# A Comparative Study of Wind Power in the United States, Europe and Japan: Strategies Applicable to Japan

by

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Submitted to the MIT Sloan School of Management

in Partial Fulfillment of the Requirements for the Degree of

**Master of Business Administration**

at the

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**ABSTRACT**

This thesis explores measures in the Japanese energy industry in order to meet the Kyoto target and further abate carbon dioxide beyond this target. To meet the Kyoto target, the Japanese government wants to increase renewable energy such as wind power as one of the measures. Wind power may be one of the most cost-effective renewable energy sources to address global warming. The world market for wind power is growing rapidly and the markets are concentrated in a few primary countries, with Europe (especially Germany) and the United States leading expansion. However, Japan is now taking its first steps to develop a large-scale commercial market for wind power.

It is now difficult for renewable energy, such as wind power, to become a major energy source due to its high cost and intermittent supply. However, it is the author's belief that Japan can increase wind power energy to reduce carbon dioxide emissions by applying appropriate policies and technical development in the power industry.

This thesis examines policies designed to encourage the development of wind power in three countries—Germany, Denmark, and the United States—and compares the policies enacted in each of these countries to policies that are used in Japan. Measures that are applicable to shaping the implementation of renewable energy, especially wind power energy are examined and future policy measures are proposed to increase the use and development of wind power in Japan, consequently reducing carbon dioxide emissions.

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## Table of Contents

## 1. Overview

This thesis explores measures in the Japanese energy industry in order to meet the Kyoto target and further abate carbon dioxide beyond this target. The Kyoto Protocol to the United Nations Framework Convention on Climate Change, an agreement among the industrialized nations of the world to reduce emissions of six greenhouse gases over a specific period of time, is a milestone in the international effort to address the anthropogenic causes of climate change. The Protocol was adopted at COP3 (the Third Conference of the Parties to the United Nations Framework Convention on Climate Change), held in Kyoto, Japan in 1997. The Kyoto Protocol requires industrialized countries agreeing to it (including Japan) to cut their greenhouse gas emissions by an average of 5.2% relative to 1990 levels. These emission reductions are to be completed by a commitment period ranging from 2008 to 2012. With Russia's ratification in November 2004, this international agreement entered into force in February 2005.

To meet the Kyoto target, the present measures by the Japanese government to reduce the carbon dioxide emissions in the energy sector rely heavily on the development of nuclear power generation. Therefore, the current delay of nuclear power development is a crucial problem to be solved to achieve the target. The Japanese government also wants to increase renewable energy as one of the measures. It is now difficult for renewable energy, such as wind power, to become a major energy source due to its high cost and intermittent supply. However, it is author's belief renewable energy can be increased in order to reduce carbon dioxide emissions by applying appropriate policies and technical development in the power generation sector. Wind power may be the most cost-effective renewable energy source to address global warming.

The world market for wind power is growing rapidly: from 14,000 megawatts in 1999 to over 48,000 megawatts in 2004.[1] Wind power markets are concentrated in a few primary countries, with Europe (especially Germany) and the United States leading the expansion in 2004. However, Japan is now taking its first steps to develop a large-scale commercial market for wind power.

Though the Japanese government has raised its wind power target to 3,000 megawatts by 2010, only 900 megawatts of wind power had been introduced by 2004.[2]

This thesis examines policies designed to encourage the development of non-hydro renewable energy such as wind power in three countries—Germany, Denmark, and the United States—and compares the policies enacted in each of these countries to policies that are used in Japan. For each country, policy development is analyzed in the context of historical non-hydro renewable generation data to try to determine which types of policies would most effectively increase non-hydro renewable generation. In this thesis, measures discussed are applicable to shaping Japan's non-hydro renewable implementation, especially wind power energy.

Chapter 2 introduces the Kyoto Protocol; Chapter 3 reexamines wind power development in Japan; Chapter 4 analyzes wind power development in the United States; and Chapter 5 analyzes wind power development in European countries. Chapter 6 compares policies in various countries that support wind power. Chapter 7 discusses the issues hindering the promotion of wind power in Japan. The final chapter, Chapter 8, proposes future policy measures to increase the use and development of wind power in Japan, consequently reducing carbon dioxide emissions.

## 2. Japan's target in the Kyoto Protocol

### 2.1 Global Climate Change and the Role of Carbon Emissions

The entire global climate and ecosystem have been altered by the accumulation of gases including carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and ozone in the atmosphere. These so-called green house gases (GHGs) are produced by various human activities, including agricultural and industrial practices, deforestation, and the burning of fossil fuels.

