electricity use from the baseline's in 2050.	20% reduction of electricity use from the baseline's in 2030. 25% reduction of electricity use from the baseline's in 2050.
Industry	EENP Program	With reference to IEA's Energy Technology Transitions for Industry 2009, the application of best available technology (BAT) could reduce energy use in the industry sector by 13%–29%. We assume the energy saving potentials increase from 0% in 2010 to 5% and 10% in 2030 (from the baseline) to 10% and 15% in 2050 (from the baseline) in the two scenarios.	Total energy use grows at a CAGR of 3.4%.	5% reduction of energy use in 2030. 10% reduction of energy use in 2050.	10% reduction of energy use in 2030. 15% reduction of energy use in 2050.

Note: BAS = Baseline, BAU = Business as Usual, APS = Alternative Policy Scenario, as defined in Section 3.

Source: Authors.

Between the two scenarios, however, the growth of electricity in the residential, commercial, and industry sectors differ. In the BAU case, there is a 2.5% reduction in electricity use in the residential sector relative to the BAS case, while in the APS case, there is a 7.5% reduction, to reflect the possible differences in the effectiveness of the labeling scheme and the "Energy Challenge" campaign.[9]

In 2001, Green Energy Management (GEM) demonstrated a reduction of 60% in electricity consumption.[10] In the commercial sector, given our understanding of the vintage of building stock in Singapore, we assume a reduction of electricity use by 15% relative to the BAS case in the BAU scenario, and by 25% in the APS in 2050. With reference to IEA's Energy Technology Transitions for Industry 2009,[11] the application of Best Available Technology (BAT) could reduce energy use in the industry sector by 13%–29%. Therefore, the energy saving potential in the industry sector is assumed to be 5% and 10% of the baseline's value in 2030 in the BAU and APS scenarios, respectively, and 10% and 15% of the baseline's value in 2050 in the BAU and APS scenarios, respectively.

4. RESULTS

The results of the model in terms of total final energy (TFE) demand under the BAS, BAU, and APS scenarios are shown in Figure 3. In the BAS scenario, total final energy (TFE) demand grows at 2.9% per annum TFE demand grows by 2.74% under the BAU scenario, and by 2.71% under the APS. Figure 3 also shows final energy demands for the *industry*, *transport,* and *others* sectors, as well as the TFE demand for the country.[12]

As expected, final energy demand for each of these sectors and for the economy-wide total are highest for the BAS scenario where Singapore's energy policies up until end 2007 are assumed to be implemented. The final energy demand for the *industry* and *others* sectors are lowest under the APS. In the two policy scenarios, the Energy Labeling Scheme, the EENP program, and BCA Green Mark Scheme retard the growth of energy use in the *industry* and *others* (which includes commercial and residential) sectors relative to the BAS scenario. The VQS reduces energy use in the *transport* sector.

---

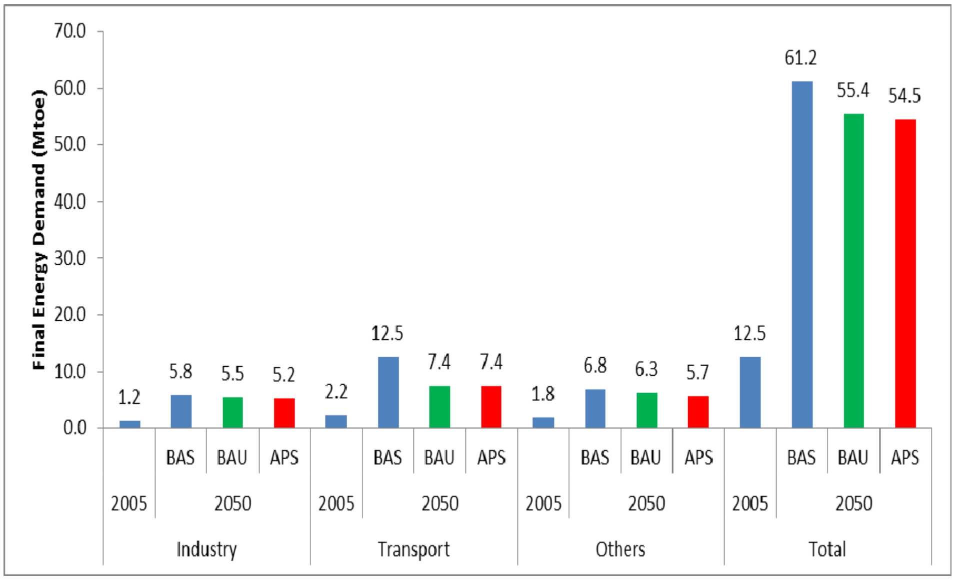
[9] 10% Energy Challenge by Energy Efficiency Programme Office, accessed at http://www.e2singapore.gov.sg/energy-challenge.html.

[10] National Energy Efficiency Committee. 2008. Case study: Green Energy Management at Grand Hyatt Singapore.

[11] International Energy Agency 2009.

[12] Figure 3 does not show final energy demand for the *non-energy use* sector (primarily petrochemicals) which is the same across the BAS, BAU scenario, and APS. It should be noted that the very high level of final energy demand for the *non-energy use* sector, as shown in IEA's energy balance table for Singapore, probably reflects the fact that it includes the energy demand for exported petrochemicals as well. At 7.4 Mtoe in 2005, final energy demand for the *non-energy use* sector was larger than that for *industry*, *transport* and *others* sectors. The next largest final energy demand was for the *transport* sector, at 2.2 Mtoe.

Figure 3: Final Energy Demand in 2050

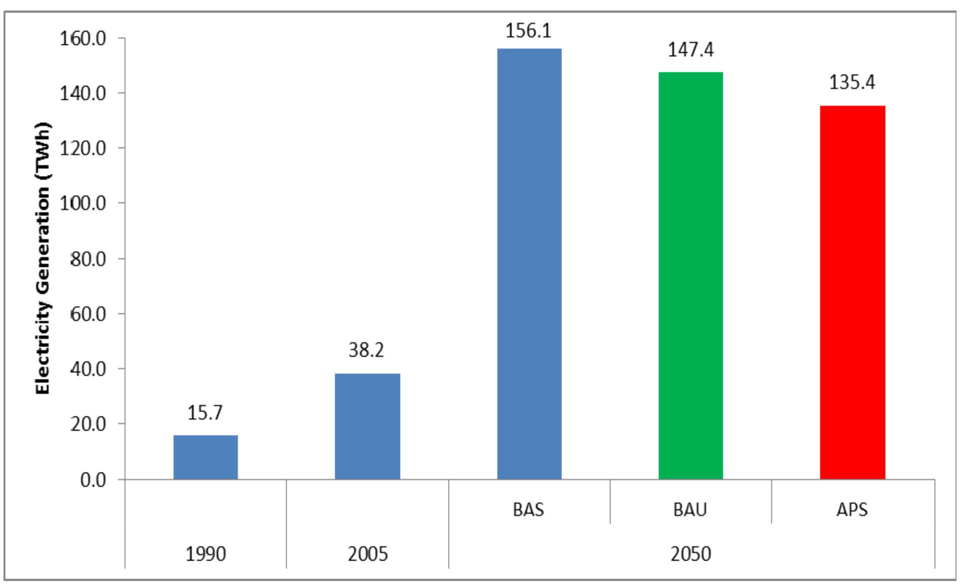


Note: BAS = Baseline, BAU = Business as Usual, APS = Alternative Policy Scenario, as defined in Section 3.

Source: Singapore Energy-Economy Model in LEAP.

Figure 4 shows the electricity generated in 2050 across the three scenarios. In the BAS, total electricity generated increases from 38.2 TWh in 2005 to 156.1 TWh by 2050. In contrast, under the BAU scenario, total electricity generated in 2030 is 147.4 TWh, while in the APS, it is 135.4 TWh. In growth terms, the APS has electricity generation growing at 2.3% per annum, while in the BAU scenario, the rate is 2.5% p.a., which is below the 2.6% per annum level for the BAS case.

Figure 4: Electricity Generation in 2050

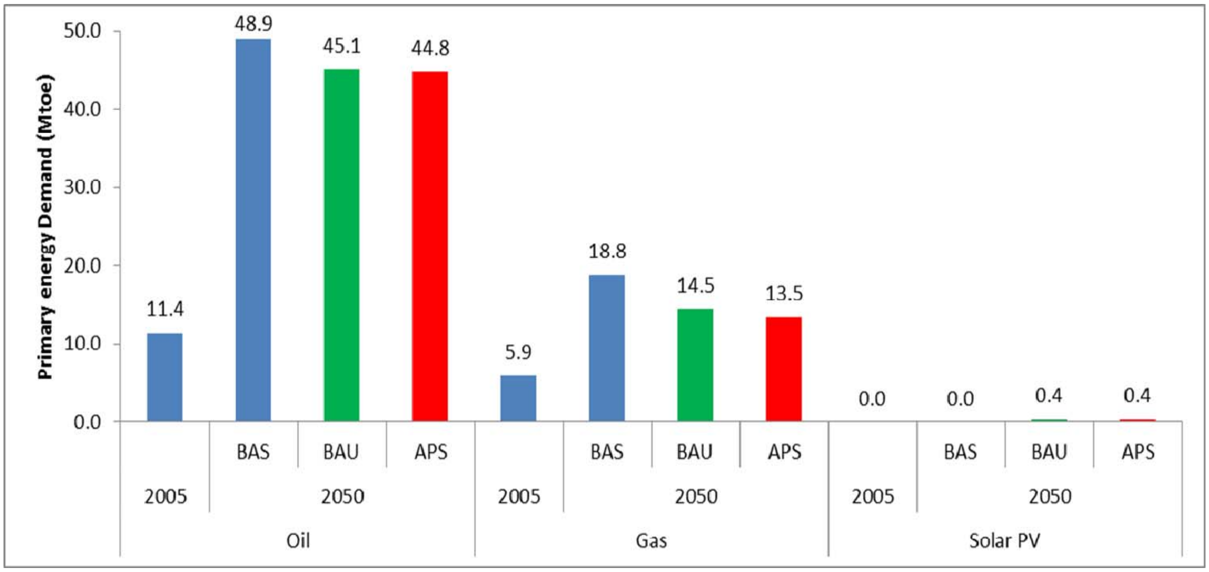


Note: BAS = Baseline, BAU = Business as Usual, APS = Alternative Policy Scenario, as defined in Section 3.

Source: Singapore Energy-Economy Model in LEAP.

In Figure 5, the results for the three scenarios are reported for primary energy demand by fuel in 2050. The use of oil in the BAS increases to 48.9 Mtoe in 2050, from 11.4 Mtoe in 2005. This compares with a reduction in the use of oil under the two policy scenarios. The difference in oil use in 2030 between the APS and BAU scenario is relatively insignificant, at only 0.3 Mtoe, reflecting the limited impact that labeling, building codes, and the EENP program is likely to have on oil use. The use of natural gas in the BAS increases to 18.8 Mtoe by 2050 from 5.9 Mtoe in 2005. This compares with 14.5 Mtoe of natural gas used in the BAU scenario and 13.5 Mtoe in the APS. There is a relatively small contribution by solar power in the BAU and APS case, at 0.4 Mtoe in 2050.

