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Energy Policy in Taiwan: Historical Developments, Current Status and Potential Improvements

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Abstract: Recognizing the importance of energy as a vital component in economic development, the Taiwanese government has been continuously revising its energy policy, seeking to balance economic development, energy supply, and environmental protection (3E). Some measures, in an attempt to achieve the 3E balance, were previously implemented in Taiwan; nevertheless, some unresolved issues departing from certain core principles of Taiwan's sustainable energy policy and an international initiative for a low carbon society remain. The aim of this paper is to examine the energy supply and demand structure of Taiwan and the present status of individual energy carriers (including coal, petroleum, natural gas and electricity). In addition, it investigates the current energy policy framework and its implementation in Taiwan, identifies unresolved issues regarding sustainable energy development, and formulates key policy solutions for certain identifiable problems to enable the achievement of a liberalized, orderly, efficient, and clean energy supply and demand system.

Keywords: economic development; energy policy; sustainable energy development

1. Introduction

Taiwan has attained sustained economic growth and corresponding improvements in living standards during the past two decades. To fuel the nation's increased activity in this area there has

been a steady increase in energy demand. Between 1988 and 2008, Taiwan's average annual economic growth rate was a vigorous 5.3% and energy consumption almost tripled, from 45.70 million KLOE (kiloliters of oil-equivalent) to 119.31 million KLOE. Per capita energy consumption has more than doubled from 2,347 to 5,134 LOE (liters of oil-equivalent). Securing adequate energy resources is becoming increasingly difficult and at the same time the government is trying to reduce emissions and promote more environmentally friendly energy policies.

The main challenges include:

1. *The lack of indigenous energy resources:* Dependence on imported energy resources rose from 94.42% in 1988 to 99.23% in 2008, with the result that Taiwan stands exposed to changes and price fluctuations in the global energy market. Furthermore, this situation threatens Taiwan's energy security.

2. *The use of fossil fuels as the primary energy sources:* At the end of 2008, 91.3% of Taiwan's primary energy was derived from fossil fuels (crude oil, coal and natural gas), while renewable energy accounted for only 0.4% of the total. Besides, the installed capacity and the generation of the thermals power plants accounted for 77.0% and 77.8% of the total power system, respectively. Due to this heavy reliance on fossil fuels, Taiwan's electricity emissions factor is comparatively high.

3. *Current limited utilization of renewable energy:* Despite ongoing development the utilization of renewable energy is presently limited due to technical constraints, high unit cost and comparative instability. The cost of renewable energy is still too expensive to be widely applicable for domestic power generations. Many non-technical barriers to the promotion of renewable energy were not anticipated. Taiwan must provide a favorable framework for the sustainable development of renewable energy, yet the "Renewable Energy Development Bill" has failed to gain approval for the last several years in Taiwan.

4. *Improvements in energy intensity:* Energy prices in Taiwan do not fully reveal the cost, which weakens the effectiveness of price signaling and reduces the incentive for improving energy efficiency. Energy intensity dropped slightly from 9.90 (LOE/ Thousand NTD) in 1988 to 8.98 in 2008. Energy prices must be adjusted to better reflecting internal cost in the near term. In the longer term, energy prices should reflect other external costs.

5. *Rapid growth of carbon dioxide emissions:* Taiwan's CO₂ (carbon dioxide) emissions totaled 113 million metric tons in 1990, or equivalent to a per capita CO₂ emission of 5.54 ton. The CO₂ emissions in 2007 reached 268 million metric tons, 137% more than that in 1990, corresponding to a per capita CO₂ emission of 11.71 ton. Annual growth rate was 5.2% from 1990 to 2007. Presently, Taiwan ranks 22nd globally in GHG (greenhouse gas) emissions (1%) [1]. In an island country vulnerable to climate change impacts, reducing GHG emissions should be a priority.

On account of worsening energy security and GHG emissions, to encourage diversification of energy sources, improve energy intensity and reduce CO₂ emission, the current energy policy was formulated to enhance sustainability, stability, efficiency and cleanness. It hopes to beneficially balance energy security, environmental protection, and industrial competitiveness. To reduce CO₂ emissions, the development of the economy must take place with attention being paid to energy and environment, continuing no-regret policy, increasing independent energy, strengthening regional cooperation, enhancing market mechanisms, increasing energy efficiency, expanding technological capacity, and developing the green industry. Some measures, in an attempt to achieve the 3E balance,

were previously implemented in Taiwan while some unsolved issues departing from certain core principles of Taiwan’s sustainable energy policy and international initiatives for a low carbon society remain. Discussion must be encouraged to provide potential improvements for these matters.

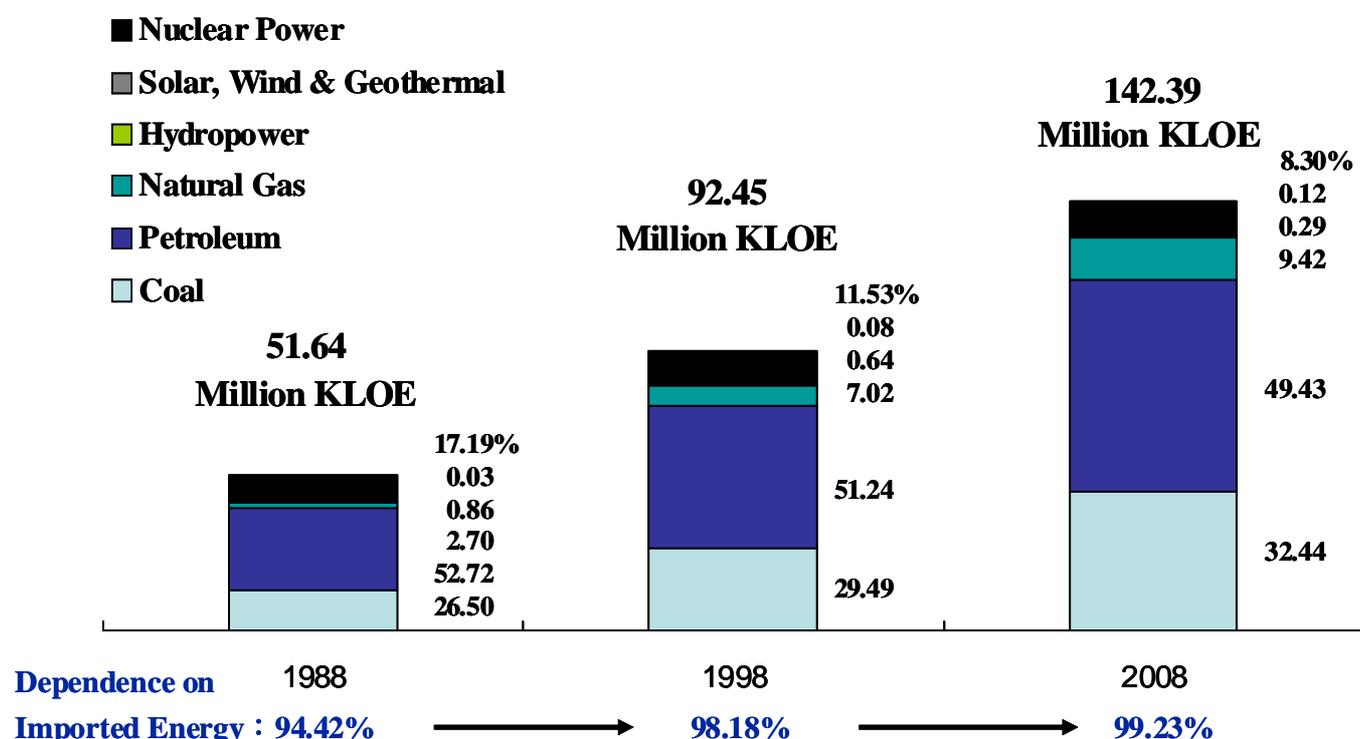
The paper examines Taiwan’s energy supply and demand situation and the present status of individual energy carriers (including coal, petroleum, natural gas, electricity). In addition, it investigates the current energy policy framework and its implementation in Taiwan, identifies unresolved issues regarding sustainable energy development, and formulates key policy solutions for certain identifiable problems to enable the achievement of a liberalized, orderly, efficient, and clean energy supply and demand system.

2. Overview of Energy Supply and Consumption in Taiwan

2.1. The Structure of Total Energy Supply

Energy supply and consumption are major economic factors in the world, while the dynamics of energy markets are driven by supply and demand equivalence. As Figure 1 shown, the total amount of Taiwan’s energy supply increased from 51.64 million KLOE in 1988 to 142.39 million KLOE in 2008, for an annual average growth rate of 5.2%.

