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Efficient, equitable and sustainable energy policy in a small open economy: Concepts and assessments

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ABSTRACT

This study aims to develop three broadly defined concepts of designing and evaluating energy policy of a small open economy, namely, efficiency, equity, and sustainability which are applied to Singapore. By analysing the historical energy and economic data and examining energy policies and programs implemented, this study finds that (1) energy intensity improves over time and three strategies employed to improve energy efficiency - tariffs, deregulation and setting energy standards - are found to have some positive effects. (2) A utility rebate programme is implemented and revised continuously to achieve equity in energy consumption across Singapore households. (3) By the weak concept of sustainability, Singapore is considered marginally sustainable. Institutional, technological and market-based approaches are being implemented to increase energy efficiency, improve energy equity and secure sustainability.

1. Introduction

The concept of energy efficiency is intuitive, but complex to clearly define. A widely accepted definition given by the Lawrence Berkeley National Laboratory is "using less input of energy to produce the same service" (IEA, 2014). In an economic analysis, energy has entered the production function explicitly only after oil shocks hit the world economy hard in the 70's (Dasgupta and Heal, 1979; Endress and Roumasset, 1994). Unlike capital and labor, energy could not be supplied without limit under current feasible technology of energy supply. Hence, the outcome would be desirable, if the energy can be used efficiently, i.e., less energy input for the same or more output. Since the world economy faces finite supply of exhaustible energy resources and technological barriers with renewable energy resources, energy efficiency could have various roles in harnessing economic growth. In the meantime, improvements in energy efficiency can help reduce carbon emissions and mitigate climate change, one of the key challenges human beings face today.[1] For the consideration of environmental and climatic impacts, however, energy efficiency improvement is not the only measure. Options of renewable and low-carbon energy sources and technologies of carbon capture and storage are equally important.

Equality of energy consumption is gauged by the share of utility expenses out of total expenditure. The poor are usually paying a relatively higher proportion of their income on energy consumption. In Singapore the proportion of expenditure spent on energy consumption decreases over the household income level. The lowest income household whose income is below $1000 spent about 5.9 per cent of their total expenditure on fuel and utilities, while the highest income household spent only about 2.3 per cent and on average 3.2 per cent in 1997/1998 (Department of Statistics Singapore, 2000).

Energy is one of the essential factor inputs for production in an economy, and securing energy supply is one of the crucial tasks that each economy has to deal with. This is particularly so in Singapore, a country with few natural resources. Each economy is depleting its own resources and/or other country's resources, and the resource depletion has to be treated in a comprehensive manner. By the concept of weak sustainability that a society is considered (weakly) sustainable as long as its consumption is remaining in a steady state, Singapore is considered marginally sustainable.[2] It is considered unsustainable that a country depends solely on the finite fossil fuels so that there have been huge efforts on developing an infinite supply of energy resources

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[1] Existing studies find that carbon emissions per energy consumption decreased over time in a coastal city in China (Ma et al., 2011). The improvement in the efficiency of power plants is one of the key factors explaining differences in greenhouse gas emissions if natural gas and coal power plants are compared (Zhang et al., 2013, 2014, 2015). They also find that natural gas contributes to less warming than coal does in the long-run.

[2] A counter concept of the weak sustainability is strong sustainability. A society is considered strongly sustainable where the cumulative negative impact is zero in the long run. For more detailed discussion on the sustainability, refer to Hartwick and Olewiler (1997) and Hanley et al. (2007).

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Table 1
Overview of Singapore Energy Policies and Regulations.