Figure 5: Primary Energy Demand by Fuel Type in 2050

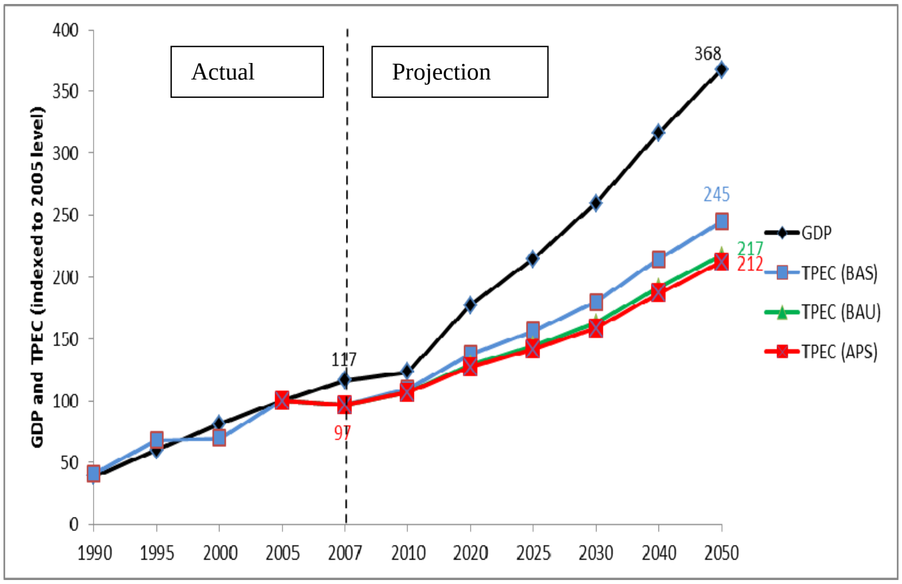


Note: BAS = Baseline, BAU = Business as Usual, APS = Alternative Policy Scenario, as defined in Section 3.

Source: Singapore Energy-Economy Model in LEAP.

Figure 6 shows the growth trajectories for GDP (which is the same across scenarios) and total primary energy (TPE) demand across the three scenarios (GDP and TPE are normalized to 100 in 2005). As seen in Figure 6, the BAU and APS scenarios have a lower growth trajectory in TPE demand relative to the BAS scenario. However, there is relatively little difference in TPE demand between these two policy scenarios.

Figure 6: Total Primary Energy Demands in 2050



Note: TPEC = Total Primary Energy Consumption; BAS = Baseline, BAU = Business as Usual, APS = Alternative Policy Scenario, as defined in Section 3.

Source: Singapore Energy-Economy Model in LEAP.

Singapore's energy intensity[13] improved by 15% between 1990 and 2005 due to the adoption of better technology in power generation and the more productive use of energy in other sectors.[14] Figure 7 shows the energy intensity[15] attained in the three scenarios as well as energy intensity targets announced in Singapore's Sustainable Development Blueprint (2009).[16] As can be seen, Singapore fails to meet its target trajectory for energy intensity in the BAS case from 2025 onwards. In contrast, when the energy policies are instituted, Singapore achieves lower energy intensity trajectories than its target trajectory represented by the dotted line (up until 2030) under both the BAU and APS scenarios.

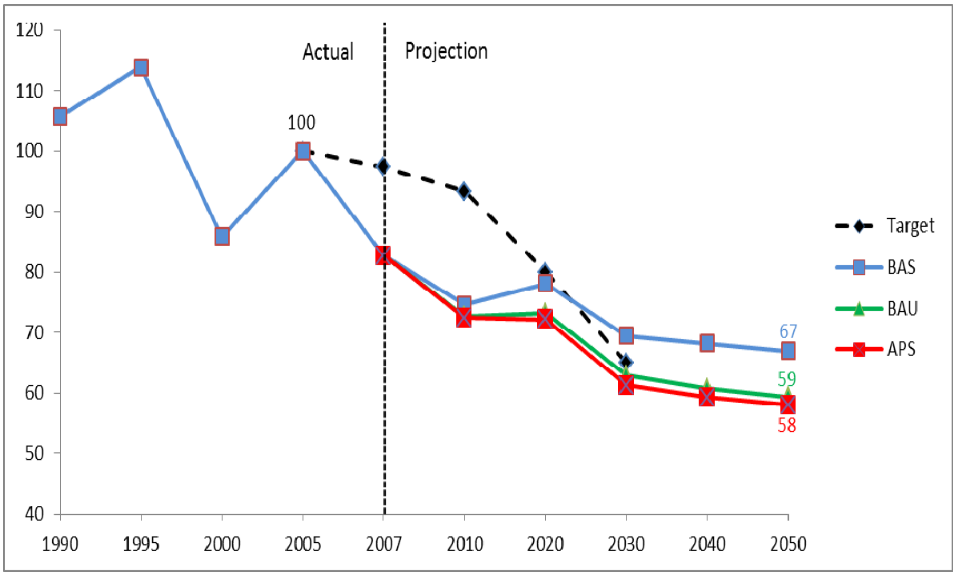
[13] On an economy-wide level, energy consumption per dollar gross domestic product ($GDP), or energy intensity, is used globally as an indicator of a country's state of energy efficiency.

[14] Inter-Ministerial Committee on Sustainable Development. 2009. *The Sustainable Development Blueprint*.

[15] Defined as TPE demand per unit GDP (constant dollar).

[16] Singapore has a national target of improving energy intensity by 20% by 2020 and by 35% by 2030 from the 2005 level.

Figure 7: Singapore's Energy Intensity Outlook



Note: BAS = Baseline, BAU = Business as Usual, APS = Alternative Policy Scenario, as defined in Section 3.

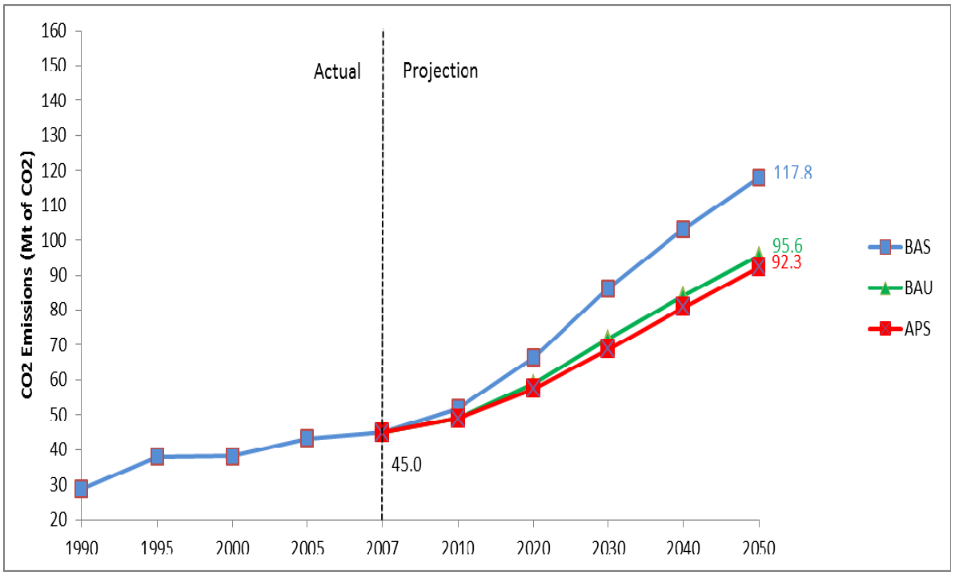
Source: Singapore Energy-Economy Model in LEAP.

In Figure 8, we show the emission trajectories under the BAS, BAU, and APS scenarios.[17] According to IEA data, Singapore's CO_2 emissions rose from 28.8 Mt-CO_2 in 1990 to 45.0 Mt-CO_2 in 2007 at a growth rate of 2.7% per annum[18] It can be seen that the difference in CO_2 emission levels between two policy scenarios is relatively insignificant. By 2050, the APS CO_2 emissions are only 3.3 Mt-CO_2 lower than that in the BAU. However, the gap between the policy scenarios and the BAS is quite large, the difference being within the 22.2–25.5 Mt-CO_2 range.

[17] Emissions are calculated from the International Energy Agency's (IEA) Energy Balance data using the methods and emissions factors from the Revised 1996 International Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (Guidelines) available at http://www.ipccnggip.iges.or.jp/public/gl/invs1.htm. More information on IEA's Energy Balances can be found at http://data.iea.org/stats/codebook/wbaldoc.html. The IPCC allows countries to use either the reference approach or the sectoral approach when reporting their CO2 emissions. The emissions shown here use the sectoral approach, which estimates emissions based on the combustion rather than the supply of fuels.

[18] International Energy Agency 2009.

Figure 8: Singapore's CO_2 Emissions



Note: BAS = Baseline, BAU = Business as Usual, APS = Alternative Policy Scenario, as defined in Section 3.

Source: Singapore Energy-Economy Model in LEAP.

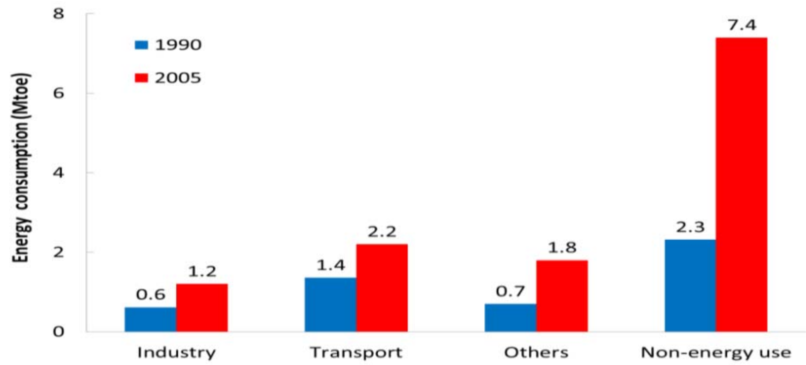
5. ENERGY USE IN SINGAPORE

Singapore has experienced significant economic growth over the past four decades—its GDP increasing from US$2.27 billion in 1971 to US$222.7 billion in 2010.[19] During the same period, Singapore's GDP per capita rose at a compounded annual growth rate of approximately 10%. This growth was accompanied by an increase in energy demand. Singapore's total final energy consumption grew at a compound annual growth rate (CAGR) of 6.3%, from 5 million tons of oil equivalent (Mtoe) in 1990 to 12.5 Mtoe in 2005. Figure 9 shows the energy consumption of the end-use sectors for 1990 and 2005. Electricity generation grew at 6.1% per annum from 15.7 Terawatt-hour (TWh) to 38.2 TWh in this period. The primary fuel composition for electricity generation has changed dramatically over the past decade. Natural gas, which accounted for 28% of electricity generation in Singapore in 2001, grew rapidly to supply almost 75% of Singapore's electricity by 2005.[20] Currently, fuel oil use for thermal power generation is around 19.3% and is seen as a reasonable "balancing" alternative to a total dependence on natural gas.

[19] Department of Statistics Singapore (http://www.singstat.gov.sg/stats/themes/economy/hist/gdp2.html).

[20] International Energy Agency 2009.

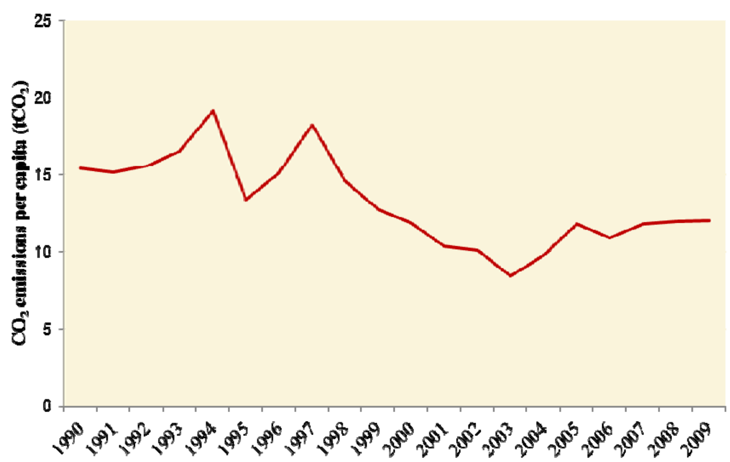
Figure 9: Energy Consumption in End-use Sectors



Source: IEA Energy Balances of Non-OECD Countries (2009).