Figure 1. The structure of total energy supply in Taiwan (by Energy Form) [2].



The shifts in the energy supply structure saw the share represented by natural gas more than triple during that period from 2.70% to 9.42%, while that of coal climbed from 26.50% to 32.44%. Oil’s contribution decreased from 52.72% to 49.73% and because of intense public controversy and political debate, nuclear power’s share was cut by half, from 17.19% to 8.30%. The majority of renewable energy was from common hydropower, amounting to 0.41 million KLOE in 2008. Since virtually all

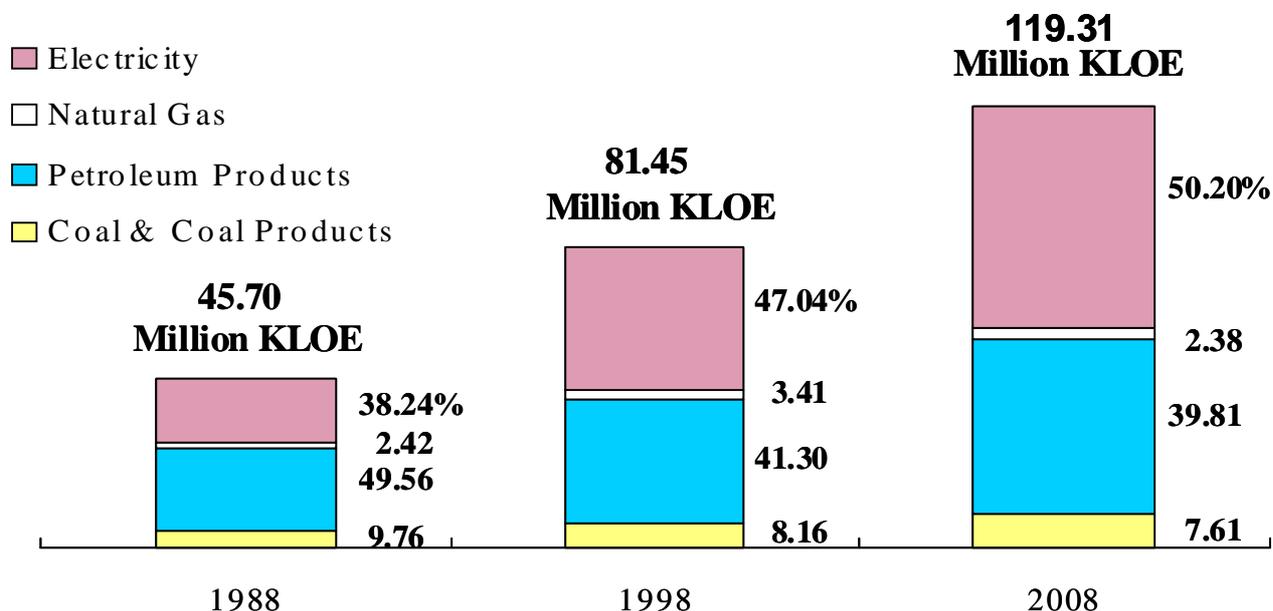
potential sites had been fully utilized, hydropower also decreased from 0.86% to 0.29%. Although other renewable resources (excluding hydropower) increased from 0.013 million KLOE to 0.047 million KLOE, it only contributed 0.12% to the energy supply.

Dividing the energy supply into indigenous and imported categories, the ratio of indigenous energy to total energy supply decreased from 5.5% in 1988 to 0.7% in 2008, while that of imported energy increased from 94.5% in 1988 to 99.3% in 2008. Imported crude oil is the major portion of energy supply, and more than 80% of crude oil is from the Middle East. LNG (liquefied natural gas) is mainly from Indonesia and Malaysia while steam coal is mainly imported from Australia, Indonesia and Mainland China. Hence, energy import costs too much in the Taiwan economy. The share of energy import in payments for total Taiwan import was around 25% in 2008, corresponding to a per capita energy import of 85,057 NTD [2]. The tendency shows that Taiwan has very limited domestic energy resources and is getting more and more dependent on imported energy.

2.2. The Structure of Total Energy Consumption

With a rapid annual economic growth rate of 5.3%, Taiwan is facing a rapidly rising growth of energy demand. Over the past two decades, total energy grew almost three times; from 45.70 KLOE to 119.31 KLOE (Figure 2). The average annual energy consumption growth rate during the period was 4.9%.

Figure 2. The structure of total energy consumption in Taiwan (by Energy Form) [2].



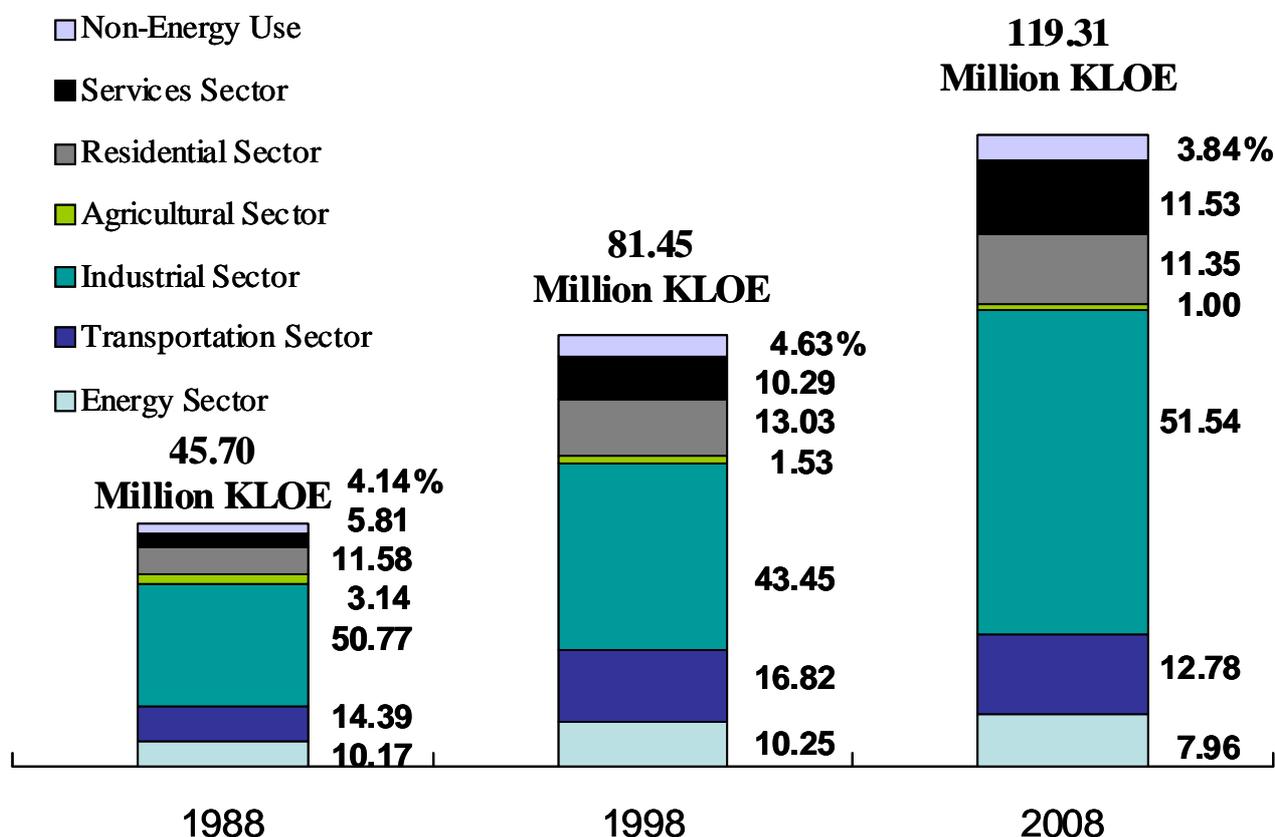
As shown in Figure 2, the energy consumption structure in Taiwan from 1988 to 2008 changed as follows:

- Coal decreased from 9.76% to 7.61%
- Petroleum decreased from 49.56% to 39.81%
- Natural gas dropped from 2.42% to 2.38%
- Electricity increased from 38.24% to 50.20%

