



## Energy security and co-benefits of energy efficiency improvement in three Asian countries

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### ABSTRACT

Energy and energy security have become important to countries aiming to go on the path of sustainable development. In this regard this paper analyses the improvement of energy security which occurs as a result of energy efficiency (EE) improvements in the power sector. In this paper energy security is measured along three main themes which are oil security, gas security and sustainability. The energy systems of the selected countries, namely Sri Lanka, Thailand and Vietnam are modeled using an integer programming based optimization model called “Model for Energy Supply Strategy Alternatives and their General Environmental Impacts” – MESSAGE. Each country is modeled with two scenarios namely the reference scenario which maintains the status quo at the start year and the EE scenario which models EE options in the demand side as supply side alternatives. The time horizon is 2007–2030, where 2007 is the base year and 2030 is the end year. The results are presented for oil security, gas security, sustainability, and also for co-benefits such as mitigation of CO<sub>2</sub> emissions, reduction in conventional primary energy use and reduction of local air pollutants such as SO<sub>2</sub> and NO<sub>x</sub>. Results show that energy efficiency in Sri Lanka significantly increases the energy security whilst also accruing co-benefits of CO<sub>2</sub> mitigation, mitigation of local air pollution and reducing the conventional primary energy use. In the case of Thailand and Vietnam, energy security is enhanced in the earlier years (2007–2015), but in the longer term of modeling horizon (2020–2030) energy security of both the reference and EE scenarios converge indicating that in terms of long term energy security implementing energy efficiency measures alone would not enhance energy security.

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*Abbreviations:* CECap, carbon emission per capita; CEInt, carbon emission intensity; DOFS, diversity of fuel share; EE, energy efficiency; GI, gas intensity; GII, gas import intensity; GMS, greater mekong sub-region; GS, gas share; GSRI, gas supply risk indicator; IAEA, International Atomic Energy Agency; IIASA, International Institute of Applied Systems Analysis; MESSAGE, model for energy supply strategy alternatives and their general environmental impacts; NCFs, non-carbon fuel share; NG, natural gas; NGID, net gas import intensity; NOID, net oil import intensity; OI, oil intensity; OII, oil import intensity; OS, oil share; OSRI, oil supply risk indicator; PG, power generation; RFS, renewable fuel share; TPES, total primary energy supply

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## 1. Introduction

Energy security has permeated into the energy lexicon of 21st century, and has gained much prominence [1]. Even though researchers conclude that there is no definitive explanation that can be given for the term ‘energy security’, the consensus is that energy security means varied things to various countries, and energy systems [2].

Many supra national institutions and developmental agencies have authored a multitude of research works on energy security. Reference [3] indicates that energy security is the “constant availability of affordable energy supplies” whilst [4] defines energy security as the “ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner, with the energy price being at a level that will not adversely affect the economic performance of the economy”. The former definition, whilst being succinct and its interpretation more suited to the layman, simplifies the context of energy security and the latter definition is more in-depth and covers the multiple context of energy security whilst connecting energy to the economy of the nation state or region.

The modern school of thought on energy security has proclaimed that energy security needs to be viewed holistically [5]. References [5–7] have mentioned the different themes which encompass the meaning of energy security in the modern day energy regime.

In terms of measurement and assessment of energy security, Ref. [8] presents the summarized review of the indicators and indices present for measuring energy security. Refs. [4,9–11] provide composite indicators for measuring energy security, oil security, gas security and vulnerability of energy systems respectively. But as mentioned before, these indicators are one-dimensional in nature, as they only account for one facet of energy security. The sustainability aspect of energy security is deemed to be of utmost importance by [12,13] and more so for developing countries. In view of that, this research study contends that the sustainability theme of energy security is also vital to assessing energy security. This presumption is well backed by [14]. Some indicators proposed to measure sustainability of an energy system are given in Refs. [15,16]. As per the review presented before, this research article will assess energy security along three main themes which are oil security, gas security and sustainability.

Another important aspect of energy security research is that the means of achieving energy security is very much temporal and contextual in nature. By this, the implication is that depending on the nature of energy-economy system the focus of energy security should shift. In a groundbreaking report published by [17], it is stated that the most effective way of achieving energy security is by focusing on energy efficiency. This report also identifies energy efficiency as an effective way of ensuring the energy security of developing countries. In addition to this report countless other reports of agencies like [18–20] also point out the importance of energy efficiency to improve energy security of developing countries. Energy efficiency in the power sector is

dealt with in Integrated Resource Planning (IRP), where the energy efficiency measures are taken into the planning framework as supply side options [21].

The comprehensive review of energy security, energy security indicators and related topics are given in Table 1. Energy security in the reviewed papers has been treated exhaustively. With the advent of increase of popularity of energy security, most papers carried explorative studies of energy security. When the understanding of energy security had permeated into mainstream conscience, more quantitative discussions are currently taking place.

All this goes onto point the impetus energy analysts and policy-makers place on the need of a country to be energy secure and validates the premise that assessing the impact of any energy policy measure on the energy security of a country is the need of the hour.

The objective of this research paper is to formulate an assessment framework of energy security, where energy security is measured as oil security, gas security and sustainability and measure the energy security and co-benefits ensuing as a result of energy efficiency measures in three developing Asian countries, namely Sri Lanka, Thailand and Vietnam. The co-benefits analyzed in this paper are CO<sub>2</sub> mitigation, air pollution reduction and the reduction in primary conventional energy use. Rather than focusing on the ways to implement and achieve energy efficiency in the power sector, this paper focuses on the effect of energy efficiency measures on energy security of developing countries. Three developing countries in Asia that have been chosen are Sri Lanka, Thailand and Vietnam. Sri Lanka is an island nation in the Indian Ocean, with an approximated population of 21 million people. In terms of its energy use, it is predominantly traditional biomass based, with an electrification rate of approximately 70% [31]. Sri Lanka does not have a well documented energy system. The present government came up with an energy policy paper [32] which gives direction to energy policy of Sri Lanka. Thailand is a Southeast Asian nation with a population of approximately 61 million people. Thailand experienced rapid growth in the 1990s, and even at present has a robust economy and growth rate [31]. Thailand does possess considerable amount of NG and a lesser amount of crude oil reserves. Thailand has a very mature and modern energy system, with electrification rate being 99% in 2009 [33]. Thailand is an important economic player in the region, having the second largest economy in Southeast Asia, and accounted for almost 50% of the GDP in the Greater Mekong Sub-region (GMS) [12]. Vietnam is a Southeast Asian country and has experienced rapid economic growth in the last two decades and the GDP growth rate is the best in the region, and second to only India and China [33].

## 2. Energy situation in Sri Lanka, Thailand and Vietnam

Before analyzing the future energy security of these selected Asian countries and its impact on energy efficiency, it is pertinent

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