"Global warming" and "climate change" are common expressions used to describe the threat to human and natural systems resulting from continued emissions of heat-trapping or "greenhouse" gases (GHGs) from human activities. These emissions are changing the composition of the atmosphere at an unprecedented rate. While the complexity of the global climate system makes it difficult to accurately predict the impact of these changes, the evidence from modeling studies, as interpreted by the world's leading scientists assembled by the Intergovernmental Panel on Climate Change (IPCC), indicates that the global mean temperature will increase anywhere from 1.4 to 5.8° C within 100 years.[3] For reference, a global increase of 2° C from today's levels would yield global average temperatures exceeding any the earth has experienced in the last 10,000 years, and an increase of 5° C would exceed anything experienced in the last 600,000 years. Moreover, it is not simply the magnitude of the potential climate change, but the *rate* of this change that poses serious risks for human and ecosystem adaptation, with potentially large environmental and socioeconomic consequences.[4]

The combustion of all carbon-based fuels, including coal, oil, natural gas, and biomass, releases carbon dioxide ($CO_2$) and other "greenhouse gases" into the atmosphere. Over the past century, emissions of greenhouse gases from a combination of fossil fuel use, deforestation, and other sources have increased the effective "thickness" of the atmospheric blanket by increasing the concentration of GHGs in the troposphere, or lower part of the atmosphere (ground level to about 10-12 km). It is this "thicker blanket" that is thought to be triggering changes in the global climate.

The warming of the earth may, in turn, have numerous secondary effects, some of which can have a potentially serious impact on the well being of both humans and the plants and animals with which we share our planet. These effects include an increase in sea level due to thermal expansion and the melting of polar ice, changes in precipitation patterns, and changes in vegetation. The timing and spatial distribution of these effects around the globe are as yet extremely uncertain.

**2.2 The Kyoto Protocol and GHG Emissions in Japan**

A milestone in the international effort to address the anthropogenic causes of climate change was the Kyoto Protocol to the United Nations Framework Convention on Climate Change, an agreement among the industrialized nations of the world to reduce emissions of six greenhouse gases over a specific period of time. The Protocol was adopted at COP3 (the Third Conference of the Parties to the United Nations Framework Convention on Climate Change), which was held in Kyoto, Japan in 1997. The Kyoto Protocol requires industrialized countries agreeing to it (including Japan) to cut their greenhouse gas emissions by an average of 5.2% relative to 1990 levels. These emissions reductions are to be completed by a commitment period ranging from 2008 to 2012. Japan ratified the Kyoto Protocol in 2002. With Russia's ratification in November 2004, this international agreement entered into force in February 2005.[5]

Under the terms of the Protocol, Japan has agreed to reduce its GHG emissions by 6% relative to 1990 levels. Japan's GHG emissions of late are 5% higher than Japan's 1990 emission levels.[6]

More than 90% of the total GHG emissions in Japan, measured in carbon equivalents, are accounted for by carbon dioxide emissions.[7] Figure 2-1 shows the pattern of carbon dioxide emissions by fuel type in Japan since 1950, illustrating both the substantial growth in emissions during the 1970s and 1980s (in particular), and a transition in fuel use from coal to oil to gas. Figure 2-2 shows Japanese $CO_2$ emissions by sector during the 1990s. The main $CO_2$ emission sources in 2000 were the energy industries including the power sector (31%), other industries (33%), and the transportation sector (21%).[8] As of 2000, Japan was fourth among nations in $CO_2$ emissions, behind only the United States, China and Russia. On a per-capita basis, Japan ranked 37th in the world as of 2000, with approximately 9.35 tonnes of $CO_2$ emissions per person.[9]