Total primary energy consumption grew at 6.1% per annum, from 11.4 Mtoe in 1990 to 27.7 Mtoe in 2005. Figure 9 shows a disaggregation of energy consumption by end-use. Singapore's sole energy source in 1990 was oil, consumption of which increased rapidly from 11.4 Mtoe in 1990 to 21.8 Mtoe in 2005, at a growth rate of 4.4% per annum Natural gas' share grew after the construction of pipelines to fuel natural gas-fired power plants. The first pipeline sourced gas from Malaysia in 1991, which was followed by two more pipelines from Indonesia. Consumption of natural gas increased from 0.4 Mtoe in 1992 to 5.9 Mtoe in 2007 at a growth rate of 20.7% per annum. To expand her import capability and sourcing options, Singapore will have an operational LNG terminal with a throughput capacity of 6 million tonnes per annum by 2013.[21]

Figure 10: CO_2 Emissions per Capita (tCO_2)

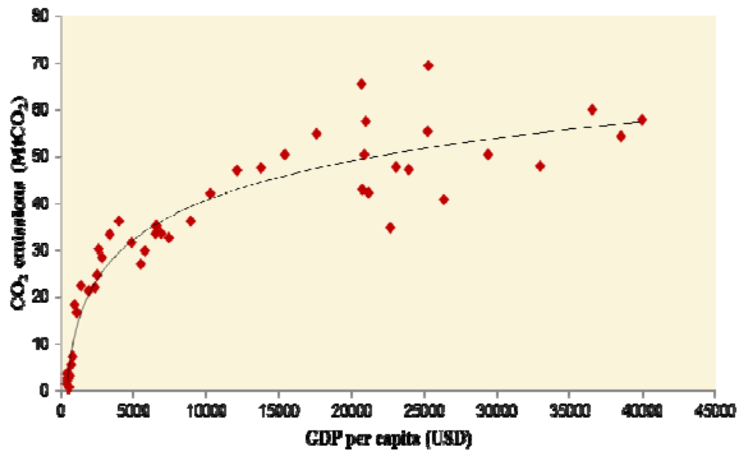


Source: WDI (2011), CDIAC (2011).

21 "Third Tank for Singapore's LNG Terminal on the Back of Strong LNG Uptake," Media Release by the Energy Market Authority of Singapore on 2 November 2010, accessed at http://www.ema.gov.sg/news/view/227.

The increase in energy consumption has been accompanied by greater CO_2 emissions. In 2009, Singapore emitted nearly 48,000 t CO_2 which is a factor of 10 increase from its value in the 1970s.[22] However, on a per capita basis, CO_2 emissions have been quite stable in the past decade, with long-term declining trend since the 1990s (see Figure 10). In fact, although the relationship between CO_2 emissions and GDP per capita is monotonically increasing this relationship seems close to plateauing (see Figure 11).

Figure 11: Relationship between CO_2 Emissions and GDP per Capita



Source: WDI (2011), CDIAC (2011).

6. ENERGY POLICY INITIATIVES: CURRENT AND PLANNED ACTIONS TO CURB EMISSIONS

Singapore's national energy policy framework strives to achieve a balance amongst three often competing dimensions, namely strengthening Singapore's competitiveness, enhancing energy security, and protecting the environment. The six key strategies under Singapore's energy policy framework seek to bring together the government, industries, businesses, and households to adopt practical and effective measures to achieve these sometimes conflicting objectives. These strategies include promoting competitive markets, diversifying Singapore's energy sources, enhancing energy efficiency, developing Singapore's energy industry, stepping up international cooperation, and taking a "whole-of-government" approach.

6.1 Promotion of Competitive Markets

Competitive markets will remain the cornerstone of Singapore's energy policy.[23] There is open competition in its oil refining, trading, and retailing industries. Competition has been introduced into the electricity and gas markets. To date, about 25% of the retail electricity market is still non-contestable. The Energy Market Authority (EMA) of Singapore is looking into the development of an Electricity Vending System (EVS) to enable full retail contestability. If successful, households and other small consumers will in future be able to choose their own electricity retailers and price plans, in the same way they can do for telecommunications providers. Singapore does recognize that markets may be unable to deliver broader environmental or energy security policy objectives due to market failures such as externalities. For example, the burning of fossil fuels adds to air pollution,

[22] International Energy Agency 2009.

[23] Ministry of Trade and Industry of Singapore 2007.

whose social costs are not internalized by the polluter. In such instances, the corrections for market failure will be in the form of market-based instruments or the imposition of standards and regulations.

The Singapore electricity and gas markets have been liberalized and transformed from a vertically-integrated, state-owned structure into a competitive one. The Energy Market Authority (EMA) was established in 2001 to regulate the electricity and gas industries and to promote competition in the electricity and gas industries. The National Energy Market of Singapore (NEMS) was established in 2003. It allowed prices to reflect supply and demand fundamentals. By 2006, approximately 75% of Singapore's total electricity demand was open to retail competition. Market competition has forced the industry to become more energy efficient with gross power efficiency increasing to 44% in 2007 from 39% in 2001. Market competition has also promoted a switch to cleaner fuels. Around 80% of Singapore's electricity is generated using natural gas (the world average is 20%).[24]

6.2 Diversification of Energy Sources

Singapore has a narrow base of energy sources. It is heavily reliant on piped natural gas from Indonesia and Malaysia for electricity generation. Nearly 80% of electricity generated in Singapore comes from piped natural gas (PNG) from these two neighbors.[25] Furthermore, over the past decade, roughly 80% of its crude oil imports come from the Middle East.[26] Energy diversification is viewed as a strategy to protect Singapore against supply disruptions, price increases, and other threats to the reliability of supply. Essentially, diversification can help enhance energy security by spreading risks. In competitive markets, companies themselves will have the incentives to diversify and reduce their own commercial risks. The government, therefore, views its role as creating an open and flexible framework that allows diversification to take place. For Singapore, there are also practical challenges to fuel diversification due to its limited energy options. Hydro, geothermal, and wind power are not available in Singapore, while nuclear energy is infeasible given the country's geographical constraints and the cost barriers to circumvent this constraint. Solar and coal-fired power generation has some potential, but they face cost and technological barriers and environmental concerns respectively. A step towards diversification is a reduction in the dependence on piped natural gas from Indonesia and Malaysia. To this end, Singapore has made the necessary investments to begin importing liquefied natural gas (LNG) by 2013.

6.3 Developing Singapore's Energy Industry

Singapore has had a long history as an energy hub, being the largest refining center east of the Suez for several decades. Oil prices are discovered in Singapore. Singapore intends to leverage on its expertise in this sector whilst pursuing its environmental goals.

6.3.1 Petrochemicals

Singapore is already one of the top five export petroleum refining centers in the world. The government intends to promote the expansion and upgrading of existing refineries and attract greenfield investment to consolidate Singapore's status as Asia's premier oil hub. Furthermore, there is a move to capitalize on its capabilities and infrastructure to become an energy trading hub. This will be achieved by developing LNG trading, biofuels trading, and carbon trading businesses.[27] Singapore seeks to develop a comprehensive energy industry sector given that

---

[24] International Energy Agency 2011.

[25] Energy Market Authority Singapore 2008.

[26] Author's calculations based on data from the United Nation's Comtrade Database.

[27] Singapore has introduced a concessionary tax rate of 5% on LNG trading income for companies under the Global Trader Programme in May 2007, see http://english.peopledaily.com.cn/200705/24/eng20070524_377600.html.

energy is a key sector of its economy (contributing around 4.5% to the GDP in 2006).[28] The goal is to increase the value-added from its energy industry to S$34 billion by 2015 (from S$20 billion as of 2007), and to triple the employment in this sector from 5,700 to 15,300.[29]

6.3.2 Clean Energy Initiatives

Singapore is also pursuing growth opportunities in clean and renewable energy, including solar energy, biofuels, and fuel cells. In the past few years, Singapore's industrial energy policy has been aimed at developing it into a global clean energy hub where clean energy solutions are developed, tested, and exported overseas. Hence, clean energy research and development (R&D) has received a substantial boost with several government agencies providing rather generous funding and entering into joint ventures with noted industry players. For instance, the National Research Foundation (NRF) has set aside S$170 million for R&D in clean energy (Clean Energy Program).[30] The Agency for Science, Technology, and Research (A*STAR), which is Singapore's premier research institute, has established an Energy Technology R&D Program, and is setting up the Singapore Initiative on New Energy Technologies (SINERGY) Centre to develop alternative energy technologies and intelligent grid management systems for distributed generation (microgrids, power dispatch).[31] The Energy Market Authority of Singapore (EMA) is setting up a S$5 million Market Development Fund (MDF) which will help to pay market charges for the test-bedding of new power generation technologies.[32].

The Economic Development Board (EDB) set up the inter-agency Clean Energy Program Office (CEPO) to promote the clean energy industry, especially solar. The USS$50 million Clean Energy Research Program (CERP) funded by CEPO aims at kickstarting research and development in clean energy.[33] The inter-agency[34] Energy Innovation Program Office (EIPO) has allocated an additional S$195 million from the National Research Foundation (NRF) to promote R&D in the energy sector in the five-year period to 2015. EDB has also launched a S$17 million Clean Energy Research and Test-bedding Program (CERT) to test-bed solar photovoltaic (PV) and other new technologies.[35] In industry, Rolls-Royce embarked on a S$10 million 3-year joint research program with A*STAR and ceramics supplier, Advanced Materials Technologies, to develop automated fuel cell manufacturing technology.

Two new energy institutes were founded in the last three years. To leverage Singapore's solar potential, the Solar Research Institute of Singapore (SERIS) was launched at the National University of Singapore (NUS) established in 2008 with funding of S$130 million for 5 years to carry out cutting-edge research in solar technology. In 2010, the S$200 million Energy Research Institute @ NTU (ERI@N) was established. Its broad-based energy research focus will be on the areas of energy materials, smart grids, solar energy, sustainable buildings, wind energy, and electromobility.

---

[28] Ministry of Trade and Industry Singapore, "Energy for Growth: National Energy policy Report," (2008), accessed at http://app.mti.gov.sg/data/pages/2546/doc/NEPR.pdf.

[29] Speech by Mr Lee Yi Shyan Minister of State for Trade and Industry at the UK-Singapore workshop on Energy Technology on 26 November 2007 accessed at http://app.mti.gov.sg/default.asp?id=148&articleID=11761.

[30] See http://www.sedb.com/edb/sg/en_uk/index/industry_sectors/alternative_energy/industry_background.html.

[31] A*STAR, "Energy@A*STAR," (2007), accessed at http://www.ices.a-star.edu.sg/media/9585/energy_astar.pdf.

[32] Energy Market Authority, accessed at http://www.ema.gov.sg/page/32/id:65.

[33] Economic Development Board, accessed at http://edb.gov.sg/edb/sg/en_uk/index/industry_sectors/alternative_energy/industry_background.html.

[34] The term "inter-agency" in the Singapore context refers to an organization that spans the various government ministries.

[35] Economic Development Board, accessed at http://edb.gov.sg/edb/sg/en_uk/index/news/articles/launch_of_s_17m_clean.html.

6.3.3 Test-Bedding Novel Energy Technologies

Singapore is positioning itself as a test-bed for novel technologies—a "living laboratory[36]." Several test-beds are being conducted in Singapore at the moment. In the transportation sector, electric vehicles (EVs) are being tested to understand the implications of adoption of this technology in the Singapore context and its potential at helping Singapore mitigate its CO_2 emissions. The EV test-bed is an Inter-Agency effort led by EMA, LTA,[37] and EDB. The test-bed will focus on gathering data and insights to guide the planning for future deployment of EVs. It will run for three years, from 2011 to 2013, with 95 vehicles being tested. The Energy Studies Institute (ESI) has been commissioned with conducting a cost-benefit analysis based on the data collected from the test-bed vehicles. Robert Bosch (SEA) Pte Ltd was chosen to be the Charging Service Provider (CSP) to roll out 60 normal charging stations and 3 quick charge stations in tandem with the roll out of EVs for the EV Test Bed.

Test-beds in the electricity sector include those for solar photovoltaics (PV) and Intelligent Energy Systems (IES). Housing and Development Board (HDB) has been testing the viability of rooftop solar PV electricity by launching a series of solar PV test-beds in HDB precincts across Singapore since 2008. In 2009, HDB announced that it would conduct a wider-scale test bedding of 3.1 MWp of solar PV installations over a 5-year period funded from the Inter-Ministerial Committee for Sustainable Development's (IMCSD) budget of S$31 million. Various incentive schemes have been put in place to assist in financing solar installations such as the Market Development Fund (MDF) (S$5 million) by EMA, the Solar Capability Scheme (SCS) (S$20 million), and the Clean Energy Research and Test-bedding (CERT) platform (S$17 million) by the Economic Development Board (EDB).

