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TABLE OF CONTENTS

A Paradigm for the 21st Century and Policy for Sustainable Development: Alternative Energy and Energy Efficiency

Hiroshi Komiyama

Abstract

In the 21st century, we human beings face a new paradigm: the Earth's limited resources, the aging of society and the explosion of intelligence. Brunei Darussalam, one of the advanced countries in Asia, will also certainly come to face issues emerging under this paradigm. Japan has experienced these problems ahead of the rest of the world, and is currently looking for proactive solutions. 'Vision 2050' was proposed by the author in 1999 and consists of three pillars: (1) Improve energy efficiency threefold; (2) Double the use of renewable energy; and (3) Establish recycling systems for materials. The 'Platinum Society' is a key to address many problems under the paradigm. It is a society where environmental problems are solved and elderly persons can live energetic lives. To realise the 'Platinum society', we need to launch new activities at a community level.

Keywords: *alternative energy, energy efficiency, Vision 2050*

This paper was presented by Hiroshi Komiyama who was a keynote speaker at the CSPS' International Conference on 'Alternative Energy and Energy Efficiency: Fuelling Economic Growth and Diversification for Brunei Darussalam' in July 2010. Hiroshi Komiyama is a distinguished and internationally respected leader in the field of chemical engineering, global environmental engineering and the structuring of knowledge. He was invited to become chairman of the Mitsubishi Research Institute in April 2009. He served as the 28th president of the University of Tokyo between 2005 and 2009, following a year each as vice-president and executive vice-president. Komiyama received his Bachelor's, Master's and Doctoral degrees in Chemical Engineering, all from the University of Tokyo, in 1967, 1969, and 1972 respectively. He became a full professor in the University of Tokyo's Department of Chemical Systems Engineering in 1988 and served as the dean of the School of Engineering from 2000 to 2002.

1.0 Introduction

During the 20th century, human beings dramatically accelerated civilisation. Subsequently, the impending depletion of resources and degradation of the environment are beginning to threaten the civilisation we have achieved. Shortages of resources are rapidly becoming a global problem because the amount of resources that can be secured on the Earth is finite while the global population continues to increase. Climate change can be expected in several areas of the world, for example, receding glaciers and rising sea levels. Food production is not expected to be sufficient for the increase in population.

In the 21st century, we human beings are facing a new paradigm: the Earth's limited resources, the aging of society and the explosion of intelligence. Brunei Darussalam, as one of the advanced countries in Asia, is expected to develop steadily. Wawasan Brunei 2035 projects its economy will grow 6% a year and its population will increase 2% a year. Brunei will certainly also come to face issues emerging under the paradigm. Among these issues, the Earth's limited resources constitute the most important problem for Brunei. Economic growth and increasing population demand energy. If Brunei makes no efforts to reduce energy use, exports of oil and gas will decrease because of increased domestic use. This might act as a brake on economic growth and it might become difficult to achieve the targets of Wawasan Brunei 2035. Brunei has to develop a strategy for energy conservation and introduce policy measures to achieve high energy efficiency.

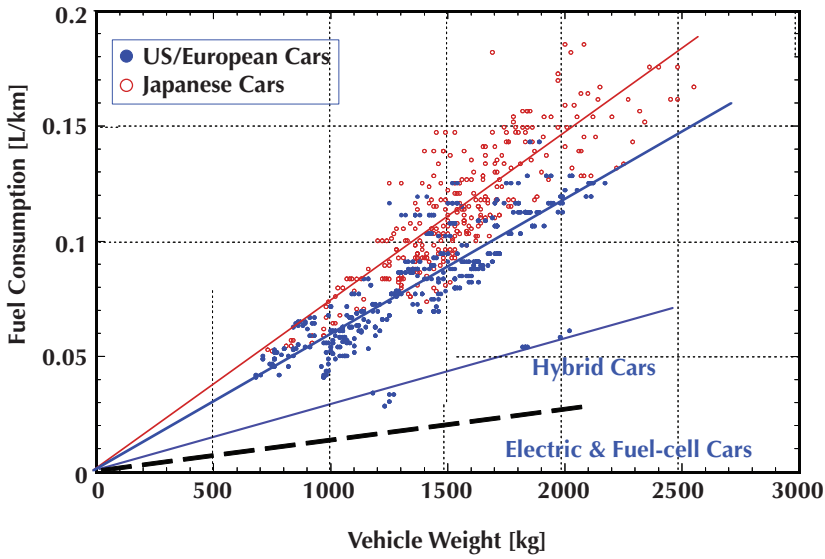
2.0 Japanese Strategy: Vision 2050

If Brunei develops a strategy and policies for energy conservation, the Japanese experience is a good reference. Japan has experienced the above-mentioned problems ahead of the rest of the world. Japan is highly industrialised, does not have many energy resources, is very densely populated on a group of small islands and has the problem of an aging population. The current situation in Japan represents the future challenges the rest of the world will face. Japan is currently looking for proactive solutions. Hence, 'Vision 2050' was proposed by the author in 1999. This comprehensive vision was taking into consideration of the growth of developing countries, maintenance of living standards in developed countries, energy and resources, environmental conservation and the potential and limitations of scientific technologies. Vision 2050 consists of three pillars: (1) Improve energy efficiency threefold; (2) Double the use

of renewable energy; and (3) Establish recycling systems for materials. These targets are theoretically and technically achievable, and provide fundamental concepts that can create an international consensus.

Figure 1 is a comparison of automobile energy consumption. Vehicle weight is plotted on the horizontal axis and fuel efficiency (volume of gasoline L/km) is plotted on the vertical axis. Assuming the same technology is applied to all cars, all the data would appear to follow a straight line passing through the origin. Japanese cars are 20% superior to American and European cars with respect to energy consumption. This shows the superiority of technologies comparing those cars. Hybrid cars can reduce the use of fuel by another half, even if the weight of the car is the same. Moreover, electric and fuel-cell vehicles can further cut energy consumption. Hence, if we assume the weight of a car will be cut by half and electric and fuel-cell vehicles will become popular, overall car energy consumption will be reduced to one tenth (1/2×1/5). Even if the number of vehicles in the world increases threefold in the future, overall car energy consumption will be cut by one third because the consumption of gasoline will be cut to one tenth.

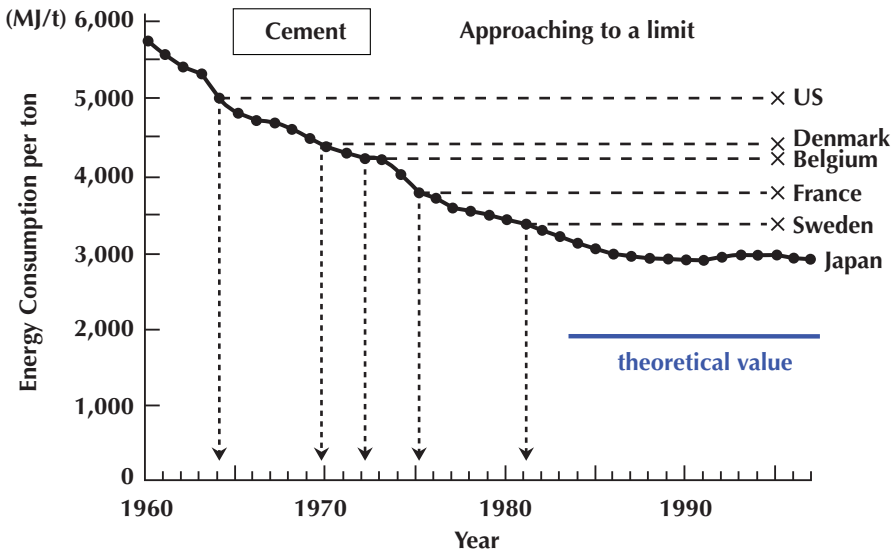
Figure 1.
Comparison of Automobile Energy Consumption



Source: Yahoo! Japan Autos

Some industries such as cement manufacturers in Japan, however, will have difficulty achieving further reductions of energy consumption. Figure 2 shows energy consumption in the cement sector around the world.

Figure 2.
Energy Consumption in the Cement Sector



Source: Japan Cement Association

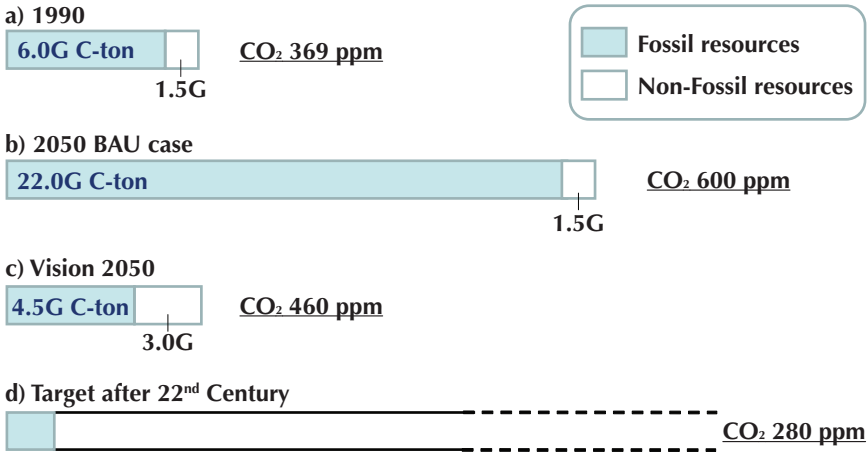
Japanese technology has allowed energy consumption in this sector to be reduced by about half over the 30-year period since 1960. Today, the sector is close to the theoretical limit of energy efficiency. On the other hand, cement manufacturers in other countries can reduce energy consumption. The US, for instance, consumes 170% more energy per production of a metric ton of cement than Japan. This is because the US has adopted a policy of keeping energy prices low.

The conclusion after examining energy efficiency from the present to 2050 in terms of major energy-consuming items such as automobiles, cement production and air-conditioners is that a threefold improvement of energy efficiency by 2050 is a very feasible target for Japan. There is another important point we should consider: Why did Japanese cement manufacturers seek to achieve high energy efficiency? The answer is that increasing energy efficiency is profitable. Installing new plants requires an initial investment, but it is returned over time because the cost of energy is cut. This is the reason they replaced conventional plants with more energy-efficient plants.

The scenario for 'Vision 2050' was developed based on the concept above. The vision was developed around 1990; however, the current situation is not very different. In 1990, 80% of total energy was supplied from fossil fuels, including oil, coal and natural gas. Twenty per cent came from non-fossil fuels. The world's population will continue to grow from six billion to nine billion according to the current trend and the living standards of developing countries

such as the BRICs (Brazil, Russia, India and China) will improve to the level of developed countries.

Figure 3.
Energy and CO_2 Scenario



Source: Vision 2050

This means the world will need three times more energy than it does now. However, 'Vision 2050' indicates that the same volume of energy will be sufficient because technology will improve threefold. As shown in Figure 3, 'Vision 2050' seeks to reduce global CO_2 emissions by about 25% compared to the Business as Usual scenario in 2050 by improving energy efficiency threefold and doubling the use of non-fossil fuels, nuclear power, hydropower, photovoltaics, wind power and biomass.

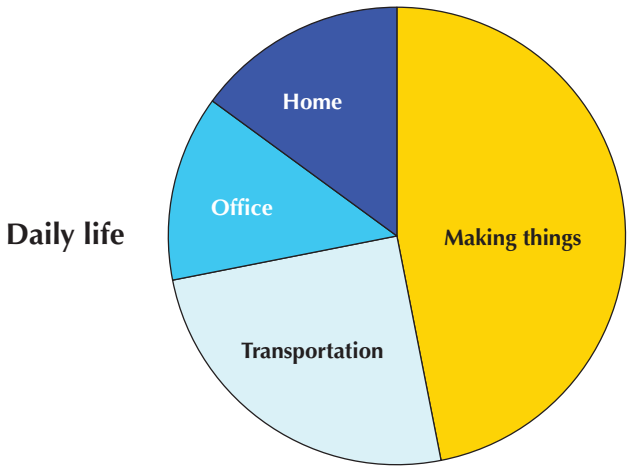
If we achieve the vision, we would have no concerns in the 22nd century and beyond because solar energy and nuclear power can supply an infinite amount of energy. Ten thousand times more solar energy is available than the energy we are consuming now. Even if we consume 10 times more, it will not be depleted. Nuclear can also be considered to be an infinite source as long as its security and safety are technically secured. Therefore, we can say that energy, CO_2 and global warming issues are the challenges of our century.

A common understanding among developing and developed countries is indispensable for addressing CO_2 issues. In 'Vision 2050', different conditions and approaches were applied. In developed countries such as Japan, the majority of citizens own houses and cars. The penetration rate of such items will not increase further. Under these conditions, energy consumption will decrease one third if energy efficiency is improved threefold. Similarly, if

non-fossil fuel energy increases twofold, CO_2 emissions will decrease by half. This is the vision for developed countries. The European Union has pledged an 80% reduction by 2050 and Japan a 60-80% reduction. President Obama has vowed that the U.S. will reduce CO_2 emissions 80% by 2050. So, these three developed regions have laid down the same goal. Although each country must have different reasons for making the 80% reduction declaration, the author believes that improving energy efficiency and increasing the use of non-fossil fuels are fundamental measures for them to achieve their targets.

The Japanese government conditionally confirmed that Japan will commit to a 25% GHG reduction by 2020 from 1990 levels under the committee of ministries. Sakihito Ozawa, the Minister of the Environment of Japan, said: "The 25% GHG reduction target is challenging, but also helps Japan to draft its growth strategy." The target is achievable.

Figure 4.
Energy Consumption by Final Use in Japan



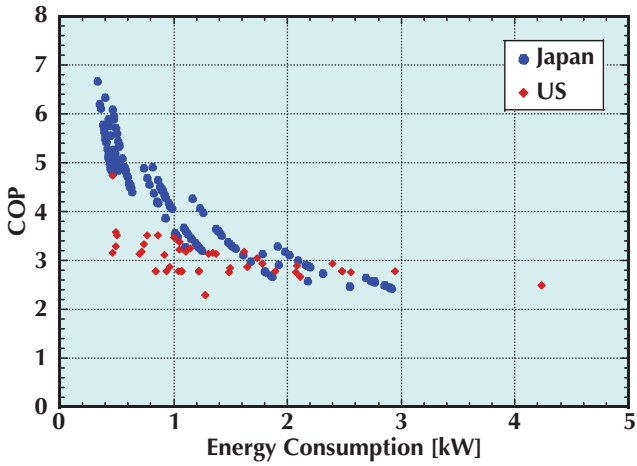
Source: Hiroshi Komiyama

Figure 4 shows energy consumption by final use in Japan. Usually, energy consumption is shown by industrial sector and residential sector. However, it is more understandable to divide it roughly into the following sectors: 'Making things', 'Daily life' and 'Energy conversion'. 'Making things' is manufacturing cars, electrical equipments, clothes, steel and plastic. 'Making things' consumes energy. Activities related to housing, offices and cars in 'Daily life' also consume energy. The power sector consumes energy, but it can be categorised into both 'Making things' and 'Daily life'. By categorising energy use as described above, 55% of Japan's energy consumption occurs in 'Daily life' activities. The remaining 45% of consumption occurs in 'Making things'.

Energy saving in 'Daily life' is measured as follows. In Japan, 30% of energy consumption in the residential sector is for heating water. Cooling and heating consume 30%. Lighting and refrigerating consume 10%. These percentages total 80%. Many components of that 80% can be reduced. If incandescent bulbs are replaced with fluorescent bulbs, energy consumption will fall by10%. The energy efficiency of refrigerators has been improved. If a ten-year-old model is replaced with a new one, energy consumption falls by one third. Similar effects can be expected with cooling and heating. Coefficient Of Performance (COP) is an indicator showing how much cooling and heating can be achieved for 1 kW. Theoretically, COP is 43 in an ideal situation. In 1990, the COP of an air conditioner was 3. COP has been improved recently. In particular, strict standards have been set for smaller equipments in Japan, so small units of less than 2 kW are very efficient in Japan, as indicated in Figure 5. If an air-conditioner manufactured in 1990 is replaced with a new Japanese air-conditioner of COP 6, half of the energy use of an air-conditioner can be saved.

Figure 5.

Performance of Air-Conditioners in Japan and the US



A 12% GHG reduction can be achieved from daily life, 3% from manufacturing, 5% from renewable power generation and increased capacity factor of nuclear power stations, and 5% from better forestry management. The accumulation of these efforts reaches a 25% GHG reduction potential. In addition, a 5% GHG reduction is possible through energy savings and renewable investment overseas.

As described above, a large volume of energy in households can be reduced. Not only will this be beneficial to the earth, but it should also be beneficial to domestic growth. It is important to export energy to the global market. The

total scale of energy businesses will be nearly one third of that of the auto industry. This provides a good example of how taking environmental measures also helps to create new businesses.

3.0 Komiyama Eco-House

Some people still doubt the author's statement regarding the potential for reducing energy consumption in households. So, the author examined it by himself at home. The home, known as the 'Komiyama Eco-House', was renovated eight years ago.

Figure 6.
The Komiyama Eco-house

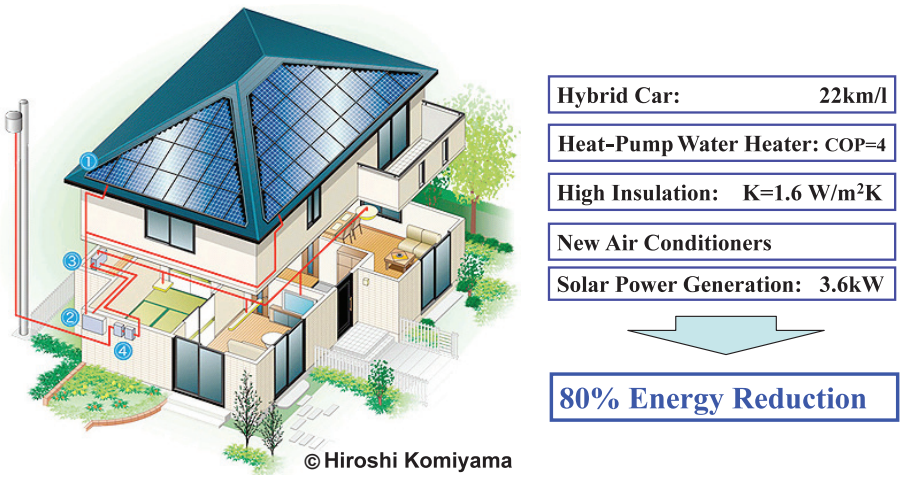


Figure 6 shows the concept of the Komiyama Eco-house. It has achieved more than an 80% reduction of energy consumption. First, double glazing was installed instead of single-pane glass windows. The latest model of eco-type air-conditioners was fitted at that time and a heat-pump water heater installed. Photovoltaics were installed on the roof. The car was replaced with a hybrid car and the refrigerator was replaced with a new model. Consequently, energy consumption was reduced by 58% from the previous level. Furthermore, the photovoltaics installed supply 23% of the energy demand of the house, so total energy consumption of 81% was cut in daily life. This cannot be achieved without an initial investment, but it will be recovered over the next 12 years. The author originally had a plan to renovate his house, so the investment explained here includes only expenses for energy efficiency and conservation. The total amount was about 34,400 USD. This includes 0.5 million JPY (~5,600 USD) for double glazing and two million JPY (~22,200 USD) for photovoltaics. The author previously paid about 300,000 JPY (~3,300 USD) annually for utilities

including electricity and gas, but the author only paid 48,000 JPY (~500 USD) last year, which means more than 250,000 JPY (~2,800 USD) can be saved annually.

The effects of energy saving in a house was experimentally verified. Regarding offices, the author tried the same at the University of Tokyo. The university is one of the biggest CO_2-emitting office complexes in Tokyo. Hence, the author tried to decrease it as president. First, the lighting was changed. 38,000 old lighting units were replaced with energy-efficient units using inverters. Energy use was reduced by half and the investment cost was recovered within 5 years. Next, when double glazing was introduced on the 8th floor where the president's office was located, heating expenses decreased 43%. Heat loss was reduced 83%. Furthermore, double glazing adjusts the temperature in the room, making it homogeneous. Using it, heat still remains the next morning. Double glazing has many more merits than single glazing.

