Prospects of Energy Development in Taiwan Under a Changing Economic Structure

*By Rong-I Wu**

Energy is essential to the operation of the modern economy. Economic growth is closely tied to the production, transportation and use of energy. In general, higher economic growth is associated with higher energy consumption. Because the exploration, development, production and use of energy emit pollutants into the environment, concern for protecting the environment grows with economic development. In addition, many of the conventional fossil energy resources are limited in supply and can be depleted in the foreseeable future. Thus, sustainable development has become a worldwide vision for growth. Applied to energy development, it is sustainable energy development.

In this article, I will review the trends of recent energy and economic developments in Taiwan, and offer my views on the prospects of future energy development from the perspective of sustainable development.

Energy Developments in Taiwan: Trends and Issues

In 2001, total domestic energy consumption in Taiwan amounted to 94.8 million kiloliters of oil equivalent. The largest share of total energy use is in the form of electricity, about 48%. Oil and oil products' share is second with about 39%. The rest are coal and coal products (11%), and natural gas and LNG (3%). In terms of economic sectors, the industrial sector has the largest share with over half of the total (or 57%). It is followed by transportation (15%), residential (12%), businesses (6%), others (6%), and non-energy use (2%). With electricity use, the industrial sector also has the largest share (56%), while the residential sector is second with 20%. Business and other sectors account for 11% each. The transportation sector is the smallest with only about 2%.

From 1981 through 2001, total energy use grew at an average annual rate of 6.9%, while total electricity use grew at 7.8%. Among economic sectors, the business sector has the highest annual growth rate of 11.7% for both total energy and electricity. Residential and other uses of electricity are also the faster-growing sectors, with 8.3% and 9.5% respectively.

In 2001, oil and oil products accounted for over half of Taiwan's energy supply (51%). Coal is second with 32%. The other sources of energy supply are, in order of percent contribution, nuclear (8%), LNG (6%), hydropower (2%) and natural gas (1%). Over the last 20 years, coal grew fastest with 10% annual rate, followed by nuclear at 6.3%. Since 1991, LNG grew fastest at almost a 12% annual rate.

Recent energy developments in Taiwan can be characterized by liberalization, diversification, energy conservation and efficiency, environmental protection/sustainable development, and promotion of renewable energy.

Liberalization. Taiwan has liberalized, or is in the process of liberalizing, her oil, electricity, and natural gas industries. Liberalization of retail, wholesale, refining, and imports of gasoline and other oil products have been largely achieved. Taiwan has opened up the electricity generation market to allow self-generation and an independent power producers. The Electricity Law is being revised to allow additional integrated electrical suppliers, open access to the transmission grid, and establishment of independent system operator. In natural gas, the wholesale price mechanism is being improved, and a second LNG receiving station is being constructed in the northern part of Taiwan. These industries are opened to foreign direct investments. The issues are:

- How to achieve the government's oil reserve target (30 days),
- How to address the problems of illegal market operators, market disruption, and tax evasion,
- Consumer protection ,
- Complete the revision of, and implement, the Electricity Law,
- Remove the barriers to further development in the natural gas industry.

Diversification. Taiwan is highly dependent on imported energy resources. In 2001, about 97% of her energy supply was imported. Oil comes mainly from the Mid-East. Coal is mainly from Australia and China. The principal LNG suppliers are Indonesia and Malaysia. To reduce the dependence on oil, the government encouraged industries to use coal in place of oil. LNG import was also opened up. Efforts were made to diversify energy resource supplying regions and nations. Over the last 20 years, dependency on oil has fallen from 68% to 50%. Correspondingly, dependence on Mid-East oil declined to 50% from 68%. Diversification issues are as follows:

- Additional facilities and infrastructure to receive imports of coal and LNG need to be constructed,
- Energy transmission and transport facilities and infrastructures need to be strengthened,
- Promote and develop new and renewable energy resources,
- How to achieve the 2020 target ratios of installed electric generation capacity set by the "National Energy Conference": coal 35-37%, oil 4-5%, natural gas 27-29%, hydro 9-11%, nuclear 19-20%, new energy resources 1-3%. (For comparison, the corresponding 2001 ratios are, respectively, coal 25%, oil 13%, gas 16%, hydro 13%, nuclear 16%, and combined heat and power 17%.)