EMA announced plans for a pilot project for an "Intelligent Energy System" (IES) during the Smart Grids 2009 Summit, which was a part of the Singapore International Energy Week 2009 (SIEW 2009). By aiming to provide consumers with more information and choice with respect to their electricity usage, the belief is that this will translate into improving energy efficiency. Test-bedding such a system would enable Singapore to ascertain teething issues that modernizing the grid would entail. Accenture Pte Ltd was appointed to design and implement this project. The IES pilot will be conducted in two phases with phase 1 (2010–2012) focusing on the implementation of the enabling infrastructure for the IES and phase 2 (2012–2013) focusing on smart grid applications.

6.4 Stepping-up International Cooperation

Given its small size and reliance on energy imports, Singapore's energy policy includes efforts to promote greater regional and international energy cooperation to further its energy interests. To enhance energy security, Singapore will continue to be actively involved in various energy-related initiatives in major fora, including the Association of Southeast Asian Nations (ASEAN), the Asia-Pacific Economic Cooperation (APEC), and the East Asia Summit (EAS). Singapore will also work towards the long-term goal of promoting a regional energy market through regional energy projects like the ASEAN Power Grid (APG) and the Trans-ASEAN Gas Pipeline (TAGP).

Security of shipping lanes is an area that requires international cooperation. Approximately 60% of the Republic of China (PRC)'s 6.9 million barrels, 90% of Japan's 5.2 million barrels, and 80% of the Republic of Korea's 2.2 million barrels of imported oil per day pass through the Straits of Malacca and Singapore (SOMS) from the Middle East.[38] To secure access and the freedom of

[36] Energy Market Authority Singapore 2009.

[37] Land Transport Authority 2008.

[38] International Energy Agency 2006.

navigation through the SOMS, the operational agencies of Singapore are collaborating with Malaysia and Indonesia to improve the security of the Straits. Because effective action against climate change needs to be carried out at an international level, Singapore will also continue it active participation in the United Nations Framework Convention on Climate Change (UNFCCC), as well as international discussions on climate change in other forums.

6.5 Taking a Whole-of-Government Approach

The growing complexity and strategic importance of energy policy demands a whole-of-government approach. The work of drawing together the different strands of Singapore's energy policy began with the formation of the Energy Policy Group (EPG) in March 2006. The EPG's role is to formulate and coordinate Singapore's energy policies and strategies. In addition to the development of a national energy policy framework comprising the strategies outlined above, the EPG studies a wide range of energy issues which include power and transport sectors, energy efficiency, climate change, energy industry, energy R&D, and engaging international energy partners. Coordinating the efforts of all stakeholders will be a constant in Singapore's energy policy efforts in the future.

6.6 Enhancing Energy Efficiency

Singapore considers energy efficiency as a key strategy to achieving its energy policy objectives. The government posits that energy efficiency is a cost-effective means of mitigating GHG emissions and improving the competiveness of Singapore's industries. It also recognizes that energy efficiency measures may not be implemented due to market barriers such as the lack of information and capability. Hence, given its pivotal role in Singapore's energy policy landscape and to overcome the barriers, the National Environment Agency (NEA) of Singapore set up the inter-agency Energy Efficiency Program Office (E^2PO) in May 2007 to identify and implement measures to improve Singapore's energy efficiency in six priority areas, namely, power generation, industry, transport, buildings, the public sector, and households.[39]

In order to develop an all-inclusive energy efficiency strategy and master plan for the country, the E^2PO has devised action plans that center on the promotion of energy efficiency technologies and measures to circumvent market barriers to energy efficiency, building local expertise and a knowledge base in energy management, raising the visibility of energy efficient practices in industry, and promoting R&D in energy efficient technologies.[40]

6.6.1 Appliance Labeling

Since January 2008, registrable goods have had to carry energy labels under the Environmental Protection and Management Act (EPMA).[41] Currently, all household refrigerators, air-conditioners, and clothes driers sold in Singapore must be energy labeled. Vehicle fuel economy labels are also affixed to vehicles at the point of sale. The mandatory energy labeling scheme will improve energy efficiency and mitigate growth of energy use in residential, commercial, and transport sectors.

[39] Energy Efficiency Programme Office of Singapore, http://www.e2singapore.gov.sg.

[40] See http://www.e2singapore.gov.sg/energy-efficiency-programme-office.html.

[41] Ibid.

6.6.2 Creating Public Awareness

In 2008, the NEA launched a "10% Energy Challenge" educational campaign to promote electricity saving in households.[42] It should be noted here that labeling standards and educational campaigns can facilitate energy conservation and efficiency improvements. However, it is not clear how effective they ultimately are. The efficacy of such campaigns depends on how responsive end-users are to these initiatives in education, labeling, and the setting of standards.

6.6.3 Power Sector

The E^2PO adopts a sectoral approach targeted at each of the five sectors—power generation, industry, transport, buildings, and households. In the power generation sector, the implementation of a competitive electricity market has incentivised efficient power generation. From 2000 to 2006, the electricity generated by natural gas increased from 19% to 78% and overall power generation efficiency improved from 38% in 2000 to 44% in 2006.[43] Cogeneration refers to the integrated production of heat and electricity, while trigeneration refers to the integrated production of electricity, heat, and chilled water. These technologies optimize the heat utilization from fuel combustion and improve overall system efficiency.

In view of the energy efficiency potential offered by these technologies, E^2PO will continue to promote cogeneration and trigeneration in Singapore. However, a challenge to the large-scale uptake of these technologies is the necessity for combined demand for electricity and heating; furthermore, space considerations come into play as co-generation and tri-generation facilities have to be sited in close proximity to industries in need of the utilities. Nevertheless, given the vast improvements in energy efficiency that these technologies entail, the government is set to integrate such facilities into the on-going and future industrial planning.

6.6.4 Energy Efficiency in Industry

Before companies can embark on any energy efficiency improvement path, they need to understand their energy usage patterns and the scope of the improvements that can be brought about. Thus, an energy appraisal is called for to identify degraded plant components that contribute to overall efficiency losses and to enable a company to take the necessary corrective actions. However, companies might be reluctant to bear the upfront cost of carrying out an energy appraisal. The Energy Efficiency Improvement Assistance Scheme (EASe) was instituted to help companies overcome this barrier. EASe was set up to encourage and help companies, which may not have the in-house energy management expertise, to engage energy consultants to conduct energy appraisals. Under EASe, NEA co-funds up to 50% of the cost of energy appraisals for buildings and industrial facilities. The NEA has found that each dollar spent on an energy appraisal uncovers about S$5-10 annual savings in energy costs.[44]

There are several other such schemes for the industrial sector that have been instituted to facilitate improvements in energy efficiency. The most cost-effective way of improving energy efficiency is at the project conceptualization and design stage itself. E^2PO introduced a Design for Efficiency Scheme to assist companies take into consideration energy efficiency considerations in the project design phase. The ninth furnace of the Singapore Olefins Plant (of Exxon Mobil Chemical Ltd), which was commissioned in 2007, was built under this scheme with this design philosophy. The Investment Allowance (IA) Scheme is administered by EDB and seeks to incentivize investments in energy efficient equipment. It is essentially a capital allowance on the cost of certain energy efficient equipment which allows for a deduction against

[42] Ibid.

[43] Ibid.

[44] See http://www.e2singapore.gov.sg/energy-challenge.html.

all chargeable income. It is awarded if energy utilization falls as a consequence of the capital expenditure.

The government launched the Energy Efficiency National Partnership (EENP) Program in 2010 to help companies put in place energy management systems and implement projects to improve energy efficiency. From 2013, the government will be introducing mandatory energy management requirements for large energy users, which consume more than 15 Gigawatt-hour (GWh) in the industry sector, under the Energy Conservation Act.[45]

6.6.5 Energy Efficiency in Transportation

In the transportation sector, LTA will continue its efforts of making public transportation the mode of choice. In order to make this happen, two more Mass Rapid Transit (MRT) lines will be functional by 2018, an increase of around 215 km of railway lines compared with 2007. The goal is to have a modal split for the morning peak hours from the current 63% to over 70% in the next 10 to 15 years. Certificates of Entitlement (COEs) give Singaporeans the right to own a vehicle. COEs are integral to the Vehicle Quota System (VQS), a landmark scheme implemented to regulate the growth of vehicle population in Singapore. Under the VQS, vehicle annual growth rate is capped at 3%, given the constrained expansion of roads and highways in Singapore's urban environment. The actual compound annual growth rate of vehicle population from 1990 to 2008 was 2.8% per annum. From 2009 to 2011, the vehicle population growth rate had been capped at 1.5% per annum.[46] To encourage energy efficiency in the road transportation sector, fuel economy labels are affixed to vehicles at the point of sale so as to inform the consumer of the vehicle's fuel economy in clear terms. The purchase of cleaner and more efficient vehicles such as hybrid cars and electric vehicles is being promoted via the Green Vehicle Rebate which entails a rebate of 40% of the car's open market value.

6.6.6 Energy Efficiency in the Building Sector

Give the urban landscape in Singapore, efficiency improvements in the building sector are an important consideration. The Building and Construction Authority (BCA) of Singapore launched the BCA Green Mark Scheme in January 2005 to promote environmental awareness in the construction and real estate sectors. Buildings are awarded Certified, Gold, GoldPLUS, or Platinum rating depending on the points scored on the key criteria including energy efficiency. New and retrofitted buildings with a gross floor area (GFA) above 5,000m^2 that has achieved "Gold" Green Mark and above will be awarded cash incentives based on GFA and the Green Mark rating achieved. Since April 2008, all new and existing buildings undergoing major retrofitting works with a gross floor area above 2,000 square meters must meet Green Mark Certified standards. The BCA Green Mark Scheme promotes adoption of green building technologies and reduces the use of electricity in the commercial sector via efficiency improvements and conservation.[47]

In 2005, NEA and the Energy Sustainability Unit (ESU) of the National University of Singapore launched the EnergySmart Labeling Scheme for offices to recognize energy efficient office buildings in Singapore. Buildings that perform in the top 25% in terms of energy efficiency and meet good indoor air quality standards are eligible for the EnergySmart Building Label. This scheme was extended to include hotels in 2007. The EASe scheme is also applicable for the building sector so as to promote the appraisal of energy utilization of buildings in Singapore. In the case of building standards, there is some uncertainty as to how effective such standards

[45] Energy Efficiency Programme Office of Singapore, http://www.e2singapore.gov.sg/.

[46] Data for vehicle quota system COE quota computation, Land Transport Authority of Singapore. http://www.lta.gov.sg/corp_info/doc/VQS_worksheet.pdf .

[47] Ibid.

setting will be in the long run, even if one can make relatively detailed calculations about expected energy savings from engineering measurements.

6.6.7 Energy Efficiency in the Household Sector

As of 2006, the household sector accounted for around a fifth of Singapore’s electricity consumption. Refrigeration and air conditioning were the household appliances that contributed the most to this consumption. The policy direction at reducing energy use in this sector revolves around encouraging consumer to buy energy efficient appliances and to opt for more energy efficient habits. The Energy Labeling Scheme requires that energy labels, which inform the consumer about the electricity consumption of the appliance, are affixed to the appliances at the point of sale (akin to vehicle energy labeling scheme). As of 2008, all household refrigerators and air-conditioners that are sold in Singapore are energy labeled. In order to educate consumers and enduce them to adopt more energy-efficient behavior, the E^2PO has embarked on a national campaign, called the 10% Energy Challenge, that will promote the complete turning off of appliances when not in use. This is purported to reduce electricity consumption by around 10%. Thus in the household sector, the emphasis is on incentivizing behavioral changes with respect to energy use.

In devising specific policies for the various sectors and having an overarching policy directive, Singapore’s energy policy direction can be characterized as being clear and well-balanced. The various stakeholders are aware of their roles as facilitators and the implementation of the policies are on track.

7. CASE STUDIES

In this section, a few case studies are considered to highlight the impact that government policy has had in three sectors: buildings, transportation, and the power sector. This will shed light on the possible lessons for other countries in the “greening” of their cities.