In addition, promoting CO_2 reductions in our everyday lives will result in increased purchases of energy-efficient or alternative energy equipments or services. These will then nurture new markets, creating more jobs and new industries for the 21st century.

4.0 'Platinum Society'

In addition to GHG concerns, we need to address many other problems under the paradigm. The aging society should be considered as seriously as energy and environmental issues. Japan has been facing an aging society since 2006, when population growth hit its peak. It is said that population growth in China and India will also slow down in the mid-2030s and by 2050 respectively. Brunei will come to face an aging society. In fact, the entire world will be facing an aging society by 2050, which makes us realise that it is not only for environmental issues, but for an aging society, that we should build a social model to create a livable and enjoyable aging society.

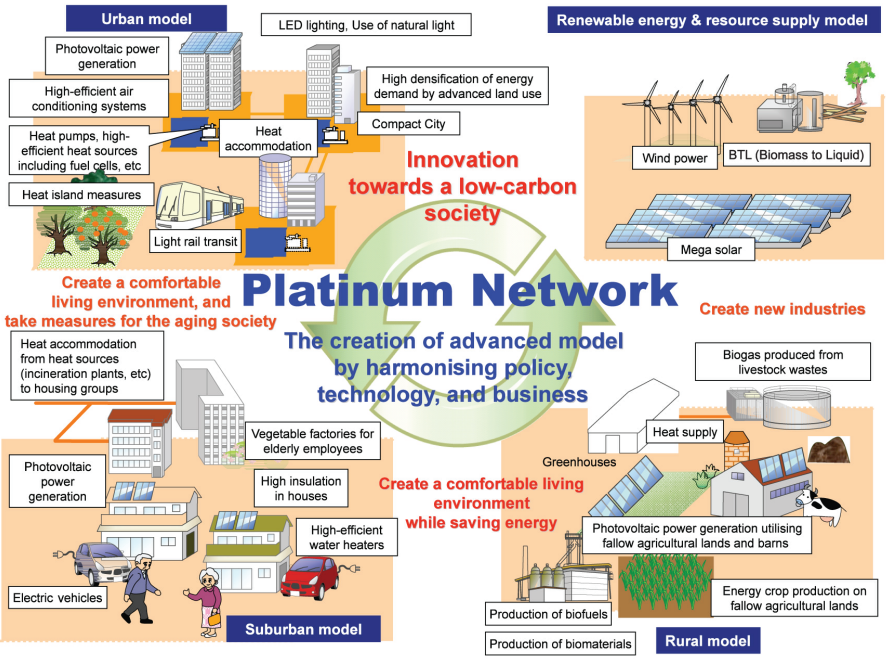
The author proposed the concept of the 'Platinum Society'. This is a society where environmental problems are solved and elderly persons can enjoy energetic lives. Developing a 'Platinum Society' enhances the competitiveness of industries and supports economic growth.

To realise a 'Platinum society', we need to launch new activities at a community level. The author proposed a 'Platinum network' as an experimental platform for developing the 'Platinum society' in collaboration with local municipalities.

We can lead the world in terms of addressing global warming and creating new industries by expanding the 'Platinum network' based on cooperation among citizens and applying the latest technologies such as photovoltaics, fuel cells, heat pumps and eco-cars. The 'Platinum network' may furthermore promote cooperation within communities in Asia in order to achieve an entirely new urban development model throughout Asia.

Figure 7.

Concept of the 'Platinum Society'



Source: Mitsubishi Research Institute Inc.

Brunei has decided to tackle issues emerging under the paradigm by promoting the use of alternative energy and improving energy efficiency. It would be wonderful if Brunei and Japan were able to enhance their collaboration to realise a 'Platinum Society' in both countries.

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Alternative Energy for Economic Growth: Paths towards the Sustainable Development of Brunei

Youngho Chang

Abstract

Energy is an essential input for economic activity and at the same time it is a final good for consumption. The oil balance, defined as the difference between indigenous oil supply and domestic consumption needs, is still positive but the situation is unsustainable. Facing looming exhaustion of fossil fuel reserves, energy security is directly related to the economics and national security for Brunei. There are three broadly defined strategies that could help Brunei ensure energy supply: develop indigenous sources of fossil fuels, cooperate with other countries in the region, and develop and expand viable sources of renewable energy resources, including solar energy. A country like Brunei could become weakly sustainable if it secures the paths of natural resource use that lead to constant consumption per capita over time. If Brunei sustains a positive population growth and a sufficient level in technological progress, it should draw down oil and natural gas stocks at such a rate that the Hotelling r-percent efficiency rule is always being satisfied.

Keywords: *alternative energy, energy security, economic growth, weak sustainability, sustainable development*

This paper was presented by Youngho Chang who was a speaker at the CSPS' International Conference on 'Alternative Energy and Energy Efficiency: Fuelling Economic Growth and Diversification for Brunei Darussalam' in July 2010.Youngho Chang is an Assistant Professor of Economics at the Division of Economics and an Adjunct Senior Fellow at the S. Rajaratnam School of International Studies (RSIS), Nanyang Technological University, Singapore. He is also a Senior Fellow at the Energy Studies Institute (ESI), National University of Singapore. Apart from academic affiliations, he is a member of Technical Committee for Clean Development Mechanism (CDM) Designated National Authority (DNA), National Environment Agency, Singapore. He published his research papers in academic journals. Apart from academic publications, he carried out consultation projects for the public and private sector. He specialises in the economics of climate change, energy and security, oil and economy, and electricity market deregulation. His current research interests are oil price fluctuations and macroeconomic performance, the economics of energy security, and energy use and climate change. He received his Ph.D. (in Economics) from the University of Hawaii at Manoa, U.S.A.

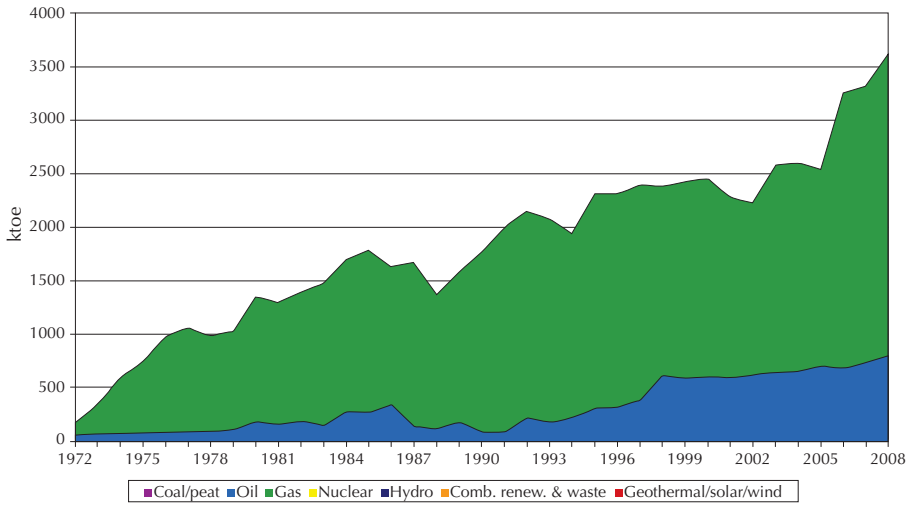
1. Energy Resources in Brunei Darussalam

Brunei Darussalam, a country with an area of 5,765 km^2 and a population of about 398,000, is endowed with rich resources of fossil fuels. The crude oil and natural gas industries are the dominant industry in Brunei Darussalam. These oil and natural gas resources account for 70% of its GDP and 78% of its exports (Oxford Business Group, 2009). According to the 2009-2010 World Economic Forum's Global Competitiveness Index, Brunei Darussalam is number one in macroeconomic stability (Oxford Business Group, 2009). Energy, as a crucial necessity in the economy of Brunei Darussalam, must meet the needs of today and the future without negative effects on the environment.

1.1 The Fossil Fuels in Brunei

Figure 1-1.

Brunei's Total Primary Energy Supply

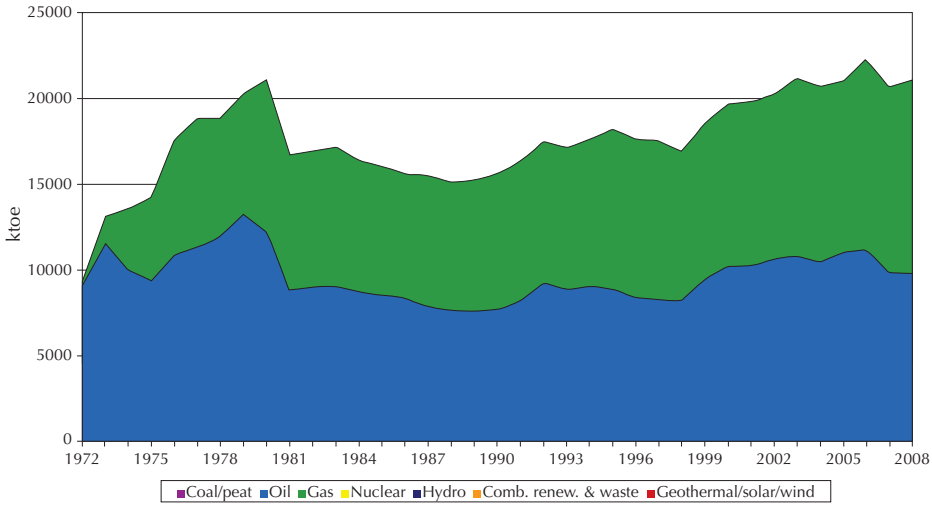


Source: IEA Energy Statistics (2010)

Brunei Darussalam has 1.1 thousand million barrels (0.1 thousand million tons) of proved oil reserves and 0.35 trillion cubic meters of proved natural gas reserves at the end of 2009 (BP Statistical Review of World Energy, 2010). The R/P ratio for oil is 17.6 and for natural gas 30.7. Figure 1-1 and Figure 1-2 show that oil and natural gas constitute the total primary energy supply and production in Brunei, which means Brunei depends totally on fossil fuels for its energy needs.

Figure 1-2.

Brunei's Total Energy Production



Source: IEA Energy Statistics (2010)

1.2 Renewable Energies in Brunei

There are few renewable energy alternatives except solar energy in Brunei. Brunei Darussalam is located in the tropical region with plenty of solar radiation. Solar thermal technologies have been investigated in the country. The average daily insolation in Brunei is about from 400 to 500 W/m^2 and its peak is over 1,000 W/m^2. A solar diesel hybrid electric power system was installed in 2000 at Ulu Temburong National Park in the Temburong district. This is an initial foray into solar technology (Renewable Energy & Energy Efficiency Partnership, 2010). In 2008, Brunei signed a memorandum of understanding with the Japanese Mitsubishi Corp to construct a test solar power plant in the country. This indicates that Brunei is trying to introduce renewable power sources to diversify its primary energy supply (Reuters, 2008). This diversification of energy resources is a step forward for the country to enhance its energy security.

Developing renewable energy resources is critical to Brunei. Although Brunei's renewable energy resources are low in quantity, they still have potential for development. Besides solar energy, Brunei has annual average wind speeds of 5 m/s in coastal regions, which suggests that the country has the potential for power generation from wind energy. The first wind turbine is to be installed in the country. Further studies are being conducted in order to ascertain the potential for further wind energy utilisation. In terms of hydropower,

Brunei has an estimated hydro-electric potential of 300 GWh per year in the Temburong Basin. The country has also investigated the potential for power generation from tidal energy. With regard to biomass, it has been identified that the proper cultivation of rainforest for energy production could be a priority for increasingly using renewable energy sources in Brunei. A prerequisite for this is that the utilisation must be such as not to damage the country's forest resources (Renewable Energy & Energy Efficiency Partnership, 2010).

1.3 The Structure of this Paper

In the following sections, the paper discusses the concept of energy security and ways to measure it in the context of Brunei in section 2. Section 3 focuses on the importance of energy infrastructure building and the impacts of an integrated regional energy market with respect to harnessing renewable energy. Section 4 discusses sustainability theory, which can shed light on what and how a country should do so as to become sustainable. The example of Dubai is introduced to elaborate the weak sustainability theory in section 5. Section 6 presents a hybrid sustainability model with an application of the model to Brunei and relevant policy implications for Brunei to develop on a weak sustainable path. Section 7 concludes the paper.

2. Energy Security in Brunei

2.1 Concept of Energy Security

There are various concepts of energy security in the literature. Conventional views on energy security are mainly focused on the adequate supply of oil. A more comprehensive concept of energy security has gained a wider acceptance. The comprehensive concept of energy security is generally defined as an adequate and reliable supply of energy at a reasonable price. Three basic components of energy security are incorporated in the concept: adequacy, reliability and reasonable price.

The adequacy is associated with availability of resources in a country. Without available resources in a country, there will be no energy supply. Take electricity supply as an example. There would be no electricity supply if there is no generation capacity in a country. As regards supplying fossil fuels, there must be economically sufficient reserves of the resources. As regards the electricity supply, there must be enough generation capacity. The reliability

component is about the stability of the transportation network in general or the transmission and distribution grid for the electricity supply. It is associated with the transportation network or transmission grid, which must be reliable. To supply fossil fuels such as crude oil or natural gas, pipelines, oil tankers or LNG facilities are required for the supply of these energy resources. To supply electricity, a transmission grid is required. There will be disruption in the energy supply if a network or grid fails, regardless of adequate supply or generation capacity. The reasonable price component requires that there are no dominant or pivotal suppliers to guard against the possibility of intentional price increases. It is associated with an assurance of affordability. Overly high prices might severely limit an economy's capability to purchase the necessary amounts of energy required for normal functioning, which may unavoidably result in energy supply disruptions and loss of economic welfare. These three components must be ensured for a country to achieve energy security. The following sections discuss the measures Brunei should take on the basis of the three components to achieve energy security.

2.2 Energy Security Measurements

Several simple and straightforward measures indicating a country's energy security can be used to elaborate on a country's status of energy security. Examples are the inverse of the number of energy resources used; the share of the most utilised resource; the share of fossil fuels utilised; and the share of the top 5 most utilised resources. All together the variety of energy resources and the dependence on fossil fuels are examined.

The inverse of the number of energy resources utilised (1/n, where n is the number of energy resources utilised) is an overall indicator, simple and straightforward. The bigger the number, the more kinds of resources are used in the country. A lower value of this indicator means that the dependence on one fuel is relatively lower and the disruption of the fuel will cause lesser damage than otherwise, and hence the more energy security the country has. Therefore, low 1/n means a relatively better energy security status for the country. The share of the most utilised resource (%) shows the degree of dominance/concentration of one kind of energy resource in a country. Hence, a lower number means less dependence on one energy resource and a better energy security status. The share of fossil fuels used (%) shows a country's dependence on fossil fuels. A lower number means less dependence on fossil fuels and more usage of non-fossil fuels. The usage of non-fossil fuels must

be renewable and/or nuclear, which could be clean. Therefore, a lower number means a better energy security status. The share of the top five most utilised resources (%) is also a useful indicator. Since the top five resources must contain non-fossil fuels in the energy or fuel mix, this indicator reflects a higher energy security status and relative energy diversity of a country. The lower the number is, the higher the level of diversification into non-fossil energy resources, and the country has a higher energy security status.

These four indicators can calculate Brunei's energy diversification and the present energy security status in Brunei. Table 2-1 shows the values of the energy security indicators and related energy security status in ASEAN countries. The figures show that Brunei's energy security status is relatively low mainly due to its high dependence on fossil fuels.

Table 2-1.

Asean Countries' Status of Energy Diversification

Country	1/Number of Resources (n)	Share of Most Utilised (%)	Share of Fossil Fuels (%)	Share of Top Five (%)
Brunei	0.5 (2)	NG (73)	100.0	100.0
Cambodia	1.0 (1)	Oil (100)	100.0	100.0
Indonesia	0.11 (9)	Oil (47)	97.7	99.6
Laos	0.33 (3)	Oil (100)	100.0	100.0
Malaysia	0.13 (8)	NG (51)	97.5	100.0
Myanmar	0.5 (2)	NG (56)	100.0	100.0
Philippines	0.13 (8)	Oil (58)	92.5	100.0
Singapore	0.33 (3)	Oil (88)	100.0	100.0
Thailand	0.13 (8)	Oil (52)	96.6	98.1
Vietnam	0.17 (6)	Oil (37)	100.0	100.0

Source: Chang (2009)

3. Energy Infrastructure and Integrated Energy Market

3.1 Energy Infrastructure in an Economy

An extended and enhanced infrastructure is a necessary condition for energy transportation and energy trade. For example, most renewable energy resources are harnessed in the form of electricity and reach end users via power grids,

which are a kind of artery of an economy like roads and railways. Without being connected to the power grids, the electricity generated from renewable sources may not reach the end users. Thus, infrastructure investment and economic development are strongly interconnected. The improvement of infrastructure can boost a country's technological innovation and advancement, and thus promote its long-term growth (Straub, Vellutini & Walters, 2008).

3.2 Integrated Regional Energy Market

3.2.1 Reasons for an Integrated Regional Energy Market in South-East Asia

Characteristics of ASEAN energy resources and market status require an integrated energy market in the region. First, the indigenous supply of fossil fuels in ASEAN is not enough to meet the demand. According to IEA estimation, ASEAN's oil consumption is projected to reach 267 Mtoe in 2030 and consumption of natural gas is expected to rise to 199 Mtoe in 2030. The region's oil production is projected to decline steadily to 2.4 mb/d in 2015 and to 1.4 mb/d in 2030, while natural gas production is projected to increase from 203 bcm in 2008 to 248 bcm in 2030. However, the surplus of supply over demand is expected to drop from 63 bcm in 2008 to 10 bcm in 2030. Unless new gas fields are discovered, natural gas exports are expected to decline. Second, there is strong potential in renewable energy such as hydropower, geothermal and biomass in ASEAN. The problem is that the utilisation level is very low compared to the huge potential. An integrated energy market will promote the development of renewable energy resources and make resource utilisation more rational. It would also benefit the environment to a large extent. Cross border energy trade involving renewable energy resources would reduce power generation from coal or oil and improve the environment. Third, there is a difficulty in the recovery of investment costs in individual countries. Demand for fossil fuel and renewable energy production call for cumulative investment, especially in the infrastructure of energy supply in South-East Asia. The investment would be $1.1 trillion over the period of 2008-2030. The power sector accounts for 55% of the investment. However, financing the power sector investment will be a big challenge (International Energy Agency, 2009).

3.2.2 Endeavours of South-East Asia for an Integrated Energy Market: Cooperative Competition

In terms of the ASEAN energy market, cooperative competition means the region works collectively towards increasing the size of the economic pie or market while each country competes to gain a larger share of the pie in the integrated market. Cooperative competition does not mean creating cooperative monopolies or abandoning competitive markets. On the contrary, it allows for the relationships among a special type of participant competing in the ASEAN energy market. Cooperation is "a basic human impulse that forms the background for healthy competition" (Fitch & Loving, 2007, p.83). Examples of cooperative competition in the ASEAN energy market include, but are not limited to, the ASEAN Power Grid and the Trans-ASEAN Gas Pipelines.

Table 3-1.