Energy Conservation and Efficiency. Taiwan has strived to promote energy conservation and improve the efficiency of energy production and use through establishment of energy conservation and efficiency policies, promulgating regulations on efficiency, providing incentives, research and development, energy services, and education and information. Conservation and efficiency targets were established for all sectors, including industrial, transportation, business, residential, electric power, and government. In addition, energy-conserving and high-efficiency technologies are being developed. Issues on this aspect are:

- Due to lack of funds, small to medium enterprises are not inclined to install energy-conserving equipment,
- The energy pricing system is unable to provide the appro-

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priate price signals to energy consumers because it does not reflect the cost differences due to time and regional variations,

- To date, energy conservation practices are concentrated on the industrial sector. There is need to promote energy conservation in the residential and business sectors., especially with respect to high efficiency appliances and air conditioners.

Environmental Protection and Sustainable Development. As Taiwan has attained a relatively high level of economic development, there is a high degree of public concern about environmental issues. Two factors are likely to further heighten the environmental protection and sustainable development perspective: the greenhouse gas emission reduction targets arrived with the Kyoto Protocol under the United Nations' Framework Convention on Climate Change in December 1997; and the "Law on the Prevention and Remediation of Air Pollution" enacted in June 2002.

Under the Kyoto Protocol, the industrialized countries, as a group, agreed to reduce emissions of greenhouse gases by 5.2% from the 1990 level in the 2008 -2012 period. Individually, Switzerland, Austria, Central and Eastern European countries, and the European Union agreed to reduce by 8%; U.S.A., 7%; Canada, Hungary, Japan, and Poland, 6%. New Zealand, Soviet Union, and Ukraine, will maintain their respective 1990 emission levels. Norway can increase by 1%; Australia, by 8%; Iceland, by 10%. Taiwan is not a signatory to the UNCCC and thus has no specific reduction target. However, as a member of the Earth village, emission reductions are being developed. Cement, petroleum refining, chemical, artificial fiber, and steel industries have developed voluntary reduction targets. In addition, electric generation and transportation are likely to be highly affected.

The Law on the Prevention and Remediation of Air Pollution sets forth rules for trading emission allowances. For example, Article 9 defines that new or modified fixed sources can only obtain emission allowances through (a) the differences between their lawfully reserved allowances for the fixed sources and their actual use; (b) allowances auctioned off by the authorities from their reserves; and (c) allowances obtained through improvement in transportation equipment and their operation, scrapping of old vehicles, and other methods in relation to moving sources; and other allowances approved by the Central Authority.

The issues in this area include:

- Assist the industries in achieving their voluntary emission reduction targets.
- Implement emission allowance trading.

Promotion and Development of Renewable Energy. Since 1998, Taiwan has enhanced the development and utilization of renewable energy resources. The planning target is for renewable energy resources to account for over 3% of total energy supply (4.5% including conventional large scale hydro) and over 15% of electric generation capacity (including large-scale hydro). Subsidies are being provided for some renewable energy installations. For example, NT$1,000 to 3,000 per square foot are provided for the installation of solar water heating systems. For wind and photovoltaic generating facilities, subsidies are being provided for up to 50% of total installation costs. In addition, Taiwan has formulated related plans and statutes such as "Report on the Study of New and Clean Energy Resources", "Articles for the Development of Renewable Energy Resources (Draft)", "Plan for the Development of Renewable Energy Resources." Some of the issues are listed below:

- The majority of the externality costs of energy resources is not yet internalized,
- The law on land use needs to be modified to allow development of renewable energy resources,
- Make explicit the procedures for filing applications for constructing renewable generating facilities, including whether land use and construction permits are needed, and which filing documents are needed,
- Enact the rules for interconnection and for sales and purchases of electricity generated and of reserve power for use during scheduled and unscheduled down time.

Economic Development in Taiwan and Its Impacts on Energy Development

Recent economic development in Taiwan is characterized by globalization, knowledge economy, industrial transition, and sustainable development.

Globalization. Under globalization, the production and/or the provision of products and services are not constrained by national or regional boundaries. The degree of international division of labor is high. "Produce at wherever the cost is lowest and market to wherever the profit is highest." International financial markets are highly interrelated and capital and funds move freely across national borders. There are increased opportunities for personal and regional choice of products and services.

Knowledge Economy. In a knowledge economy, the most important factor inputs are the possession, creation, and application of knowledge, and innovation. The market is dynamic and globally competitive. Enterprises are highly mobile and are organized as a worldwide network, not a hierarchy or bureaucracy. Industrial production is highly flexible, rather than mass production. Technology is driven by digitalization, not by mechanization. Research and development is essential to a firm's success and is largely provided by innovative firms, not by existing firms. Competitive advantage derives mainly from innovation, quality, and timeliness of market entry, not by economies of scale and lower costs. Firms characteristically team and collaborate with others in research and development, instead of going it alone.