7.1 Energy Efficient Buildings

The Building and Construction Authority (BCA) had established a S$20 million Green Mark Incentive Scheme (New Buildings) in 2006. The Green Mark Scheme is a rating system that provides a metric to gauge the environmental impact and performance of a building. Since 2008, all new buildings have to be Green mark certified. Buildings are classified into the following categories: Certified, Gold, GoldPlus, and Platinum. These correspond to the energy efficiency improvements of 10–15%, 15–25%, 25–30%, and greater than 30%.[48] The Green Mark scheme is green in that it considers not only energy but other factors such as water efficiency, project development and management, indoor air quality, environmental quality and management, and innovativeness of building design.

In March 2008, the Ocean Financial Centre received the Green Mark Platinum Award from the BCA.[49] The developers of the project, Keppel Land, looked at creating a sustainable office environment. This building has eco-features that reduce energy consumption by 35%, which is approximately 9 GWh per year, and water consumption by 37%, which is about 42,000 m^3 per year. This design entailed greater expense than a similar-sized conventional building. However, Keppel Land’s evaluation estimates that the reduced energy and water consumption will allow for a payback period of 7 to 9 years.

---

[48] See http://www.bca.gov.sg/greenmark/green_mark_buildings.html.

[49] Inter-Ministerial Committee on Sustainable Development (IMCSD) 2008.

Several features allow for these energy savings. Triple-glazed glass with low emissivity coating allows for maximum light transmission with minimum heat transmission. Energy efficient air-conditioning and a hybrid water chilling system have the greatest impact in terms of energy consumption reduction. The elevators are powered by regenerative drives that substantially reduce energy consumption. The Energy Efficiency Index[50] for this building is calculated as being 174 kWh/m^2/year. Water use is minimized on account of the efficient water fittings. Further reductions in the use of water are achieved as condensate from the air handling units is collected and reused. The practice of rain water harvesting reduces the need for piped water supply.

7.2 Road Transportation

Research has shown that innovative management policies are required if an economy is to move away from private modes of transport to public ones.[51] This is precisely what Singapore has accomplished. Policy has evolved from measures that became ineffective when the fleet size increased, such as high import fees and road taxes, to a sophisticated mix of a vehicle quota system and road pricing.[52] Singapore's road transport policy focuses on managing travel demand and maximizing road space, accessibility of all parts of the city, improving the efficiency of the public transit system, allowing for the efficient ownership of vehicles, and improving traffic management.[53] We shall now discuss the vehicle quota scheme, the road pricing scheme, and the policies of public transportation.

7.2.1 Vehicle Quota System (VQS)

The VQS scheme enables policy and the market mechanism to work together to allocate vehicles to users and hence manage the vehicle population. The government plans for a rate of growth of the vehicle population according to the prevailing traffic conditions and road capacity. This rate is translated to the number of new vehicles to be added to each of the vehicle categories, taking into consideration the existing vehicle population and the number of vehicles to be deregistered at the end of the preceding year.[54] This determines the supply of the vehicle quota. On the demand side, all purchasers of new vehicles are required to bid for a license known as a Certificate of Entitlement (COE). A public tender is held twice a month by the Registry of Vehicles (ROV).

Essentially, the price of a COE is determined by the willingness to pay. The COE lasts for 10 years. A rebate is awarded to the owner for early deregistration of a COE. This rebate depends on the COE premium that was paid, prorated by the number of months remaining of the 10 years.[55] From 1 September 2008, car owners are allowed to encash the Preferential Additional Registration Fee (PARF) and Certificate of Entitlement (COE) rebates. This change was to encourage car owners to shift to public transport users.[56]

The VQS is effective in controlling the vehicle population in Singapore. In the 1990s, the VQS had successfully reduced the annual growth rate of vehicles to 3%. This was a significantly

---

[50] Energy Efficiency Index = Building's Annual Energy Consumption/Building's Total Floor Area.

[51] Black 2000.

[52] Chin and Smith 1997.

[53] The idea that congestion reduction would be the corner stone of Singapore's road transport policy has its roots in the influential report by Wilbur Smith and Associates. The study emphasized the problem that unconstrained growth in private car ownership would have in the Singapore context (Wilbur Smith and Associates 1974).

[54] Koh and Lee 1994.

[55] Phang, Wong, and Chia 1996.

[56] LTA 2008.

slower rate of growth compared with an average of 6.8% in the 3 years under the old policy before 1990.[57] From 2009, the vehicle population growth rate will be further reduced to an annual 1.5%. This is planned for at least three years before it is reviewed, as the road expansion program slows down from the current 1% per annum to about 0.5% per annum over the next 15 years.[58] Controlling the vehicle population in Singapore has had a substantial impact on energy consumption and emissions of pollutants such as CO_2, NO_x, SO_x, etc. Energy use is estimated to have been reduced by around 50%.[59]

7.2.2 Road Pricing

Singapore's road pricing began in 1975 with the introduction of the Area Licensing Scheme (ALS). To reduce the congestion problem in Central Singapore, which includes Singapore's CBD and its commercial and retail corridor along the "Orchard Road,"[60] a permit system was introduced. In 1990, around 315,000 jobs in the retail and tourism sectors were located within the restricted zone. This high concentration of activities and jobs generates huge travel demand and traffic congestion. The "user pay" element of the permit charge was expected to reduce this traffic demand by charging all vehicles except ambulances, fire engines, police vehicles, and public buses for entering the zone. All vehicles had to purchase and display a special permit to enter the zone.

In 1998 this system was replaced by Electronic road pricing (ERP). The main advantage of ERP is convenience and flexibility. This system combines the use of radiofrequency, optical-detection, imaging, and smart-card technologies to facilitate the collection of road charges. An in-vehicle unit which can be detected by a road sensor is installed in all vehicles. This unit can process a cash card so that charges are automatically deducted each time the vehicle passes a sensor. The latter is installed on gantries which are visible as entry or exit points of a charging area/road. The ERP technology is advanced enough to handle multiple vehicles travelling at high speeds (i.e., 120 km per hour or faster).

Statistics show that the ERP is effective in controlling traffic volumes. In the first month of its operation, the average daily traffic flow during weekdays in the central area fell in volume by more than 20%.[61] Traffic speed increased by 10 km per hour from 30–35 km per hour under the old ALS to 40–45 km per hour under the new ERP system. On weekends, traffic volumes fell by almost 20%. Experiments with higher ERP charges in selected areas had a further effect on traffic. The ability to vary the charges at different times and on different routes shows another advantage of using ERP as compared to manual road pricing schemes such as ALS. [62] Reduced traffic in the charging zone has led to an estimated 176,400 pound reduction in CO_2 emissions and a 22 pound reduction in particulate matter (soot).[63]

7.2.3 Trigeneration Facilities

Through TPGS Green Energy, a joint venture with Gas Supply Pte Ltd, Tuas Power pioneered the introduction of cogeneration and trigeneration technologies to large manufacturing facilities such as pharmaceutical and petrochemical plants in Singapore. These highly efficient technologies simultaneously produce two or three types of utilities such as steam and electricity

---

[57] Sharp 2005.

[58] LTA, 2008.

[59] D'Souza 2011.

[60] Foo 1997.

[61] Foo 2000.

[62] LTA, 2008.

[63] Environmental Defense 2006.

that are critical to the customers' plant processes, thus reducing their energy costs and carbon footprint at the same time.

Pfizer Incorporated, a large international pharmaceutical company, began operating the first trigeneration facility in Singapore in 2006 at one of its S$600 million "multi-purpose" plants near Tuas South Biomedical Park, where 265 employees manufacture pharmaceutical ingredients. Built at a cost of US$8 million with a nameplate capacity of 4.6 MW of power, the facility also generates up to 12 metric tons of steam and 2,500 refrigerant tons of chilled water per hour. Fired by natural gas, the trigeneration facility achieved 83% thermal efficiency in its first year of operation. It will help Pfizer reduce its annual electricity costs by about US$500,000 per year (and cut carbon dioxide equivalent emissions by 17% annually). The trigeneration unit is operated under a 15-year agreement with TPGS and the plant can be expanded to accommodate another 4.6 MW natural gas turbine to handle future demand for steam and electricity.

8. OTHER GOVERNMENT INITIATIVES THAT ARE COMPATIBLE WITH GREEN GROWTH

Given the important role that the energy sector plays in determining the extent of pollution generated in a country, the focus of analysis in the previous sections has been Singapore's energy policies. However, a green path to growth is a broader concept linked to the efficient use of resources and improving environmental quality. Singapore has, through long-term planning, done quite well in this sphere. There have been several policies instituted to ensure that the city state is green and clean. We shall consider these initiatives in this section. Since carbon markets and climate change finance would play a key role in the region's green growth goals, we will consider the role that Singapore might play as the region's carbon hub.

8.1 From a Garden City to a City in a Garden

Since Singapore's inception, its leaders had envisioned the development of a sustainable city. The concept of turning Singapore into a Garden City, a place where there would be a balance between economic and environmental goals, was used as the basis for policy planning for the city state. The Parks and Recreation Department (PRD) was established in 1976 to undertake the task of greening Singapore. Given the lack of greenery in Singapore's streetscape, the PRD focused first on increasing shrubbery and tree populations in the city. A combination of fast-growing indigenous trees, such as Angsana, and free flowering trees and shrubs, such as Bougainvilleas, were planted across the city. In conjunction, coordination between government agencies allowed for the development of road codes to allow for adequate planting areas.

Developers of residential areas were also required to plant roadside trees and set aside land for open spaces. Paved areas, such as car parks, were also included in the planning exercise. Trees were required to be planted in area with extensive asphalt surfaces as a means of attenuating the urban heat island effect. Creepers were planted on concrete structures, such as flyovers, so as to provide visual relief from the built environment. Parks were viewed as a means of providing the cityscape with "green lungs." Hence, land was set aside for the development of parks. The island-wide park development program was also accelerated to cater to the diverse recreational needs of the population. Under this program, existing old parks were improved upon and many new ones were developed.

Despite competing land needs, the government has set aside space for parks, trees, and greenery. Under the Concept Plan 2001,[64] 4400 hectares of parkland will be set aside when Singapore's population reaches 5.5 million. Singapore now has 2,787.02 hectares of parks, connectors, and open spaces, including some 358 parks and playgrounds. In addition, it has 3,347 ha of nature reserve and 2,664 hectares of roadside greenery. These numbers are quite impressive given the 100% urbanization of Singapore. These large swathes of green are now managed by NParks, a government agency. NParks is in the process of developing a Streetscape Greenery Master Plan for Singapore that will drive the future development of the Garden City concept. To complement the lush streetscape greenery, NParks' greening approach is now moving upwards through the greening of rooftops and sides of high-rise buildings which is viewed as means of ensuring optimal land use whilst improving the quality of life in Singapore.

The Garden City concept is now witnessing an evolution in the minds of the city planners. The idea is the creation of a City in a Garden. This concept implies that the city state's green infrastructure of parks and streetscapes will be contiguous thus playing an essential part in the lives of Singapore's residents and engendering a greater awareness of the value of the environment.

8.2 Waste Management

Singapore has been refining the efficiency of its waste management system over the years. Waste is currently collected from homes on a daily basis, which ensures public hygiene and high levels of cleanliness. Given Singapore's land constraints, instead of using up land for a landfill, Singapore incinerates its waste in "waste-to-energy plants" that are highly efficient and subject to strict emission standards. These plants generate approximately 2%–3% of Singapore's electricity needs.

The ash from the incineration process is sent to Singapore's only landfill, the Semakau landfill. It is an island located around 8km from mainland Singapore. At the current rate of usage, it is expected to last for approximately 40 years. Thereafter, it will become a part of Singapore's land stock. The landfill was constructed with sustainability in mind. This has resulted in the existence of a rich diversity of flora and fauna on the island.

Singapore aims to reduce the need for incineration and the use of land for landfill. To this end there have been efforts to get Singapore residents to recycle. The National Recycling Program was established, which provides centralized recycling bins and fortnightly collection of recyclables.