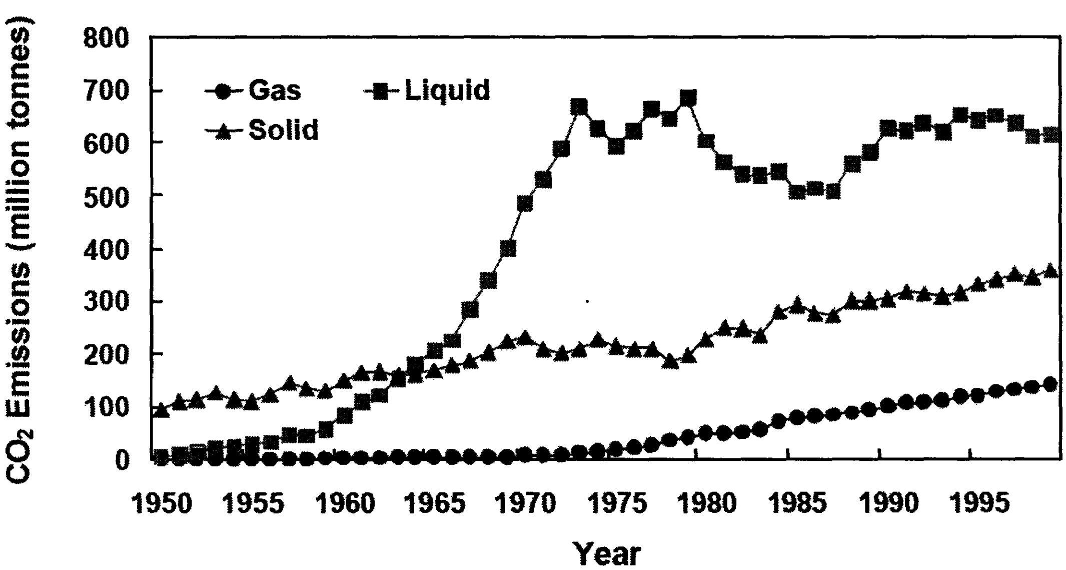



**Figure 2-1 Historical $CO_2$ Emissions in Japan by Fuel, 1950 to 2000 [10]**

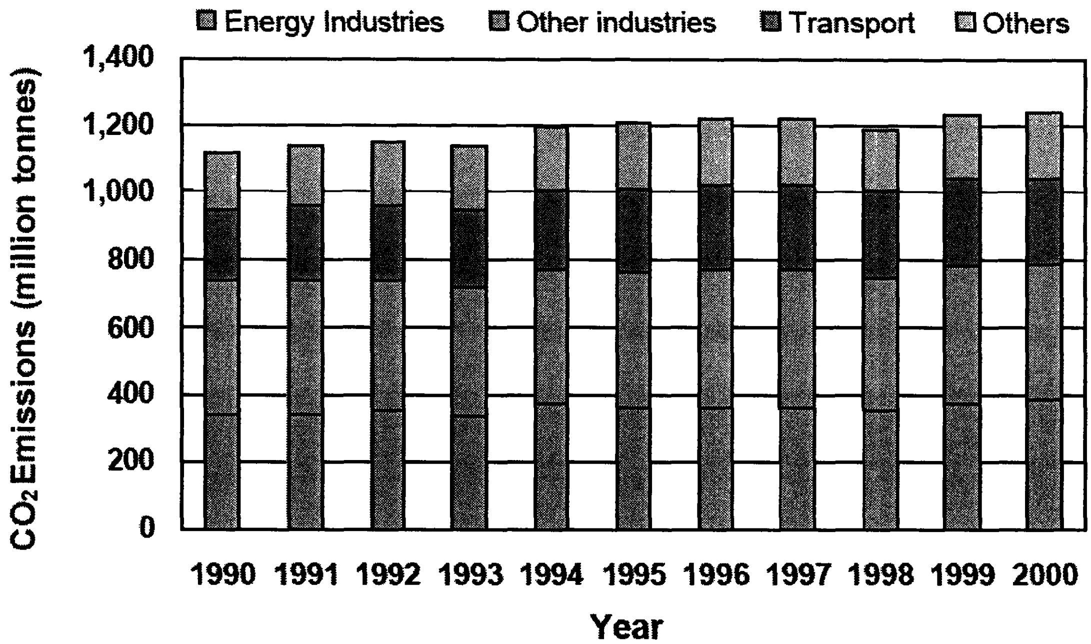



**Figure 2-2 $CO_2$ Emissions in Japan by Sector, 1990 to 2000** [11]

According to the Japanese Government's "Guideline for Measures to Prevent Global Warming," the GHG reduction targets relative to 1990's emissions levels for the sectors of the Japanese economy and specific GHG sources and sinks are as follows:

- $CO_2$ from energy sources (0%),
- $CO_2$ from non-energy sources, $CH_4$ and $N_2O$ (-1.2%),
- Development of innovative technologies and further extensive efforts by the public (+0.6%),
- HFCs, PFCs and $SF_6$ (+0.1%),
- Sinks (-3.9%).

Additional cuts necessary to meet the overall emission reduction target (-1.6%) will be covered by Japan's share of savings achieved elsewhere as allowed through Kyoto mechanism initiatives such as Emissions Trading, the Clean Development Mechanism, and Joint Implementation. [12]

This plan suggests that Japan's $CO_2$ emissions could be reduced most by energy conservation efforts of all sectors and by the aggressive adoption of energy efficient technologies. Given, however, that the efficiency with which energy is used in Japan is already relatively high —as an indicator, annual electricity consumption per capita in Japan as of 2000 was 8.3 MWh, versus 13.8 MWh per person-year in the US[13] —it is likely that the level of national GHG reductions required by the Kyoto Protocol will be difficult to achieve by relying solely on energy efficiency improvements and other forms of energy conservation.

