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A framework for evaluating Singapore's energy security

B.W. Ang, W.L. Choong *, T.S. Ng

Department of Industrial and Systems Engineering, National University of Singapore, Singapore

HIGHLIGHTS

- This paper proposes a framework to track Singapore's energy security.
- The framework takes into consideration the economic, energy supply chain and environmental dimensions.
- It shows that Singapore's energy security has been stable for the past 20 years.

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ABSTRACT

Following a literature survey which shows the existence of large variations among studies in the construction of energy security indexes, this paper proposes a framework with a composite index and three sub-indexes for evaluating Singapore's energy security. The sub-indexes capture the economic, energy supply chain and environmental dimensions of energy security. A total of 22 indicators, normalised using the banding approach, are aggregated to form the sub-indexes and the composite index referred to as the Singapore Energy Security Index (SESI). These indexes are generated for selected years from 1990 to 2010. The results show that Singapore's energy security has remained fairly stable throughout the period. Further analysis shows that the energy supply chain and environmental sub-indexes have improved, but the improvement was offset by the decline in the economical sub-index. The proposed framework allows quick identification of deficiencies within the Singapore's energy supply chain in the context of energy security by pinpointing its main weaknesses. It is particularly suitable for quantifying energy security of countries that are highly dependent on energy imports to meet their energy requirements.

1. Introduction

In many countries, energy-related decisions and actions have been dictated or influenced by growing energy needs and the desire to have stable energy supplies. These two issues are closely associated with the notion of what is normally known as energy security. Indeed, interest in energy security has been increasing. This is evident from the growing number of studies in the literature, including reports by national agencies and international organisations. A recent comprehensive literature survey by Ang et al. [1], for instance, reveals a total of 104 energy security studies from 2001 to 2014 and the number of publications per year has been rising over time.

Energy security has been defined and measured in many different ways. A total of 83 energy security definitions are found in the literature [1]. From these definitions the study identifies the following seven major energy security themes or dimensions: Energy availability, infrastructure, energy prices, societal effects, environment, governance, and energy efficiency. It is also found that concerns and perception of energy security have been changing over time. To be reflective of recent developments in the literature and for the purpose of the present study, we may define energy security as ensuring continuity and maintaining the affordability of energy services while at the same time reducing the environmental impacts of the energy system.[1]

A challenging problem for researchers and analysts is how can energy security be quantified and be made useful for policymaking. An approach to addressing this issue is through the use of indicators and the construction of energy security indexes from these indicators. There are many studies which propose indicators and indexes to measure the energy security of a single country. Not surprisingly, there is much interest in the energy security of large

* Corresponding author. Tel.: +65 6516 2203; fax: +65 6777 1434.
E-mail address: cwld87@gmail.com (W.L. Choong).

[1] In the 1970s and 1980s, energy security was often defined as ensuring a security of energy supplies and in particular oil supplies. Since 2000, environmental sustainability including climate change has emerged as an energy security issue and is included in a growing number of studies.

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energy consumers such as China [2–4] and the United States [5,6]. In [2], the energy security of the Chinese industries is studied together with energy efficiency and also carbon emissions. Thirty-eight sectors are divided into five clusters via principal component analysis and analysed using combined indicators. Wu et al. [3] utilize a different approach and analyse China's energy security based on supply security and energy using security. The study focuses on evaluating how effective were implemented policies at reducing energy consumption and carbon emissions. Another dimension of China's energy security is studied by [4], where the oil import security is analysed using eight indicators and the following four dimensions are used to study the oil import security: external dependence, supply stability, trade economy and transportation safety.

In the case of the United States, the energy security is evaluated by the Institute for 21st Century Energy [6] using the "Index of U.S. Energy Security Risk". This framework consists of four dimensions (geopolitical, economic, reliability and environmental) and employs thirty-seven energy security indicators. The study analyses historical energy security performance from 1970 and produces projections of future energy security trends to 2030. Dunn and Dunn [5] also examine the energy security of the United States. Their methodology focusses on the share of total primary energy consumption that is produced domestically and incorporates related elements such as exports, import diversity and political stability. Regional differences within the country are also explored.