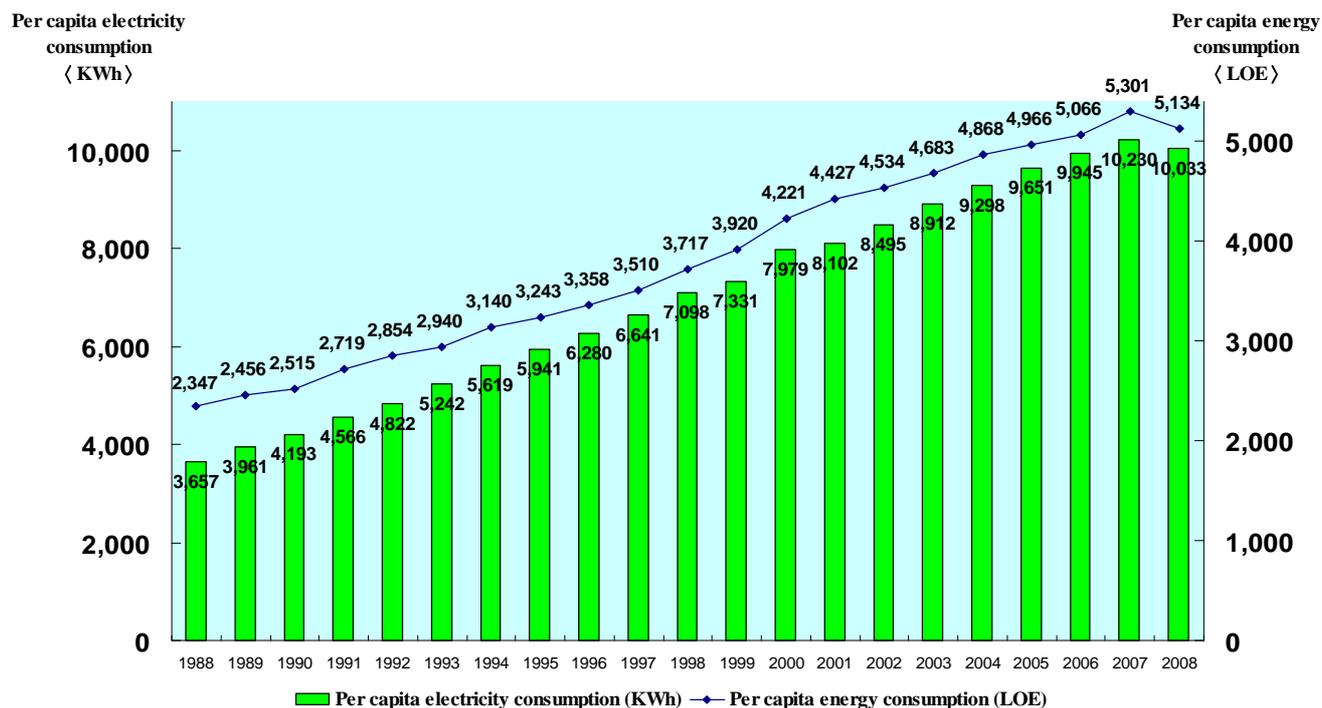
The structure indicates that the share of electricity in total consumption has increased gradually, while petroleum products decreased over past two decade. At present, half of the total energy consumption is composed of electrical power, representing a strong growth resulting from wider electrification.

When the structure of energy consumption is investigated by sectors (Figure 3), the largest energy consuming sector was industry, which used around half of total energy, and increased from 50.77% to 51.54%. Consumption by the service sector also grew very fast in 2008, from 5.81% in 1988 to 11.53%, while the transportation and residential requirements decreased slightly in the same period. As for the current status, it can be seen that industry is the leading sector (51.54%), followed by the transportation (12.78%), service (11.53%) and residential (11.35%) sectors. The agriculture sector has the lowest proportion, accounting for only 1.00% in the total energy consumption [3].

Figure 3. The structure of total energy consumption in Taiwan (by Sector) [2].



A substantial per capita energy consumption increase has accompanied rapid economic growth and rising living standards. As shown in Figure 4, per capita energy consumption has risen from 2,347 LOE in 1988 to 5,134 LOE in 2008 for an annual average growth rate of 4.0%, while per capita electricity consumption climbed from 3,657 KWh to 10,033 KWh for an annual average growth rate of 5.2% in the same period.

Figure 4. The structure of per capita energy consumption and electricity consumption [2].

3. Status of Energy Mix in Taiwan

Coal, petroleum, natural gas and electricity are considered of most relevance to the formation of policies because consumption demand is increasing gradually and production and installed capacity is expanding. Besides, in line with the world's mega-trend [4], energy market liberalization (such as petroleum and electric power market) in Taiwan has become an important issue. The current status of the individual energy resources is as follows:

3.1. Coal

Being the cheapest and most abundantly available fossil fuel, coal will always have a role in the energy mix of a particular country. As a matter of fact, in some countries like China, coal is the main source of fuel, and Taiwan is not exempt. Coal is its second largest contributor. Coal production in Taiwan totaled more than five million metric tons annually from 1964 to 1968. Thereafter, production tapered off due to increasing competition from imported coal and spiraling local production costs resulted from increasingly difficult mining conditions. Coal has been totally imported from foreign countries since 2001 [5].

The island's coal supply totaled 63.84 million metric tons in 2008. Coal consumption that year totaled 62.81 million metric tons (Table 1). The largest consumer of coal is power generation, with a share of 76.60%, followed by iron and steel production with a share of 9.20%. Cement production and other use accounts for the remaining share. Based on coal products, steam coal has the highest proportion (91.78%) followed by coking coal (8.22%).

In 2008, Taiwan imported 63.84 million metric tons of coal; the steam coal came mainly from Australia, Indonesia, Mainland China and Russia, and the coking coal chiefly from Australia and

Canada. To meet future requirements of power generation and industry, a diversification of procurement is needed. In addition, in order to secure a stable supply of coal, exploration and development of overseas sources on a joint-venture basis should be pursued [5].

Table 1. Coal supply and consumption [5].

Item	1988		2008		1988-2008
	Million metric tons	%	Million metric tons	%	Growth rate %
Total Supply	18.68	100.0	63.84	100.0	6.34
Imported	17.45	93.42	63.84	100.0	6.70
Indigenous	1.23	6.58	0.0	0.0	-
Total Consumption	16.84	100.0	62.81	100.0	6.80
Power Generation	8.22	48.81	48.11	76.60	9.24
Iron and Steel	4.33	25.71	5.78	9.20	1.45
Other use	4.29	25.48	8.92	14.20	3.73

3.2. Petroleum

● Liberalization of the Petroleum Market

In an effort to improve Taiwan's international competitiveness and in line with the world's mega-trend, oil market liberalization in Taiwan has been in progress since the second half of the 1980s. The liberalization of the petroleum market in Taiwan has been implemented step by step, beginning from the downstream sale of petroleum, progressing to the upstream refinery business, and finally resulting in the opening of petroleum product imports. Table 2 presents Taiwan's progress in liberalizing its oil market [6].

Table 2. Progress of the liberalization in Taiwan's petroleum industry [6].

Year	Progress
1987	Liberalization of retail sector (gasoline stations)
1993	Adoption of Oil Price Adjustment Formula (greater flexibility of price adjustment)
1996	Liberalization of oil refinery sector
1999	Import liberalization of Fuel Oil, Jet Fuel, and LPG
2000	1. Formosa Petrochemical Corporation came on stream 2. Oil Price Adjustment Formula abolished
2001	1. Petroleum Administration Law implemented 2. Import of all oil products liberalized
2002	Esso Taiwan entered domestic gasoline and diesel market
2003	Esso Taiwan exited domestic gasoline and diesel market

The Chinese Petroleum Corporation, Taiwan (CPC), a state-owned enterprise, has monopolized the domestic oil market since 1946. The government began to liberalize the oil market in 1987. Thereafter, private gasoline stations were permitted to sell gasoline and diesel oil. In June 1996, the establishment of privately owned and operated petroleum refinery enterprises was allowed. This gave these new firms the right to produce, import/export, and market petroleum products.

The market was opened up to include fuel oil, jet fuel, and LPG in January 1999, with full opening to all petroleum product imports at the end of December 2001. Registration for gasoline and diesel oil wholesale businesses was opened in June 2001. The “Petroleum Administration Act” was promulgated on October 11, 2001. With the promulgation of the “Regulations Governing Installation and Administration of Gas and LPG Stations,” the first LPG filling station for automobiles started operating in 1995.