**2.3 Power Generation Sector**

Emissions associated with the energy transformation sectors alone are estimated to be over 30% (including indirect emissions) of Japan's total national $CO_2$ emissions. As a consequence, substantial efforts to reduce GHG emissions in the power sector—which accounts for over half of the energy transformation emissions—could have a significant impact on climate change mitigation in Japan. It is therefore imperative for Japan's power sector to consider switching to less carbon-intensive fuels and energy resources. As shown in Figure 2-3, carbon dioxide emissions from electricity generation in Japan increased by 16.5% between 1990 and 2000. This increase is largely the result of an overall increase in electricity production in Japan (27.8% between 1990 and 2000), that has occurred even though there has been a small overall reduction in the fraction of total generation produced in thermal power plants. Figure 2-4 shows how the composition of electricity production has changed between 1990 and 2000.[5]

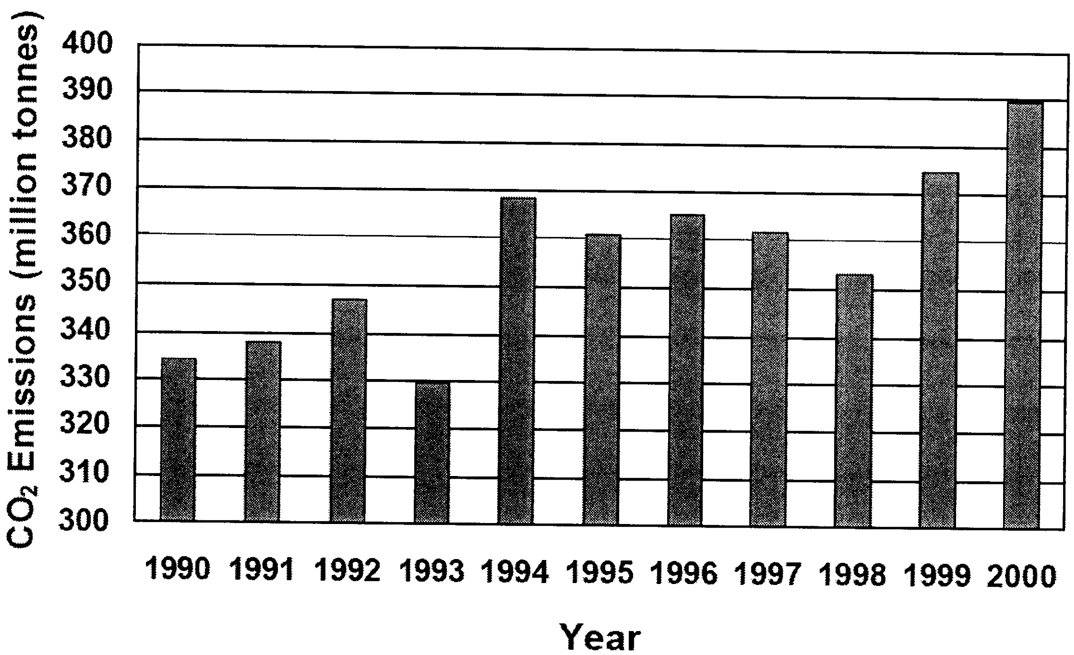



**Figure 2-3 Carbon Dioxide Emissions from Electricity Generation in Japan[14]**

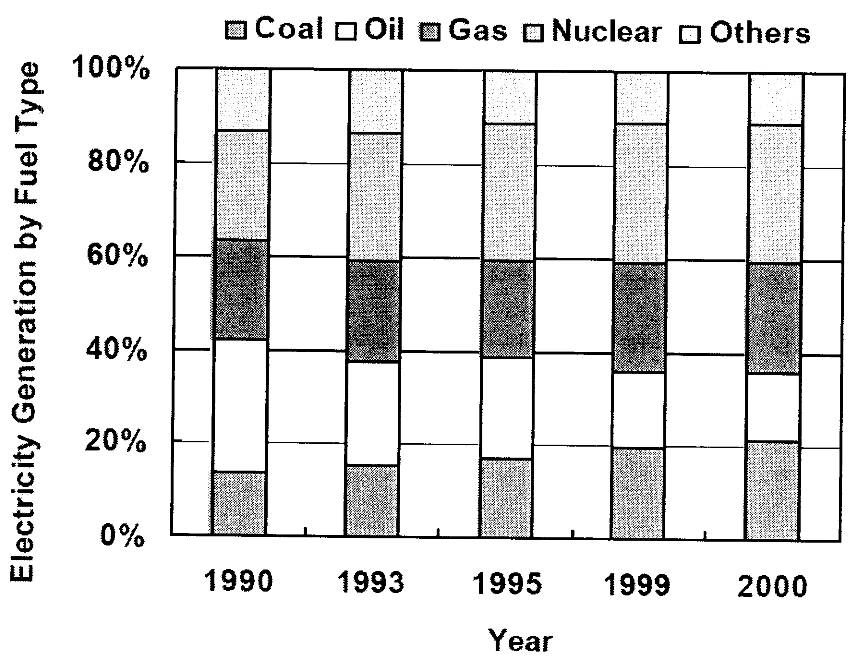



**Figure 2-4 Electricity Generations in Japan by Fuel Type, 1990 to 2000[15]**

The major fuel-switching options for electricity generation that are currently under consideration by the Japanese government to reduce GHG emissions, as evidenced by the recent Long-Term Energy Outlook, are a large increase in the use of nuclear power, an increase of utilization of coal-fired power plants using high thermal efficiency generation technologies, an increase in the use of natural gas and gas-fired technologies for generation, and a variety of technologies for the expanded generation of electricity using renewable fuels and resources. Among these options, governmental and also semi-governmental research groups have focused most extensively on the emissions reduction potential of increased nuclear power development.

The most recent Long-term Energy Outlook[16] for Japan published by METI (Ministry of Economy, Trade and Industry) includes the assumption that Japan's GDP (Gross Domestic Product) growth rate will be 2% annually through 2010. This assumption implies a continued increase of energy consumption and the necessity of emphasis on nuclear and fossil fuel use—especially coal—and modest increases in the use of renewable energy. In the METI outlook, although oil consumption as a primary energy input to the Japanese economy is projected to decrease from 52% in 1999 to 45% in 2010, coal use and the use of nuclear power (despite extreme difficulties related to the siting of new coal and nuclear facilities in Japan) will increase. Non-conventional energy (new energy) including renewable sources will account for 3% of Japan's primary energy by 2010 in the METI's "business as usual" case.[5]

All other $CO_2$ emission reduction scenarios that comply with the government energy outlook, not surprisingly, conclude that it is difficult for Japan to meet the national target for greenhouse gas emissions reduction set at the Kyoto Conference.

