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The long-term forecast of Taiwan's energy supply and demand: LEAP model application

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ABSTRACT

The long-term forecasting of energy supply and demand is an extremely important topic of fundamental research in Taiwan due to Taiwan's lack of natural resources, dependence on energy imports, and the nation's pursuit of sustainable development. In this article, we provide an overview of energy supply and demand in Taiwan, and a summary of the historical evolution and current status of its energy policies, as background to a description of the preparation and application of a Long-range Energy Alternatives Planning System (LEAP) model of Taiwan's energy sector. The Taiwan LEAP model is used to compare future energy demand and supply patterns, as well as greenhouse gas emissions, for several alternative scenarios of energy policy and energy sector evolution. Results of scenarios featuring "business-as-usual" policies, aggressive energy-efficiency improvement policies, and on-schedule retirement of Taiwan's three existing nuclear plants are provided and compared, along with sensitivity cases exploring the impacts of lower economic growth assumptions. A concluding section provides an interpretation of the implications of model results for future energy and climate policies in Taiwan.

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1. Introduction and country overview

Taiwan, with a total land area of only about 36,000 square kilometers (14,400 square miles), similar to Holland and Switzerland, lies on the western edge of the Pacific Ocean, south of Japan, north of the Philippines, and off the southeastern coast of mainland Asia, across the Taiwan Strait from Mainland China. Two-thirds of Taiwan is covered by rugged mountain ranges with 258 peaks over 3000 m high, but most of the country's 23 million people, live in the plains in the west of the island. Taiwan spans the Tropic of Cancer, and its climate is tropical to subtropical, except at higher altitudes.

Taiwan's total GDP as of 2008 was US\$ 392 billion, with a per capita GDP of US\$ 17,116. Agriculture accounts for 1.7% of GDP, while Services accounts for the largest share at 73.2%, and Industry around 25.3%. Real growth in GDP has averaged about 8% annually during the three decades between 1970 and the late 1990s. Foreign trade has been the engine of Taiwan's rapid growth during the past 50 years, and Taiwan's economy remains export-oriented.

Taiwan has transformed itself from an underdeveloped, agricultural island to an economic power that is nowadays a leading producer of high-technology goods. Taiwanese economic policies shifted from an emphasis on subsidized import-substitution in the

1960s to export-led growth. As a result, Taiwan moved from mostly cheap, labor-intensive manufactures to an expansion of heavy industry and infrastructure in the 1970s, and then to production of advanced electronics and other high-value-added products in subsequent decades.

With the prospect of continued relocation of labor-intensive industries to economies with cheaper work forces, such as in China and Southeast Asia, Taiwan's recent development has had to rely on further transformation to a high technology and service-oriented economy, causing a shift in the overall energy intensity of its economic output. As Taiwan's economy has become increasingly linked with China's, Taiwan firms are increasingly acting as management centers that take in orders for goods, which are then produced in Taiwan, on the mainland, or in Southeast Asia, with the final products then shipped to the U.S. and other markets (Taiwan Government Information Office, 2009; Wikipedia, 2010; Council for Economic Planning and Development, 2010; United States Department of State, 2009; Travel Document Systems, 2010)

In contrast with its economic performance, Taiwan has been endowed with relatively little in the way of natural resources. Taiwan's deposits of coal, natural gas, limestone, marble, and other energy and mineral commodities are limited, and as a result, Taiwan depends almost exclusively on imported energy (more than 99%). Despite this historical dependence on imports, it was not until the first energy crisis struck in 1973 that the government started to formulate a formal energy policy framework. The "Energy Policy of the Taiwan

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Area” was approved and promulgated at the same time, and has subsequently been revised four times to cope with and respond to temporary energy shocks and long-term global trends. These shocks and trends include energy supply crises in 1979 and 1984, the oil price impacts of the Gulf War in 1990, the liberalization of energy industries in 1996, the environment protection movements, and others. Since its latest revision, the goal of Taiwan’s energy policy has been set to establish a liberal, orderly, efficient, clean, and sustainable energy demand and supply system. The approaches used in carrying out Taiwan’s energy policy have included stabilizing energy supply, increasing energy efficiency, deregulating energy markets, emphasizing energy security and environmental protection, enhancing energy research and development, and promoting energy education (Bureau of Energy, Ministry of Economic Affairs (MOEA), 2010).

Taiwan’s government established the Energy Commission under the Ministry of Economic Affairs in 1979 to implement energy policies such as the “Energy Management Act”, “Electricity Act”, “Petroleum Administration Act”, “Regulations Governing Administration of Gas Utilities”, and other energy-related regulations. In comparison with energy policy, Taiwan’s environmental protection policies were developed at a later stage in comparison with its energy policies, and it was not until 1987 that Taiwan established the “Environmental Protection Administration” (EPA) as the authority in charge of environmental protection. The EPA has been actively responding to the United Nations Framework Convention on Climate Change, and is currently facilitating the legislation included in the “Greenhouse Gases Reduction Act,” gradually establishing a legal system for the administration of greenhouse gases emissions and emissions reduction.