Status of South-East Asian Power Grid Interconnection Projects

Interconnection Project	Type	Capacity	Status, Start
1. Thailand-Lao PDR	HVAC PP	2,015/1,578 MW	AP, 2008/2010
2. Thailand-Myanmar	HVAC PP	1,500 MW	AP, 2013
3. Thailand-Cambodia	HVAC EE	300 MW	AP, 2016
4. Lao PDR-Vietnam	HVAC PP	1,887 MW	AP, 2007/2016
5. Vietnam-Cambodia	HVAC PP	80/120 MW	UC, 2003/2006
6. Peninsular Malaysia-Sumatra (Indonesia)	HVAC EE	600 MW	UC, 2008
7. Peninsular Malaysia-Singapore	HVAC PP	700 MW	Planned, 2012
8. Sumatra (Indonesia)-Singapore	HVAC PP	600 MW	Planned, 2014
9. Batam (Indonesia)-Singapore	HVAC PP	200/200/200 MW	UC, 2014/15/17
10. Sabah/Sarawak (Malaysia)-Brunei Darussalam	HVAC EE	300 MW	Planned, 2019
11. Sarawak (Malaysia)-W. Kalimantan (Indonesia)	HVAC EE	300 MW	Completed, 2009

Source: APERC (2004)

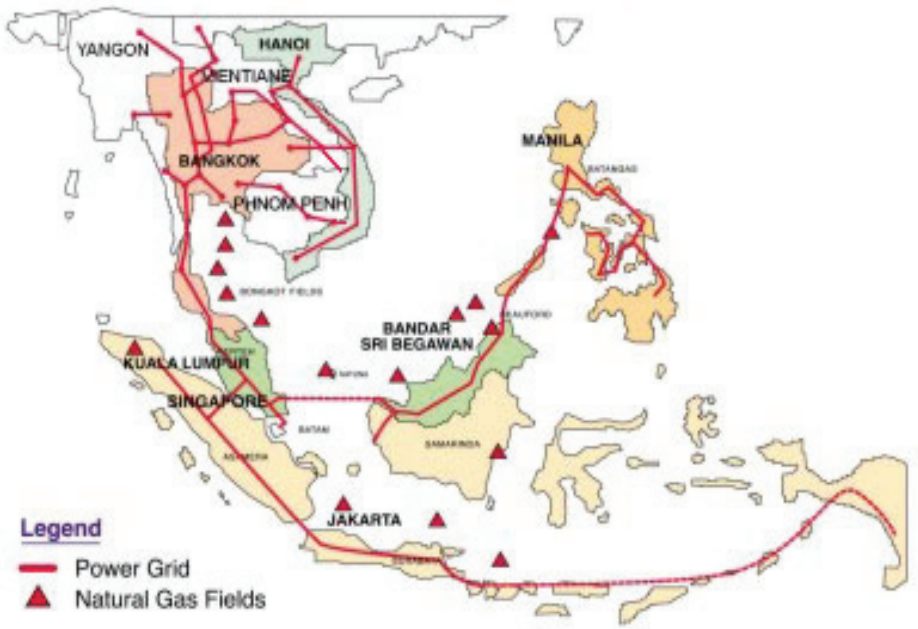
Note: HVAC = high voltage alternating current HVDC = high voltage direct current
PP = power purchase EE = energy exchange
AP = advanced planning UC = under construction

The regional master plan study on the ASEAN Power Grid, called the ASEAN Interconnection Master Plan Study (AIMS), selected eleven power grid projects for implementation. Table 3-1 shows the interconnection projects between ASEAN countries. These interconnections will greatly add power line capacity

throughout ASEAN. Figure 3-1 shows ASEAN power grid interconnection, covering all ASEAN states. Of these proposed interconnections, the project of interconnection between Sabah/Sarawak in Malaysia and Brunei Darussalam is planned to be completed in 2019, which involves Brunei's direct participation.

Figure 3-1.

ASEAN Power Grid

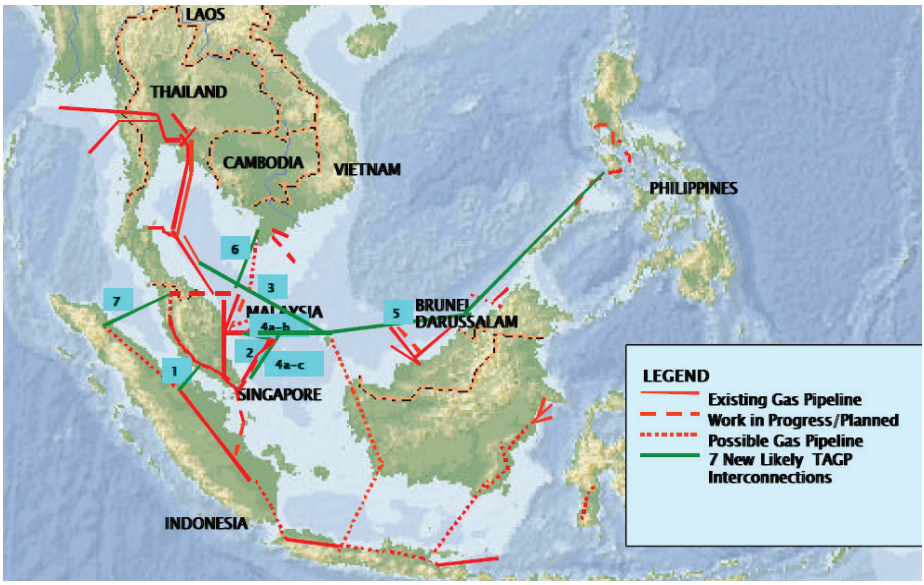


Source: ASEAN Centre for Energy

ASEAN countries also signed the ASEAN Memorandum of Understanding (MoU) on the Trans-ASEAN Gas Pipeline (TAGP) in July 2002 for the purpose of assuring a long term reliable energy supply. The routes of the gas pipeline grid are similar to those of the ASEAN power grid. Figure 3-2 shows the existing and planned gas infrastructure in South-East Asia.

Brunei should seek opportunities in cooperating with other ASEAN countries in the development of its energy resources. This cooperation could be carried out through infrastructure building and energy market integration in the region. By integrating its energy infrastructure with that of other countries in the region, Brunei could approach varied regional sources of energy supply. The above illustrated ASEAN Power Grid and Trans-ASEAN Gas Pipelines will help Brunei realise the cooperation.

Figure 3-2.
Existing and Planned Gas Infrastructure in South-East Asia



Source: ASCOPE Secretariat

4. Theory of Sustainable Development

4.1 An Overview of Sustainability

The concept of sustainable development originated in the early 1970s with various studies focused on the concerns about economic development and environmental constraints. A notable publication on this is 'The Limits to Growth', which explores how exponential growth interacts with finite resources (Meadows, Meadows, Randers & Behrens III, 1972). The idea of sustainability and the term 'sustainable development' formally came to international public attention in 1987 when the World Commission on Environment and Development issued the report 'Our Common Future' (also called the *Brundtland Report*). It presented a broad definition of sustainable development, which is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p.54). This implies that the central objective of an economic approach for sustainability is to find paths of natural resource use that lead to constant consumption per capita, which could guarantee that the needs of future generations are not compromised.

4.2 Weak Sustainability versus Strong Sustainability

With regard to the concept of sustainability, a critical question to be answered is what and how do we need to sustain? Answers to this question can be divided into 'strong' and 'weak' approaches. The notion of strong and weak sustainability is derived from the economic concept of capital: a stock of resources. The capital stock has been disaggregated into four types: manufactured capital, human capital, social/organisational capital, and natural capital (Ekins, 1992). The two approaches then are focused on the issue of substitutability of the different forms of capital in achieving sustainability. The key assumption of strong sustainability is that natural capitals (for example, fuels and minerals) are not substitutable by man-made capitals (for example, machines, buildings and knowledge). Strong sustainability hence requires the protection of certain absolute levels of natural capital, which means that substitutability is very limited in this sense. It prohibits the depletion of natural capital such as trees and water. Strong sustainability gives a priority to the preservation of ecological goods, such as the existence of species or the functioning of particular ecosystems, whereas there is little consideration of the costs of attaining sustainability. Strong sustainability is ecological sustainability and its focus is on the environment (Bell & Morse, 2008).

Weak sustainability requires that the total value of capital stock does not decline. It presumes that all the four types of capital stock are perfectly substitutable. It disregards specific obligations to sustain any particular goods, only following a general principle to leave future generations no worse off than the current generation is. This means that financial or other costs of attaining sustainability are important and ecological environments can be traded against economic gains. To apply this in the energy arena, for example, weak sustainability requires that the accumulation of man-made capital such as machine capital balances off the depletion of natural capital such as fossil fuels. This is the balancing of disinvestment (in natural capital) with positive investment (in machine capital) to yield zero net investment, which will keep output constant.

4.3 Setting Sustainability for Exhaustible Resources

Sustainability theory, no matter whether weak or strong, is not too difficult to implement for renewable resources. For example, in the fishing economy, stock and harvest can be easily balanced to sustain natural capitals. For non-renewable resources, however, application of sustainability theory is more

complex, since it requires constant consumption of non-renewables, such as fossil fuels. In the oil economy, therefore, sustainability theory requires more subtle management of the two types of capital: natural capital and man-made capital. A criticism has been made that the requirement for constant consumption is too conservative. 'Perpetual non-increasing consumption' may be a better concept for the application of sustainability theory for non-renewable resources.

5. Sustainability in Action: The Case of Dubai

Propelled by an oil-rich economy, the United Arab Emirates (UAE) has been progressing steadily on the path of development over the last three decades. Dubai is one of the seven emirates that form the UAE federation. Although construction and real estate contributes most to Dubai's GDP, natural resource depletion is also intensive in the country. Thus, Dubai, as a growing city, needs to plan its development path in a sustainable way to reduce its natural resource depletion and its negative environmental impacts.

5.1 Development of the Dubai economy

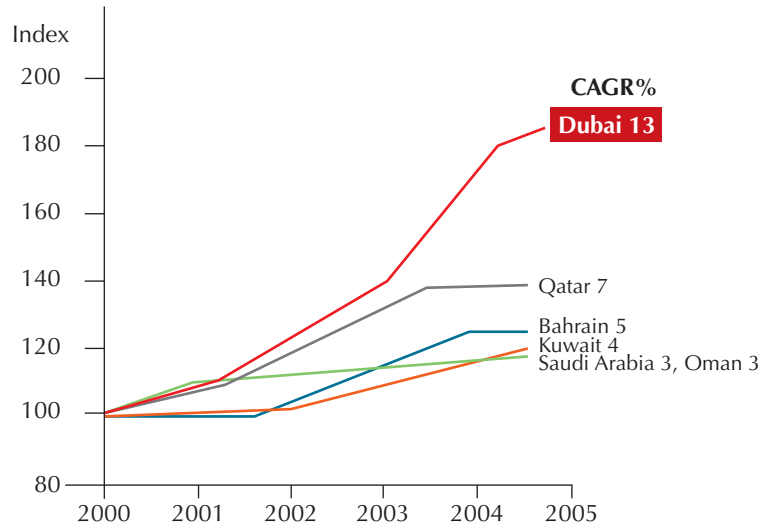
The discovery of oil in the 1960s spurred Dubai's development. Within the UAE, Dubai produces relatively minor amounts of crude oil, compared with Abu Dhabi. The two largest refineries are in Abu Dhabi (EIA, 2011). In consequence, Dubai oil revenues are not as great as those of Abu Dhabi. When oil was discovered in 1966, the oil revenues were used to develop hospitals, roads and a modern telecommunications network in Dubai, which is the key element for its weak sustainable development path. Dubai also built a new port and terminal building at Dubai International Airport. The largest man-made harbour in the world was constructed with a free zone created around the port. Dubai's formula for development was described as "visionary leadership, high-quality infrastructure, an expatriate-friendly environment, zero tax on personal and corporate income and low import duties" (Department of Economic Development, 2011). In the 1990s, along with a decrease in oil production, Dubai decided to become a major international tourism destination. Tourism has brought large revenues for Dubai. As a result, Dubai has become a business and tourism hub for the region and the world.

With a more dynamic and diversified economy, excellent infrastructure and liberal government policies, Dubai has been extremely successful in attracting FDI. In 2008, Dubai attracted a total of 342 FDI projects, amounting to $21 billion of capital investment. The number of FDI projects set up in Dubai grew by 59% over 2007. Capital investment soared from $9bn to $21bn between 2007 and 2008, increasing by 123% (Department of Economic Development, 2011). To sum up, trade, (oil and gas) industry, tourism, investment, and finance have helped Dubai achieve a high degree of expansion and diversification in its economy, and thus develop on a weak sustainable path.

5.2 Dubai's Weak Sustainable Development

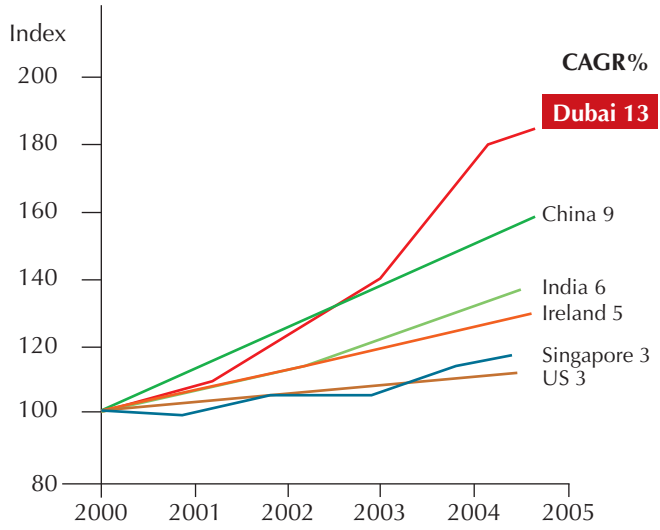
Dubai is a typical case to illustrate how a country develops on a weak sustainable path. Man-made capitals are largely invested with the revenues from oil and natural gas resources. The result is its dramatically fast growth of real GDP. Figure 5-1 shows that during the period from 2000 to 2005, Dubai's real GDP growth was impressive, with a compounded annual growth rate of 13%, far more than that of other Gulf Cooperation Council (GCC) countries (Department of Economic Development, 2009).

Figure 5-1.
Real GDP Growth - Dubai vs. GCC Countries (2000-2005)



Source: Department of Economic Development (2009)

Figure 5-2:
Real GDP Growth - Dubai vs. International Benchmarks (2000-2005)



Source: Department of Economic Development (2009)

Dubai's economy has grown not only faster than the other GCC countries, but faster than emerging economies such as India and China, and developed economies such as the US, Singapore and Ireland (Department of Economic Development, 2009). Figure 5-2 presents the comparison.

6. Towards A Hybrid Sustainability Model

How can Brunei reach a desirable sustainable state of development? First, the 'desirable sustainable development state' must be defined. The desired sustainable development state could be a hybrid of strong and weak sustainability. Strong sustainability requires us to give up the assumption that natural and man-made capitals are substitutable to each other, which is too restrictive a condition. Weak sustainability focuses more on economic development and can fare poorly in environmental aspects, at least in the view of strong sustainability. In addition, weak sustainability assumes that natural and man-made capitals are highly substitutable, which is difficult to justify. Considering the environmental laxity of weak sustainability and the impeccable environmental stringency of strong sustainability, the chosen desirable sustainable development state would be something between the two, a hybrid sustainable state (Chang & Tan, 2009).

6.1 Hybrid Sustainability Model (HSM)

Based on the weak sustainability rule, HSM is derived and expressed as

$$sY = \left(\frac{\alpha}{g_A + \alpha} \right)(Y_R - a)R + nK,$$

where s is the saving rate, Y is the output, R is the non-renewable capital, K is the renewable capital, g_A is the growth rate of overall technology level, Y_R is the marginal productivity of non-renewable capital, α is the parameter associated with renewable capital (i.e. the capital share of output), a is the cost of using non-renewable capital and n is the population growth rate. This equation is also the investment rule for the hybrid model. It suggests how much should be invested in man-made capital so as to keep consumption per capita constant. Compared with the Hartwick Rule, this new investment rule is more practical since it adds the factors of technological progress and population change, which are held constant in the Hartwick Rule.

In the equation, $(Y_R - a)R$ is the Hotelling rents. Intuitively, the higher the population growth rate, n, the more we need to invest, while the faster the rate of technical progress, g_A, the less we need to invest.

The amount of investment in man-made capital needed to maintain per capita output at the current period cannot be more than the entire Hotelling rents (i.e. the proceeds from selling oil and natural gas). For a country like Brunei, positive population growth and technological progress are relevant. If Brunei maintains its entire Hotelling rents no less than its per capita output, it may develop on a weak sustainable path. Brunei has had some practice in this. It tries to manage its reservoir and the reserve replacement ratio. Brunei's standard is the so called 'always greater than one', which means that Brunei can only extract one barrel of oil when it is known there is another barrel down there. By this standard, Brunei's reserve replacement ratio is always greater than one. This is the standard for Brunei to have sustainability (Goh & Bandar, 2011). To slow down the rate of extraction of its hydrocarbons is a feasible way to help sustain Brunei's economy. In addition, if Brunei's population is increasing and if the desired level of per capita income in Brunei rises over time, the required investment to sustain its income is to invest its rental income abroad (Tisdell, 1998). In other words, Brunei should save and invest a part of current output that is equal in value to the net on the amount of oil and natural gas currently extracted and used up. The following numerical example of the

hybrid sustainability model shows that the amount of investment in man-made capital needed to maintain per capita output in the current period should be not more than the entire Hotelling rents (i.e. the proceeds from selling oil and natural gas).

To sum up, economies are generally more than weakly sustainable when the rates of population growth and technological progress are positive, since the residual Hotelling rents are still left positive after constant per capita output is ensured. The following section explores how the usage of the residual Hotelling rents leads to strong sustainability.

6.2 Digression: Strong Sustainability

The Hybrid Sustainability Model suggests that weak sustainability could be achieved by investing part of an economy's Hotelling rents. However, weak sustainability alone cannot ensure sustainable development because of the market's undervaluation of ecological goods and services. Therefore, a strong sustainability approach is also needed in the process of seeking sustainable development. HSM adopts the Safe Minimum Standards (SMS) approach as its Strong Sustainability definition. Compared to SMS, the HSM does not require maintaining all stocks of natural resources at the SMS level, since it is assumed that non-renewable natural resources are substitutable by man-made capital and thus the HSM only requires that the stock of renewable natural resources is maintained at the SMS level. Hence, the HSM can ensure that ecological goods and services will be enjoyed by the next generations at the same level with those the current generation is enjoying. That is to say, to ensure strong sustainability in the HSM, the residual Hotelling rents must be invested in a way to ensure that the stock of renewable natural resources remains at least at or above the SMS level.

6.3 Policy Implications for Brunei

Considering Brunei's looming depletion of fossil fuel reserves, Brunei must take up strategies to ensure its energy supply. First, it should develop indigenous sources of fossil fuels at full scale by exploration and production activity and technological development. In a recent interview, Brunei's Minister of Energy stated that most of the national revenues were from the oil and gas industry. For example, downstream activities in Brunei are still very limited. Brunei should

try to expand its oil and gas supporting industries. Since Brunei is heavily dependent on oil and gas exports for government revenues, it must develop downstream oil and gas projects so as to diversify its export base, especially in an unstable energy price market, which could mitigate negative impacts by fluctuations in energy prices.

Second, Brunei should seek cooperation in the development of energy resources by integrating its energy infrastructure with that of other countries in the region. The ASEAN Power Grid and the Trans-ASEAN Gas Pipelines will help Brunei tap into foreign energy supply sources. Since the resources in South-East Asia are not well connected, to upgrade and extend Asia's infrastructure networks will create large benefits and a win-win situation for all the participating countries. Brunei should positively participate in the connection of energy infrastructure and resource integration so that it could obtain the large welfare benefits of reduced costs, increased trade volume and more efficient energy utilisation.

Third, although the possibilities of developing renewable sources are low, Brunei needs to put more efforts into developing and expanding viable sources of renewable technologies, including solar energy, mini-hydro and wind power. Brunei's problem is that many of these renewable resources are still at an infant stage of development. Brunei should develop these renewable energy resources seriously to diversify its energy supply. Another reason for Brunei to develop renewable energies is high energy prices. Although high energy prices bring high government revenues for Brunei, they also put high pressures on the Brunei government to subsidise the nation's petrol and electricity consumption. Hence, Brunei must carry out policies to promote renewable energy and energy efficiency (Ubaidillah, 2009). Due to Brunei's heavy dependence on fossil fuels for its energy needs, the efficient use of fossil fuel is the most cost-effective measure for Brunei to stave off the risk of high energy prices. It is also an effective measure to prolong the country's fossil fuel reserves. For Brunei, a country heavily dependent on crude oil and natural gas exports, conserving energy and increasing energy efficiency is one of the most effective methods towards sustainability (Goh & Bandar, 2011; Lawrey & Pillarisetti, 2011). Increasing energy efficiency also contributes to improved environments. Brunei has a national target to reduce its national energy intensity by 25% by 2030 (Renewable Energy & Energy Efficiency Partnership, 2010). Institutional facilities should be established to support this development.

Finally, to become at least weakly sustainable, Brunei must save and invest a part of current output that is equal in value to the net on the amount of oil and natural gas currently extracted and used up. Brunei's 'always greater than one' standard is such a standard to meet the Hotelling rents rule.