Industrial Transition. Taiwan's economy has been led by exports. In recent years, due to significant international and domestic economic developments, such as international economic fluctuations, Taiwan's entry into the World Trade Organization, and fast growth of the Chinese economy, the industrial structure of Taiwan is in a period of transition. For example, the focus of industrial development has shifted from the traditional industries of food and other necessities and basic industries to high-technology industries with high skill intensity. The former two industries include food, textile, clothing, paper, chemical materials and products, petroleum, plastic, and metals. High skill-intensity industries include computers, fiber optics, and biotechnology. Further, planning for the "National Energy Conference" calls for the percentage contribution to manufacturing output from skill-intensive industries to be 55%, with basic industries 25%,

and traditional industries 20%. For comparison, in 1996, the corresponding percentage shares respectively were 34%, 40% and 26%. Also, services, together with the skill-intensive industries, will grow in importance. Another notable trend is that, due to shifting comparative advantages, traditional industries are moving out of Taiwan. As a result, many of the traditional enterprise zones are being converted into science-based industrial parks.

Sustainable Development. "Sustainable development is development that meets the needs of the present generation as long as resources are renewed or, in other words, that does not compromise the development of future generations."[1] Needs, limitations and equality are the three elements in sustainable development. The basic needs of human beings must be met. However, in satisfying present and future human needs, technological conditions and social organizations such as population, the environment, and resources would impose certain restrictions on the environment. Equality means trans-generational equity, as well as equality among different groups and regions in the present generation. In some ways, these three elements are at the same time conflicting and complementary with one another. For example, huge increases in basic needs would cause damage to the environment, slowing down economic growth. On the other hand, insufficient demand will not necessary be good for the environment. As an example, because of poverty, many underdeveloped countries intensively develop and extract their natural resources, damaging their environment and ecology.

Impacts on Energy Development. With globalization, bottlenecks on energy supply would cause an economy to miss opportunities for profitable trade. Foreign direct investment in domestic energy businesses will become a fact of life. Domestic energy enterprises can also participate in foreign energy ventures. With her knowledge economy and the transition in industrial structure, Taiwan's electricity industry needs to provide more reserve generating capacity to meet the need for higher-quality electricity for the growing high-tech industries. Further, some energy conservation or load management measures, such as interruptible power, would become inappropriate. Nevertheless, developing and utilizing new and clean energy resources, such as renewable energy, is a positive way to address the limitations inherent in sustainable development. Another point is that one long-term strategy to simultaneously achieve the objectives of economic development, energy security, and environmental protection is to invest in research and development in energy technology so as to achieve breakthroughs in both technology and costs.

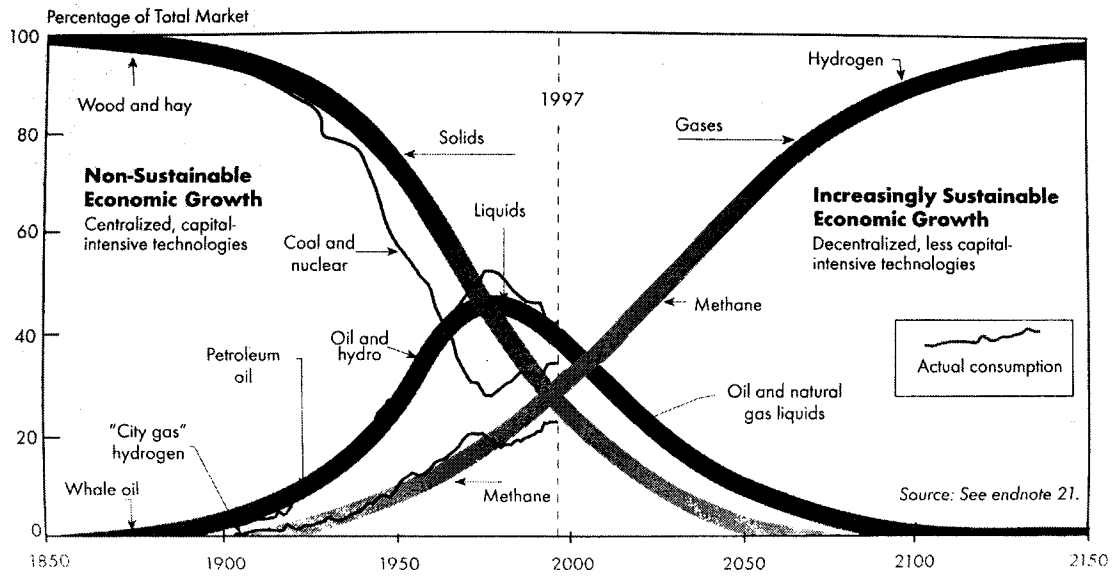
[1] See footnotes at end of text.