Since the 1990s, Taiwan’s energy policy has focused on sustainable development, and its core principle has been shifted to the balancing of the “three Es”, seeking a “Win-Win-Win Solution” for energy security, environment protection, and economic competitiveness. In June 2009, the Legislative Yuan passed a renewable energy act aimed at promoting the use of renewable energy, boosting energy diversification, and helping to reduce greenhouse gas emissions. The new law authorizes the government to enhance incentives for the development of renewable energy using a variety of methods, including the direct acquisition of renewable energy systems, incentives for demonstration projects, and the loosening of regulatory restrictions in order to increase Taiwan’s renewable energy generation capacity by 6.5 million kilowatts to a total of 10 million kilowatts within 20 years. Over the next 5 years, US \$0.6 billion is set aside for investment into advanced technologies in seven “Green Energy” industries: solar energy, LED lighting, wind power, hydrogen energy and fuel cells, biofuels, energy information and communications technology, and electric vehicles. In coordination with a re-structuring of governmental organizations in 2012, the Bureau of Energy, currently under the Ministry of Economic Affairs, will be upgraded as the Ministry of Economy and Energy, and the EPA will be upscaled to the Department of Environment and Resources. These structural changes are clear signs that the government will put more emphasis on energy and environment in the future.

Although Taiwan is a densely populated island, with only limited natural resources and almost entirely dependent on energy imports, energy prices have been kept low and stable historically, starting in the early stages of Taiwan’s economic development, and continuing to the present day as the government focuses on sustainable development. Compared with other natural resource-poor economies, such as Korea, Japan, Hong Kong, and Singapore, energy prices have been much lower in Taiwan, even during the oil-price spikes in mid-2008. For example, prices for 95 Unleaded Gasoline (US dollars per liter) were \$0.64 in 2002, gradually rose to \$0.97 in 2007, and then dropped to \$0.66 in 2008 and \$0.77 in May 2009. Premium diesel oil prices have been lower than those for

gasoline; \$0.49 in 2002, rising to \$0.86 in 2008, and dropping to \$0.53 in May 2009. Average electricity prices (US\$/kWh) were lower than \$0.07 for the two decades from 1988 to 2007, and rose to \$0.08 in 2008 (Bureau of Energy, MOEA, 2009a).

Energy prices being consistently maintained in Taiwan at relatively low levels has led Taiwanese energy consumers to believe that it is the government’s duty to maintain low prices even when world-wide energy prices hikes occur. As the energy industry is highly regulated and most energy companies are state-owned, the government has incentive to freeze energy prices as much as it can. Because of this tradition of low energy pricing, market signals that would normally induce energy efficiency gains do not get through to consumers, as energy efficiency improvements and energy conservation actions do not translate into significant economic savings. To correct the current low pricing of fuels and electricity, and thus to provide more of an incentive to improve energy efficiency, the high-profile Tax Reform Committee (of which the first author is an active member; May 2008–Dec. 2009) under the Executive Yuan proposed a Green Tax Reform to levy energy taxes and carbon taxes on exhaustible fossil fuels on a revenue-neutral basis; that is, by recycling Green Tax revenues into income tax cuts and subsidies for public transportation systems, in order to provide incentives for all energy users to save energy and reduce CO₂ emissions without hurting the economy and the poor. Owing to the worldwide financial crisis, however, the government has delayed in putting the Green Tax Reform proposal into policy. The most recent move by the Ministry of Finance has been to ask researchers (including the first author of this article) to do further research and policy design to make the Green Tax system more feasible so as to fulfill the President’s commitment made in the 2008 presidential election campaign. (Shiaw and Huang, 2009; Huang, 2003; Huang et al. 2008).

2. Taiwan’s energy status

2.1. Analysis of energy supply

Taiwan produces little of its own energy, but its energy demand continues to increase dramatically in order to feed the island’s strong economic growth. Based on data from the Bureau of Energy, Ministry of Economic Affairs (2008a) and the Taiwan Power Company (2008a), the energy supply in Taiwan grew from 41.61 million kLOE (thousand liters of oil equivalent) in 1986 to 138.8 million kLOE in 2006, with an annual growth rate averaging 6.2%. The ratio of imported energy to total energy use in Taiwan has also increased steadily, rising from 90% in 1986 to 96% in 1996, peaking in 2007 at 99%.

Since the government started importing liquefied natural gas (LNG) from Indonesia and Malaysia in 1980, the share of energy supplies provided by petroleum has fallen such that the 146.6 million kLOE total energy supply nationwide as of 2007 comprises a reduced petroleum fraction of 51.3%, an increased coal fraction of 32.1%, nuclear power generation equivalent to 6.9% of total energy supplies, a liquefied natural gas share of 8.2%, a natural gas (from wells on Taiwan and in nearby waters) fraction of 0.3%, a hydroelectric power share of 1.4%, and a renewable energy share of 0.1%. See Table 1 for details.

2.2. Analysis of energy demand

The energy consuming sector’s 37.73 million kLOE of energy demand in 1986 increased to 112.28 million kLOE in 2007, with an average annual growth rate of 5.5%. The distribution of final energy consumption by fuel (Fig. 1) for 2007 shows that about 60% of final energy demand was provided by petroleum products, with

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