With progressive changes in the social environment, and in response to deepening market liberalization relaxing the security reserve threshold for petroleum imports, as well as for securing the stability of domestic petroleum supply and market order, the Act shall be further amended. After the draft of the “Partial Article Revision on Petroleum Administration Act” was drawn up and revised, it was promulgated by Presidential Decree on January 16, 2008. These deregulations include lowering the security reserve threshold for petroleum importers and relaxing partial import tariffs on petroleum products, reducing the security reserve requirement from 50,000 kiloliters to 10,000 kiloliters, and proposing that the Ministry of Finance reduce import tariffs for gasoline, jet fuel, and kerosene by an appropriate amount, so as to remove market obstacles and boost competition in the industry.

Furthermore, in response to international energy conditions and the fluctuation of oil prices, the measures such as promotion of the use of ethanol gasoline and biomass diesel, and coordination with the domestic development of renewable energy as well as the conservation of oil and gas, are now under promotion.

● **Current Status of the Petroleum Market**

There are two petroleum refining companies in Taiwan, the state-owned CPC and the Formosa Petrochemical Corporation (FPCC). The former operates three oil refineries, with a total refining capacity of 720 thousand barrels per day. In addition, the latter operates an oil refinery with a refining capacity of 540 thousand barrels per day. Taiwan’s total refining capacity has thus reached 1,260 thousand barrels per day, exceeding the domestic demand for petroleum products. The surplus petroleum products are exported to adjust the market situation.

As shown in Table 3, 52.96 million kiloliters of crude oil were supplied in 2008, of which 0.02 million kiloliters were indigenous products (only 0.03% of the total) and 52.94 million kiloliters were imported, accounting for 99.97% of the total. Of the crude oil supply, the Middle East remained the major source of crude oil for Taiwan in 2008, supplying 83.6% of all imports. The remaining 16.4% came from other sources.

The consumption of petroleum products in 2008 totaled 49.57 million KLOE. The consumption share by sector consists of industrial use (46.48%), transportation (29.78%), power generation (8.37%), non-energy uses (4.90%), energy sector own use (4.24%), residential use (2.76%), services use (2.48%), and agricultural use (0.99%).

Table 3. Petroleum supply and consumption [6].

Item	1988		2008		1988-2008
	Million kiloliters	%	Million kiloliters	%	Growth rate %
Crude Oil Supply	21.47	100.0	52.96	100.0	4.62
Imported	21.33	99.35	52.94	99.97	4.65
Indigenous	0.14	0.65	0.02	0.03	-9.27
Refinery Intake	21.13	-	52.37	-	4.64
	Million KLOE	%	Million KLOE	%	Growth rate %
Petroleum Products Consumption	26.62	100.0	49.57	100.0	3.16
Power Generation	3.97	14.91	4.15	8.37	0.22
Energy Sector Own Use	2.07	7.78	2.10	4.24	0.07
Industrial	9.31	34.97	23.04	46.48	4.63
Transportation	6.52	24.49	14.76	29.78	4.17
Agricultural	0.96	3.61	0.49	0.99	-3.31
Services	0.98	3.68	1.23	2.48	1.14
Residential	1.20	4.51	1.37	2.76	0.66
Non-Energy Use	1.61	6.05	2.43	4.90	2.08

3.3. Natural gas

● Current Status and Future Plan for the Natural Gas Market

As in the petroleum sector, Taiwan has extremely limited indigenous natural gas reserves. The domestic natural gas consumption depends mainly on imported LNG [7]. In view of the meager reserves of natural gas, CPC has imported LNG from Southeast Asia since 1990. Currently, the CPC's Yungan LNG Receiving Terminal in southern Taiwan can handle 9 million tons of LNG per year. As shown in Table 4, the total amount of natural gas supplied in 2008 was 11.88 billion cubic meters, of which 0.36 billion cubic meters were indigenous products (2.94% of the total) and 11.88 billion cubic meters (equivalent to 9 million tons) were imported, accounting for 97.06% of the total. Of the latter, 34.02% came from Indonesia and the other 30.44% from Malaysia.

Natural gas consumption in 2008 totaled 12.19 billion cubic meters. The consumption consists of power generation (78.18%), industrial use (7.67%), residential use (7.55%), energy sector own use (3.76%) and service use (2.84%).

Since natural gas produces low-carbon emissions and is relatively clean among the fossil fuels, the government has planned the "Expanding Domestic Natural Gas Consumption Project," setting a goal for natural gas consumption of 10.5 million tons in 2010, 16 million tons in 2020, and 20 million tons in 2025. To meet the increasing demand for natural gas, the CPC has been aggressively negotiating with Australia, the Middle East, and South America for long-term contracts and has built its second domestic terminal at Taichung Harbor in order to enhance the stability of supply. With a design capacity of 3.00 million tons per year, this terminal will start partial operations, with a handling capacity of 690 thousand tons in 2008 and is due to be completed by the end of 2010.

Table 4. Natural gas supply and consumption [6].

Item	1988		2008		1988-2008
	Billion cubic meters	%	Billion cubic meters	%	Growth rate %
Total Supply	1.39	100.0	12.24	100.0	11.49
Imported LNG	0	0	11.88	97.06	-
Indigenous	1.39	100	0.36	2.94	-6.53
Total Consumption	1.11	100.0	12.19	100.0	12.73
Power Generation	0	0	9.53	78.18	-
Energy Sector Own Use	0.04	3.19	0.46	3.76	12.99
Industrial	0.15	13.82	0.93	7.67	9.55
Services	0.11	9.51	0.35	2.84	5.96
Residential	0.52	46.92	0.92	7.55	2.89
Non-Energy Use	0.29	26.56	0	0.00	-

● Promoting Legislation on the “Natural Gas Business Act”

Currently in Taiwan, the production and import of natural gas is carried out by the state-owned CPC, in accordance with the laws for the administration of state-run enterprises along with its own internal regulations. The 23 private and two public owned local distribution companies downstream of the CPC are presently regulated by the Ministry of Economic Affairs according to the “Statute for Regulating Privately Owned Public Utilities and the Rules Governing the Administration of City Gas Companies”. Since the above-mentioned Statute is applicable to all public utilities, the contents may seem outdated. In anticipation of the fact that the CPC is to be privatized in the near future and other gas importers might appear in the market before long, the “Natural Gas Business Act” has been drafted and was approved by the Executive Yuan on February 22, 2006 in order to enhance the administration of public gas utilities, as well as to provide a general legal basis for gas production and importation. Aggressively negotiation with the Legislative Yuan for the passage of the “Natural Gas Business Act” is being carried out.

The contents of this draft law lay out the aims of its legislation and define the objects to be regulated and the competent government authorities, as well as give concrete provisions for relevant matters such as guiding principles for the operation of relevant businesses, the safety of related facilities, the prevention of disasters, the reasonable assurance of customers’ rights, and the establishment of a safety inspection system. Concrete provisions are set out for these matters, and appropriate penalties are provided for violation of the regulations. Once the law has been enacted by the Legislative Yuan, subsidiary laws regarding natural gas transport and storage facilities, as well as safety regulations, will be established as quickly as possible to facilitate implementation [6].

3.4. Electricity

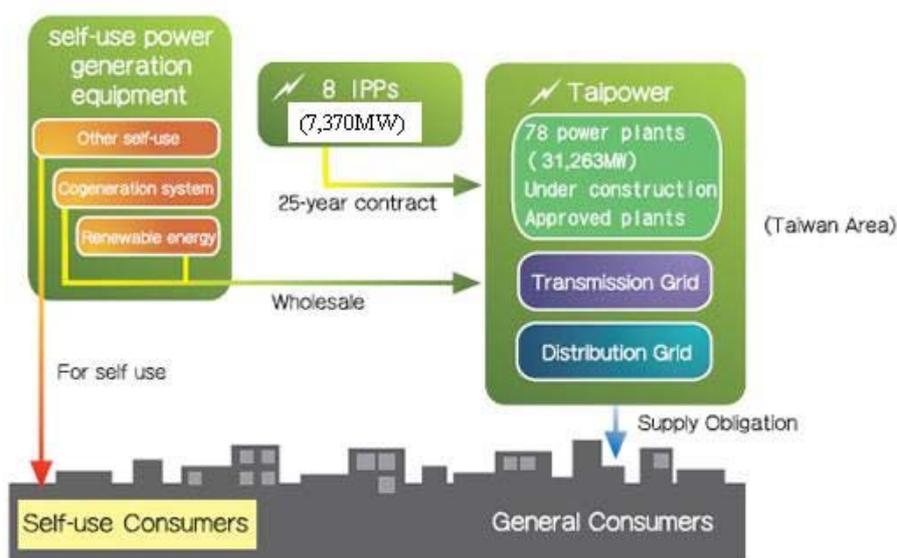
● The Evolution of the Power Market

The state-owned Taiwan Power Company (Taipower) is entrusted with the development, generation, supply, and marketing of electric power in Taiwan. Under government policy, industrial plants operated by private corporations have been encouraged to develop cogeneration systems and to sell their surplus power to Taipower for its own distribution. Development by Taipower has been obstructed in recent years. In order to maintain a stable electricity supply, the Ministry of Economic Affairs (MOEA) has promoted the opening of the market to Independent Power Producers (IPPs) in different stages: the first starting in January 1995, the second starting in August 1995, the third starting in January 1999, and the fourth starting in June 2006, respectively. In addition, to expand foreign participation, the government decided in January 2002 that foreign investors could be permitted to own up to 100% of an IPP. Applications for foreign investment are reviewed by the MOEA and approved by the Executive Yuan.