In addition to the difficulties described above, global liberalization of energy markets might also negatively affect Japan's progress toward its $CO_2$ emission reduction target. Japan has few indigenous fossil fuel energy resources. Japan has regulated all domestic energy markets, and has put its strongest energy policy emphasis on securing a stable energy supply. The government has been protecting Japan's energy markets from the risks associated with competition through the use of large energy subsidies and centralized implementation of national energy policy. The global trend of energy market liberalization, however, cannot be avoided. METI realizes that to some degree Japanese domestic energy markets must ultimately open up to fair competition and start promoting a more open market liberalization. In recent years, the Japanese public has become aware of the real costs—including social and environmental costs—of energy, and especially of nuclear power generation, and partially as a result, along with increasingly severe difficulties in siting facilities, there has been less private investment in what is perceived as a risky, inflexible, large, centralized power system.[5]

If, as a result, nuclear power plant development will not occur on the time scale projected by METI, then the reduction of Japan's $CO_2$ emissions to meet the target set by the Kyoto Protocol will be even harder to achieve.

Some research has been accomplished to examine alternative measures to achieve the target for the electric power sector. For example, the Ministry of Environment of the Japanese government analyzed auxiliary measures to reduce GHG emission. To achieve the reduction by 2010, which is a relatively short period for the electric power industry and definitely limited for the introduction of new technologies, realistic measures which are in the mature stage of the technological development that could be installed by 2010 should be considered.[5]

From the perspective of the technological maturity and feasibility, acceleration of the introduction of renewable energy, especially wind power generation, seems to be one of the key issues. We recognize that it is now difficult for renewable energy, such as wind power, to become a major energy sources due to its high cost and intermittent supply. However, I believe that we can increase renewable energy to reduce carbon dioxide emissions by applying appropriate policies and technical development in the power generation sector. Wind power may be the most cost-effective renewable energy source to address global warming.[5]

## 3. Wind Power development in Japan

Japan's wind energy industry has surged forward in recent years, partly spurred by a government requirement for electricity companies to source an increasing percentage of their supply from renewables. Development has also been encouraged by the introduction of market incentives, both in terms of the price paid for the output from renewable plants and in the form of capital grants towards clean energy projects. Power purchase agreements for renewables also have a relatively long lifespan of 17 years, which helps to encourage investor confidence. The result has been an increase in Japan's installed capacity from 644 MW at the end of 2003 (fiscal year) to more than 900 MW by 2004.[2] (See Figure 3-1, 3-2)