Apart from the large energy consumers such as China and the United States, energy security studies using energy security indexes have also been reported for several other economies such as India, Lithuania, Taiwan and Thailand. Narula [7] studies the sustainable energy security of India based on the dimensions of availability, acceptability, affordability and efficiency. Twenty-two Sustainable Energy Security Indicators were selected to track the trends of energy security in India from 1972–2007. For Lithuania, Augutis et al. [8] develop a methodology to evaluate the energy security level using 38 indicators. These indicators are group under three blocks: technical, economic and socio-political. The aim of the study is to evaluate the impact of the closure of the Ignalina nuclear power on Lithuania's energy security. Chuang and Ma [9] analyse Taiwan's energy security via multi-dimensional energy security indicators. The dimensions selected are dependence, vulnerability, affordability and acceptability. A total of seven indicators are used and the energy security situation is measured for 2010 and projected at five year intervals to 2030. Lastly, the energy security of Thailand is measured both at the national level and also the provincial level by Martchamadol and Kumar [10]. Twenty-five indicators from the social, economy and environmental dimensions are utilized in the Aggregated Energy Security Performance Indicator proposed. The historical energy security performance is calculated from 1986 to 2009 and projections are made under various policy scenarios for 2010–2030.

Related to energy security indicators and indexes are studies on energy sustainability. The dimensions and indicators selected for analysis are largely similar to those considered in energy security studies. Examples of these include the studies on the sustainability of the Greek energy system by Angelis-Dimakis et al. [11] and on Mexican energy policy and sustainability indicators by Sheinbaum-Pardo et al. [12]. Both these studies examine energy sustainability through the social, economic and environmental dimensions and use less than ten indicators to evaluate the national performance.

A few observations can be made from the review of national energy security or energy sustainability indicators and indexes proposed in the literature. Firstly, dimensions such as economy, environmental and social are usually included to provide a holistic assessment. A national perspective of energy security issues would revolve around the economic competitiveness of its industry, the environmental impact of emissions from the energy system and also the social issues related to energy such as energy poverty and affordability. Secondly, the studies differ in many ways such as the proposed frameworks to organise the indicators and also the indicators themselves. The main determinants of these are the goal of the study and also the special national energy circumstances of a country, such as its dependence on energy imports and energy infrastructure. For example, a country with nuclear energy like Lithuania would include some indicators related to this energy source, whereas a country like China which imports large quantities of crude oil would be more concern about the continuity of these imports. The observation that energy security is largely context-dependent is in agreement with Chester [13] which concludes that energy security is polysemic in nature. The implication is also that to construct a national energy security measurement framework, the circumstances and policies of the country need to be thoroughly considered. Lastly, there is a large disparity across the number of indicators used. For instance, the Lithuania study [8] employs 68 indicators whereas less than ten were used in others [4,11,12]. Thus, there is no consensus on how data intensive an energy security index should be and how this would affect the results obtained.

In this study, we attempt to develop an energy security indexing framework for Singapore. The framework comprises three energy security dimensions, namely the Economic, Energy Supply Chain, and Environmental dimensions. It is designed to provide the Singapore Energy Security Index (SESI) and three sub-indexes, one for each dimension. The framework allows weaknesses in the energy supply chain to be pinpointed while at the same time takes into account what is known as the energy trilemma faced by a country, i.e. balancing among the three competing ends of energy security, economic competitiveness and environmental sustainability in providing reliable, affordable and clean energy solutions. A total of 22 indicators are used to construct SESI. The choice of indicators and the design of the framework take into account the special national circumstances of Singapore. Application of the framework leads to some interesting results. The policy implications of these results are discussed. Moreover, since a standard approach to analysing the energy security of a country does not exist, this study, like many other studies, helps to enrich our knowledge on and understanding of energy security issues. In constructing SESI, we also deal with certain fundamentals of energy security index construction, such as the choice of indicators, banding and aggregation techniques, and index framework design, which will be of interest to other researchers.

The next section introduces the methods that have been used to measure energy security and our proposed framework. This includes the indicators selected and how these indicators are aggregated to form SESI and the sub-indexes. Section 3 presents the results obtained by SESI and compares them with those obtained by other studies. Section 4 discusses several issues concerning the use of our proposed framework. Section 5 deals with the policy implications from SESI and discusses the conclusions of this study.

2. Methods

The construction of an energy security index usually follows the following steps. A framework is first proposed which addresses the scope and objective and structures indicator selection. The selected indicators are normalised. The normalised indicators are weighted according to their perceived importance and aggregated to form a composite index. In the process, data availability may affect the choice of indicators and normalisation method. The composite index that is constructed is taken as a measure of a country's