7. Conclusion and Suggestions for Brunei's Energy Security and Sustainable Development

This paper reviews Brunei's energy resources and analyses Brunei's energy security status within the energy security framework. To enhance its energy security, Brunei must develop its energy infrastructure and integrate its energy market with relevant regional and international markets. Energy infrastructure is necessary for energy transmission and energy trade. It also helps establish an integrated energy market. An integrated ASEAN energy market, in which Brunei participates, will enhance its energy security by ensuring sufficient energy supplies.

This paper also examines the sustainability of Brunei's development path. Sustainable development is a path that ensures the well-being of future generations as well as intragenerationally. It reviews two sustainability models: weak sustainability and strong sustainability, and proposes a hybrid sustainability model applicable to Brunei. Dubai is a case to elaborate weak sustainable development. A hybrid sustainability model explains how a country such as Brunei could develop on a weak sustainable path. Suggestions such as developing indigenous energy sources, seeking cooperation in energy development and trading with neighboring countries, putting more efforts into developing renewable energy, and sticking to the 'always greater than one' standard in the extraction of fossil fuels are given for Brunei's weak sustainable development.

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Developing the Knowledge Economy and Integrated Employment Areas in Brunei Darussalam: The Innovation Challenge

Sasha Lennon

Abstract

A desire to transition the economy of Brunei Darussalam away from its dependence on the country's oil and gas resources to one which is more akin to that of a 'knowledge economy' underpins the government's policy of economic diversification. This paper explores the fundamental characteristics of a knowledge economy and knowledge-based industries as they apply to 21st century economic development. It then considers the concept of 'integrated employment areas' as a means of encouraging 'knowledge economy' business investment through land optimisation. Particular attention is paid to the critical success factors (such as location of land, size, configuration, amenity and infrastructure services) for establishing integrated employment areas in the Brunei context. As an example to consider through further research and analysis, the paper relates the integrated employment area concept to one segment of the developing knowledge economy, that being the creative industries. The creative industries have helped reaffirm 'place' as a driver of economic development. This is acknowledged by policy makers throughout the world who recognise the contribution that creative enterprises can make to urban renewal and revitalisation. Integrated employment areas (as evidenced by recent developments such as the Creative Industries Precinct in Brisbane, Australia for example) can provide many of the preconditions necessary for these new industries to develop and flourish. But, as the paper argues, this requires a strong commitment from the government. To this end, the paper concludes that in Brunei strategies for economic diversification will need to be supported by a strategic land use planning framework which promotes and facilitates co-ordination and integration of economic opportunity with physical planning. To achieve this will not only require innovation to grow new industry such as the creative industries (as just one example), it will also require, and in fact fail, without an innovative and collaborative government.

Keywords: *knowledge economy, innovation, land use, economic development, creative industries, diversification, integrated employment areas, collaboration, government*

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1.0 Economic Diversification and the Knowledge Economy

The Centre for Strategic and Policy Studies (CSPS) has commissioned SGS Economics and Planning to prepare a 'Land Optimisation Strategy for Industrial and Commercial Growth in Brunei Darussalam'. The purpose of the strategy will be to help drive Brunei's economic diversification using the guiding principles of balanced and sustainable growth. The study will complement and further the objectives of the National Land Use Master Plan 2006-2025 (NLUMP 2006-2025).

The land optimisation strategy, which is expected to be completed in early to mid-2012, has a strong economic development dimension, in that it will provide strategies to facilitate foreign direct investment and the development of economic sectors (or clusters) to drive Brunei's economic diversification and development. In Brunei, like anywhere, economic diversification will require innovation. To 'innovate' means to introduce a new process or way of doing things. The concept of innovation is embedded in Brunei's economic development policy settings, which are underpinned by a desire to transition the economy away from its heavy reliance on the country's oil and gas reserves towards one which is more akin to the concept of a 'knowledge economy'.

In March 2011, the Honourable Minister of Finance II at the Prime Minister's Office, YB Pehin Orang Kaya Laila Setia Dato Seri Setia Awang Haji Abdul Rahman bin Haji Ibrahim, announced Brunei's $5.13 billion budget for the 2011/2012 Financial Year. Referring to the allocation of nearly $40 million to the Info-Communications and Information Technology Sector, the Honourable Minister said: "The allocation will encompass efforts to improve the country's human resource and infrastructure towards realising a knowledge-based economy".[1] The Organisation for Economic Co-operation and Development (OECD) defines a 'knowledge economy' as one which is "directly based on the production, distribution and use of knowledge and information" (OECD, 1996).

Economic diversification, by definition, means the identification, establishment and development of new industries. 'Knowledge-based industries' are many and varied and include, for example, financial and legal services, telecommunications, scientific and technical services, the creative industries and even certain segments of the manufacturing sector. Importantly, 'knowledge' is not a separate sector of the economy but rather is embedded in all industries.

[1] "$5.13 Billion Budget Approved by LegCo", *Borneo Bulletin*, Monday 14 March 2011, p.3.

This notion is supported by the US-based Oregon Council for Knowledge and Economic Development (OCKED), which describes a knowledge economy as one "where the keys to wealth and job creation are the extent to which ideas, innovation and technology are embedded in all sectors" (OCKED, 2002). As Professor Michael Porter, the originator of the 'economic cluster' term has been quoted as saying: "There are no low tech industries, only low tech firms" (Porter, 1996). This reiterates the notion that all industry sectors can potentially engage with and become an integral component of a knowledge economy.

2.0 Brunei's Economic Diversification and Land Use Challenge

Brunei has one of the highest per capita incomes in Asia and one of the highest rates of macroeconomic stability in the world. The World Economic Forum's 'Global Competitiveness Report 2008-2009' ranked Brunei second out of 134 countries in terms of its macroeconomic stability, bettered only by Kuwait (Oxford Business Group, 2009). In 2009-2010, Brunei replaced Kuwait to take the number-one position globally (Oxford Business Group, 2010). This gives Brunei considerable appeal in the eyes of foreign investors who seek above many things to minimise investment risk.

But despite its wealth, Brunei's economic fortunes rely almost entirely on the country's oil and gas industry, which contributes 54% of GDP. The oil and gas sector in turn props-up the public sector, which employs approximately 70% of Brunei's workforce.

Besides oil and gas, other industries which contribute to Brunei's economic wealth include manufacturing, government services, construction, trade and finance. However, the contribution of these industries pale in comparison to the nation's mineral wealth. Nevertheless, as a number of recent studies have demonstrated, there are opportunities to capitalise on these capabilities for economic development and to discover and grow emerging industries like Islamic tourism, international education and the production and export of halal foods for example.

Although Brunei's economic strength and stability offers some appeal to prospective investors, it is limited by way of a clear land use strategy for commercial and industrial development. This is significant because land, as one of the essential factors of production alongside a skilled and flexible workforce, is an essential precondition for economic development.

Specifically, commercial and industrial land must be appropriately zoned, located, serviced and administered in order to deliver the right signals to the market. In the case of Brunei, those signals need to encourage and accommodate the development of advanced, high-value forms of industrial and commercial activity which can deliver high returns (in the form of healthy national economic multipliers through import replacement and export development) and, ultimately, a diversity of employment choice across a selection of industry sectors.

To this end, a new approach to Brunei's economic development is needed, one of commercial and industrial land use planning, economic diversification and investment attraction. This means that strategies for economic diversification in Brunei need to be supported by a strategic land use planning framework which promotes and facilitates co-ordination and integration of economic opportunity with physical planning.

This challenge is well-recognised in Brunei and a number of significant policy plans and developments on land use to achieve Brunei's goal of economic diversification have already been formulated. The most recent of these is the NLUMP 2006-2025, which is also Brunei's principal strategic land use planning document. The NLUMP highlights one of the key challenges faced by Brunei in meeting its developmental goals is the effective optimisation of land use.

Brunei's National Development Plan 2007-2012 emphasises the need to improve land productivity through intensification of land use. It specifically calls for a restructuring of the country's unoccupied land to achieve sustainable economic development. This means that more effective and integrated solutions through which the distribution of land use can complement Brunei's short- and long-term strategic developmental plans is required, to optimise land use for economic diversification.

3.0 The Importance of 'Knowledge' to 21st Century Economic Development

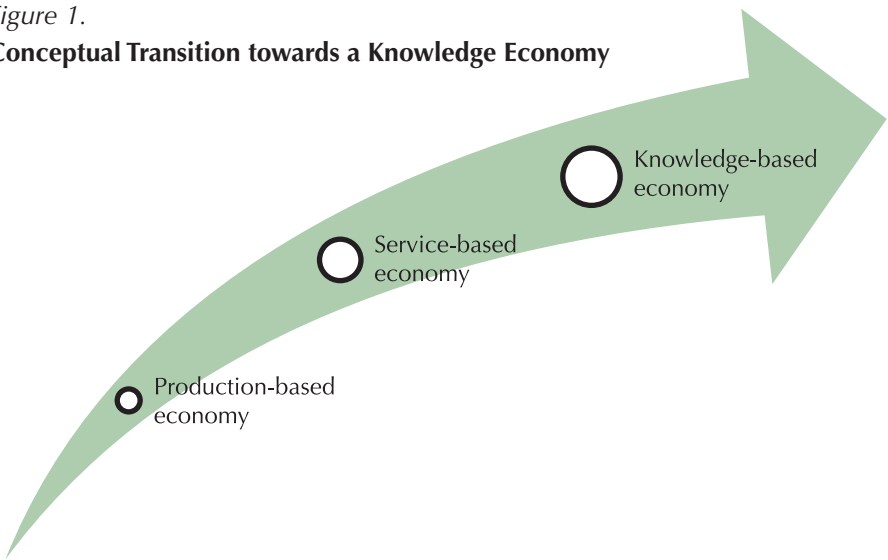
In today's global economy, economic prosperity is not just about the nation's stock of natural resources or amount of land, labour and capital (as fundamental as these factors of production are). More than ever before, countries like Brunei need to identify their 'smarts' in combining input and talent, leveraging

economies of scope, discovering new markets, inventing, and increasing productivity. In short, they need to be innovative.

A number of research reports link knowledge with economic growth. For example, the OECD (1998) concluded that "long-term growth rates in OECD economies depend on maintaining and expanding the knowledge base, while making it more responsive to economic and social needs". And the OECD's (2000) Science, Technology, and Industry Outlook found that growth in real value added for knowledge industries was consistently greater than overall growth rates for OECD member countries. The World Bank (1998) in its 'World Development Report: Knowledge for Development' stated that "today's most technologically advanced economies are truly knowledge-based…creating millions of knowledge-related jobs in an array of disciplines that have emerged overnight".

These findings reflect a general consensus amongst international researchers, academics and think tanks that those countries which adapt most readily and exploit the opportunities offered by the knowledge economy will enjoy rising incomes and prosperity while those which lag behind may face relative economic decline. The transition towards a knowledge economy can take place via a slow, evolutionary process or, in what might be called a more 'revolutionary' or step-change fashion. In Brunei, with a supportive, innovative and collaborative governance framework, the latter may be possible.

Figure 1.
Conceptual Transition towards a Knowledge Economy



Source: SGS Economics and Planning

4.0 Knowledge Economy Attributes

For Brunei, which has set itself an ambitious target of economic diversification over the next twenty years and beyond, a fundamental challenge will not necessarily be one of identifying which industry sectors to focus on but more importantly, how to provide the preconditions necessary for knowledge-intensive firms to flourish.

Central to the notion of knowledge-based economic development is strong innovation and technology uptake across the economy supported by the availability of appropriate 'enabling' infrastructure. This includes, amongst other things:

- **Knowledge workers** – The economy is characterised by a skilled and adaptable workforce, in other words, people who are able to sell their skills and expertise on the global market;

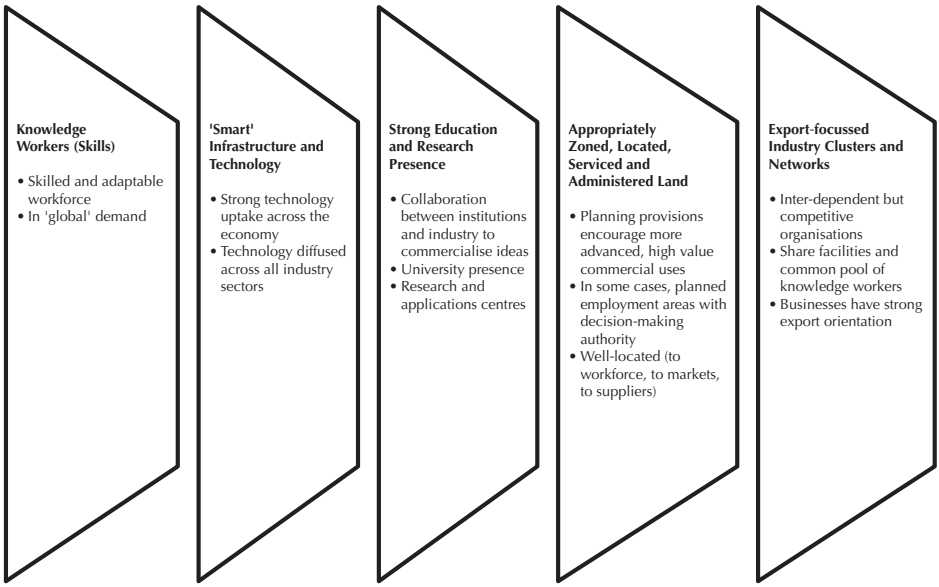
- **'Smart' infrastructure and technology** – Strong technology uptake with knowledge that is diffused throughout the entire economy and not just selected industry sectors;

- **A strong education and research presence** – Collaboration between education/research institutions and industry that results in the commercialisation of their joint work;

- **Appropriately zoned, located, serviced and administered land** – Planned, well-located employment areas with decision-making authority and which are supported by planning provisions which encourage knowledge-based industries (a key challenge facing Brunei); and

- **Export-focussed industry clusters** – The formation of interdependent but competitive organisations that share research and knowledge, trade goods and services, share lifestyle facilities and have a common pool of knowledge workers.

Figure 2.
Knowledge Economy Attributes



Source: SGS Economics and Planning

5.0 Knowledge-Based Industries

As noted earlier in this paper, 'knowledge' is not a separate sector of the economy but rather is applicable to all industries. Nevertheless, government agencies around the world, such as the Queensland Government in Australia, have attempted to define knowledge-based industries using the OECD's Science, Technology and Industry Scoreboard.

In the OECD's framework, "knowledge-based industries are those that are relatively intensive in their inputs of technology and human capital. Chief among these industries are aerospace, chemicals/biotechnology, ICT equipment and services, and consumer electronics. In addition, there are a number of knowledge intensive sectors in the services/tertiary sector of economies" (Queensland Government, 2005).

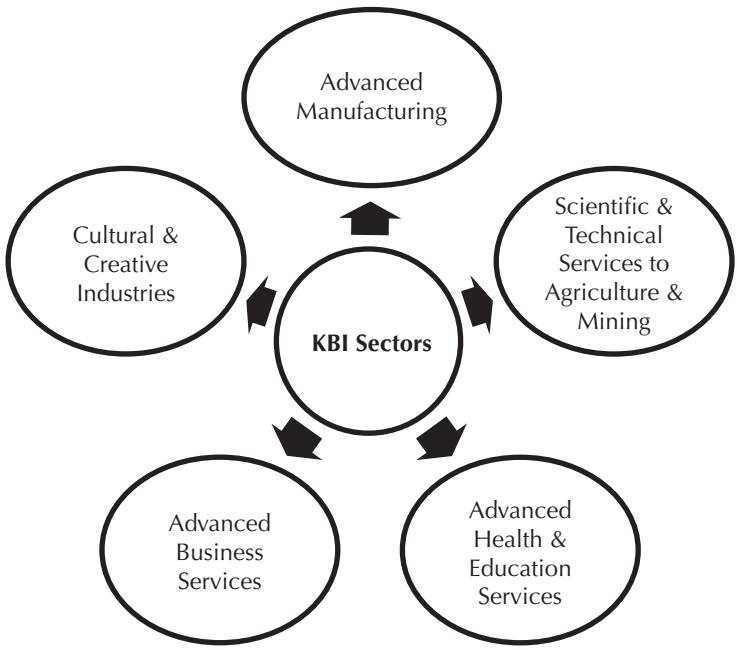
Using the OECD's industry classifications and based on further research and analysis conducted over many years of consulting, SGS Economics and Planning has expanded the 'knowledge-based industries' list to incorporate the

growing services sector (especially business, health and education services), key agricultural subsectors and the creative industries, which are considered to be a subset of knowledge-based industries. This broadens the research and technology emphasis of industries that are considered to be 'knowledge-based'.

The individual industry sectors (of which there are almost 100 according to the Australian and New Zealand Standard Industrial Classification) can be grouped into five broad segments based on logical groupings of related industry sectors. The five knowledge-based industry segments, as defined by SGS Economics and Planning are:

- Advanced Manufacturing;
- Scientific and Technical Services to Agriculture and Mining;
- Advanced Business Services;
- Advanced Health and Education Services; and
- Cultural and Creative Industries.

Figure 3.
Knowledge-Based Industry Segments



Source: SGS Economics and Planning

6.0 Innovation and Entrepreneurship in the Knowledge Economy

Entrepreneurship and entrepreneurial environments are key contributing elements to the development of knowledge economies. Recent US studies have indicated that not only does entrepreneurship enhance the economic impact of investments on innovation, but that innovation without entrepreneurship generally yields minimal economic impact (Advanced Research Technologies, 2005). Research has shown that while innovations are highly portable, entrepreneurship is 'place-based' and results from of a variety of infrastructure, education and industry-oriented factors, which ultimately support a knowledge economy.

Subsequently, entrepreneurship should not be viewed as a discrete element unto itself, but one enmeshed in the supporting factors (including suitable employment land) in the economy. It is in this area where government can directly influence the preconditions for creating an entrepreneurial and innovative environment. The roles required of governing bodies in facilitating the development of entrepreneurial environments are numerous. However, the primary aim is generally focused upon strategies to stimulate economically productive activity by entrepreneurs and investors in the private sector.

Preconditions for Innovation

According to the US-based State Science and Technology Institute (2006), the critical conditions for the support of innovation and entrepreneurship include:

- The presence of, and access to, adequate technology;
- Experienced management talent;
- Sufficient sources of funding and capital;
- Social as well as professional networks; and
- Available facilities and physical spaces (land and supporting facilities) for both established and start-up companies.

The presence of these elements, combined with a suitable environment for cultivating entrepreneurial talent (i.e. education and networking facilities) are key supporting factors for the development of a knowledge economy. The Brunei Government can directly and indirectly influence each of these. One area where it can have a particularly influential role is in the provision

of appropriately zoned, serviced and administered industrial and commercial land. An emerging phenomenon in this context is the concept of the Integrated Employment Area (IEA).

7.0 Land Use in the Knowledge Economy: Integrated Employment Areas

Integrated Employment Areas Defined

Integrated Employment Areas (IEAs) are a modern concept for employment development that are unlike (old) industrial areas of the past.

IEAs generally involve low-impact employment generating activities such as office parks, business parks and 'high-tech' parks, often in campus-like settings. The concept of an IEA has emerged in recognition of the fact that traditional land use planning controls for business and industry areas have in the past been too restrictive. This is because they fail to recognise advances in manufacturing and environmental technology that enable disparate activities to co-locate, and the benefits that such co-location can potentially deliver (through, for example, industry clustering and more efficient use of infrastructure and services).

In the case of Brunei, a lack of stringent land use planning regulations has allowed incompatible land uses to co-locate (for example, housing next to noisy automotive workshops or factories). In the Brunei context therefore, IEAs offer the potential to encourage disparate but otherwise economically compatible activities to co-locate.