Five IPPs started commercial operation during the first and second stage, accounting for the total installed capacity of 5,270 MW. Two of them, the Mailiao power plant with an installed capacity of 1,800 MW and the Ever power plant with an installed capacity of 900 MW, started commercial operation in September 2000 and October 2001, respectively. Following these two power plants, the Hsin Tao power plant with 600 MW capacity, the Ho-Ping power plant with 1,300 MW capacity, and the Chiahui power plant with 670 MW capacity, started commercial operation in March 2002, September 2002, and December 2003, respectively.

For the third stage, three private power plants have started commercial operation: the Kuo Kuang power plant with a capacity of 480 MW, the Fon Der power plant with a capacity of 980 MW, and the Star Energy power plant with a capacity of 490 MW. In addition, the application for the Star Buck power plant with a capacity of 490 MW was approved by the MOEA in July 2006, and the new plant is expected to start commercial operation in June 2009. In June 2006 the MOEA announced the “Fourth Stage Program for the Establishment of Independent Power Producers,” which was approved by the Executive Yuan for the addition of 1,980 MW of IPP-generated power from 2011 to 2013 [8].

Figure 5. The current structure of power market in Taiwan [8].



To sum up, the current structure of power market in Taiwan consists of the one state-owned integrated utility (Taipower), eight IPPs, and self-use power generation utilities including cogeneration systems and renewable energy generation equipment (Figure 5). The opening of the power market to IPPs has the goal of helping to enliven the private sector, stabilizing the supply of electricity, enhancing operating efficiency, and promoting the liberalization of electricity supply.

● Current Status of the Power Market

The Taiwan electricity sector capacity in 2008 is shown in Table 5. Total installed capacity by year-end 2008 was 46,302 MW with 31,263 MW from Taipower, 7,370 MW from IPPs and 7,669 MW from self-use power generation equipments. Installed capacity distributable by the Taipower electricity system is 38,633 MW (excluding self-generating sources), accounting for 83.4% of total installed capacity.

By energy form, 17,660 MW, or 38.1%, was coal-fired; 13,218 MW, or 28.5%, LNG-fired; 5,144 MW, or 11.1%, nuclear; 4,809 MW, or 10.4%, oil-fired; 2,826 MW, or 6.1%, renewable energy (including conventional hydro power plant); 2,602 MW, or 5.6%, pumped storage hydro, and 43 MW, or 0.1% was waste heat recovery and other energy sources [9].

Table 5. Total installed capacity in Taiwan in 2008 [9].

Item	Taipower	IPPs	Self-use power generation equipments	Total
Coal-fired	8,800	3,097	5,763	17,660 (38.1%)
LNG-fired	9,077	4,120	21	13,218 (28.5%)
Nuclear	5,144	—	—	5,144 (11.1%)
Oil-fired	3,610	—	1,199	4,809 (10.4%)
Renewable energy	2,031	153	642	2,826 (6.1%)
Pumped storage hydro	2,602	—	—	2,602 (5.6%)
Waste heat recovery and other energy	—	—	43	43 (0.1%)
Total	31,263 (67.5%)	7,370 (15.9%)	7,669 (16.6%)	46,302

Unit: MW

The total power generation of Taiwan's electricity sector in 2008 is shown in Table 6. Total power generation in 2008 was 219,960 GWh with 155,270 GWh produced by Taipower, accounting for 70.6% of total output, followed by 35,170 GWh from IPPs (16.0%), and 29,520 GWh from self-use power generation equipment (13.4%).

By energy form, 110,730 GWh was coal-fired, accounting for 50.3 % of total electricity generation, 46,660 GWh LNG-fired (21.1%), 39,260 GWh nuclear (17.8%), 14,040 GWh oil-fired (6.4%), 5,640

GWh renewable energy (2.6%), 3,460 GWh pumped storage hydro (1.6%), and 180 GWh was waste heat recovery and other energy sources (0.1%). To sum up, total installed capacity reached 46,302 MW, with power generation amounting to 219,960 GWh in 2008 [9].

Thermal power and nuclear power are the current dominant sources of electricity supply in Taiwan, accounting for 88.1% of total installed capacity. However, further expansion of capacity in nuclear is restricted by intense public controversy and political debate and concerns regarding the disposal of radioactive waste from nuclear power plants in Taiwan. Economic growth continues to drive power consumption, therefore power expansions must meet growing demand. The correlation between renewable energy costs and fossil fuel price is relatively low. Hence, in addition to increased power supply from thermal power plants, extending the proportion of renewable energy technologies in the generation portfolio will help diversify price fluctuation risk of imported fossil fuel.

Table 6. Total electricity generation in Taiwan in 2008 [9].

Item	Taipower	IPPs	Self-use power generation equipments	Total
Coal-fired	65,400	19,940	25,390	110,730 (50.3%)
LNG-fired	31,850	14,760	50	46,660 (21.1%)
Nuclear	39,260	—	—	39,260 (17.8%)
Oil-fired	10,890	—	3,150	14,040 (6.4%)
Renewable energy	4,410	470	750	5,640 (2.6%)
Pumped storage hydro	3,460	—	—	3,460 (1.6%)
Waste heat recovery and other energy	—	—	180	180 (0.1%)
Total	155,270 (70.6%)	35,170 (16.0%)	29,520 (13.4%)	219,960

