SUSTAINABLE RESOURCE AVAILABILITY BY OPTIMIZING ECONOMIC AND ENVIRONMENTAL FACTORS IN MALAYSIA'S POWER GENERATION MIX

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ABSTRACT

Population growth and economic development contribute to the rise in the demand for electricity. To meet the demand, electricity generation has been relying on fossil fuels. This practice has three major drawbacks: inevitable resource depletion, environmental concerns, and supply risk. Renewable fuels are touted to be the future of sustainable power generation. However, there is a need to assess and optimize the use of the available resource in an effective and efficient manner. In order to accomplish the desired objectives, this study adopted the multi-perspective approach for efficient utilization of resources, both in terms of cost and diversification, and also aimed to propose the optimum combination of technologies for electricity generation in Malaysia. In this regard, first, the potential of the resources was identified from the Malaysian prospective compliance with the five fuel energy action plan 2020. All the five fuels were examined in terms of economic, environmental and security parameters, and evaluated in the terms of cost to measure the total exposure in monetary units. For the economic analysis, the LCOE cost quantification method was used. Similarly for the restriction of carbon emission, a carbon-tax policy was proposed and a novel technique was designed for the quantification of excessive cost of security in the electricity generation industry. This study applied the simulation mathematical modelling and the graphical evaluation approach to optimize the power generation mix in terms of cost and diversity index. Hence, this study will assist the policy-makers in making efficient long-term policies considering the impact of various factors on total generation cost while adopting the concept of diversification for an efficient and uninterrupted power generation process.

Keywords: energy security, levelized cost of energy (LCOE), carbon-tax, excessive cost of security, power generation mix optimization.

ABSTRAK

Pertambahan populasi dan pembangunan ekonomi menyumbang kepada peningkatan keperluan bekalan tenaga elektrik. Bagi memenuhi keperluan tersebut, tenaga elektrik dijana dengan menggunakan sumber bahan api fosil. Kaedah berkenaan mempunyai tiga kelemahan utama iaitu pengurangan sumber, kebimbangan alam sekitar, dan risiko bekalan. Bahan api yang boleh diperbaharui dikategorikan sebagai sumber jana kuasa yang mampan. Walau bagaimanapun, terdapat keperluan untuk menilai dan mengoptimumkan penggunaan sumber yang sedia ada dengan cara yang lebih berkesan dan cekap. Untuk mencapai matlamat tersebut, kajian ini menggunakan pendekatan pelbagai perspektif bagi memastikan penggunaan sumber yang cekap, sama ada dari segi kos dan kepelbagaian, serta bertujuan untuk mencadangkan gabungan teknologi yang optimum dalam penjanaan tenaga elektrik di Malaysia. Dalam hal ini, sumber yang berpotensi telah dikenal pasti berlandaskan kepada pematuhan prospektif Malaysia dengan pelan tindakan lima tenaga bahan api 2020. Kelima-lima bahan api telah diselidik dari segi ekonomi, alam sekitar dan parameter keselamatan, serta dinilai dari segi kos untuk mengukur jumlah bebanan dalam bentuk kewangan. Untuk analisis ekonomi, kaedah pengkuantitian kos LCOE digunakan. Begitu juga sekatan terhadap pelepasan karbon, dasar cukai karbon telah dicadangkan dan teknik baharu direka untuk pengkuantitian kos keselamatan yang berlebihan dalam industri penjanaan elektrik. Kajian ini menggunakan model matematik simulasi dan pendekatan penilaian grafik bagi mengoptimumkan campuran penjanaan kuasa dari segi kos dan indeks kepelbagaian. Oleh itu, dapatan kajian ini dapat membantu penggubal dasar dalam merangka dasar jangka panjang yang cekap dengan mengambil kira faktor-faktor yang mempengaruhi jumlah kos penjanaan semasa mengamalkan konsep kepelbagaian untuk proses penjanaan kuasa yang efisien dan konsisten.

Kata kunci: Keselamatan Tenaga, Kos Tahap Tenaga (LCOE), cukai karbon, kos keselamatan yang berlebihan, pengoptimuman campuran penjanaan kuasa.

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LIST OF ABBREVIATIONS

LCOE	Levelized Cost of Energy
SDR	Supply Disruption Risk
MW	Mega Watt
KWH	Kilo Watt Hour
IEA	International Energy Association
NEB	National Energy Balance
GDP	Gross Domestic Product
BP	British Petroleum
BBl	Barrel of Oil
IPCC	Intergovernmental Panel on Climate Change
TWH	Tera Watt Hours
GHG	Greenhouse Gas
ASEAN	Association of Southeast Asian Nations
OECD	Organization for Economic Cooperation and Development
GWH	Giga Watt Hour
LNG	Liquid natural Gas
PIM	Probability Impact matrix
HHI	Herfindahl-Hirschmann index

CHAPTER ONE
INTRODUCTION

1.1 Background of Study

In modern society, the importance of electricity is paramount. Electricity is essential and is largely linked to several facets of life because power is the lifeblood of human activities in the modern world. According to Gilbert (2005), the tremendous advancement in the modernization of technology is a contributor to the raised demand for energy in 21st century besides the rapid increase in the world population. IEA (2015) reveals the facts that about 17 trillion watts of energy are being used worldwide. It has been foreseen by the experts that the further requirement of 30 trillion watts would be needed by 2030 due to the rapid rise in global population and brisk economic growth (Timmons, Harris and Roach, 2014).