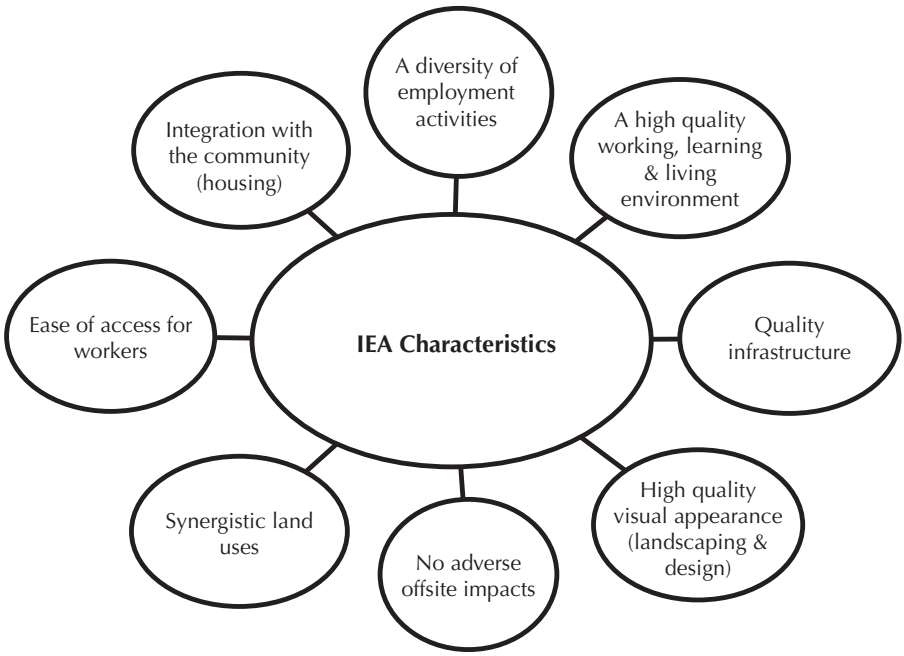
Characteristics of Integrated Employment Areas

IEAs present a new way of enabling low-impact and productive employment uses to locate closer to residential areas mixed in with other activities including retail, recreation, leisure and entertainment. Typical characteristics of IEAs include:

- A range of employment activities;
- Ease of accessibility for workers;
- No adverse off-site impacts on adjoining land uses;
- Integration with the community (including the provision of local employment for local residents);

- Access to essential services for workers and a high quality working environment;
- High quality visual appearance through landscaping and building design;
- Efficient and effective road networks;
- Climate-sensitive and energy-efficient site planning; and
- Opportunities for linkages between synergistic uses.

Figure 4.
Characteristics of Integrated Employment Areas



Source: SGS Economics and Planning

Critical Success Factors

For an Integrated Employment Area to be successfully developed and operational over the long term, a number of attributes need to be apparent, including:

- **Proximity to an appropriately skilled workforce.** A skilled and flexible workforce can be supported by responsive education and training programmes with access to meaningful employment, adapting to changing economic circumstances or new opportunities as they arise. Promoting economic development is not the primary role of universities and other tertiary learning institutions. Their primary roles are to educate students and

produce new knowledge. Therefore, the Brunei Government can play an important role in helping to match the economy's skills flow with identified industry needs by providing the necessary policy platform.

- **Strong links between businesses, research and education.** The location of a university and research organisation(s) with strong links to/interaction with the business community is desirable.
- **Lifestyle attributes.** In designing IEAs, emphasis is placed on the benefits of living and working in the same area and with the availability of a full range of recreation, leisure, entertainment, retail, and community facilities and services. The provision of housing and services in close proximity to where the jobs are located is an important attractor of residents who prefer to work close to home in a quality environment. Relatively recent developments in Australia such as the Kelvin Grove Urban Village and Creative Industries Precinct in Brisbane, provide a good example of this new approach. In Brunei, strategic planning documents such as the National Land Use Master Plan and Wawasan 2035 promote this concept of local employment for local communities with the aim of promoting a more efficient and effective urban form, alleviating pressure on the country's infrastructure and encouraging a diversity of industry and economic activity through the attraction of investment and development of economic clusters.
- **Accessibility to services and facilities in other activity centres** is also desirable, as well as access to the CBD/capital, the airport and the port. While public transport access is desirable, access via an arterial road network into the metropolitan system is critical. For Brunei, the optimisation of land for industrial and commercial growth will not be realised without a considered, strategic approach to transport provision and the development of the country's major port and airport.
- **Economic linkages and complementarity with the existing urban system.** Newly established or developing IEAs should not conflict with the city's established network of activity centres and employment nodes. In Brunei, the development of industrial and commercial land must be responsive to the country's existing urban form.
- **Choice.** The capacity to provide existing and potential new businesses with a choice of locations, lot sizes and configurations, building types, and ancillary services and facilities are important elements which help to make any location an attractive investment proposition.
- **Supportive governance structures,** including a land administration and a planning approvals process that provides certainty for investors. If

the Brunei Government can communicate a clear vision for economic development (as it has through its diversification policy and as stated in documents such as Wawasan 2035 and the National Development Plan) and the sorts of industries it wants to attract and grow, this provides greater certainty for investors looking to establish or relocate a business.

In Brunei, the government can help facilitate the development and export potential of emerging knowledge-based industries by providing the infrastructure, services and support programmes necessary for a vibrant social, cultural and, therefore, economic environment to flourish.

The emergence of the knowledge economy and those who drive it (the entrepreneurs, the innovators and the 'knowledge workers') has reaffirmed 'place' as a driver of economic competitiveness. Knowledge-based industries are characterised by dynamic exchanges of information and collaboration between sectors. For this to occur, they need to be in an environment that attracts knowledge workers, and which nurtures their growth and development. This is what the IEA concept is intended to facilitate.

One segment of the knowledge economy which places a particular emphasis on the importance of place - and one which is yet to be fully explored as an opportunity for Brunei - is the creative industries.

8.0 Potential New Industries for Brunei: The Creative Industries

The Economic Contribution of Creative Industries

In Brunei, the National Development Plans, which traditionally set the direction and pace of economic growth and overall development, have consistently emphasised the need for diversification. Over the years, studies designed to inform strategies for Brunei's economic diversification have considered a variety of industry sectors. Most recently, the National Development Plan 2007-2012 promotes Brunei's economic competitiveness through, among other things, investment in downstream industries and other economic clusters selected on the basis of Brunei's competitive strengths, export potential and employment opportunities for local people.

Economic diversification aligned with knowledge-based activities features prominently in the National Development Plan. Industries which are identified as being worthy of further investigation include ICT, business and financial services, the halal food industry, tourism, and logistics and transportation.

In commissioning the land optimisation strategy for industrial and commercial growth, CSPS directed SGS Economics and Planning to consider other potential industry clusters which might have potential to help diversify and grow Brunei's economy. One of these industries currently under consideration and which will be the subject of rigorous investigation and analysis as part of the land optimisation strategy is the creative industries.

'Creative industries' is a relatively new phrase in government policy, industry and academic discourse. In places like Australia, Singapore and the United States, the term has been used for perhaps a little over 10 years.

In Australia, the Queensland Government, which paved the way for creative industries policy development in that country, contends that "creative industries are centered on activities originating from innovation and ideas" (Queensland Government, Department of State Development, 2004). Highly reliant on creative talent, their economic value lies in their intellectual property. All industries have embedded in them a degree of creativity just like all industries rely on knowledge and information. The creative industries can be differentiated because unlike other industries, 'creativity' is their primary source of value.

Data produced by the Australian Research Council Centre of Excellence for Creative Industries and Innovation (April 2010) shows that the creative industries contributed over $30 billion towards Australia's Gross Domestic Product in 2007/2008 (more than industries such as agriculture, hospitality and accommodation, and communications). Over the 11 years to 2008, creative industries grew at a rate of 5.8 per cent per annum compared to an average of 3.4 per cent for all industries.

In Hong Kong, a 2003 study estimated that the creative industries contributed over $46 billion to the Hong Kong economy, accounting for 4 per cent of GDP (Hong Kong Central Policy Unit, 2003).

In Singapore, the latest available data (Singapore Government, 2003) shows that the creative industries contributed approximately $3 billion or 2 per cent of total GDP and around 4 per cent of Singapore's total employment. The creative industries sector with the highest contribution to national wealth and employment in Singapore was the IT and Software Services sector, which accounted for 38 per cent of the creative industries' contribution to GDP and 31 per cent of employment in 2000.

According to the United Nations Conference on Trade and Development (November 2003), creative industries account for an estimated 7 per cent of the world's GDP and are forecast to grow on average by 10 per cent per annum.

Defining Creative Industries

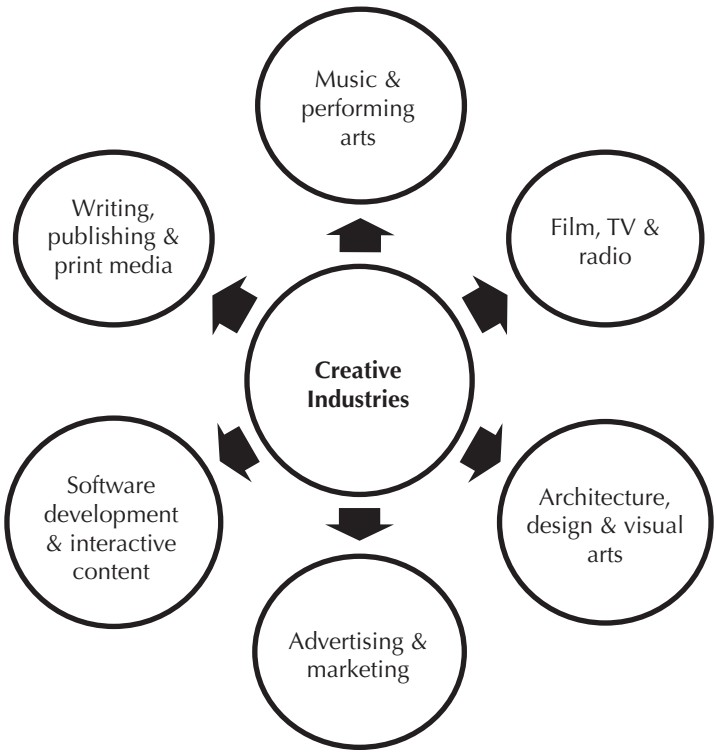
In Australia, the accepted definition of 'creative industries', at least for the purpose of statistical analysis, consists of: music and performing arts; film, television and radio; advertising and marketing; software development and interactive content; writing, publishing and print media; and architecture, design and visual arts (Centre for International Economics, June 2009). This is a fairly common grouping and is similar to classifications used overseas, as demonstrated for example in New York (Center for an Urban Future, December 2005), Hong Kong (Hong Kong Central Policy Unit, 2003) and Singapore (Singapore Department of Statistics, 2003).

While these categorisations are valid and also very useful for the purpose of statistical analysis, 'creativity' extends beyond rigid industry groupings. As Hartley (2005) notes, the creative industries depend on "some decidedly anti-industrial folk". Rather than being separate sectors of the economy, creative industries are a pervasive input to many, if not all industries.

A feature of economic globalisation has been what Spiller (2003) calls the 'unbundling' of the value chain, where key corporate input is increasingly outsourced by larger firms to specialist providers of technical services. Creative entrepreneurs and enterprises work well within this model, which "is to contrast modern business operations, which generally feature clear divisions between core and non-core operations, from now industrially ancient models where enterprises were, in relative terms, much more self-contained" (Spiller, 2003).

Creative industries and creative entrepreneurs provide inputs that are central to businesses across many industries, from manufacturing and construction to retailing and entertainment. Representing what is in effect, a 'creative services economy', creative enterprises add value to production through design, technical performance, packaging and branding.

Figure 5.
The Six Creative Industries Segments



Source: ARC Centre of Excellence for Creative Industries and Innovation

The potential of the creative industries as a driver of economic development cannot be understated. According to a recent report by the United Nations, *Creative Economy Report 2010: A Feasible Development Option*, global trade in creative goods and services has remained robust, growing at 14 per cent even as world commerce declined by 12 per cent in 2008 as a result of the global financial crisis. According to the report, global trade in creative goods and services such as arts and craft, audiovisuals, books, film, music and new media more than doubled from 2002 to 2008, reaching nearly $600 billion.

According to the United Nations, the report findings demonstrate that along with traditional sectors of the economy, well-nurtured creative industries

can be a source of growth, job creation, innovation and trade, while at the same time contributing to social inclusion, cultural diversity and sustainable development.

Creative Industries and the Importance of Place

One social implication of the emergence of creative industries is that they have helped to reaffirm 'place' as a driver of community and economic development. This has been acknowledged by policy makers, particularly urban planners, who recognise the contribution that creative entrepreneurs and creative enterprises can make to urban renewal and revitalisation. Florida (2002) argues that creative people value and rely on those elements of an economy that support and encourage their creativity and the diffusion of ideas. They place a high value on an area's lifestyle attributes like its recreation and leisure facilities and its cultural infrastructure. In Australia for example, the emergence of new research, learning and employment nodes like Queensland University of Technology's Creative Industries Precinct in Brisbane demonstrates the interrelationships between economic development, education, housing, urban planning and cultural policies that are far more developed than they once were.

If Brunei can create the right sort of environment for creative industries (through the provision of well-serviced and located commercial space), and if it can identify those segments that present genuine potential to capture regional market share – like in the software development and interactive content segment for example – then there may be scope for this segment of the knowledge economy to contribute to Brunei's economic growth and diversification over the long term. As demonstrated in various studies referred to in this paper, in Singapore, Hong Kong, the US, the UK and Australia, creative industries' growth has averaged between 5 per cent and 10 per cent per annum over the past ten years, suggesting that if regional and world markets can be captured, there is substantial room for creative industries growth in Brunei Darussalam.

9.0 Growing Knowledge-Based Industries: Brunei's Innovation Challenge

Central to the concept of knowledge-based economic diversification and development is the notion of innovation. This refers not only to innovation in industry but also to innovation in government. To develop an innovation

framework and encourage economic development, Brunei must meet a multiplicity of challenges. Broadly speaking, these challenges include the need to: co-ordinate knowledge economy growth initiatives; build policy momentum across all industries; and close the gaps in the innovation framework.

1. Co-ordinate knowledge economy growth initiatives

All agents of change in government need to agree on and co-ordinate priorities for the benefit of Brunei. If political commitment to national development priorities (as articulated in the National Development Plan and Wawasan 2035) is sustained, then the likely productivity of resources invested in moving Brunei towards a knowledge economy will be enhanced, freeing up other planning and development resources for complementary activities.

2. Build policy momentum across all industries

This refers to the benefits of building on Brunei's existing competitive industry strengths and attributes, a concept which features prominently in Wawasan 2035. As previously expressed in this paper, a key premise of knowledge economy development is that 'knowledge' is not a separate sector of the economy but is a pervasive input to all industries.

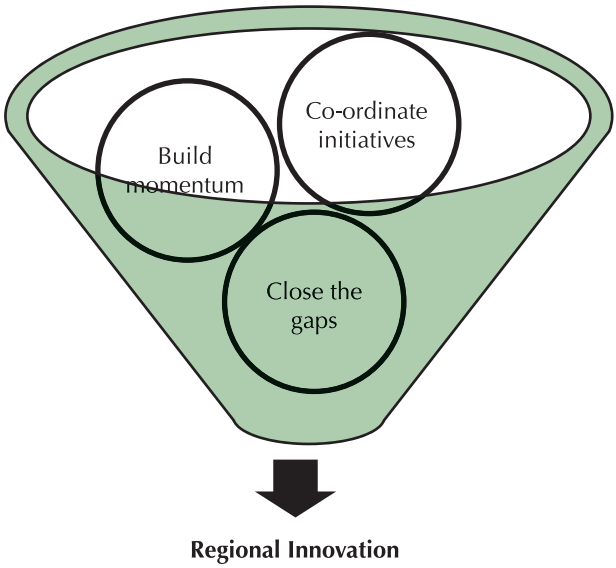
Nevertheless, some industries naturally have stronger 'knowledge' traits than others. A critical component of Brunei's economic development strategy is to highlight where the country's competitive advantages can be capitalised upon and where challenges remain.

3. Close the gaps in the innovation framework

There are a number of gaps in Brunei's innovation framework, limiting Brunei's appeal as a location for investment and its potential to diversify and grow its economy. Previous studies have highlighted the constraints on economic development that stem from, for example, bureaucratic red tape, a lack of dynamism in the country's corporate sector and an insufficiently qualified workforce (see for example Bhaskaran, 2008). These are critical gaps in the innovation framework that need to be addressed. But closing these gaps will require a concerted funding and human resource effort.

Gap closure is a dynamic thing and a flexible approach to facilitating knowledge economy growth is required. Government funding and industry incentives programs can come and go and some avenues send good projects off course inadvertently. A strategic and a proactive approach which is co-ordinated across all government ministries and departments will help Brunei to immunise itself against such spurious results.

Figure 6.
Brunei's Innovation Challenge



Source: SGS Economics and Planning

10.0 Encouraging Innovation: the Role of Government

Consensus, Collaboration and Co-ordination

In responding to the challenges for growing Brunei's innovation framework to support economic diversification and development, international experience has identified two key elements of success:

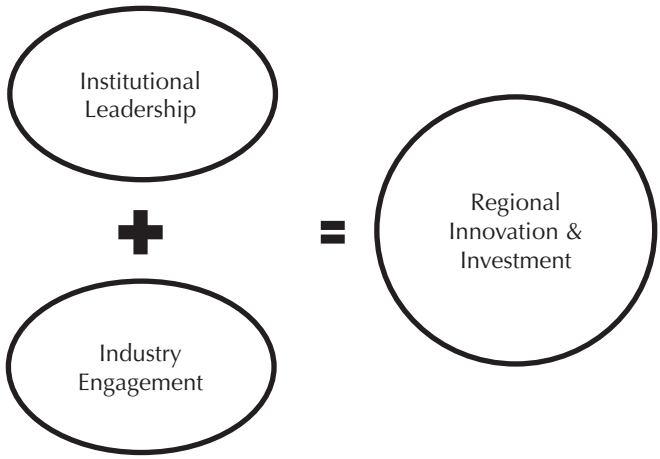
- Institutional leadership; and
- Industry engagement.

For a nation to be innovative, it needs innovative leadership. So, with this in mind, one might ask how Brunei's Government agencies, together with institutions including universities and chambers of commerce, should engage

in innovative approaches to economic development. The answer lies first and foremost in the establishment and maintenance of productive partnerships. In other words, consensus, collaboration and co-ordination are the keys to success.

With respect to institutional leadership, governments play a formative role in establishing 'collaborative' structures to facilitate innovation and economic development. Given such arrangements, universities and other research institutions can optimise their contributions to developing an innovation framework by building a critical mass in a limited number of strategic research areas and across a carefully selected range of teaching disciplines, and ensuring that these activities are well connected to members of relevant industry value chains.

Figure 7.
Encouraging Innovation: Elements of Success



Source: SGS Economics and Planning

The government must also lead by delegating authority to selected agencies and by putting in place mechanisms to ensure accountability (such as key performance indicators which reflect strategic planning objectives).

Providing the Preconditions for Economic Development

With respect to industry engagement, the government must continually engage with business and industry as the principal driver of economic growth and development. This is important. In a diversified economy, it will not be the government which drives Brunei's economic growth. The government's

primary role will be to put in place the necessary preconditions to ensure that industry in well placed to compete and prosper on the global stage.

These preconditions or 'enablers' of economic development include: efficient and effective physical infrastructure; a skilled and flexible workforce; a quality living environment to attract and retain that skilled workforce; appropriately located and serviced employment land; connectedness between members of industry clusters (businesses, government agencies, labour, and research and learning institutions); and a supportive governance structure.

Returning to the argument for land optimisation in Brunei Darussalam, strategies for economic diversification will need to be supported by a strategic land use planning framework which promotes and facilitates co-ordination and integration of economic opportunity with physical planning. To achieve this will not only require innovation to grow new industry such as the creative industries as just one example, it will also require, and in fact fail without, an innovative and collaborative government.

Therefore, collaboration may be the best form of innovation. Only then can Brunei move forward and realise optimal land use for economic diversification.