Unit: GWh

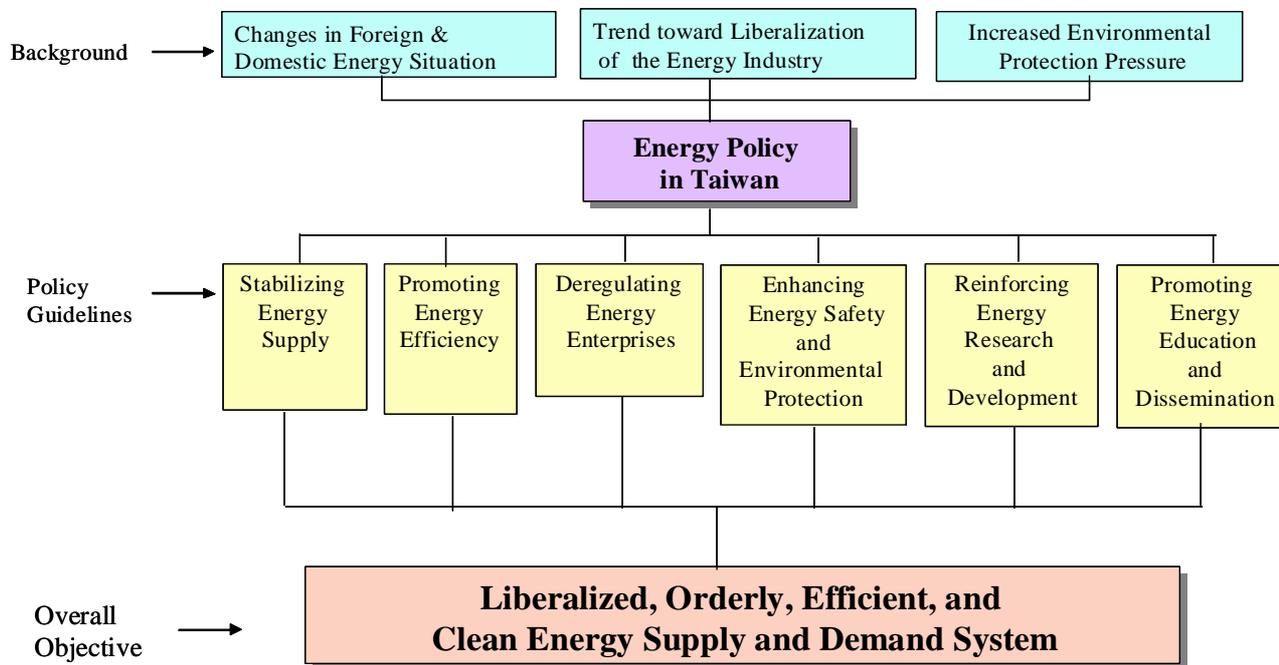
4. Energy Policies Pursued in Taiwan

4.1. The Development of Energy Policy and its Core Principles

The first version of “The Energy Policy of the Taiwan Area” was approved by the Executive Yuan and promulgated in April 1973. Afterwards, in response to the impact of energy crises and changes in the energy situation, the energy policy was revised three times in 1979, 1984, and 1990. However, the energy policy needed further review and revision in response to dramatic changes in the local and international energy situations and operating environment. Thus, the Executive Yuan revised the policy a fourth time on July 25, 1996. In addition, Two National Energy Conferences were convened in Taipei on May 26th and 27th, 1998 and June 20th and 21st, 2005, for the purposes of formulating strategies and measures in response to the impact of the United Nations Framework Convention on

Climate Change and to seek a balance among economic development, energy supply, and environmental protection in Taiwan.

Figure 6. The framework of power market in Taiwan [10].



Through the above process the government has formulated the current national energy policy. The overall energy policy framework is shown in Figure 6. The primary policy guidelines and its contents are described as follows [10]:

1. *Stabilize energy supply*: (1) Intensification of integrated energy planning; (2) Promotion of diversification of kinds and sources of primary energy; (3) Consideration of the use of land for regional energy development; (4) Precise stipulation of various kinds of energy safety reserve and reserve capacity; (5) Promotion of energy-related mines exploration, development and investment.

2. *Promote energy efficiency*: (1) Enhancement of energy productivity; (2) Stress on energy conservation; (3) Laissez faire determination of market; (4) Reasonable reflection of social costs in energy prices.

3. *Deregulate energy enterprises*: (1) Review and revision of laws and regulations governing energy related enterprises in order to establish a fair and competitive environment; (2) Promotion of the liberalization and privatization of energy-related enterprises.

4. *Enhance energy safety and environmental protection*: (1) Enhancement of energy safety; (2) Active introduction and production of clean energy; (3) Promotion of high efficiency burners and pollution prevention equipment and technology; (4) Formulation of an appropriate energy strategy for mitigation of the greenhouse effect to cope with the development of international environmental protection.

5. *Reinforce energy research and development*: (1) Promotion of R&D and application of energy conservation technologies; (2) Review and research in renewable energy, and promotion of its utilization on a cost effective basis; (3) Encouragement of private enterprises to engage in

energy-related technologies with local comparative advantage; (4) Enhancement of international cooperation and information interchange in energy research.

6. *Promote energy education and dissemination*: (1) Extension of education in energy knowledge to all levels in educational institutions and encouragement of correct energy concepts amongst students; (2) Promotion of energy education for the public; (3) Education of professional energy personnel.

The prevailing energy policy aims to establish a liberalized, orderly, efficient, and clean energy supply-and-demand system, based on the current environment, local characteristics, future prospects, public acceptability, and practicality. The central ideal is to achieve a 3E balance.

4.2. Implementation Measures

The measures, in terms of supply and demand sides, currently implemented in order to reduce Taiwan's high dependency on imported energy, in response to fluctuating energy prices, and accommodating the trend for GHG emission reduction as well as the achievement of above policy objectives are as follows [10]:

1. Supply

(1) *Secure energy supply and promote energy diversity*

- Develop and promote the use of carbonless renewable energy: The long-term target for the production of renewable energy is to reach 12% of the total electricity capacity.
- Expand the use of low-carbon natural gas: Increase the capacity factor of natural gas generators, and establish new natural gas power plants. The total consumption of natural gas is expected to reach 10.5 million tons in 2010, 16–20 million tons in 2020, and 20–22 million tons in 2025. Planning and extending construction of infrastructures, such as natural gas storage tanks, pipelines and receiving terminals.
- Complete the fourth nuclear power plant project (2,700 MW) and maintain the previous 1st, 2nd, 3rd nuclear power plants in operation (5,144 MW).

(2) *Improve electricity structures and enhance electricity generation efficiency*

- Enhance thermal efficiency standards of new-established and renewed coal-fired units from 35% to 40%.
- Enhance thermal efficiency standards of new-established and renewed combined power-cycle gas-fired units from 45% to 53%.
- Develop clean coal technology.
- Improve power cables to reduce the line loss. The long-term line loss is expected to be reduced under 5%.
- Continue promotion of the cogeneration system. The installed capacities of the cogeneration system are expected to reach 8 GW by 2010 and 10 GW by 2020.

(3) *Deregulate energy enterprises, and liberalize the energy market*

- Lower the threshold for oil enterprises to enter into the petroleum market.
- Continue to deregulate the installment of independent power plants, while considering load demand and the balance of regional power supply.
- Speed up the amendment of the “Electricity Act” and the legislation of the “Natural Gas Business Act” to facilitate liberalization of the energy market.

(4) *Enhance R&D and expand technological capacity*

- Expand the budget allocated to energy technology research, increasing its budget share annually.
- Plan integrated projects in terms of energy technology development, which focus on the improvement of energy efficiency and development of renewable energy to achieve the national goal of developing renewable and clean energy.

(5) *Emphasize environment and security: balancing the development of 3E*

- Consider energy assessments in industrial, environmental, and social-economic projects.
- Build up the energy sector's capacity to cope with GHG emissions reduction.

2. *Demand*(1) *Enhance energy efficiency management*

- The energy intensity is planned to be reduced 2~2.2% annually during 2006 to 2025. Besides, the energy intensity in 2025 is expected to be 22~27% below the level of 2005.
- Revise the energy efficiency standards of electrical appliances and conduct the mandated energy efficiency labeling system.
- Promote voluntary consumer conservation programs and governmental energy conservation measures.
- Establish technical service systems and technology for energy conservation.

(2) *Enhance market mechanisms and promote rationalization of energy prices*

- The electricity price should be allowed to be adjusted flexibly based on changes in fuel costs.
- Implement the flexible oil price mechanism to realize the resolution of the Conference on Sustaining Taiwan's Economic Development, which reads "Rationalize the energy price structure to reflect the fuel cost in the short run and the external cost in the long run."

(3) *Promote educational campaigns and increase public participation*

- Energy conservation needs the participation of agencies, municipal governments and of private citizens, so that energy saving concepts can be implemented fully in the fields of industrial development, architecture and design, communication, administration, education, a tax enacted effectively reduce GHG emissions.

Through current implementation, there has been some improvement in the overall energy efficiency. The growth of CO₂ emissions has also slowed in recent years. Meanwhile, renewable energy continues its growing trend. The following evidence demonstrates the effect of implementing current energy policy.

- The energy intensity of Taiwan has steadily decreased since 2003. It was 9.54 and 9.24 LOE per 1000 NTD in 2005 and 2007 respectively, with an average annual growth rate of -1.6%.
- The CO₂ emissions of Taiwan increased 137% from 1990 to 2007, with the average annual growth rate of 5.2%. If we divided this period into two stages, before and after the year of the Kyoto Protocol being signed, it is found that the CO₂ emissions increased 72.8% from 1990 to 1998, with an average annual growth rate of 7.1%, whereas it only increased 31.1% from 1999 to 2007, with an annual growth rate of 3.4%. Accordingly, Taiwan's efforts have already borne fruit.

- The capacity of renewable power generation reached 2,826 MW by the end of 2008, accounting for 6.1% of the total power generation capacity. The electric power generated by renewable sources could reach 5.64 TWh, which could meet the electricity demand of 1.4 million households.

5. Framework of Taiwan's Sustainable Energy Policies

Since 2008, the new administration is taking the lead in promoting sustainable energy by signing the World Environment Day carbon-reduction declaration and approving sustainable energy policies. In order to create a triple solution in energy, environment, and economy, energy policies should support the efficient use of energy resources, the development of clean energy, and the security of energy supply. Hence, the objectives of sustainable energy policies are introduced as follows [11]:

1. *Efficiency (improving energy efficiency)*: The goal is to improve energy efficiency by more than 2% per annum, so that when compared with the level in 2005, energy intensity will decrease 20% by 2015. Supplemented by further technological breakthroughs and proper administrative measures, energy intensity will decrease 50% by 2025.