Table 2 below provides a snapshot of Singapore's waste management system over four years. We can see that the total waste generated every year has been increasing. However, the percentage of waste that is being recycled has also been increasing.

[64] The Concept Plan is Singapore's long-term strategic land use and transportation plan. It guides Singapore's development over a timeframe of a few decades. Government agencies involved in Singapore's economic, social, environmental, and infrastructural development jointly draw up this Plan and review it every ten years.

Table 2: Singapore's Waste Management Statistics

Solid Waste Management	Unit	2007	2008	2009	2010
% of population with access to waste collection services	%	100	100	100	100
Total waste generated	mil tons/yr	5.6	5.97	6.11	6.52
Total waste recycled	mil tons/yr	3.03	3.34	3.49	3.76
	%	54%	56%	57%	58%
Total waste incinerated	mil tons/yr	2.38	2.45	2.48	2.59
	%	43%	41%	41%	40%
Total waste landfilled	mil tons/yr	0.19	0.18	0.15	0.17
	%	3%	3%	2%	2%
Total domestic waste disposed	mil tons/yr	1.5	1.48	1.52	1.6
Domestic waste disposed per capita	kg/day/person	0.88	0.84	0.84	0.86
Total non-domestic waste disposed	mil tons/yr	1.07	1.14	1.11	1.16
Total energy produced from incineration	MWh	974,945	1,048,072	1,064,956	1,173,298
Lifespan of Landfill	years	35-40	35-40	35-45	35-45

Source: Ministry of the Environment and Water Resources.

8.3 Pollution Management

Singapore has had clear, rigorous environmental regulations since its inception. The city has been planned so that industrial and residential areas are segregated, to improve the quality of life for Singapore's residents. Heavy industry is located on Jurong Island and Tuas. Strict pollution control standards are imposed on new industrial developments and these are complemented by strict monitoring and enforcement.

Singapore's ambient air quality is measured using the Pollutant Standards Index (PSI) developed by the United States Environmental Protection Agency (USEPA). In Singapore, the PSI is calculated from the concentrations of five key pollutants—particulate matter (PM10), sulphur dioxide, ozone, carbon monoxide, and nitrogen dioxide. Figure 12 below illustrates the air quality in Singapore over a decade. The air quality for a year is defined in terms of the proportion of days for which the PSI falls within a particular category. If the PSI is below 50, then the day is classified as good, if it lies within the 51–100 range the air quality for the day is moderate, and when it ranges from 101–200, it is classified as unhealthy. The figure indicates that for the most part, Singapore has good air quality. The presence of unhealthy days in a year is largely due to the effects of trans-boundary pollution, as can be seen for 2006.

Figure 12: Air Quality in Singapore

Source: Ministry of the Environment and Water Resources.

8.4 Singapore as a Carbon Hub

Carbon finance and carbon markets will be central to global efforts to mitigate climate change. Singapore can potentially set itself up as a carbon hub, capitalizing on two distinct opportunities. Firstly, South-East Asia is likely to see increased inward flows of climate change finance and carbon market finance, given that the Association of Southeast Asian Nations (ASEAN) economies[65] are classed as developing economies under the United Nations Framework Convention on Climate Change (UNFCCC) and significant mitigation potential exists in many ASEAN economies. In particular, Indonesia is likely to receive financial support aimed at protecting its forests via the United Nations's Reduced Emissions from Deforestation and Forest Degradation (REDD) program; for instance, in 2010 Norway agreed to provide US$1 billion in finance to Indonesia for forest conservation and protection (beginning with a 2-year moratorium on clearing implemented in June 2011).[66]

Singapore, which is already a regional financial hub and possesses mature capital markets that have received exposure to carbon trading, is thus well-equipped to set itself up as the regional hub for climate finance in carbon markets, emission mitigation projects, Green Funds management, etc. As senior minister of state for trade and industry, Mr. S. Iswaran pointed out in an opening speech to the Carbon Asia Forum 2009, that Singapore has a number of other features in favor of its becoming an Asia-Pacific Carbon Hub, including the presence of companies already involved in carbon financing and trading, the strong commodities trading base (that can be leveraged to support carbon trading), and incentive schemes for commodity derivatives trading and fund management that now extend to emissions derivatives as well.[67]

---

[65] The current ASEAN member countries are Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

[66] Fogarty 2011.

[67] "Singapore Highlights Its Role in Expanding CDM Activities in the Region," *Government Monitor*, 26th Oct 2009, http://www.thegovmonitor.com/world_news/asia/singapore-highlights-its-role-in-expanding-cdm-activities-in-the-region-12455.html.

Furthermore, Singapore is the largest marine bunkering hub in the world [68] and one of the world's top three export refining centers. [69] Thus, Singapore could play a key role in the management of any funds generated from curbing global emissions on shipping. In addition, Singapore is an important aviation hub as well[70] and could thus also become a regional hub for the management of funds generated from curbing emissions on aviation. The aforementioned expertise of Singapore in financial markets and funds management will give a further boost to Singapore's chances of becoming a hub for the management of climate finance generated from curbing international transport emissions.

Singapore's positioning as a carbon hub will allow for the leveraging of private finance which is deemed crucial for climate change mitigation efforts. This would thus create demand for the kinds of institutions and markets that, in the ASEAN region, can only be found in Singapore.

9. CHALLENGES AHEAD

As a city state with limited resources, Singapore faces several challenges in "greening" its economy. A growing economy puts pressure on its land, water, and energy resources. Moreover, its transition to a green economy is made more difficult by the fact that certain sectors of Singapore's economy are large consumers of energy and hence contributors to greenhouse gas emissions.

9.1 Industry

Over time, Singapore has evolved into a world leader in several areas including shipping and oil refining. The port of Singapore has been amongst the top five busiest ports in the world for several decades. The American Association of Port Authorities (APPA) in 2009 ranked Singapore as the world's busiest container seaport on the basis of the total number of actual "twenty-foot equivalent units" transported through the port and second, after Shanghai, in terms of total cargo volume. [71] Singapore consistently ranks as one of the world's top competitive ports, in terms of tonnage and port efficiency.[72] The oil industry has been integral to Singapore's economy, contributing approximately 5% to Singapore's GDP in 2007. When considered together, Singapore's energy and chemical complex contributed S$57 billion of its manufacturing output in 2009 (28% of Singapore's total manufacturing output).[73] Policies aimed at emissions reductions, be they local or global, will necessarily impact these key tradable goods sectors affecting the output of the Singapore economy.

The Kyoto Protocol assigned responsibility for reducing bunker greenhouse gas emissions to developed (Annex 1) countries working through the International Maritime Organisation (IMO), an agency of the United Nations. The IMO has focused on technical discussion around standards such as fuel efficiency, fuel quality, slow steaming, [74] etc. The debate is now deadlocked over whether any measures to reduce CO_2 emissions should be global or

---

[68] Economic Development Board Singapore 2009. http://www.edb.gov.sg/etc/medialib/downloads/industries.Par.33625.File.tmp/Energy%20Factsheet.pdf.

[69] BP 2009.

[70] Airports Council International 2009.

[71] APPA 2009.

[72] Pillai 2005.

[73] Economic Development Board Singapore 2011.

[74] This is essentially a reduction in speed by ships. The energy use of a ship per kilometer increases approximately with the square of the speed.

differentiated. Developed countries want global measures so as to avoid competitive distortion. Bunker fuel use typically represents 10%–15% of developed countries' transport emissions, but in some cases the figure is much higher than this, around 20%–40%. In the Netherlands, it is over 50%.[75] Governments consequently fear political difficulties due to competitive distortions if unilateral action is taken to regulate bunker fuels.

Table 3: Distribution of International Bunkers

Distribution of International Bunkers (in CO2 terms, mn tonnes)	
US	88
Japan	19
EU-27	171
Singapore	86
Taipei,China	7
UAE	41
Saudi Arabia	8
Republic of Korea	33
Brazil	11
Annex-1 Total	**287**
Non-annex 1 Total	**295**

Source: Mark Lazarowicz, UK Prime Minister's Special Representative, "Global Carbon Trading: A Framework for reducing emissions" (2009).

The carbon content of bunker fuels is a target for tax or cap-and-trade. The IMO and key shipping associations will play a critical role in climate change talks. The industry is itself divided into two camps, one that supports cap-and-trade and the other that supports a carbon tax. Those advocating cap-and-trade are the Australian Shipowners' Association, the Norwegian Shipowners' Association, the Swedish Shipowners' Association, and the UK Chamber of Shipping. Those that favor a carbon tax include Denmark, the Hong Kong Shipping Association, and A P Moller Maersk.

75 Dings 2009.

Table 4: World Bunker Market Sales (2007)

Country/City	Mn Tn	% of World Market
Singapore	30.2	11.70%
Fujairah	16.5	6.30%
Rotterdam	13.1	5.00%
Antwerp	8.5	3.20%
Amsterdam	1.2	0.40%
World Total	**258**	**100%**

Mn = million. Tn = tones.

Source: FGE estimates.

Singapore, Fujairah, and Amsterdam-Rotterdam-Antwerp are among the more important global bunkering centers (see Table 4). Climate change policy will have an outsized impact on these three regions. Given its premier status in bunker market sales, shipping is a crucial issue for Singapore in climate change discussions. As one of the top four financial centers in the world and given the size of its marine operations, Singapore is well-placed to become the global center for either bunker tax administration or for a cap-and trade regime for shipping emission reductions. Singapore would be the preferred location for a greenhouse gas fund administrator, a center for shipping emissions R&D, and a cap-and-trade financial and price discovery center. However, the issue of "carbon leakage" is a factor that will affect the prospects of a global agreement on shipping emissions and compliance. Essentially, ports that are not subject to emission constraints, which may be due to their location in a non-Annex 1 country, might be in a position to attract non-compliant shipping.

Table 5 shows the distribution of refineries by location. We see that refinery capacity in Asia has witnessed substantial growth. For instance, from 1998 to 2008, the PRC and India posted growth rates of approximately 6.10% and 8.24%, respectively. However, this growth was largely to meet rising domestic product demand. With refining capacity of nearly double its rate of petroleum products consumption, Singapore has maintained its position as a global oil refining and trading center (see Table 6). Singapore is home to a constellation of activities, such as physical oil and derivatives trading, insurance, consulting, and news and price reporting services that have been driven by its status as a refining hub. As an "oil center," forward and backward linkages are extensive, from manufacturing, banking and insurance, to commodity trading, shipping, and risk management.

Table 5: Global Refining Centers—Houston, Rotterdam (ARA), and Singapore

Country	1998	2008	2008 over 1998	share of total (2008)
US	16,261	17,621	0.81%	19.88%
Greater Houston Area		*1,207*		*1.36%*
Belgium and Netherlands	*1,998*	*2,006*	*0.04%*	*2.26%*
Australia	810	734	-0.98%	0.83%
PRC	4592	7812	6.10%	9.50%
India	1,356	2,992	8.24%	3.38%
Singapore	*1,246*	*1,255*	*0.07%*	*1.42%*
Exxon Mobile Jurong Island		605	0.00%	0.68%
SRC Jurong Island		285	0.00%	0.32%
Shell Pulau Bukom		458	0.00%	0.52%
Republic of Korea	2,598	2,712	0.43%	3.06%
Taipei,China	732	1,197	5.04%	1.35%
Thailand	890	1,187	2.92%	1.34%
EU	15,262	15,788	0.34%	17.81%
Total World	79,699	88,627	1.07%	100.00%

Source: British Petroleum (BP). 2009. Statistical Review of World Energy. June..Data for Greater Houston Area is from US Energy Information Administration. 2009. Refinery Capacity Report. 25 June. Data on Singapore refineries is obtained from the Oil and Gas Journal (various issues).

Table 6: Petroleum & Petroleum Products Trade for Major Ports, 2008 (million tons)

Port	Incoming	Outgoing	Total	Outgoing as % of Incoming
Houston	67.3	24	91.3	36%
Rotterdam	136.3	22.7	159	17%
Singapore	130.9	110.9	241.8	85%

Source: Port of Houston Authority; Port of Rotterdam; Singapore Bunker sales (outgoing), Maritime Port Authority, "Annual Report 2008," (2009); BP, "Statistical Review of World Energy," (2009); estimates for bunker trade in Singapore, excluded from the BP data, provided by FGE.