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A Macro-Econometric Model of Brunei Darussalam

Koh Wee Chian

Abstract

Brunei Darussalam is heavily dependent on oil and gas, which accounted for more than half of GDP and more than 80 per cent of exports and government revenue in the past decade. Economic activity is mainly influenced through government expenditure, guided by 5-year National Development Plans. Economic diversification remains a major challenge as the economy is vulnerable to fluctuations in oil and gas production and exogenous price shocks. While inflation is not an immediate threat, unemployment is a concern as the labour force is growing faster than the demand for jobs. Economic recovery, expected global demand for energy and the rise in oil and gas prices will see the economy achieve real growth of 2.2 per cent in 2011. Despite the increase in exports, the real trade balance will decline as Brunei continues to be dependent on imports for domestic consumption. The inflation rate is projected to remain relatively low at 1.9 per cent while the unemployment rate is projected to increase to 4.8 per cent.

Keywords: *econometric modelling, economic forecasts, diversification*

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1.0 Introduction

Brunei Darussalam is well-endowed with abundant oil and gas. Substantial revenues from oil and gas production and accumulation of foreign reserves have allowed the country to fund a large public sector, maintain an extensive welfare system, and invest heavily in health, education and infrastructure. However, as oil and gas extraction becomes more difficult and production dwindles, the inevitable result is the shrinking of the economy unless the non-oil and gas sectors grow fast enough.

Population growth also exceeds GDP growth, so that a direct consequence is the decline in GDP per capita rankings over the years, posing a threat to the fulfilment of the Wawasan 2035 goals. While oil and gas accounted for more than half of GDP and more than 80 per cent of exports and government revenue in the last decade, employment in the oil and gas sector only accounted for less than 20 per cent of total employment. The non-oil and gas sectors need to be the engine of growth to provide more job opportunities for the growing labour force. The government is the largest employer in the non-oil and gas sector due to relatively higher wages and benefits, which crowds out the labour market. Besides, increasing government expenditure is obviously not the way forward in view of volatile government revenue from hydrocarbons.

The objective of this paper is to build a macro-econometric model of Brunei's economy to understand economic relationships and inter-dependencies of key macroeconomic variables, which can then be used for forecasting and policy design. There does not appear to be much literature on macro-econometric modelling of Brunei's economy. Likewise, official economic forecasts are not published by the national statistical agency. The only publicly available forecasts are through reports from the International Monetary Fund (IMF) and the Asian Development Bank (ADB). Hence this paper aims to fill this void to build a working model, albeit simple, of Brunei's economy. This will hopefully generate further interest in econometric modelling of Brunei's economy.

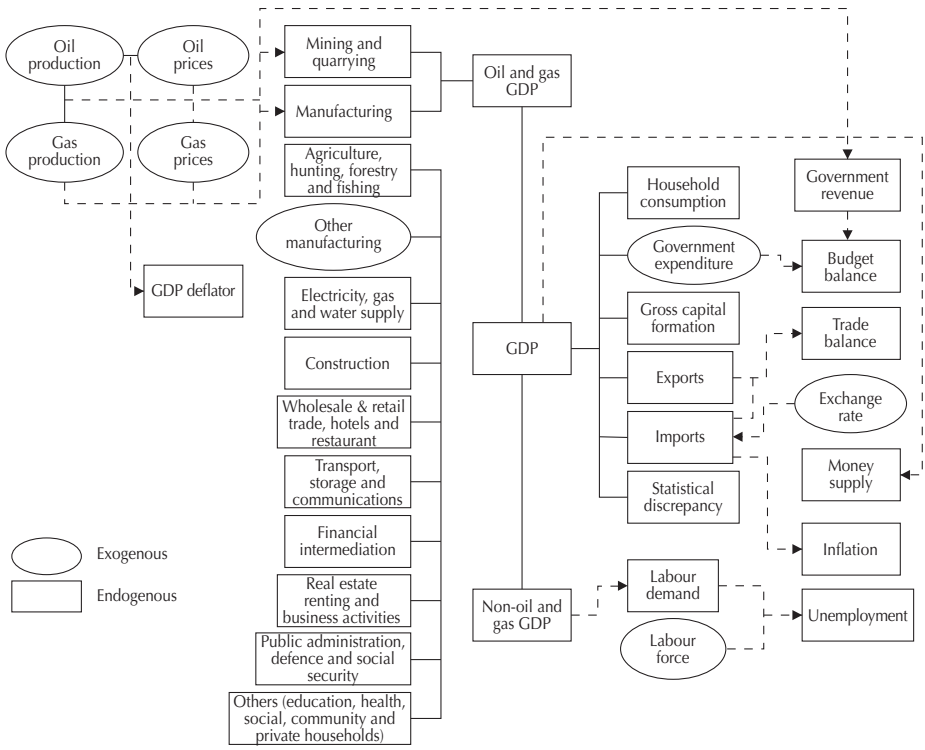
2.0 Model Specifications

The macroeconomic model structure of Brunei is depicted in Figure 1. The approach taken is to estimate each equation in the system separately, following comments from Le (2008) that single equation estimation is easier and more flexible compared to using more complex estimation methods such as two-

stage least square (2SLS) or three-stage least squares (3SLS) for simultaneous equations, given that observations are limited. Thus, in this model, ordinary least squares (OLS) is applied. Serial correlation, which is to be expected in time series regressions, is corrected using the Hildreth-Lu procedure. In this procedure, a set of usually spaced values is used to serve as guesses to estimate ρ, the correlation coefficient between errors. For each value of ρ, the original regression equation is transformed, and the equation with the lowest sum-of-squared residuals is selected as the best equation.

Annual data from 1985 to 2009 were used in this paper. Estimated equations, along with regression coefficients, standard errors (in parentheses), R-squared and Durbin-Watson statistics are reported below. ** indicates significance at the 0.05 level, * indicates significance at the 0.10 level. The list of variables is included in the appendix.

Figure 1.
Brunei Macro-Economic Model



2.1 Aggregate Supply

On the supply side, the model consists of two main sectors – oil and gas, and non-oil and gas. The oil and gas sector consists of oil and gas extraction as well as the manufacture of liquefied natural gas (LNG). Oil and gas production is dependent on the remaining reserves, extraction complexity and technology, and government conservation policies, among other factors, while prices are globally determined. Hence, they enter as exogenous variables.

The non-oil and gas sector is broken down into ten sub-sectors. The other manufacturing sub-sector consists mainly of the textile and garment industries, which have been declining since the United States eliminated its garment quota system in 2004. Value-added for this sub-sector will thus be treated as exogenous. Real sectoral value-added, lagged real household consumption, lagged real government consumption and lagged real government capital expenditure were used to derive value-added equations for the other sub-sectors. For example, we would expect an increase in household consumption to have a positive effect on value-added in sectors such as wholesale and retail trade, financial and business services, and education and health services. Likewise, government expenditure in sectors like agriculture and public utilities, should also have a positive effect on value-added. Obviously there are other important factors which determine value-added in these sub-sectors, for example, input and output prices that affect supply-demand conditions. However, lack of data renders a more detailed specification impossible. The lag variables enter as one-year lags since specifications with longer lags have been estimated and they do not yield better results. Hence, a parsimonious model is chosen.

The oil and gas and non-oil and gas value-added are totalled up to determine the value of aggregate supply of the economy.

2.1.1 Mining and Quarrying

Real value-added for mining and quarrying (essentially production of oil and gas) form about thirty-five per cent of real GDP. Oil and gas production, which enter as exogenous variables, are the determinants of value-added in this sector. The estimated equation is:

$$YM(t) = 81.23 + 15.72\ OP(t) + 2.58\ GP(t) \qquad R\text{-sq} = 0.93 \qquad DW = 1.96$$
$$(88.93)\ (1.37)^{**} \qquad (1.14)^{**}$$

Ninety-three per cent of the variation in real value-added by mining and quarrying is explained by oil and gas production. Increases in oil and gas production will lead to an increase in sectoral value-added, which is expected.

2.1.2 Manufacturing

Real value-added for manufacturing of LNG, which depends on gas production, makes up about twelve per cent of real GDP. The estimated equation is:

$$YG(t) = -111.84 + 3.47\ GP(t) \qquad R\text{-sq} = 0.88 \qquad DW = 1.94$$
$$(198.18)\ \ (0.45)^{**}$$

Eighty-eight per cent of the variation in real value-added by manufacturing can be explained by gas production. Increase in gas production will lead to an increase in sectoral value-added, which is expected.

2.1.3 Agriculture, Hunting, Forestry and Fishing

While there has been an increased emphasis on development in this sector, its contribution to total GDP has only increased marginally, making up only one per cent of GDP. Real value-added for this sector depends on inertia from past real value-added and lagged government expenditure. The estimated equation is:

$$YA(t) = 0.64 + 0.80\ YA(t\text{-}1) + 0.01\ G(t\text{-}1) \qquad R\text{-sq} = 0.88 \qquad DW = 1.44$$
$$(5.43)\ \ (0.11)^{**}\ \ \ (0.01)$$

Eighty-eight per cent of the variation in sectoral real value-added can be explained by lagged real value-added, and lagged real government expenditure. However, the coefficient for lagged real government expenditure is insignificant.

2.1.4 Electricity, Gas and Power Supply

Public utilities are heavily subsidised and consumption has been increasing steadily with the prices having been fixed for a long time. Its contribution to total GDP is less than one per cent. Real value-added for this sector depends on inertia from past real value-added, lagged real household consumption and lagged real government expenditure. The estimated equation is:

YE(t) = -4.20 + 0.81 YE(t-1) + 0.002 C(t-1) + 0.01 G(t-1) R-sq = 0.97 DW = 1.78
(4.96) (0.10)** (0.00) (0.00)

Ninety-seven per cent of the variation in sectoral real value-added can be explained by lagged real value-added, lagged real household consumption and lagged real government expenditure. However, the coefficients for lagged real household consumption and lagged real government expenditure are insignificant.

2.1.5 Construction

Real value-added for construction makes up about four per cent of total GDP, and it depends on inertia from past real value-added and lagged real government capital expenditure. Government capital expenditure normally increases towards the final years of the National Development Plan. This is entered as an exogenous variable. The estimated equation is:

YC(t) = 104.48 + 0.30 YC(t-1) + 0.17 GC(t-1) R-sq = 0.59 DW = 2.00
(93.67) (0.17)* (0.05)**

Nearly sixty per cent of the variations in sectoral real value-added can be explained by lagged real value-added and lagged real government capital expenditure. An increase in real government capital spending leads to an increase in construction real value-added, which is expected.

2.1.6 Wholesale and Retail Trade, Hotels and Restaurants

Real value-added for this sector makes up about five per cent of GDP, and it depends on inertia from past real value-added and lagged real household consumption. The estimated equation is:

YW(t) = 34.27 + 0.87 YW(t-1) + 0.01 C(t-1) R-sq = 0.76 DW = 2.34
(54.09) (0.14)** (0.02)

Seventy-six per cent of the variation in sectoral real value-added can be explained by lagged real value-added and lagged real household consumption. However, the coefficient for lagged real household consumption is insignificant.

2.1.7 Transport, Storage and Communications

Real value-added for this sector makes up about five per cent of GDP, and it depends on inertia from past real value-added and lagged real household consumption. The estimated equation is:

$$YT(t) = 9.51 + 0.67\,YT(t-1) + 0.05\,C(t-1) \qquad R\text{-}sq = 0.92 \quad DW = 2.04$$
$$(24.75)\ (0.14)^{**}\qquad (0.02)^{**}$$

Ninety-two per cent of the variation in sectoral real value-added can be explained by lagged real value-added and lagged real household consumption.

2.1.8 Financial Intermediation

Real value-added for financial intermediation makes up about four per cent of GDP, and it depends on inertia from past real value-added and lagged real household consumption. The estimated equation is:

$$YF(t) = 9.28 + 0.90\,YF(t-1) + 0.01\,C(t-1) \qquad R\text{-}sq = 0.96 \quad DW = 1.83$$
$$(14.21)\ (0.09)^{**}\qquad (0.02)$$

Ninety-eight per cent of the variation in sectoral real value-added can be explained by lagged real value-added and lagged real household consumption. However, the coefficient for lagged real household consumption is insignificant.

2.1.9 Real Estate, Renting and Business Activities

Real value-added for this sector makes up about four per cent of GDP, and it depends on inertia from past real value-added, lagged real household consumption and lagged real government expenditure. The estimated equation is:

$$YR(t) = 10.47 + 0.85\,YR(t-1) + 0.01\,C(t-1) + 0.01\,G(t-1) \qquad R\text{-}sq = 0.95 \quad DW = 1.93$$
$$(9.47)\ (0.09)^{**}\qquad (0.01)\qquad (0.01)$$

Ninety-five per cent of the variation in sectoral real value-added can be explained by lagged real value-added, lagged real household consumption

and lagged real government expenditure. However, the coefficients for lagged real household consumption and lagged real government expenditure are insignificant.

2.1.10 Public Administration, Defence and Social Security

The public administration sector is by far the largest non-oil and gas sub-sector, making up about twenty per cent of GDP. Real value-added for public administration depends on inertia from past real value-added. The estimated equation is:

YP(t) = 25.15 + 1.01 YP(t-1) R-sq = 0.93 DW = 1.98
(58.70) (0.06)**

Ninety-three per cent of the variation in sectoral real value-added can be explained by lagged real value-added.

2.1.11 Others (Education, Health, Social, Community and Private Households)

Real value-added for this sector makes up about eight per cent of GDP, and it depends on inertia from past real value-added and lagged real household consumption. The estimated equation is:

YS(t) = -12.47 + 0.99YS(t-1) + 0.02 C(t-1) R-sq = 0.97 DW = 1.86
(22.56) (0.01)** (0.02)

Ninety-seven per cent of the variation in sectoral real value-added can be explained by lagged real value-added and lagged real household consumption. However, the coefficient for lagged real household consumption is insignificant.

2.2 Aggregate Demand

On the demand side, the model consists of household (private) consumption, government expenditure, gross capital formation (government and private), exports, imports and balances for statistical discrepancy. Government expenditure is guided by the National Development Plans and hence it is considered exogenous. The other components of aggregate demand are determined within the model.

2.2.1 Household Consumption

Real household consumption depends on inertia from lagged past real consumption values as well as real GDP, which serve as a proxy for disposable income since disposable income series are not available. Furthermore, taxes, corporate profits and transfers are also not available; hence it is not possible to calculate disposable income at an acceptable level of accuracy. The estimated equation is:

$$C(t) = -627.03 + 0.65\,C(t-1) + 0.17\,Y(t) \qquad R\text{-}sq = 0.92 \qquad DW = 1.64$$
$$(375.17)^{*} \quad (0.15)^{**} \quad (0.07)^{**}$$

Ninety-two per cent of the variation in real household consumption can be explained by lagged real consumption and real GDP. An increase in real GDP means that real disposable income increases as well, which lead to an increase in household consumption, which is expected.

2.2.2 Gross Capital Formation

Gross capital formation consists of additions to the fixed assets of the economy plus net changes in the level of inventories. This includes both private and government fixed investments, which are dependent mainly on construction activities. Hence, real gross capital formation is determined by lagged real government capital expenditure. The estimated equation is:

$$I(t) = 47.07 + 4.20\,YC(t) \qquad R\text{-}sq = 0.88 \qquad DW = 1.82$$
$$(98.79) \quad (0.33)^{**}$$

Eighty-eight per cent of the variation in real gross capital formation can be explained by construction real value-added. An increase in construction real value-added increases the fixed assets of the economy, which is expected.

2.2.3 Exports

Since exports are mainly oil and gas exports, it is obvious that real exports depend on oil and gas production. The estimated equation is:

$$X(t) = -1711.71 + 21.85\,OP(t) + 13.01\,GP(t) \qquad R\text{-}sq = 0.85 \qquad DW = 1.74$$
$$(674.09)^{**} \quad (5.24)^{**} \quad (3.08)^{**}$$

Eighty-five per cent of the variation in real exports is explained by oil and gas production. An increase in oil and gas production increases real exports, which is expected.

2.2.4 Imports

Brunei depends heavily on imports such as food, manufactured goods, machinery and transport equipment. As such real imports depend on real domestic demand as well as the exchange rate. Brunei's exchange rate is tied to the Singapore dollar; hence Brunei cannot independently conduct foreign exchange policy. Exchange rate is thus an exogenous variable. The estimated equation is:

$$M(t) = 2890.53 + 0.39\ DD(t) - 2205.09\ E(t) \qquad R\text{-sq} = 0.92 \qquad DW = 1.75$$
$$(739.70)^{**}\ \ (0.06)^{**}\ \ (507.19)^{**}$$

Ninety-two per cent of the variation in real exports is explained by real domestic demand and the exchange rate. An increase in real domestic demand increases real imports, while an appreciation of the US dollar makes imports expensive, reducing real imports. Hence both coefficients have the expected signs.

2.3 Government Revenue

Government revenue receipts come mainly from the oil and gas sector in the form of corporate income tax, royalties and dividends. Hence exports, which consist mainly of oil and gas, can be used as a determinant of government revenue. The estimated equation is:

$$GR(t) = 2.41 + 0.72\ X(t) \qquad R\text{-sq} = 0.93 \qquad DW = 1.96$$
$$(352.95)\ \ (0.05)^{**}$$

Ninety-three per cent of the variation in government revenue can be explained by exports. An increase in exports increases government revenue, which is expected.

2.4 Labour Demand

While the oil and gas sector contributes more than half of GDP, employment in this sector is small and highly specialised. Most of the labour demand hence

comes from the non-oil and gas sector. The estimated equation is:

LD(t) = 44988.50 + 20.61 YN(t) R-sq = 0.89 DW = 2.01
(9603.15)** (7.61)**

Eighty-nine per cent of the variation in labour demand can be explained by real non-oil and gas value-added. An increase in real value-added from the non-oil and gas sector increases the demand for labour, which is expected.

2.5 Money Supply

Money supply is dependent on its lagged value and GDP. The estimated equation is:

M2(t) = 1365.60 + 0.12 M2(t-1) + 0.59 Y(t) R-sq = 0.85 DW = 1.64
(609.54)** (0.15) (0.11)**

Eighty-five per cent of the variation in money supply is explained by lagged money supply and GDP. An increase in GDP leads to an increase in money supply, which is expected.

2.6 Consumer Price Index (CPI)

CPI is a weighted index of a basket of commodities that is used to measure domestic inflation. It depends on imports and the supply of money. The estimated equation is:

CPI(t) = 71.60 + 0.006 M(t) + 0.0004 M2(t) R-sq = 0.78 DW = 0.47
(4.23)** (0.00)** (0.00)

Seventy-eight per cent of the variation in CPI is explained by imports and money supply. An increase in imports and money supply leads to an increase in CPI, which is expected. The inflation rate is then calculated as [CPI(t) – CPI(t-1)]/CPI(t-1).

2.7 GDP Deflator

The GDP deflator depends very much on oil prices. High oil prices swing the GDP deflator upwards. The estimated equation is:

GD(t) = 0.08 + 0.01 PO(t) R-sq = 0.88 DW = 1.92
(0.01)** (0.00)**

Eighty-eight per cent of the variation in GDP deflator can be explained by oil prices. An increase in oil price leads to an increase in the GDP deflator, which is expected.

3.0 Forecasting and Policy Considerations

3.1 Model Evaluation

Since this model was built with forecasts in mind, a small standard error of forecast is desirable. Hence, the model is evaluated on the basis of root mean square per cent error (rms per cent error), which is defined as

$$\text{rms per cent error} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^e - Y_t^a)^2}$$

where Y_t^e = estimated value of Y
Y_t^a = actual value
T = number of periods

Results of the key macroeconomic variables are displayed in Table 1.

Table 1.
Root Mean Square Per cent Error of Key Macro-Economic Variables

	YO	YN	Y	X	M	UEMP	INF
rms per cent error	0.8%	1.9%	0.8%	3.1%	5.9%	2.5%	3.3%

The root mean square per cent error ranges are fairly small; hence this model can be used for forecasting purposes.

3.2 Exogenous Variables

Exogenous variables are determined outside the model; therefore, the subjective judgement of the forecaster plays a crucial role. In order to eliminate any guesses, a less subjective approach is used by employing a first-order

autoregressive model, AR(1), for the exogenous variables. The exceptions are for other manufacturing real value-added, oil prices, oil and gas production, exchange rate and government capital expenditure, where some numerical estimates are used to be more realistic. The exogenous variables are presented in Table 2.