2. *Cleanliness (developing clean energy)*: Reduce nationwide CO₂ emissions, so that, between 2016 and 2020, total emissions can return to their 2008 level, and be reduced, by 2025, to the 2000 level. Increase the share of low carbon energy in electricity generation systems from the current 40% to 55% in 2025.

3. *Stability (securing stable energy supply)*: Build a secure energy supply system to meet economic development goals, such as 6% annual economic growth rate from 2008 to 2012, and 30,000 USD per capita income by 2015.

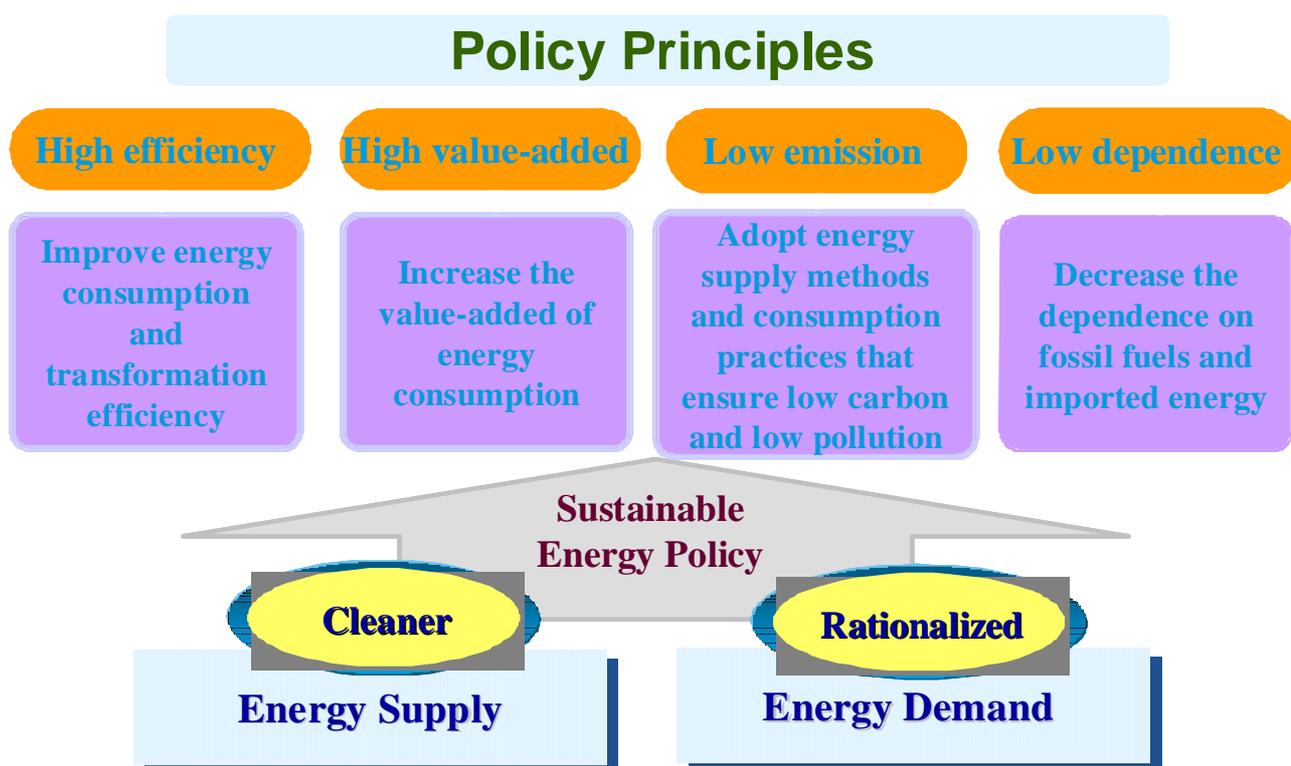
As shown in Figure 7, the basic principles of sustainable energy policies are to establish the *2-high* and the *2-low* energy consumption and supply systems. The *2-high* means “high efficiency” and “high value-added”, while the *2-low* indicates “low emission” and “low dependence (on imported energy)”. Furthermore, the strategies of sustainable energy policies are divided into two parts: the cleaner energy supply, which focuses on restructuring energy mix and improving energy efficiency, and the rationalized energy demand, which advocates energy conservation schemes in various sectors.

Among the strategies, the share of carbon-free renewable energy and low carbon natural gas in the electricity system will reach 8% and 25% by 2025, respectively. Meanwhile, nuclear power is considered as a no-carbon energy option. Clean coal technology and CCS (carbon capture and storage) technology will be introduced through international cooperation to reduce the CO₂ emissions of power generating system. On the rationalized energy demand side, measures put emphasis on improving energy efficiency schemes in various sectors, e.g. raising the fuel efficiency standard for private vehicles by 25% in 2015 and raising appliance efficiency standards by between 10% and 70% by 2011.

To sum up, the Taiwan government is continuously considering international requirements and domestic economic and social conditions and reviewing its energy policy in order to ensure that the country is moving towards a 3E balance. The new administration also approved Taiwan's sustainable energy policies, setting stability, efficiency and cleanness as the core principle. It seeks to achieve a balance between energy security, environmental protection, and industrial competitiveness, and to

reduce CO₂ emissions through balancing the development of the economy, energy and environment, continuing the no-regret policy, increasing independent energy, raising energy efficiency, expanding technological capacity, and developing the green industry. By deploying clean energy with low or no carbon emissions, the new government expects to return the nationwide emissions to year 2008 levels some time between 2016 and 2020, and to year 2000 levels by 2025. Meanwhile, the percentage of low-carbon energy in the total energy generated in Taiwan would increase from the present 40% to 55% in 2025, according to the policies.

Figure 7. The policy principles and strategies of Taiwan’s sustainable energy policies [11].



6. Potential Improvements of Taiwan’s Energy Policy

Preliminary assessments show that some measures, in an attempt to achieve a 3E balance, have previously been implemented in Taiwan. As mentioned in Section 4, there has been some improvement in raising energy efficiency, reducing CO₂ emissions and a continuing growth trend in renewable energies. However, some unsolved issues departing from the core principle of Taiwan’s sustainable energy policies and the international initiative for a low carbon society remain. The rationalization of energy prices, rapid passage of the “Renewable Energy Development Bill” and reconsideration of the “Nuclear-Free Home” policy are three critical issues in Taiwan. In this section, we identify these unresolved issues, and formulate key policy solutions for the problems as follows.

6.1. Rationalization of Energy Prices

In relation to various concerns such as living, industries, and so on, some energy resources’ prices cannot reasonably reflect their true costs. This would make it harder to improve energy efficiency by

utilizing the price mechanism. Energy prices in Taiwan are generally lower than those in the international market. Taking the electricity price as an example, it has risen little in the past two decades. Electricity rates in Taiwan are not only much lower than in more developed countries like Japan and Singapore, but also cheaper than developing countries like Thailand and Malaysia. Cheap electricity, however, provides no incentives to conserve energy or shift to renewable energy sources that are currently more expensive existing electric rates. Consequently, companies do not feel the need to improve energy efficiency, restructure their manufacturing processes or reduce emissions. The lower price is the main reason why energy supply could not be adjusted to a low carbon supply structure in Taiwan, and deviates from the objective of Taiwan's sustainable energy policies (improving energy efficiency) and the international initiative for a low carbon society. Only by promoting rationalization of energy prices, reflecting energy (imported) cost in the short-term, will energy come to be used more efficiently.

Among energy prices, petroleum and electricity price rationalization are the most urgent problems. Considering the policy of energy pricing, in order to leave the process of price determination open and reasonable and free it from non-economic factors, energy pricing should return to the market mechanism. The current floating price mechanism is implemented for gasoline and diesel after considering the change in global crude oil prices. It corresponds to the spirit of the market mechanism, so the market can function under the principles of reflecting real cost effectively, ensuring reasonable profit and reducing government intervention. In the future, the implementation of a floating oil price should be accompanied by such tailor-made measures as information transparency, average price by period, separation of accounts by sectors, and a mechanism in which the floating oil price and the legal reserve are interplayed. On the other hand, it should assess the feasibility of varying the domestic petroleum products price with the international petroleum products market and not only with the global crude oil market [12]. As for the electricity price, it should be adjusted flexibly, based on changes in fuel costs. Using considerations of social equity, the users should be divided into several categories and higher unit price would be charged to the larger users. So as to provide a conservation incentive, every customer can be charged less if they use less electricity in comparison with the same period of the previous year.