Future Prospect of Energy Development in Taiwan

In looking toward the future of sustainable energy development in Taiwan, the focus is on two non-traditional aspects. One is a view of the long-term transition of the global energy system and its future in the hydrogen economy. The other is a brief discussion on Nano-technology and its potential application in energy development.

Global Energy System Transition. The relative shares of three categories of energy resources–solid, liquid, and gaseous fuels–over three centuries from 1850 to 2150 are shown in Figure 1. The share of solid fuel started with 100 percent. Initially, it declined gradually. In the mid- 1900s, the pace quickened. Over the long term, it traces out to be a reverse "S" curve. The share of liquid fuels, the second category, started with zero and grew until it accounted for about 40-45% in the late 20th century. Then it started to decline. By 2100, it will have a relatively small share. Over the long haul, it forms a bell-shaped curve. In contrast, gaseous fuels started even later than liquid fuels. Its share grew slowly but consistently and forms an elongated "S"

Figure 1
Global Energy Systems Transition, 1850-2150



Source: Jiqiang Zhang, "The Prospect of Hydrogen Economy - A Strategic Decision for Every Nation" Undated presentation

curve. In terms of actual fuels, solid fuels include wood, hay, coal, and nuclear (uranium). Liquid fuels include whale oil, petroleum, hydro, and liquid natural gas. Gaseous fuels include city gas, methane, natural gas, and hydrogen. In this view of the world, the single most important fuel of the future is hydrogen. It is based on the important assumption that technological breakthrough in the production and use of hydrogen will occur in the next decade or two. Figure 1 shows that in the early years, or in the left end of the chart, the world economy was highly dependent on solid fuels. It represents non-sustainable development. In contrast, after 2000, the world economy has become more dependent on gaseous fuels. Especially after 2100, or in the right end of the chart, it is highly dependent on hydrogen. It is a hydrogen economy and represents sustainable development.

Hydrogen Economy. In the hydrogen economy, hydrogen is the primary energy used in electricity generation, transportation, industrial, business, and residential sectors. Use of hydrogen reduces reliance on imported oil, coal, and LNG, thereby enhancing national security. Hydrogen is a renewable energy resource and can reduce the impacts on the environment, contributing to clean air and clean water. Hydrogen can be produced using primary energy sources such as solar power, wind, biomass, and fossil fuels, and clean energy technology, such as photo-conversion, generation, electrolysis and re-forming. Existing technology for gas storage and transportation can be improved for use in storing and transporting hydrogen. Use pipeline or liquid form for large quantities and long-distance transportation. For small quantity and short-distance transportation, use compressed gas. For short -distance transportation, use metal hydrides.

For large quantity and the long-term, use underground storage. For small quantity and the short term, use compressed air storage. For small quantity use metal hydrides or carbon Nano- tube.[2]

Nano-technology. A Nano meter equals 10^{-9} meter or one thousandth of a micro- meter. Nano-technology is the study of very small things, measured in Nano-meters. It combines physics, chemistry, and material sciences and can help us understand, handle and change the composition of materials and substance, create new materials, develop new products and applications. It can have tremendous impacts on industrial development. Examples of potential energy applications of Nano-technology include:

- Use of the carbon Nano-tube for storing hydrogen. It will have high storage capacity, and can be used in fuel cells and hydrogen cars,
- Introduce Nano particles into heat conducting agents such as water or coolant to form Nano-fluids. It will raise the heat conducting coefficient, and increase efficiency,
- Use as high-efficiency lighting sources or solar cells,
- Use Nano-materials to improve upon permanent magnets and raise the efficiency of motors,
- Use Nano-crystals for the agent in light for eliminating poisonous gases,
- Use Nano-coatings to improve the quality of heat-insulating materials,
- Use the Nano-characteristics of negative and positive charges to improve the efficiency of rechargeable batteries.

Concluding Remarks

Recent energy developments in Taiwan are characterized by liberalization, diversification, energy conservation and high efficiency, environmental protection and sustainable development, and promotion of renewable energy development. At the same time, the Taiwanese economy is in transition under the influence of globalization, the knowledge economy, changing industrial structures, and concern for sustained development. As a result, traditional industries are moving away from Taiwan, and skill-intensive industries are growing in importance. Looking to the future, it is absolutely essential for Taiwan to invest in research and development in technology and innovation and their applications in order to create job opportunities and sustainable economic development. In terms of sustained energy development, it is hypothesized that the hydrogen economy is a likely future and that Nano-technology will have both energy and economic applications.

Footnotes

[1] The World Commission on Environment and Development, *Our Common Future,* Oxford University Press: Oxford, 1987.

[2] See the source cited with Figure 1.