Figure 1.1 illustrates that in 2013 the most of the energy generated (approximately 87%) was comprised of fossil fuels like oil, coal, and gas. In the 20th century, fossil fuels were given preferences for power generation due to their comparatively lower prices (BP Statistical Review 2014). Regrettably, it is a well-known fact that human health is severely affected by the catastrophic climatic changes caused by fossil fuels (Holgate, 1999), global warming (Letcher, 2009) and their reservoirs are gradually depleting (Simmons, 2005). The utilization of fossil fuels for electricity generation has been exposed to two major challenges: (1) finite resources and (2) environmental degradation. Energy experts have predicted that naturally available fossil fuel reservoirs are depleting continuously and will expect to remain one more century (Sovacool and Watts, 2009). The second challenge points towards the catastrophic emission of carbon (CO_2), nitrogen (NO_2) and sulfur (SO_2) emits during utilization

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APPENDIX A

Please rate the level of agreement with the following statements.

#	Questions	Probability Survey Scale: 1=Low 2=Moderate 3=High 4=Extreme 5=Not Related	Risk Impact Survey Scale: 1=Low 2=Moderate 3=High 4=Extreme 5=Not Related
1	Risk/Impact of supply disruption due to geological events E.g. (Resource depletion/Shortage)	1 2 3 4 5	1 2 3 4 5
a	Coal	1 2 3 4 5	1 2 3 4 5
b	Gas	1 2 3 4 5	1 2 3 4 5
c	Hydro Power	1 2 3 4 5	1 2 3 4 5
d	Biomass	1 2 3 4 5	1 2 3 4 5
e	Solar Power	1 2 3 4 5	1 2 3 4 5
2	Risk/Impact of supply disruption due to geopolitical events E.g. Political instability (war, Terrorism) high import dependency	1 2 3 4 5	1 2 3 4 5
a	Coal	1 2 3 4 5	1 2 3 4 5
b	Gas	1 2 3 4 5	1 2 3 4 5
c	Hydro Power	1 2 3 4 5	1 2 3 4 5
d	Biomass	1 2 3 4 5	1 2 3 4 5
e	Solar Power	1 2 3 4 5	1 2 3 4 5
3	Risk/Impact of supply disruption due to Economical events E.g. Lack of investment on extraction of resources	1 2 3 4 5	1 2 3 4 5
a	Coal	1 2 3 4 5	1 2 3 4 5
b	Gas	1 2 3 4 5	1 2 3 4 5
c	Hydro Power	1 2 3 4 5	1 2 3 4 5
d	Biomass	1 2 3 4 5	1 2 3 4 5
e	Solar Power	1 2 3 4 5	1 2 3 4 5
4	Risk/Impact of supply disruption due to geopolitical events E.g. Political instability (war, Terrorism) high import dependence	1 2 3 4 5	1 2 3 4 5
a	Coal	1 2 3 4 5	1 2 3 4 5
b	Gas	1 2 3 4 5	1 2 3 4 5
c	Hydro Power	1 2 3 4 5	1 2 3 4 5
d	Biomass	1 2 3 4 5	1 2 3 4 5
e	Solar Power	1 2 3 4 5	1 2 3 4 5
5 (a)	Risk/Impact of supply disruption due to Climatic events E.g. Extreme Weather conditions	1 2 3 4 5	1 2 3 4 5
a	Coal	1 2 3 4 5	1 2 3 4 5

b	Gas	1	2	3	4	5			1	2	3	4	5			
c	Hydro Power	1	2	3	4	5			1	2	3	4	5			
d	Biomass	1	2	3	4	5			1	2	3	4	5			
e	Solar Power	1	2	3	4	5			1	2	3	4	5			
5 (b)	Risk/Impact of supply disruption due to Climatic events E.g. Intermittency Risk	1	2	3	4	5			1	2	3	4	5			
a	Coal	1	2	3	4	5			1	2	3	4	5			
b	Gas	1	2	3	4	5			1	2	3	4	5			
c	Hydro Power	1	2	3	4	5			1	2	3	4	5			
d	Biomass	1	2	3	4	5			1	2	3	4	5			
e	Solar Power	1	2	3	4	5			1	2	3	4	5			

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