In the longer term, energy prices should reflect other external costs. According the perspective of economic theory, taxes are essential instruments for internalizing external costs. The main objectives of the energy tax (or carbon tax) are to induce energy saving, enhance energy efficiency, develop renewable energies and reduce CO₂ emissions. In addition, the revenues collected from the energy tax are intended first to improve the environment, and secondly to cover the tax loss due to a decrease in the individual income tax rate. With a lower tax rate, not only can the tax burden be lessened but saving and investment can also be encouraged. In this way a “double dividend” can be gained from the energy tax. The Taiwan government is currently drafting and legislating “Regulations on Energy Tax” to reflect the external cost of energy consumption. Thereafter, rapid passage of the “Regulations on Energy Tax” is a key factor in improving energy efficiency and rationalizing energy price.

6.2. Rapid Passage of the “Renewable Energy Development Bill”

Certainly, not only for the probability of fossil fuels exhaustion but also for reasons such as supply security, environmental contamination, and dependence on importing, renewable energy has gained significant importance in terms of sustainable development [13]. There is no exemption for Taiwan and to counter future energy security and GHG reduction challenges, the promotion of renewable energy as well as development of green energy industries has become one of the key pieces in Taiwan's energy policy [14]. However, as shown in Table 6, renewable energies accounted for only 2.6% of total electricity generation by the end of 2008. Apparently, there lies a big gap between the current power generation and future goals in Taiwan's sustainable energy policies (reaching 8% by 2025). As a result, it is necessary to find out unsolved blocking mechanisms in the current renewable energy system, so the developmental goal could be met.

Due to the high unit cost and technical constraints, the renewable energies must rely on government support for effective promotion. The Taiwan government has established various incentives, including system subsidies (installation and exploration), financial incentives like tax credits, two-year accelerated depreciation and low interest loans, and also interim electricity purchase subsidies. However, the incentives are distributed over many laws currently. In order to more actively support renewable energy, these measures should be integrated into one law, taking as examples the general price guarantee for each kWh of green power granted in Germany and the capacity auctions practiced in the United Kingdom. Following the example of Germany, a law could be drafted that offers price incentive grants to renewable energy producers [15].

In Taiwan, renewable energy incentives have concentrated on financial assistance (such as system and purchased electricity subsidies), but have rarely involved legal or institutional assistance (such as land-use, building codes, grid connections standards, etc.). Therefore, Taiwan must provide an integrated framework for the sustainable development of renewable energy. In light of this, a "Renewable Energy Development Bill" has been submitted to the Legislative Yuan since 2001 for ratification to establish a legal environment for renewable energy so facilitating its sustainable utilization. The Bill would oblige the national power company to buy renewable energy from private concerns, set a price formula for such transactions that would encourage private investment in the sector, and eliminate various institutional barriers hampering the development of renewable energy. It has to date failed to gain approval. Consequently now, rapid passage of the "Renewable Energy Development Bill" in the Legislative Yuan is a crucial factor in expanding the market, offering a promising investment option and achieving the developmental goal of renewable energy in the future.

6.3. Reconsideration of the Current "Nuclear-Free Home" Policy

Taiwan is presently hampered by the intense public controversy and political debate that swirls about the prospect of nuclear power. The disagreement between for- and against-nuclear power groups was initiated by Tai-power's project for No. 4 nuclear power plant in early 1980s. Anti-nuclear groups claim that Taiwan is unable to afford the impact brought by nuclear disasters and nuclear wastes, so they insist on a nuclear-free homeland and the abolition of nuclear power plants, and further advocate developing renewable energies. On the contrary, for-nuclear groups assert that CO₂ emitted from nuclear power plants are less, that the lack of nuclear power plants may lead to the insufficient

electricity supply for the economic development, and that unfledged renewable energy technology can not provide ample electricity, and its high generating costs can result in soaring electricity prices.

Numerous debates on the nuclear power issue have last for many years but the consensus hasn't been achieved so far. However, in order to take national sustainable development, world trends and the spirit of international conventions into account, Taiwan has responded positively to the goal of GHG reduction in "Sustainable Energy Policies". Nuclear power is not directly emitting CO₂ emissions; its indirect CO₂ emissions attributable to plant construction, operation, fuel mining and plant decommissioning are much better than coal, oil, and natural gas electricity generators [16]. Thus, it not only is a way to control global warming and decrease CO₂ emissions, but also is an important option for fulfilling Taiwan's sustainable energy policies goals. Besides, nuclear fuel prices are less volatile and less extreme than fossil fuel prices. Nuclear energy could also be regarded as a "quasi-indigenous" type of energy due to the relatively small size of fuel material and the resultant transportation convenience. However, the option of expanding use of nuclear is restricted by the current "Nuclear-Free Home" policy in Taiwan. If nuclear power is excluded from the energy options, it may have a passive influence on energy variety which will decrease the stability of energy supply. On the other hand, it also diverges from the development toward a low carbon society.

The development of renewable energies must be the top priority for ensuring the stability of energy supply and reducing CO₂ emissions in Taiwan. However, according to the research result of Huang and Wu [17], it indicates that even if renewable energy is highly utilized, the maximum expected contribution is 15% of total installed energy capacity for reasons related to the geography of Taiwan. Renewable energy will only play a more significant role in electricity generation should its energy density improve in terms of unit capacity and conversion efficiency. In the current stage, nuclear electricity generation is seen as a potential "bridge" during the transition from fossil-fuel-based power production to a more sustainable system based on renewable energies. Hence, reevaluating the current "Nuclear-Free Home" policy could be worthwhile. Furthermore, due to the contribution of nuclear power for decreasing CO₂ emissions, studies of the possibility of life extension and new construction of nuclear power plants should be undertaken, so as to fulfill Taiwan's sustainable energy policies goals.

7. Conclusions

Energy is the propeller underlying national development and economic activities. All economic activities of a nation, including industrial development, transportation, housing, business, and daily life, are associated with energy. Because of a rapid annual economic growth rate up to 5.3%, Taiwan is facing a rapidly rising growth of energy demand in order to fulfill the requirement for the nation's activity. Over the past two decades, total energy grew by a factor of almost 3 from 45.70 KLOE to 119.31 KLOE with an annual growth rate of 4.9%. However, Taiwan depends almost exclusively on imports of energy resources. These imported fossil fuels are vulnerable to price fluctuations in the global energy market and also contribute to the emissions of carbon dioxide. The only exception to this is the small contribution of renewable energies (including conventional hydro) that has hardly amounted to 1% of the total energy supply.

On account of worsening energy security and GHG emissions, Taiwan needs an effective energy policy to address these problems. The effective energy policy should ultimately address the needs and opportunities in the social, environmental and economic dimensions of sustainable development. It was found that the Taiwan government has been continuously reviewing its energy policy in recent years in order to move the country towards a sustainable energy economy. It is undeniable that the Taiwan government had taken proactive steps and attempted to achieve a 3E balance in the current energy policy. Preliminary assessments show that there has been some improvement in raising energy efficiency, reducing CO₂ emissions and a continuing growth trend in renewable energy.

However, some unresolved issues departing from the core principle of Taiwan's sustainable energy policy and the international initiative for a low carbon society remain. Among them are the rationalization of energy prices, the rapid passage of the "Renewable Energy Development Bill" and reconsideration of the "Nuclear-Free Home" policy. These are three critical issues in Taiwan.

To further ensure Taiwan's energy policy toward a low carbon society in the future, key policy measures such as continuing and revising current floating oil price mechanisms, adjusting the price of electricity flexibly, and reconsidering the current "Nuclear-Free Home" policy must be addressed. In addition, rapid passages of the "Regulations on Energy Tax" and "Renewable Energy Development Bill" are crucial requirements for improving energy efficiency and expanding the renewable energies market in the future. To effectively put the above policy measures into practice, it is necessary to set up a platform for information exchange, to reach consensus among all parties, and to achieve a liberalized, orderly, efficient, and clean energy supply and demand system in Taiwan.

Acronyms

3E Economic development, Energy supply, Environmental protection

CO₂ Carbon Dioxide

CCS Carbon Capture and Storage

GHG Greenhouse Gas

LNG Liquefied Natural Gas

NTD New Taiwan Dollar

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