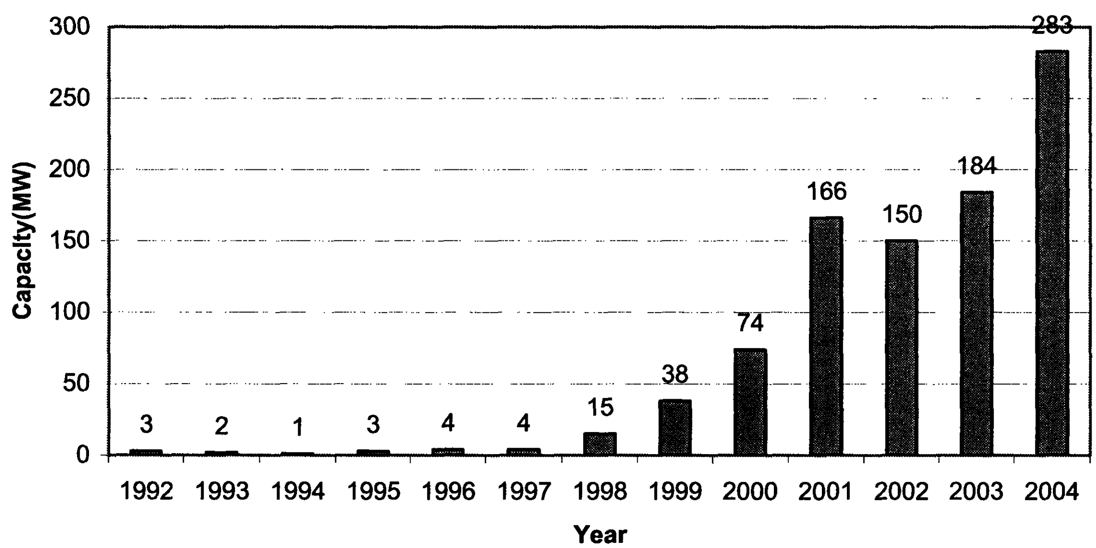



**Figure 3-1 Annual installed wind power capacity (MW) in Japan**

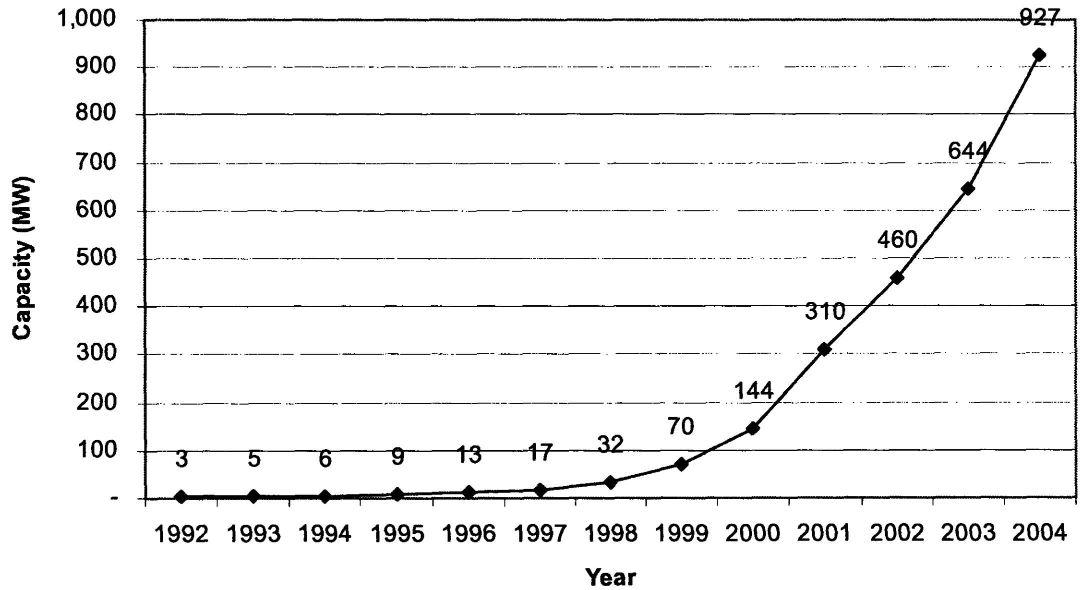



**Figure 3-2 Cumulative installed wind power capacity (MW) in Japan**

In pursuit of the Kyoto Protocol objectives, Japan has a target to reduce the level of its greenhouse gas emissions by 6% (compared to their 1990 level) by 2008-12. To help achieve this goal, the Japanese government introduced a Renewable Portfolio Standard (RPS) law in April 2003 with the aim of stimulating renewable energy to provide 1.35 per cent of total electricity supply in 2010.

However, the law has a number of weaknesses, including a very low target (almost one tenth of Germany's), the inclusion of electricity generated by waste incineration as "renewable" and insufficient market incentives. Apart from the RPS, the Japanese wind industry also benefits from the government's Field Test and New Energy Business Support Programs.