Refined oil products and petrochemicals are highly fungible products competing in international commodity markets. While long-lived capital investments are sticky in the short and medium terms, refinery runs and capacity utilization are a function of marginal operating costs. If binding carbon emission restraints apply, higher operating costs will encourage higher capacity utilization among refiners not subject to emission constraints—an instance of "carbon leakage." For example, Singapore refiners will face competitive pressures from refineries in Thailand and even as far away as Gujarat. Singapore's refining industry is thus quite susceptible to climate change policies.

9.2 Regional Cooperation

Energy was identified as a key area for cooperation in the early days of ASEAN. In the aftermath of the oil crisis in 1973, the heads of ASEAN member countries formed the ASEAN Council on Petroleum in October 1975, to promote cooperation among its member countries in times of emergency due to oil shortages. Initially, cooperation was viewed as a way of enhancing energy security, but since recently climate change and the environment have also been viewed as factors in support of a regional approach to the energy sector.

ASEAN Vision 2020 called for an "energy-integrated" Southeast Asia which would "establish interconnecting arrangements in the field of energy and utilities for electricity, natural gas and water within ASEAN through the ASEAN Power Grid and a Trans-ASEAN Gas Pipeline and Water Pipeline, and promote cooperation in energy efficiency and conservation, as well as the development of new and renewable energy resources".[76] The "ASEAN Plan of Action for Energy Cooperation (APAEC) 2010–2015" covers the energy component of the ASEAN Economic Community Blueprint 2015 signed by ASEAN leaders in November 2007. The Plan aims to "enhance energy security and sustainability for the ASEAN region including health, safety and environment through accelerated implementation of action plans, including, but not limited to: a) ASEAN Power Grid, b) Trans-ASEAN Gas Pipeline, c) Coal and Clean Coal Technology, d) Renewable Energy, e) Energy Efficiency and Conservation, f) Regional Energy Policy and Planning, and g) Civilian Nuclear Energy."

9.2.1 The Trans-ASEAN Gas Pipeline (TAGP)

The region's most ambitious mega-project, the TAGP, aims to connect the gas reserves of the Andaman Sea, Gulf of Thailand, and South China Sea to the urban and industrial demand centres of Southeast Asia. Among its objectives are to ensure the reliability of gas supply to ASEAN members, encourage the use of an environmentally cleaner fuel, and to reduce dependence on oil and coal where economically substitutable.

ASEAN formed the TAGP taskforce in 1999, and ASEAN members signed an MOU on the project in 2002. According to APAEC 2010–2015, the "updated ASCOPE–TAGP Masterplan 2000" involves the construction of 4,500 kilometers of pipelines worth US$7 billion.[77] There are a range of other estimates regarding the size and cost of TAGP, with one source citing US$16 billion of investments for 5,100 km of new pipelines.[78] Potential link-ups with East and South Asia could increase investment requirements to over US$65 billion, according to another source. [79]

All large scale multi-lateral infrastructure projects face critical hurdles in the financing, construction, operation, and maintenance of networks. These include the requirements of common technological specifications and standards; stable contractual arrangements to handle supply, transport, and distribution; open access arrangements to common infrastructure; and norms and legal frameworks for arbitration and dispute resolution. The TAGP mega-project is no different, facing key challenges in all these dimensions. The heterogeneity of ASEAN members with respect to income levels, stages of social and economic development, legal systems, and domestic pricing regulations of natural gas has posed significant challenges to the

[76] ASEAN Vision 2020 http://www.aseansec.org/1814.htm.

[77] See "ASEAN Plan of Action for Energy Cooperation (APAEC) 2010–2015", accessed at http://www.asean.org/22675.pdf.

[78] Sovacool 2009.

[79] Ohli 1994.

TAGP. Given the scale of the project, it has naturally been a subject of a number of feasibility and planning studies. [80]

Currently, there are eight cross border natural gas pipelines in operation, with a total length of over 2,500 km. The cross-border pipelines connect Peninsula Malaysia to Singapore (delivering gas since 1992); Myanmar to Thailand from the Yadana (1999) and Yetagun (2000) fields, Indonesia to Singapore with two pipelines, one from West Natuna (2001) and the other from South Sumatra (2003); and Thailand to Malaysia from the Joint Development Area in the Gulf of Thailand (2006).[81] An estimated US$14.2 billion has already been invested in some 3,900 km of bilateral pipelines in 2008.[82]

The successful financing and construction of these cross-border pipelines have occurred on the basis of commercial consortia that involve a range of private and public sector stakeholders in the energy sector, not as part of state-led multilateral negotiations envisioned by the ASEAN proponents of the TAGP project. Finance by multi-lateral agencies such as the ADB has played a role in some of the pipeline projects involving the less developed member countries of ASEAN with weak fiscal systems such as Indonesia.[83] Nonetheless, existing investments in cross-border gas pipelines in Southeast Asia are the result of successful negotiations between sovereign owners of natural gas resources in the region and the international oil and gas companies who typically provide private equity and commercial debt instruments along with the requisite technology and expertise to exploit such resources. Where commercial criteria of risk and reward simultaneously satisfied policymakers' perceptions of national interest in the exploitation of gas resources, projects reached final investment decisions. If cross-border transport of gas helped commercialize otherwise "stranded" gas resources, by reaching paying customers with long-term sales and purchase agreements, then pipelines got built.

9.2.2 The Natural Gas Outlook for Southeast Asia

Quite apart from the inherent challenges that all large-scale multilateral CBI projects face, the TAGP now faces a more basic question of relevance. Since it was first conceived and discussed,[84] the natural gas situation in Southeast Asia has changed profoundly. If the TAGP project seemed over-ambitious when it was first mooted among ASEAN planners and diplomats in the mid-1980s, it now seems that the grand vision of a regionally-interconnected grid of natural gas pipelines for ASEAN faces the threat of redundancy due to fast-paced developments in the natural gas industry over the past two decades.

Southeast Asia has been among the fastest growing economic regions in the world over the past three decades. Rapid economic growth in the region has been accompanied by rising demand for energy, and in particular, electricity. Natural gas use in Southeast Asia is expected to grow rapidly in the power generation, industrial, and household sectors in the medium-term. The region boasts three well-established Liquefied Natural Gas (LNG) exporting countries, Malaysia, Indonesia, and Brunei Darussalam, two of which, Malaysia and Indonesia, were the

[80] In 1994, for example, ASEAN commissioned a regional "Masterplan Study on Natural Gas Development and Utilization in ASEAN" with technical assistance from the EU. See "ASEAN Plan of Action for Energy Cooperation 1999–2004", accessed at http://www.aseansec.org/11704.htm.

[81] See "Natural Gas Infrastructure Development: Southeast Asia", Asia Pacific Research Centre, 2000; various press reports.

[82] "ASEAN and ASCOPE lay foundation for growth", *Petromin Pipeliner* (January–March 2011), accessed at http://www.pm-pipeliner.safan.com/mag/ppl0311/r12.pdf.

[83] See, for instance, Asian Development Bank 2008.

[84] While energy cooperation in ASEAN was first mooted in the aftermath of the oil crisis in 1975 with the formation of ASCOPE, the concept of a network of gas pipelines connecting the region was first discussed in 1986, and formally announced at an ASEAN meeting on Energy Cooperation in 1990. See Sovacool 2009.

world's second and third largest exporters, respectively, in 2009.[85] However, without further major discoveries and large new gas field development projects, regional gas supplies are dwindling relative to the rapid growth in domestic demand. Both Malaysia and Indonesia have expressed concern over their ability to meet rapidly growing domestic demand while sustaining their LNG and pipeline export commitments.

In 2007, Indonesia switched its gas policy from an almost exclusively export-focused one to one that includes both meeting domestic demand and continuing to be a significant exporter as the country's industrial sector faced an acute shortage of natural gas. According to local media reports, the Indonesian government may no longer extend the existing LNG contracts to meet the surge in the domestic demand.[86] While the country will continue to remain an important LNG exporter, it expects to be an importer of LNG as well, by as early as 2013. Its first floating storage and regasification terminal will be operational by 2012, and a slate of other small regasification terminals are planned to come on-stream in 2012 at various locations in Java and Sumatra. LNG exports from Indonesia are projected to decrease consistently, to less than 5 mtpa by 2030.

Malaysia is also expected to become an importer of LNG as its domestic supply is expected to drop to 1.4 Bcf/d by 2025 from a projected 2 Bcf/d in 2015.[87] The first LNG import terminal aimed at helping to ease the gas supply shortage in peninsular Malaysia is expected to be operational from July 2012.[88] Supply to this 3.5 mtpa terminal will be based on open sourcing for the first two years, because a long-term contract for supply from Australia will only start from 2014.

Press reports citing Malaysian and Indonesian officials indicate that pipeline gas exports to Singapore are likely to decline due to pressing domestic needs. According to one recent media report, Indonesia is looking at re-negotiating with Singapore, to replace its pipeline gas exports with LNG from East Kalimantan or Papua, so that Sumatran gas can be used domestically in nearby Java.[89]

Given the basic supply and demand outlook for natural gas in the region's main gas producers, the outlook for extensive new pipeline development in Southeast Asia is constrained. Instead, the most notable development in the region's natural gas sector is the number of announcements of new LNG regasification terminals being planned. Among the several countries in Southeast Asia that have announced plans or have already begun construction of LNG regasification terminals are Singapore, Thailand, Viet Nam, and the Philippines, apart from those planned in gas exporters Malaysia and Indonesia. It is apparent that the ability to import LNG has become a preferred option: it facilitates access to gas supply quickly. Floating LNG regasification vessels make for even quicker turnaround times to project completion.

Indonesia's giant East Natuna field (formerly known as Natuna D. Alpha) in the South China Sea, the region's largest gas field by far with an estimated 46 tcf of recoverable gas, is seen as the lynchpin of the TAGP. Among the pipelines envisaged in the TAGP, East Natuna is expected to supply gas via pipelines to Viet Nam, Malaysia, Indonesia (Java), and Thailand. Excluding the "deferred" proposed pipeline to the Philippines, the gas reserves of the East Natuna field are to support about 4,500 km of pipeline supplies to demand centres in four countries.

[85] See BP 2010.

[86] See, for instance, *Xinhua*, 18 February 2010, "Indonesia will no longer renew LNG export contracts".

[87] *World Gas Intelligence* 2010.

[88] See Lee 2010.

[89] *Jakarta Post*, 17 June 2011.

However, given the very high CO_2 content of East Natuna's gas reserves (up to 70% of total estimated reserves of over 220 tcf), exploiting the reserves will be technically and economically challenging. Reflecting the sheer scale and complexity of any project to exploit the East Natuna field, official projections for gas production from the field see first output only after 2020.[90] In the current context where there are a number of large LNG projects at various stages of planning in the region, particularly in Australia, the eventual development and exploitation of East Natuna remains highly uncertain. While the TAGP project may see little progress in a multi-lateral framework, cross-border pipeline development will occur when commercially viable.

9.2.3 ASEAN Power Grid (APG)

The ASEAN Power Grid (APG) was announced in 1997 by the ASEAN Heads of States/Governments under the "ASEAN Vision 2020" declaration, with its declared aims to ensure regional energy security and the efficient utilization of electricity resources. It envisages development in stages: bilateral interconnections will be gradually expanded to a sub-regional basis and then to a totally integrated Southeast Asian power grid system. There are currently four on-going projects, with 11 new projects planned through to 2020.[91]

ASEAN member countries vary considerably with regard to their power sector regulations, market structure and technical characteristics, such as plant efficiency, transmission and distribution losses, HVAC/DC transmission lines, etc. Reflecting the heterogeneity of electric power markets among the ASEAN group, power tariffs for both industry and households differ markedly among different ASEAN member states. Key countries such as Malaysia and Indonesia have subsidized electricity, although both countries have announced their intention to slowly reduce such subsidies in favor of more targeted social welfare programs.[92]

Brunei Darussalam, Cambodia, Lao PDR, and Myanmar have traditional vertically-integrated state-owned power utilities, while Indonesia, Malaysia, Thailand, and Viet Nam have state-owned utilities operating together with private independent power producers (IPPs). In ASEAN, only the Philippines and Singapore have "unbundled" power sectors, with privatized power generators and independent grid operators.