Table 2.
Assumptions of Exogenous Variables

Variable	Assumptions
YZ	Assumed to decline 5% per year as it is a diminishing industry
PO	2010: US$ 78.60 per barrel (average of 2010) 2011: US$ 99.70 per barrel (average of 2011 first quarter) 2012: US$ 100.00 per barrel
OP, GP	Assumed to increase 2% per year in view of rising demand
E	2010: B$/US$ 1.36 (average of 2010) 2011: B$/US$ 1.28 (average of 2011 first quarter) 2012: B$/US$ 1.25
GC	Following trend of n^{th} year expenditure of previous National Development Plans
G, ID, LF	AR(1)

3.3 Baseline Forecast

Results of key macroeconomic forecasts using the model and exogenous inputs are shown in Table 3. Actual figures for 2007-2009 are also displayed for comparison purposes.

Table 3.
Economic Forecasts

		YOr	YNr	Yr	X%Y	M%Y	TB%Y	UEMP	INF
Actual	**2007**	-6.9%	8.4%	0.2%	58.5%	41.8%	16.7%	3.4%	0.3%
	2008	-6.2%	2.5%	-1.9%	56.0%	47.3%	8.7%	3.7%	2.7%
	2009	-4.6%	0.9%	-1.8%	54.0%	47.8%	6.2%	3.7%	1.8%
Forecast	**2010**	2.3%	2.0%	2.2%	55.0%	49.0%	5.9%	4.1%	1.9%
	2011	2.3%	2.1%	2.2%	55.6%	50.2%	5.4%	4.8%	1.9%
	2012	2.2%	1.8%	2.0%	56.2%	50.4%	5.7%	5.7%	0.9%

Real GDP growth is estimated to have grown 2.2 per cent in 2010 after experiencing negative growth in 2008 and 2009. This is due to a recovery in global demand for energy and production is assumed to increase. There is also a projected increase in economic activity as the economic situation improves; hence both oil and gas and non-oil and gas sectors will see improvements compared to 2009. The momentum will likely carry over to the following year and real GDP growth for 2011 is projected to be 2.2 per cent.

As oil and gas production increases, so will real exports. However, real imports will likely grow faster than real exports due to an increase in real domestic demand, resulting in a decline in the real trade balance. This highlights the importance of expanding the export base to rely less on hydrocarbons.

As a result of the growing labour force and limited expansion of the non-oil and gas sectors, the unemployment rate is projected to increase to 4.1 per cent in 2010 and 4.8 per cent in 2011. The private sector must provide job opportunities rather than relying on the public service.

The inflation rate is projected to remain relatively low and stable, at 1.9 per cent in 2010 and 2011. The impact of imported inflation is contained through several subsidies such as on staple foods. Public utilities such as water and electricity are also highly subsidised.

3.4 Changes in Oil and Gas Production

Real GDP growth is sensitive to fluctuations in oil and gas production. Table 4 shows the results of various changes in oil and gas production.

Table 4.

Impact of Oil and Gas Production Changes

2010	YOr	Yr	X%Y	TB%Y	2011	YOr	Yr	X%Y	TB%Y
-4%	-3.5%	-0.6%	51.7%	1.4%	-4%	-3.5%	-0.5%	49.0%	-3.4%
-2%	-1.6%	0.3%	52.8%	3.0%	-2%	-1.6%	0.4%	51.3%	-0.5%
0%	0.3%	1.2%	53.9%	4.5%	0%	0.4%	1.3%	53.4%	2.5%
+2%	2.3%	2.2%	55.0%	5.9%	+2%	2.3%	2.2%	55.6%	5.4%
+4%	4.2%	3.1%	56.0%	7.4%	+4%	4.2%	3.1%	57.7%	8.2%

As seen from the above table, small changes in production can swing the economy from positive growth to negative growth, and vice versa. For example,

if oil and gas production declines by two per cent instead of increasing by two per cent, almost two whole per centage points are shaved off real GDP growth. A further two per cent decline in production will lead to negative growth. The real trade balance will then also be negative in 2011.

3.5 Changes in Government Expenditure

Since non-oil and gas economic activities depend in part on real government expenditure, it is expected that an increase in real government expenditure will lead to growth and hence an increase in job opportunities as well. Results of various changes in real government expenditure are shown in Table 5.

Table 5.
Impact of Real Government Expenditure Changes

2010	YNr	Yr	UEMP	INF	2011	YNr	Yr	UEMP	INF
-10%	2.0%	2.2%	4.1%	1.0%	-10%	1.5%	1.9%	5.1%	0.8%
-5%	2.0%	2.2%	4.1%	1.4%	-5%	1.8%	2.0%	5.0%	1.3%
0%	2.0%	2.2%	4.1%	1.9%	0%	2.1%	2.2%	4.8%	1.9%
+5%	2.0%	2.2%	4.1%	2.3%	+5%	2.4%	2.3%	4.6%	2.4%
+10%	2.0%	2.2%	4.1%	2.7%	+10%	2.6%	2.5%	4.5%	3.1%

The table shows that increase in government spending can stimulate growth in the non-oil and gas sector, which in turn produces more job opportunities, which is seen by the reduction in the unemployment rate (there is a lagged impact since it is lagged government expenditure that enters the value-added equations). However, the trade-off is the increase in inflation that comes with increased economic growth. There is a need to balance between unemployment and inflation. Clear policy statements on economic growth, inflation and unemployment must be formulated.

While fiscal spending is a viable short-term policy solution, increasing government expenditure is not a prudent policy measure as government revenue receipts are highly volatile depending on oil and gas production and prices. The government can easily run into a budget deficit and it will then be necessary to transfer funds from the General Reserve Fund to finance budgetary shortfalls. It is imperative to have other effective policy tools to complement government spending.

A related issue is that the bulk of government expenditure is on current expenses, which consist mostly of salaries, pensions and gratuities. Unless the increase in government spending is on properly-targeted investment projects, the expenditure increase will not automatically translate to real economic growth.

4.0 Conclusions and Further Research

As this model is a first attempt to quantitatively understand the workings of the Brunei economy, a simple estimation approach using OLS is preferred. However, it is sufficiently robust to be used for forecasting purposes and macro policy analysis evaluation.

An obvious feature of the model is the high dependency on oil and gas, which reinforces the urgent need for economic diversification. Volatility in hydrocarbon prices and production leads to fluctuations in exports (and the trade balance), government revenue (and the budget balance) and GDP growth. Moreover, fiscal policy tools such as increasing government spending can spur economic growth and create job opportunities in the short run. However, a balanced view must be taken as increasing government expenditure can lead to increased inflation.

Several directions for further research are apparent. Firstly, total government expenditure is used as an independent variable to determine sectoral value-added. It would be more accurate to break down government expenditure into current and capital expenditure, with a further decomposition of capital expenditure by sectors. This would perhaps lead to a better understanding on the effect of government spending on sectoral economic growth. Secondly, gross capital formation includes both government and private fixed investment. Segregating this into appropriate segments would allow us to see the different impacts of investment on growth. Thirdly, input and output prices for each sector are possibly important determinants for private sector growth. For example, wages and building costs are important inputs for price-elastic private business activities and construction respectively, while prices will determine the supply of goods and services which impact value-added. However, data availability remains a big challenge as finer statistics are not collected.

APPENDIX

Endogenous Variables

Y	Real GDP
Yr	Real GDP growth rate
YO	Real oil and gas GDP
YOr	Real oil and gas growth rate
YN	Real non-oil and gas GDP
YNr	Real non-oil and gas growth rate
YM	Sectoral real value-added for mining and quarrying
YG	Sectoral real value-added for manufacturing
YA	Sectoral real value-added for agriculture, hunting, forestry and fishing
YE	Sectoral real value-added for electricity, gas and water supply
YC	Sectoral real value-added for construction
YW	Sectoral real value-added for wholesale and retail trade, hotels and restaurants
YT	Sectoral real value-added for transport, storage and communications
YF	Sectoral real value-added for financial intermediation
YR	Sectoral real value-added for real estate, renting and business activities
YP	Sectoral real value-added for public administration, defence and social security
YS	Sectoral real value-added for others (education, health, social work, community and personal services)
C	Real household consumption
I	Real gross capital formation
X	Real exports
M	Real imports
TB	Real trade balance
GR	Real government revenue
LD	Labour demand
UEMP	Unemployment rate
M2	Money supply
CPI	Consumer Price Index
INF	Inflation rate
GD	GDP deflator

Exogenous Variables

YZ	Sectoral real value-added for other manufacturing
PO	Oil price
PG	Gas price
OP	Oil production
GP	Gas production
G	Real government total expenditure
GC	Real government capital expenditure
E	Exchange rate
ID	Import deflator
LF	Labour force

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Overcoming Barriers to Move Forward to the Transactional Stage of E-Government for Brunei Darussalam: From the Perspective of Online Security

Yeoul Hwangbo and Hazri Kifle

Abstract

Brunei has initiated e-government and rolled out e-services, not just to achieve an efficient and effective public administration, but for national development. Despite the considerable efforts made, most developing countries have only conducted basic e-services such as providing information and face the challenge of rolling out fully fledged e-services for the public. More meaningful and significant e-government services are available through exploiting transactional e-services, including applying for government certificates, passports, business licences and paying taxes. Likewise, most countries which have implemented e-government were able to arrive at the emerging, enhanced, interactive stage without particular difficulties but might not be able to achieve transactional and connected e-services without an appropriate strategy. From consideration of the e-government surveys released by the United Nations Department of Social Affairs (UNDESA) between 2003 and 2010, there are crucial barriers that must be overcome before e-government can progress to the advanced stages. Types of e-government barriers have been identified through discussion with practitioners working for the E-Government National Centre (EGNC) and the Authority for Info-communications Technology Industry (AITI) in Brunei Darussalam. The research also deals with online security to ensure and promote secure transactional e-services and therefore draws on the national public key infrastructure (PKI), with particular emphasis on nationwide institutionalising, legal issues, and strategies needed to boost transactional e-government services. As a result, the National Brunei Public Key Infrastructure (NBPKI) can form the foundation to overcome the four barriers to transactional e-services and the practical recommendations would be useful in setting up secure transactional services.

Keywords: *e-government, e-government stage, online security, Public Key Infrastructure, PKI, transactional e-services, transactional stage*

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1.0 Introduction

Brunei Darussalam identified Info-Communication Technology (ICT) as one of the key catalysts for sustainable socio-economic development. The ICT sector introduced in Brunei Darussalam's 8th National Development Plan (RKN8) was given greater priority in RKN 2008-2012[1]. The first e-government strategic framework was launched in 2001, recognising that the e-government initiative is the prime mover for information communication technology (ICT) development in Brunei Darussalam as part of the national development plan (RKN) with development goals and objectives comprising (i) strengthening the foundation of a knowledge-based economy (KBE); (ii) human resource development (HRD) to enlarge the size of the highly skilled labour force; and (iii) strengthening the institutional capacity[2]. The E-Government Strategic Plan 2009-2014 with a vision of being an e-smart government in the 21st century[3], was mapped out in alignment with the national vision of Wawasan 2035. Despite these efforts, the government has faced difficulties in rolling out satisfactory e-services for the public. When reviewing e-government services conducted and implemented by the government, there would be crucial barriers preventing Brunei from moving forward advanced e-government stages, taking into account the insignificant outcomes achieved in the approximately ten years movement towards e-government initiated by the government. Accordingly, a set of research questions are raised as follows: (i) What major barriers does Brunei Darussalam face in providing e-government services and moving forward to the advanced e-government stages such as the transactional and connected stages?; (ii) What constitutes the prerequisites for rolling-out a transactional e-service in such a way as to strengthen online security?; and (iii) How is the framework and policy to be mapped out to realise a secure transactional e-service? In order to answer the above questions, the research has been conducted through analysis of recent policy papers issued by UN and OECD and interviews with practitioners working for government agencies, including the E-Government National Centre (EGNC) and the Authority for Info-communications Technology Industry (AITI).

2.0 E-Government Barriers to the Advanced E-Government Stage

Brunei Darussalam has developed, implemented and conducted e-government services since the first e-government strategic plan was launched in 2001[4].

[1] JPKE, 2008, *Brunei Darussalam Long-Term Development Plan.*
[2] JPKE, 2008, op. cit.
[3] JPKE, 2009, *The E-Government Strategic Plan 2009-2012*.
[4] JPKE, 2009, op. cit.

However, the outcome and results cannot be said to be satisfactory.

When examining the e-government readiness index in Brunei between 2003 and 2010, Brunei was ranked as 55th in 2003, 63rd in 2004, 73rd in 2005, 87th in 2008 and 68th in 2010 (refer to Table 1), and was positioned among the upper middle countries among UN member countries. The human capital index has relatively high figures while the web measure and telecom index are low. However the e-government standards of Brunei cannot be viewed as a progressive trend, due to an inconsistent set of indices.

Table 1.
Trends of E-Government Development Index (EGDI)
(a: Online Service Component)

Year	Brunei Rank / Countries	Web Measure or Online Service[5] (Rank/ Countries)	Telecom Index[6] (Rank/ Countries)	Human Capital Index[7] (Rank/ Countries)	E-Government Development Index (EGDI)[8]
2003	55/191	0.266	0.250	0.860	0.459
2004	63/191	0.266	0.233	0.890	0.463
2005	73/191	0.246	0.226	0.870	0.448
2008	87/192	0.246	0.256	0.876	0.467
2010	68/192	(88/192)	(67/192)	(63/192)	0.479

Source: UN E-Government Surveys (2003 - 2010)

[5] The research team assessed each country's national website as well as the websites of the ministries of education, labour, social services, health and finance. Associated portals and subsidiary websites were considered part and parcel of the parent sites and taken into consideration when assigning values to survey responses. The first of these includes questions relating to attributes that would be considered typical of an emerging online presence, the second to an enhanced presence, the third to a transactional presence and the fourth to a connected presence. Almost all questions in the survey call for a binary response of yes or no, with 'yes' given one point and 'no' zero. For example, if country 'x' were to score 233, with the lowest score of any country equal to 20 and the highest equal to 403, then the online services value for country 'x' would be: *Online service index (country 'x')* = (233-20) = 0.5561, UNDESA, 2010, *UN E-Government Survey*.

[6] The telecommunication infrastructure index for country 'x' is then the simple arithmetic mean of each of the five normalised indicators derived in this way: *Telecommunication infrastructure index = Average (personal computer index + Internet user index + telephone line index + mobile subscription index + fixed broadband index),* UNDESA, 2010, op. cit.

[7] The human capital index is a composite of two indicators: adult literacy rate and the combined primary, secondary, and tertiary gross enrollment ratio. The two indicators were normalised by taking their values for a given country subtracting the lowest value for any country in the survey and dividing by the range of values for all countries. For example, if country 'x' were to have an adult literacy rate of 66.8 per 100 inhabitants, with the lowest value of any country equal to 28.7 and the highest equal to 99.5, then the normalised value of this indicator for country 'x' would be given by: *Adult literacy index (country 'x')* = (66.8-28.7) = 0.5381 (99.5-28.7). The human capital index for country 'x' is then the weighted arithmetic mean of the two normalised indicators derived in this way with adult literacy assigned a weight of 0.6667 and gross enrollment 0.3333: *Human capital index* = ⅔ × *adult literacy index* + ⅓ × *gross enrollment index,* UNDESA, 2010, op. cit.

[8] Mathematically, the EGDI is a weighted average of three normalised scores on the most important dimensions of e-government, namely: scope and quality of online services (or web measure), telecommunication connectivity, and human capacity. Each of these sets of indexes is itself a composite measure that can be extracted and analysed independently: *EGDI* = (0.34 × *online service or web measure index*) + (0.33 × *telecommunication index*) + (0.33 × *human capital index*), UNDESA, 2010, op. cit.

According to reports released by the United Nations Department of Social Affairs (UNDESA), e-government evolution takes the following five stages in terms of maturity of evolution: (i) emerging; (ii) enhanced; (iii) interactive; (iv) transactional; and (v) connected[9], while at the same time, the OECD defines four possible stages of online service delivery comprising (i) information; (ii) interactive; (iii) transactions; and (iv) data sharing[10]. Added to this, other e-government models were proposed by Bhatnagar[11] and Layne & Lee[12]. As such, several international surveys about e-service development have been carried out using a similar model, but there is no general agreement on how to define the stages of e-government evolution. Taking cognisance of similar models regardless of different organisations, this research adopts the UN definition as follows[13]:

- Stage I - Emerging: A government's online presence mainly comprise a web page and/or an official web site with links to ministries or departments. Most of the information is static and there is little interaction with citizens.
- Stage II - Enhanced: Governments provide more information on public policy and governance. They have created links to archived information that is easily accessible to citizens, for instance, documents, forms, reports, laws and regulations, and newsletters.
- Stage III - Interactive: Governments deliver online services such as downloadable forms for tax payments and applications for license renewals. In addition, the beginnings of an interactive portal or web site with services to enhance the convenience of citizens are evident.
- Stage IV - Transactional: Governments begin to transform themselves by introducing two-way interactions between 'citizen and government'. It includes options for paying taxes, applying for ID cards, birth certificates, passports, and license renewals, as well as other similar G to C interactions, and allows the citizen 24/7 online access. All transactions are conducted online.
- Stage V - Connected: Governments transform themselves into a connected entity that responds to the needs of its citizens by developing an integrated back-office infrastructure.

Many countries have been able to reach the interactive stage without particular difficulties but might not be able to achieve transactional and connected

[9] UNDESA, 2010, op. cit.
[10] OECD, 2003, *E-Government Imperatives*.
[11] Bhatnagar, S., 2004, *E-Government: From Vision to Implementation: A Practical Guide with Case Studies*.
[12] Layne, K. and Lee, J., 2001, *Developing Fully Functional E-government: A Four Stage Model*.
[13] UNDESA, 2010, op. cit.

e-services without efforts and appropriate strategies. Table 2 shows that less than 20 per cent of UN member countries have implemented transactional e-government services such as online bidding for public contracts, online tracking of permits, online form submission and online payment, proving that most developing countries are at a standstill in providing basic e-services, not overcoming barriers underpinning the transactional stage.

Table 2.
Transactional E-Services Conducted by UN Member Countries

Transactional Service	Number of Countries	Percentage
Online bidding for public contracts is available	21	11%
Online tracking of permits is available	11	6%
Online form submission	39	20%
Online payment by card available	31	16%
Online payment of individual registrations/permits	29	15%
Online payment of business registrations/permits	29	15%

Source: UN, UN E-Government Survey (2008)

According to the 'Brunei e-service delivery by stages' issued by UN, utilisation percentages of emerging, enhanced and interactive stages stood at 5, 41, and 31 respectively, in comparison with one per cent of transaction and connected stages[14] (refer to Table 2), which implies that most e-government services can be viewed as simple e-services, allowing citizens to have access to the government website for getting information, but do not seem to easily fulfill sophisticated requirements of citizens such as two-way interactions between the government and citizens. More meaningful and significant e-government services are available through exploiting transactional e-services, including applying for government certificates, passports and driving license renewals in the area of transactions between government to citizen (G2C), conducting e-procurement, online business licences, and e-taxation in the area of transactions between government to business (G2B), and even exploiting consolidated information resources in transactions from government to government (G2G).

The prominent nature of the stages of the e-government model does not, however, guarantee a smooth pathway for governments to follow in their ICT journey. The implementation of ICT projects is still very challenging and many have shown prominent failures. According to Stoltzfus[15], e-government

[14] UNDESA, 2008, *UN E-Government Survey*.
[15] Stoltzfus, K., 2004, *Motivations for Implementing E-Government: An Investigation of the Global Phenomenon.*

programmes not only present challenges in preparation, but are also difficult to execute successfully.

This suggests that the five-stage model may not be followed, as it is very normative or quite simplistic. Atkinson and Leigh[16] explained that most government websites remain stuck in the transaction stage, as the next transformation stage requires organisational changes that challenge the current bureaucratic and political culture of most agencies. They further added that this "requires a fundamental change in outlook in the part of government, with the focus being placed on the needs of citizens." As Geiselhart et al.[17] pointed out, the stages in the model should offer more possibility of policy engagement.