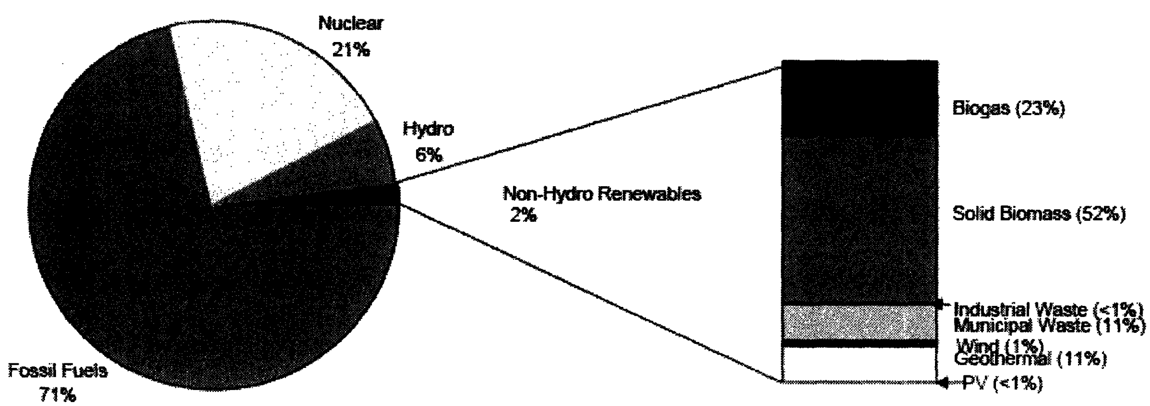
The leading regions for wind power development in Japan are Tohoku and Hokkaido, two areas located in the northern part of the country, with an installed capacity respectively of 275 and 159 MW, and Kyushu, situated in the south, with 113 MW. [1]

Two other issues have created challenges for Japanese wind developers. Firstly, the country is relatively densely populated in areas where construction is feasible, and secondly, the capacities of acceptance of wind power in each utility company are limited because of its intermittency.

The official government target for wind power in Japan by 2010 is 3,000 MW. Achieving this figure could face unnecessary difficulties, however, due to the current RPS law and the lack of co-operation from power companies in introducing renewable energy, especially wind projects, into the grid.

### 3. 1 Background of renewable energy[17]

Japan is an island nation of about 127 million people living in a land area slightly smaller than California.[18] Japan generated 1,097 billion kWh of electricity in 2002, of which 71% was generated from fossil fuels, 21% from nuclear power plants, 6% from hydropower and 2% from non-hydro renewables.[19] (See Figure 3-3) Japan got electricity from non-hydro renewables such as waste, biomass, geothermal, solar, and wind sources.




**Source:** International Energy Agency, Energy Statistics of OECD Countries, 2001-2002, OECD/IEA, 2004, Paris.

**Figure 3-3 Japanese Electricity Generation, 2002**

As with Germany and Denmark, Japan became interested in renewable energy during the energy crises of the 1970s. In 1973, Japan used oil to supply 76% of its energy needs. This dependence had declined to 68% by the late-1980s.[20] Japan's reaction to the energy crisis was to work towards securing stable oil supplies, promoting the development of nuclear power and renewable energy sources, and encouraging energy conservation.[21]

In 1997, Japan hosted the Third Conference of the Parties to the United Nations Framework Convention on Climate Change. During this meeting, the Conference negotiated the Kyoto Protocol, the implementation mechanism of the Climate Change Convention. Japan ratified the Protocol and has agreed to reduce its $CO_2$ emissions to 6% less than 1990 levels by 2012. While Japan's initial interest in renewable energy was fueled by energy supply and security concerns, environmental considerations, including climate change, have continued to drive policies in recent years.

### 3.2 Renewable Policies[17]

Japan's support of renewable energy began in 1974 with the Sunshine Project, a program meant to develop alternative energy resources (including solar, geothermal, coal gasification/liquefaction, and hydrogen) through R&D efforts.[22] Solar energy efforts focused initially on solar thermal applications rather than photo voltaics, but after 1980, Japan began to fund more R&D for PV.[23] The Moonlight Project, targeting R&D for technologies promoting energy efficiency began in 1978. Together these two projects oversaw R&D programs that conducted basic research and applied the research in the projects undertaken cooperatively by government, industry, and academia.[24]

In 1980, Japan passed the Law Concerning the Promotion of Development and Introduction of Petroleum Substituting Energy, which charged the government with adopting guidelines for the use of alternative energy sources and technologies and fiscal measures to promote their development.[24] The law also created the New Energy Industrial Technology Development Organization (NEDO) which was established to urge the development of new, non-petroleum sources of energy.[25]