There are significant technical and economic benefits to interconnecting power grids as envisaged in the APG. System electricity generation reserve capacity requirements would be reduced the larger the size of the system. Load factors would improve in a larger system due to higher utilization factors. This would allow for diversification of energy supply sources. Integration efficiencies could also encourage electricity market reforms in the region, as the benefits of shared power become apparent. In the Greater Mekong Subregion (GMS), there is vast potential for exploiting hydroelectric power in Lao PDR and Cambodia for export that is yet untapped.

There are significant technological, operational, and institutional barriers to interconnecting the different power grid systems in ASEAN. The electric power sectors in different countries have evolved separately, and standards and technologies are different. Policy preferences with respect to reliability and affordability differ across the region. As already mentioned, the market structure in power generation and distribution differ across countries in ASEAN. Some countries still have vertically integrated utilities with a monopoly over generation, transmission, distribution and retail of electricity. In gas-exporting countries such as Brunei Darussalam, Indonesia, and Malaysia, gas is offered to electricity producers at subsidized prices. IPP's and foreign investors

[90] In December 2010, Pertamina, the Indonesian national oil company, appointed ExxonMobil, together with Petronas and Total S.A., as partners in the development of the East Natuna gas block. See Maulia 2011.

[91] The Heads of ASEAN Power Utilities/Authorities (HAPUA) commissioned the ASEAN Interconnections Masterplan Study (AIMS) which was completed in 2003. See Roesli 2006.

[92] See, for instance, *Reuters*, 4 February 2008, "Malaysia to revise electricity tariffs" and *The Jakarta Globe*, 24 March 2010, "Indonesia to lift subsidies gradually."

cannot compete in an "uneven playing field", unless they are guaranteed off-take at predictable prices. International electricity grid interconnections are complex, and power purchase and pricing agreements need to be sorted out prior to the start of grid interconnection projects. Liabilities of various parties have to be decided upon across different legal jurisdictions.

In countries where market pricing, unbundling, and privatization have not been achieved, the financial burden often falls on already-stretched public sectors in key ASEAN countries such as Malaysia and Indonesia, not to mention the less developed countries such as Lao PDR and Cambodia. Market pricing, to reflect real costs of power, can have destabilizing consequences for governments intent on subsidizing power for social welfare of its poorer citizens.

Progress in interconnecting power grids in ASEAN is likely to continue on a bilateral basis, except in cases where there is strong motivation for a regional approach, such as in the Greater Mekong Sub-region. Progress is likely to be slower than projected by government planners, as ASEAN member states are still far away from privatizing or "unbundling" electricity sectors and encouraging full-fledged energy trading. Power surplus countries such as Lao PDR with ample hydro resources could emerge as major electricity exporters within ASEAN, supplying much needed power to rapidly growing neighboring countries such as Thailand and Viet Nam.

10. CONCLUSION

Singapore has achieved much progress over the past four decades. Prudent policies and a changing economic structure have led to more efficient use of energy, as evidenced by Singapore's declining energy intensity. Given the energy policies instituted up until 2010, our results suggest that under a hypothetical baseline scenario (BAS), which assumes that only the policies in place by the end of 2007 are implemented, Singapore will be able to reduce its final energy consumption by around 12%–14% (in the BAU and APS scenarios) from the BAS level by 2050. Energy intensity will similarly fall by 12%–14% (in the BAU and APS scenarios) from the BAS level by 2050. The model predicts that CO_2 emissions will fall by 19%–22% (in the BAU and APS scenarios) from the BAS level by 2050.

However, the country will face several challenges on its path to green growth. There is considerable uncertainty as to the evolution of a global agreement on CO_2 emissions reductions and the exact nature of the commitments that countries will be held to. Given Singapore's status as a preeminent shipping center and global oil refining center, CO_2 emissions policies that will affect these industries will negatively impact Singapore's economy if issues of "carbon leakage" are not adequately addressed. Given the complexities of cooperating with neighboring nations with regard to energy and environmental goals, progress might be slow on this front.

Singapore has been built on the basis of long-term integrated planning that is pragmatic and cost-effective. It has sought to boost resource efficiency by pricing resources appropriately, providing information for better decision-making, boosting energy efficient designs, processes and technologies, promoting public transport, and minimizing upstream waste. The urban environment has been enhanced by the conservation of urban biodiversity, regular review of pollution standards, improving water quality, and enhancing greenery. There has been a focus on building capability by investing in research and development of novel technologies and the facilitation of sharing of knowledge. Finally, there has been an effort to get the community to act in a unified manner by promoting community development efforts and with the government taking the lead in several sustainability initiatives. Cohesive policy initiatives have put Singapore on the path to a sustainable future and will provide the impetus for future policy success.

REFERENCES

Airports Council International (ACI). 2009. *Cargo Traffic 2008 Final*. Montreal, Canada: ACI.

American Association of Port Authorities (APPA). 2009. *World Port Rankings*. Alexandria, VA: APPA.

http://aapa.files.cms-plus.com/PDFs/WORLD%20PORT%20RANKINGS%202009.pdf

ASEAN Vision 2020. Accessed at http://www.aseansec.org/1814.htm.

ASEAN Plan of Action for Energy Cooperation (APAEC) 2010–2015. Accessed at http://www.asean.org/22675.pdf.

ASEAN. 1994. ASEAN Plan of Action for Energy Cooperation 1999–2004. Accessed at http://www.aseansec.org/11704.htm.

Asian Development Bank. 2008. Loan 1357–INO: Gas transmission and distribution project. Accessed at http://www.adb.org/Documents/Environment/ino/ino_gas_transmission.pdf.

Asia Pacific Energy Research Centre (APERC). 2000. *Natural Gas Infrastructure Development: Southeast Asia.* Various press reports. Tokyo: APERC.

Asia Pacific Energy Research Center (APERC). 2009. *APEC Energy Overview*. Tokyo: APERC.

Black, W.R. 2000. Socio-economic barriers to sustainable transport. *Journal of Economic Geography* 8: 141–47.

British Petroleum (BP). 2011. *Statistical Review of World Energy 2010*. London: BP.

Chin, A., and P. Smith. 1997. Automobile ownership and government policy: the economics of Singapore vehicle quota scheme. *Transportation Research Part A: Policy and Practice* 31(2): 129–40.

Dings, J. 2009. Bunker fuels and the Kyoto Protocol: How ICAO and the IMO failed the climate change test. Brussels: European Federation for Transport and Environment (T&E).

D’Souza, N.S. 2011. *The Energy Saving Potential of Singapore’s Road Transportation Sector. Analysis on Energy Saving Potential in East Asia*. Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA).

Economic Development Board Singapore. 2011. *Industry background*. Singapore: Economic Development Board.

http://www.sedb.com/edb/sg/en_uk/index/industry_sectors/Chemicals/industry_background.html.

Economic Development Board Singapore. 2009. *Singapore—Asia’s Energy Hub*. Singapore: Economic Development Board. http://www.edb.gov.sg/etc/medialib/downloads/industries.Par.33625.File.tmp/Energy%20Factsheet.pdf.

Energy Market Authority Singapore. 2009. *Test-bedding of Electric Vehicles in Singapore from 2010.* Singapore: Energy Market Authority.

http://www.ema.gov.sg/media/news_pdfs/1254366883Test-bedding%20of%20Electric%20Vehicles%20in%20Singapore%20from%202010.pdf.

Energy Market Authority Singapore 2008. Billing consumers isn't the only way. *The Straits Times*. 10 October 2008.

Environmental Defense. 2006. *Singapore: a pioneer in taming traffic*.

Fogarty, D. 2011. Indonesia forest decree to help CO2 projects. *Reuters.* 1 June. http://www.reuters.com/assets/print?aid=USTRE74U12R20110531.

Foo, T.S. 1997. An effective demand management instrument in urban transport: the area licensing scheme in Singapore. *Cities* 14(3): 155–64.

Foo, T.S. 2000. An advanced demand management instrument in urban transport: electronic road pricing in Singapore. *Cities* 17(1): 31–49.

Government Monitor. 2009. Singapore highlights its role in expanding CDM activities in the region. 26 October.

http://www.thegovmonitor.com/world_news/asia/singapore-highlights-its-role-in-expanding-cdm-activities-in-the-region-12455.html.

Inter-Ministerial Committee on Sustainable Development (IMCSD). 2008. A Lively and Liveable Singapore: Strategies for Sustainable Growth. Singapore: IMCSD.

International Energy Agency (IEA). 2010. *Projected Costs of Generating Electricity.* Paris: IEA.

International Energy Agency (IEA). 2010. Projected Costs of Generating Electricity. Paris: IEA.

International Energy Agency (IEA). 2009. *Energy Statistics of Non-OECD Countries*. Paris: IEA.

International Energy Agency (IEA). 2006. *World Energy Outlook*. Paris: IEA.

Jakarta Post. RI may lower gas export to Singapore. 17 June.

Lee, K.P. 2012. Petronas CEO: Regas plant to be ready July 2012. *Dow Jones Newswire*. 4 October.

Koh, W., and D. Lee. 1994. The vehicle quota system in Singapore: an assessment. *Transportation Research Part A: Policy and Practice* 28(1): 31–47.

Land Transport Authority (LTA). 2008. LTA news release: Motorists can encash PARF and COE rebates from 1 September 2008. http://motoring.asiaone.com/Motoring/News/Story/A1Story20080701-73917.html

Land Transport Authority (LTA). 2008. *Land Transport Masterplan*. Singapore: LTA.

Maulia, E. 2011. E. politicians question ExxonMobil's presence in East Natuna. *The Jakarta Post*. 27 January.

Ministry of Trade and Industry Singapore. 2008. Energy for Growth: National Energy policy Report.

http://app.mti.gov.sg/data/pages/2546/doc/NEPR.pdf.

Ministry of Trade and Industry. 2007. National Energy Policy Report—Energy for Growth. Singapore: Ministry of Trade and Industry.

Ohli, P. 1994. Trans-Asian gas network could cost $66 billion. *Pipeline and Gas Journal* 221(8): 1–2.

Phang, S.Y., W.K. Wong, and N.C. Chia. 1996. Singapore's experience with car quotas: issues and policy processes. *Transport Policy* 3(4): 145–53.

Pillai, J.S. 2005. Historical Assessment of the Port of Singapore Authority and its progression towards a 'High-Tech Port'. *Discussion Paper*. Asia Pacific School of Economics and Government, Australian National University.

Reuters. 2008. Malaysia to revise electricity tariffs. 4 February. http://uk.reuters.com/article/2008/02/04/malaysia-economy-fuel-idUKKLR4031820080204.

Roesli, A.P. 2006. HAPUA and the ASEAN Power Grid for Optimum Use of Energy Resources. http://www.asean-sustainable-energy.net/documents/libraries/001/HAPUASecretary%20akhir%20Bangkok%206-10-06.pdf.

Sharp, L. 2005. The Journey—Singapore's Land Transportation Story. Singapore: Singapore Land Transport Authority.

Sovacool, B. 2009. Energy policy and cooperation in Southeast Asia: the history, challenges and implications of the trans-ASEAN gas pipeline (TAGP) network. *Energy Policy* 37: 2356–67.

Sovacool, B. 2009. Energy policy and cooperation in Southeast Asia: the history, challenges and implications of the trans-ASEAN gas pipeline (TAGP) network. *Energy Policy* 37: 2357–58.

The Jakarta Globe. 2010. Indonesia to lift subsidies gradually. 24 March. Accessed at http://www.thejakartaglobe.com/business/indonesia-to-lift-electricity-subsidies-gradually/365652

Wilbur Smith and Associates. 1974. Singapore Mass Transit Study, Phase 1 Final Report. Singapore: Wilbur Smith and Associates.

World Gas Intelligence. 2010. Malaysia LNG's new sick man? 15 December.

Xinhua. 2010. Indonesia will no longer renew LNG export contracts. 18 February.