The research attempts to identify e-government barriers to solve the challenge confronted by the government so that Brunei might not remain at a standstill in the fundamental level of e-government such as the emerging, enhanced and interactive stage. In this regard, the OECD has classified the general types of e-government barriers which have been continuously impeding e-government evolution[18] as follows:

- Legislative and regulatory barriers can impede the uptake of e-government
- Budgetary frameworks can restrict e-government
- The adoption of e-government solutions can lag behind technological change
- The digital divide impedes the benefits of e-government

Table 3.
Brunei E-Service Delivery by Stages

Stages	Unidentified	Emerging	Enhanced	Interactive	Transaction	Connected
Utilisation[19] (%)	12	5	41	31	1	1

Source: UN, E-Government Survey (2008)

For this research, the above types of e-government barriers are adjusted and elaborated into qualified variables or statements (see Table 3), which have been identified through discussion with practitioners working for the E-Government National Centre (EGNC) and the Authority for Info-communications Technology Industry (AITI).

[16] Atkinson, R.D. and Leigh, A., 2003, *Customer-Oriented E-Government: Can We Ever Get There?*
[17] Geiselhart, K. et al., 2003, *What Lies Beyond Service Delivery – An Australian Perspective*.
[18] OECD, 2001, op. cit.
[19] Utilisation is defined as services provided as a percentage of the maximum services in the category.

3.0 Online Security for Transactional E-Services

There has been a close relationship between transactional e-services and online security. In this regard, APEC recognised the reliance of transactional e-services on online security and identified the services based on public key infrastructure (PKI) as shown in Table 5. These transactional services should be rolled out together with online security such as (i) identification and authentication for sender and document; (ii) information integrity for checking falsification and forgery of electronic documents; (iii) information confidentiality to prevent exposure of electronic documentation and thereby protect documentation from wiretapping; and (iv) non-repudiation to settle conflicts between sender and receiver using digital signatures[20].

Table 4.
Transaction E-Services Using PKI Identified by APEC[21]

	Services/Applications	Remarks
E-Government	- E-Invoice and E-Tax filing - Applications of registration - Business closure - Company information inquiry - E-Passport and national ID Card, E-Voting - ID applications - Household or cadastral information inquiry or Medicare services - E-Procurement	Secure e-government services to citizens (G2C) and businesses (G2B)
E-Finance	- E-Payment - E-Billing - Online securities trading - E-Insurance services	(i) For e-billing, electronic delivery and presentation of financial statement, bills, invoices, and related information sent by a company to its customers, (ii) For security trading, stock, bonds and fund applications, and (iii) For insurance, indemnification, and information inquiry
E-Documentation	- Document management - E-mail security	For document management, filing, retrieval, archiving and exchange

Source: APEC Survey (2010)

[20] Adams, C. and Lloyd, S., 1999, *Understanding Public-Key Infrastructure*.
[21] APEC, 2010, Survey forms.

To ensure safe transactional services, several online security measures have been put in place, ranging from (i) password; (ii) biometrics; (iii) global positioning system (GPS); to (iv) PKI. When examining the above online security measures, considering that different technologies have different purposes, only the PKI method can fulfill the above-mentioned four online security purposes comprising authentication, integrity, confidentiality and non-repudiation. As a result, PKI can be evaluated as the online security technology suitable for Internet-based transactions and therefore constitutes the prerequisite for roll-out of transactional e-services.

Table 5.
Online Security Methods

Methods	Description	Cases	Possible Risks
Password	What you memorise	ID, Residence Registration Number, Credit Card Number	Memory Limit and Outflow, Vulnerability to Hackers
Token	What you have	IC (Smart) Card, Secure Token	Risk of Loss
Bio-information	The features of the human body	Fingerprints, Eye Retina, Voice Analyser, DNA	Immature Technology, Privacy Infringement
Location	Where you are	Global Positioning System (GPS)	Expensive to establish the facilities
PKI and Digital Certificate	Digital Certificate that CA issues	Accredited Digital Certificate	Require Infrastructure and Legislation

In particular, user verification and authentication are crucial to make use of various services on the Internet and in this context PKI has been considered as an effective authentication and identification method among other alternatives.

4.0 Analysis of the Barriers in Brunei Darussalam

Brunei has put an emphasis on ICT security in initiating e-government: (i) EGNC developed a government public key infrastructure (PKI); (ii) security and trust were identified as one of the key strategic priorities to achieve smart government to best serve the nation[22]. However, online security has not been fully implemented to support transactional e-services for the public, mainly resulting from a lack of a nationwide PKI. In order to make an analysis of

[22] JPKE, 2009, op. cit.

the barriers impeding secure transactional e-services, the research adopts the OECD analysis on e-government barriers and modifies its results to suit the current situation of Brunei Darussalam (refer to Table 6).

Table 6.
Barriers to Transactional E-Government Stage
(a: digital divide barrier is replaced by application barrier in this research)

OECD's barriers impeding e-government initiatives	**Identified barriers in Brunei to moving forward to the transactional e-government stage**
Legislative and Regulatory barrier	Lack of regulation applicable to regulate and support transactional e-services Nationwide institutions not established to function for secure transactional e-services
Budgetary barrier	Government budget that does not cover service charges for citizens and businesses to use transactional applications
Technological barrier	National cryptography policy not put in place
Digital divide and Application barrier	Flagship e-services having a broader effect on the public and thereby promoting e-government usage for general citizens not put in place

4.1 Legislative and Regulatory Barrier

A barrier on evolution to the transactional stage is attributed to inappropriate laws and lack of regulations applicable to the regulation and support of transactional e-services. The provision for a sound security and legal framework was not fully established during the RKN 8 period. For example, the 'Computer Misuse Order' and the 'Electronic Transaction Order'[23] (Order under section 83(3))[24] were promulgated in 2000. The 'Electronic Transaction Act' (ETA) as the amendment to ETO has been put in place to establish a secure ICT environment. According to ETA article 41, the controller of certification authority is defined as follows[25]:

- 41 (1) The Minister shall be the Controller of Certification Authorities for the purposes of this Act. And under the interpretation, "Minister" means the Minister of Finance.
- 41 (2) The Minister may appoint such number of Deputy and Assistant Controllers of Certification Authorities and officers as he considers

[23] http://www.bit.gov.bn/downloads/computer.pdf.
[24] http://unpan1.un.org/intradoc/groups/public/documents/apcity/unpan006031.pdf.
[25] ETA, Article 41 (1) and (2), http://unpan1.un.org/intradoc/groups/public/documents/unpan/unpan040449.pdf.

necessary to exercise and perform all or any of the powers and duties of the Controller under this Act or any regulations made thereunder.

In the context of the government structure, the Ministry of Finance is not the champion, even though positioned as the key stakeholder in (i) managing e-government finance; (ii) operating an information system associated with treasury and revenue; and (iii) making policy and regulations regarding e-payment which has been considered an important transactional e-service and one of the flagship projects. In order to resolve the problem, the controller should be changed into an agency that may be able to deal with ICT, taking into account that online security is a part of the information technology needed for transactional e-services. Added to this, the 'Electronic Transaction Regulation' (ETR) needed to materialise ETA has not been legislated so far, which will cause a legal problem: the government PKI system, which was implemented by EGNC, has not ironically been licensed by the Controller due to the lack of a specific procedure and forms to be stipulated by ETR, while PKI for citizens and businesses have not been put in place, which may cause difficulties in conducting transactional e-services.

4.2 Budgetary Barrier

As per norm, the traditional government budget has the following features: (i) single year expenditures; (ii) programme-by-programme; (iii) ongoing operations; and (iv) control. For these reasons, the traditional budget mechanism fails to fulfill the criteria for budgeting for ICT investment[26]. E-government funding for transaction services has the following characteristics[27]: (i) the treatment of certain ICT spending as capital rather than recurrent expenditure is a major challenge. Not all ICT expenditure is of a capital or investment nature, but involves maintenance and associated recurrent costs; and (ii) there are a number of budgetary rigidities that prevent shared funding arrangements.

Transactional e-services implemented by the government may go through similar difficulties under traditional government budget mechanisms. In the case of the digital certificate service, PKI constitutes the prerequisite for transactional e-services (refer to section 3) and requires up-front costs and management costs. Public private partnerships (PPP) can be used to overcome the government budget constraints, including obtaining capital, disincentives

[26] Harvard Policy Group, 2001, *Improving Budgeting and Financing for Promising IT Initiatives*.
[27] OECD, 2001, op. cit.

for innovation and maintenance costs, ensuring that funding is suited for transaction e-services. Likewise, PPP can help reduce the need to obtain sufficient up-front funding to establish e-services and related online security, by enabling costs to be covered through a series of recurrent payments. In order to exploit secure transaction e-services, subscribers or users would pay for the digital certificate fee to be collected by the certification authority (CA) for the purpose of covering a recurrent cost needed to operate the system. Moreover, PPP enables the government to receive the benefits from the partnership (for example, acquiring IT security skills and embracing an innovation atmosphere).

4.3 Technological Barrier

Most government security agencies have conducted ICT surveillance as part of the main intelligence operations to prevent, frustrate and prosecute unlawful activities[28]. In the context of national security, cryptography technology is required to be designed and implemented in such a way that the government may be able to decrypt any communication and files with a super key, which may bring about a dilemma on privacy issues. As a part of ICT security, cryptography is incorporated into the core component of PKI, which has been recognised as an effective tool to ensure confidentiality, integrity of data and a variety of applications to be exploited. In the case that Brunei increasingly relies on foreign security products embedded in cryptography technology, the country may face serious risks such as (i) a threat to national ICT security; and (ii) excessive development/adaptation costs to accrue from establishing an online security system. In order to iron out the above problems, a national cryptography policy should be designed and put into practice.

4.4 Digital Divide and Application Barrier

The digital divide is brought out when people cannot access and benefit from e-government services[29]. This research reviews the digital divide barrier in association with transactional e-service applications. As part of ICT security, PKI has been recognised as an effective tool using a cryptography technology to be incorporated into implementation of secure transaction services. Currently, around 500 digital certificates embedded in security tokens have been issued and distributed to government officials to use secure e-mail and file encryption and decryption for security reasons. However, PKI was not fully exploited and

[28] Aljifri, H. and Navarro, D.S., 2003, *International Legal Aspects of Cryptography.*
[29] OECD, 2002, *Information Technology Outlook.*

rolled out due to the lack of flagship projects or services – so-called killer applications - which might not be able to benefit from advanced e-government services, with particular emphasis on transactional G2B and G2C services. Additionally, it does not seem easy for end users without IT knowledge, experience of usage of digital signatures, management of their private keys (for example, how to subscribe to a digital certificate with the certification authorities, generate keys pairs - private key and public key - and manage their private key in a secure way). As a result, the lack of sufficient awareness of PKI may make it difficult for the country to take the step forward to transactional e-services such as e-taxation, e-payment, e-procurement, e-government portal and even e-business. To break the barriers, the following recommendations are proposed: (i) online security guidelines should be developed for end users to use transactional e-services; (ii) flagship e-services having a greater effect on the public should be conducted, focusing on consumer rather than supplier; and (iii) an appropriate user interface should be designed and implemented to cater for end users that have no IT security knowledge and skills.

5.0 National Brunei PKI (NBPKI) Framework for Promoting Transactional E-Services

While cyber transactions on the Internet have been rapidly developed and widely exploited not just for e-government but also e-commerce, ICT security poses a challenge. Likewise, ICT security threats are expected to become more widespread and increasingly more sophisticated. As cryptography is incorporated into Public Key Infrastructure (PKI), a variety of transactional services have been developed and exploited in a secure way, while at the same time the widespread use of cryptography may raise a number of serious issues and challenges: (i) maintaining public safety; (ii) protecting national security; (iii) ensuring the right to privacy and (iv) enforcing existing laws.

Even though most countries have launched PKI within their own national security framework[30] and international organisations encouraged the government to adopt PKI through their security guidelines, Brunei has not developed a national online security policy. Although the government PKI has been implemented for public servants, PKI for citizens and businesses has not been put in place for the public. Accordingly, the lack of the PKI framework on

[30] OECD, 2007, *The Development of Policies for the Protection of Critical Information Infrastructures (CII):* A Comparative Analysis in Four OECD Countries: Canada, Korea, the United Kingdom and the United States, the government information system is managed in a similar way in countries such as Canada, Korea, the United Kingdom, and the United States, in which governments have an authority to issue security policy, monitor, and report systems.

a national level beyond the government may make it more difficult to provide an efficient and effective e-service. This section attempts to draw an outline structure of a national PKI framework for Brunei Darussalam at a contextual level, define the roles of Brunei's agencies that are involved in PKI, and proposes some recommendations on the national PKI structure. In principle, the roles of entities involved in PKI can be defined as follows:

- The Controller deals with legal affairs including licensing CAs and monitoring their PKI services;
- The Root Certification Authority (RCA) certifies Certification Authorities (CAs);
- The Certification Authority (CA) issues a digital certificate signed by the issuing CA;
- The Registration Authority (RA) has the role of: (i) establishing the identity of subscribers; (ii) initiating a certificate process with a CA on behalf of subscribers (for example, registration of certain attributes of the subscriber); and (iii) generating key materials including a private key and public key on behalf of the subscriber; and
- The Subscriber uses secure transactional e-services using a digital certificate signed by the CA.

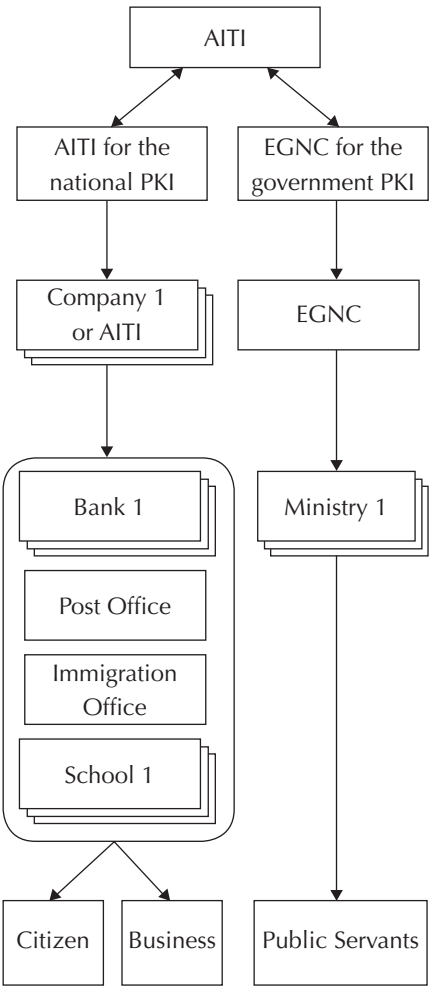
As shown in Table 7, the PKI framework of Brunei Darussalam is dichotomised into (i) the private PKI (hereafter the national PKI); and (ii) the government PKI, because different sectors have pursued different purposes. For this reason, the government PKI used for G2G transactions may have difficulty in taking responsibility for issuing and distributing as many digital certificates as the number of citizens who have access to e-services. The government PKI therefore, needs to be confined to G2G transactions and interoperability should be established to link the government PKI with the national PKI. When designing the NBPKI, the Authority for Info-communication Technology Industry (AITI) as the statutory body in Brunei Darussalam is recommended to play the controller role in the national PKI and may be able to regulate and promote both transactional e-services and the national PKI, taking into consideration the following missions of AITI[31]: (i) to ensure the supply of reliable, affordable and accessible info-communication technology (ICT) services to the public; and (ii) to provide a regulatory framework that would enhance effectiveness, efficiency and accountability of players in this industry. Brunei agencies or entities are allocated to function as actors involved in the national Brunei PKI as follows:

[31] http://www.aiti.gov.bn/about-mission.html.

- The agencies in charge of root CAs that certify CAs are separated into AITI for the public and EGNC for the government in accordance with the dichotomised PKI framework. Respective root CAs have limited responsibilities and may therefore be able to avoid the risks related to online security services through responsibility for different areas.
- Once possible CAs - regardless of the sector, whether public or private - want to provide digital certificate services for citizens and businesses, they can apply for CA. AITI as the controller will proceed with evaluating the applicants including: (i) assessing technology and capital capabilities as to whether the applicants are eligible to conduct CA services; and (ii) licensing qualified CAs to meet with requirements. As examined in section 4 analysis, the electronic transaction act (ETA) has not been put in place and should therefore be passed to designate the detailed processes and forms associated with a CA application. EGNC is required to go through the application process and be licensed by the controller. AITI cannot be ruled out as one of the CAs for citizens and businesses in a similar way that EGNC is positioned as the government CA.
- Agencies and organisations working as a Registration Authority (RA) should provide good accessible points for various users - including public servants, citizens and businesses. In this regard, bank branches are regarded as appropriate places for citizens to have access, followed by post offices, immigration offices and schools. These agencies are believed to identify potential subscribers to digital certificates without any difficulties and are therefore expected to act as RAs. For the government PKI, respective ministries and government agencies may be able to easily identify the public servants within their organisation and initiate the registration process in accordance with the policy of EGNC. As a result, the role of RAs should be highlighted to ensure end user's convenience. In the initial stage of launching a digital certificate, end users without ICT knowledge and skills should be supported and assisted by trustworthy RA agencies. Otherwise, they might not be able to make use of the digital certificate in a secure way, bringing serious problems (for example, a lost private key causing serious security problems)
- The subscriber as end user should be familiarised with (i) secure management of their private key and (ii) usage of a digital certificate for transaction e-services. Citizens and businesses pay the annual fee for a digital certificate for the national PKI to be operated and managed and the amount of the annual fee is subject to a certificate practice statement (CPS). However, the digital certificate fee can be paid by the RAs. For this reason, RAs would be major stakeholders who want to increase the

number of customers (for example, banks) and may be able to pay for digital certificate fees of subscribers to CAs so as to attract customers. As usual, RAs such as banks or financial institutions may have leeway to pay a digital certificate fee for their subscribers from their revenue. If RAs pay the digital certificate fee for their customers, subscribers resistance can be avoided through removing the financial burdens on subscribers.

Table 7.
Outline of National Brunei PKI (NBPKI) Framework

	Agencies to be positioned	Hierarchy
Controller	AITI	
Root Certification Authority (RCA)	AITI	
Certification Authority (CA)	- EGNC for the government - Companies for the private sector	
Registration Authority (RA)	- Ministries and government agencies for the government - Banks for the public - Immigration Office for the public - Post Office for the public	
Subscriber	- Public officials for government PKI - Citizen and Business for national PKI	

6.0 Conclusion and Recommendations

This research explored the barriers to transactional e-services and suggested a national online security framework for Brunei Darussalam, with particular emphasis on public key infrastructure (PKI). The research questions addressed are answered as follows: (i) online security is a crucial barrier to advanced e-government services being rolled out and the crucial barrier has been identified as the lack of regulation, with the national Brunei PKI (NBPKI) framework as the legislation barrier, notwithstanding the private sector's role as the budgetary barrier, national cryptography policy not having been put in place as the technological barrier, and insufficient flagship e-services and lack of awareness of digital certificates; (ii) PKI has been proven to be a safe, secure, reliable method to realise online security and therefore constitutes a prerequisite for transactional e-services; and (iii) the private sector as major stakeholders involved in PKI needs to initiate the national PKI to facilitate transactional services in the area of G2B and G2C. The NBPKI can resolve four barriers on transactional e-services and the following recommendations are suggested to operate the framework. In conclusion, a change is needed in policy to solve the structural barriers to the transactional stage and a strong leadership is of paramount importance to overcome the resistance to change.

- In accordance with Part X of ETA, Electronic Transaction Regulation (ETR) should be passed into law in order to (i) process CA applications and (ii) license qualified CAs.
- AITI is recommended to (i) be appointed as the Controller or deputy/ assistant Controller; (ii) be justified as one of the licensed CAs for citizens and businesses and EGNC as the government CA should be licensed from the Controller to ensure the legal effects of its PKI services.
- PKI based e-government applications/services should be identified, implemented and deployed, with particular emphasis on transactional e-government projects including BLS, e-procurement, e-payment, GEMS, e-taxation, and e-government portal.
- Financial institutions such as banks and post offices are to be appointed as Registration Authorities (RAs) of citizens and businesses PKI in order to (i) provide good access points for identification of subscribers; (ii) disseminate digital certificates; and (iii) promote e-payment based on PKI.
- Interoperability between countries should be established to roll out global e-services such as ASEAN single windows.
- Key pairs and certificates for the purpose of encryption should be separated from those of signature and private key for encryption and should be backed up or escrowed by CAs.

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