	Characteristics
• National Climate Change Strategy 2012 • Singapore Sustainable Blueprint 2015 • Intended National Determined Contribution	Setting up clear national strategy, quantity targets and international commitments for energy efficiency and emission reductions
• Energy Conservation Act • Energy Efficient Singapore	Integration of energy-saving/efficiency measures and projects, intensive management of information on sector-specific measures and public relations
• Energy Innovation Programme, National Innovation Challenge on Energy Resilience for Sustainable Growth • Green Building Innovation Cluster • Test-beds for clean vehicle technologies, Encouraging Living Lab Programs	Committed for extensive R & D efforts for energy efficient and clean Singapore
• **Industry:** Design for Efficiency Scheme, Grant for Energy Efficiency Technologies and the Investment Allowance, Energy Efficiency Improvement Assistance Scheme, Singapore Certified Energy Manager, Accelerated Depreciation Allowance for Energy Efficient Equipment and Technology • **Commercial and Residential:** Green Mark Incentive Scheme for Design Prototype, Green Mark Incentive Scheme for Existing Buildings, Pilot Building Retrofit Energy Efficiency Financing Scheme • **Transport:** Early Turnover Scheme, Vehicle Quota System, Rebates under Carbon Emissions-Based Vehicle Scheme, Higher emission standards for vehicles, Fuel Economy Labelling Scheme for cars and light goods vehicle	Diversification and improvement of financial subsidies in various sectors
• The Green Building Master Plan, Minimum Green Mark Standards for Buildings, Minimum Energy Performance Standards, Green Data Centre Standard, Mandatory Energy Labelling Scheme • Waste to Energy Plants, Integrating Water and Waste Management by 2030 • Raise the adoption of solar power in electricity system to 350 MWp by 2020	Implementing unique mandatory energy efficiency measures in all sectors of the economy
• Energy Efficiency National Partnership Programme, Energy Performance Contracting • Save Money Save Energy Initiatives, Tips of Home Audit, Life Cycle Cost Calculator, Public Sector Taking the Lead in Environmental Sustainability, Energy Services Companies Accreditation Scheme, Walk2Ride Programme, National Cycling Plan	Various voluntary initiatives to promote energy efficiency in all sectors of the economy

in Singapore.

The three concepts, efficiency, equity, and sustainability could direct the way that energy policy is designed and accordingly evaluated. These concepts consequently set goals in energy policy: improving efficiency of energy use, achieving equity in energy consumption across households, and securing sustainability in energy supply.

Table 1 gives an overview of current energy policies and regulations in Singapore. This study critically reviews energy policy in Singapore with respect to the three concepts and examines how efficiency, equity and sustainability have been reflected in its energy policy design and implementation of the policy.

The remainder of this study is structured as follows. Section 2 discusses efficiency of energy use in Singapore. Specifically, it reviews how energy sector has evolved in Singapore and examines the trends of energy consumption in the residential and commercial sectors and the changes in the economic structure as well as energy policies with respect to energy efficiency. Section 3 examines equity of energy consumption in Singapore by reviewing a utilities-save scheme that has been implemented since 1997. Section 4 discusses various measures taken to secure sustainable energy supply in Singapore. The last section concludes with presenting some thoughts on energy policy.

2. Efficiency of energy use in Singapore

Energy is a factor of production along with capital and labor. Beyond mere production factor, energy sector has contributed huge impetus for Singapore to grow as an industrial economy. This section reviews evolution of the energy sector since the independence of Singapore and how energy consumption has changed over time; following that energy efficiency status is investigated and discussed; and finally, current energy policy in Singapore is examined with respect to energy efficiency.

2.1. Economic development and energy consumption

Since its independence, Singapore has invested huge efforts in the oil industry chiefly in refining capacities (Chang, 2014). A share of petroleum exports out of total exports ranged from 20 per cent to 32 per cent from 1977 to 1987 (Doshi, 1989). The petroleum industry once contributed 40.1 per cent to manufacturing output and 6.3 per cent to gross domestic product. When Singapore's industrial structure is diversified into other manufacturing sectors, the share of oil-related outputs has decreased below 10 per cent from around 40 per cent during the late 70's and early 80's. Its share of value-added also plummeted from above 14 per cent to below 5 per cent in the 90's (Horsnell, 1997). Singapore's refineries were collectively the third largest refining centre in the world after Rotterdam and Houston, accounting for 68.1 million tonnes of global oil exports in 2007 (British Petroleum, 2008). Most recently, refined petroleum products amounts to 18 per cent of manufacturing output, 3 per cent of GDP, and 0.1 per cent of value added of manufacturing establishments in 2013. The share of petroleum exports out of total exports is also reduced to 17 per cent in 2014 (Department of Statistics Singapore, 2015).

According to the report by the Inter-Agency Committee on Energy Efficiency (IACEE, 1999), Singapore's energy needs have grown in tandem with its economic growth. Over the period from 1980 to 1995, while the average annual growth in GDP over the same period was about 7.6 per cent, the annualized growth in energy demand was 11.9 per cent.

The change in energy consumption in Singapore is mainly caused by three factors. First, more people live in a larger-room house (as shown in Table 2). There is a decline in the percentage of people living