In 1981, NEDO began conducting wind R&D under the auspices of the Sunshine Project. Between 1981 and 1986, the R&D program successfully developed a 100 kW pilot wind plant and conducted research on materials, reliability, control properties, power generation, and the potential impact of wind-generated electricity on power grids. In 1986, the focus of R&D shifted to larger, MW-sized machines. The 1990s were characterized by a series of demonstration projects and further research, particularly into interconnection and grid stability issues.[26] In the mid-1990s, the Ministry of International Trade and Industry (MITI, now METI) declared a goal of 20 MW of installed wind capacity by 2000, and 600 MW by 2010.[27] The goal of 600MW by 2010 was met in 2003, so METI decided to set another goal, 3,000MW, to be met by 2010. By the end of 2004, wind power capacity in Japan was over 900 MW.[28]

In 1992, the government introduced the New Sunshine Program to further support alternative sources of electricity. This program combined the R&D efforts of the Moonlight Project and the original Sunshine project together into one program.[29]

In May 2002, Japan instituted an RPS, the "Law on Special Measures for the Utilization of New Energy, etc." This law, passed to ensure energy security and curb global warming, promotes the use of solar, wind, biomass, geothermal, and small hydro (less than 1,000 kW). This measure allows power companies to meet their obligations by producing power from new generation sources, purchasing allowable generation from others, or trading with other power companies via a renewable energy certificate trading system. Eight-year goals are to be re-evaluated and set every 4 years.[30]

## 4. Wind Power development in the United States

2003 came close to being a record-breaking year in the United States, with 1,687 MW installed, just a few megawatts shy of the 1,696 MW installed in 2001. By December 2004, following the credit's renewal, the industry brought into service only 389 MW of new equipment — well under what would have otherwise been installed. [31] The cumulative capacity stood at 6,740 MW at the end of 2004, with utility-scale turbines operating in 30 states.[32] 2005 was a record-breaking year for the United States wind energy industry, with up to 2,500 MW of new capacity installed. This should confirm the position of the United States as one of the largest wind power markets in the world.[1] (See Figure 4-1, 4-2)

In 2005, the development of wind energy included a number of wind farms of well over 100 MW capacity, arrays which it is possible to accommodate in the wide open spaces of many states. Projects that were to be completed before the end of the 2005 include wind farms in Washington State, Montana, Kansas and north central Iowa. Each of these projects was projected to have an eventual capacity of 150 MW. FPL Energy, the largest developer of wind farms in the United States, said its goal was to add up to 700 MW of capacity by the end of 2005.This included the 220 MW Horse Hollow wind farm near Abilene in Texas.[1]

The American Wind Energy Association (AWEA) estimated that these new developments in 2005 would produce enough clean power for the equivalent of 700,000 US homes, bring US$3 billion of immediate investment into the power generation sector and generate an estimated 10,000 jobs of employment nationwide. [1]

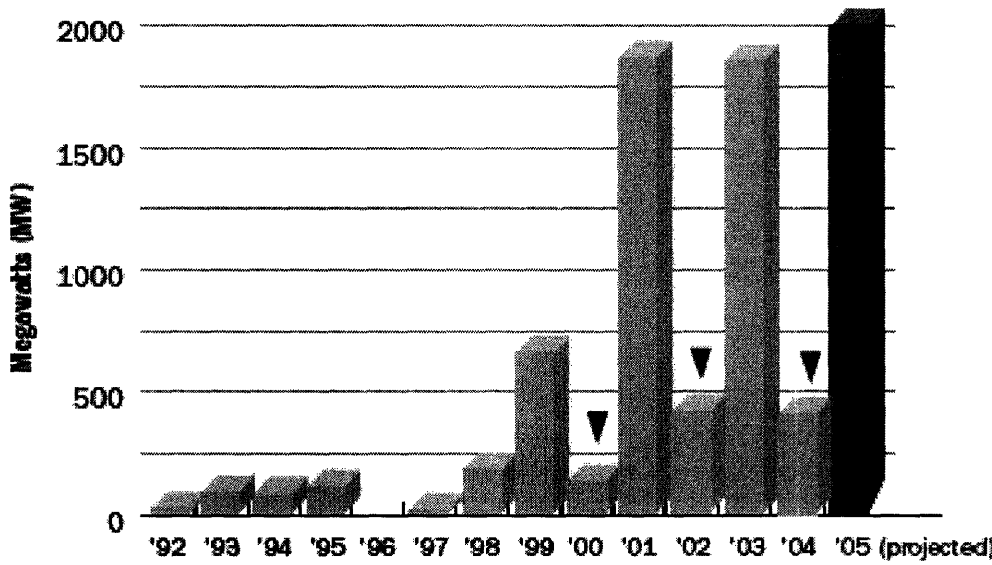



**Figure 4-1 Annual Installed Capacity in the United States**[32]

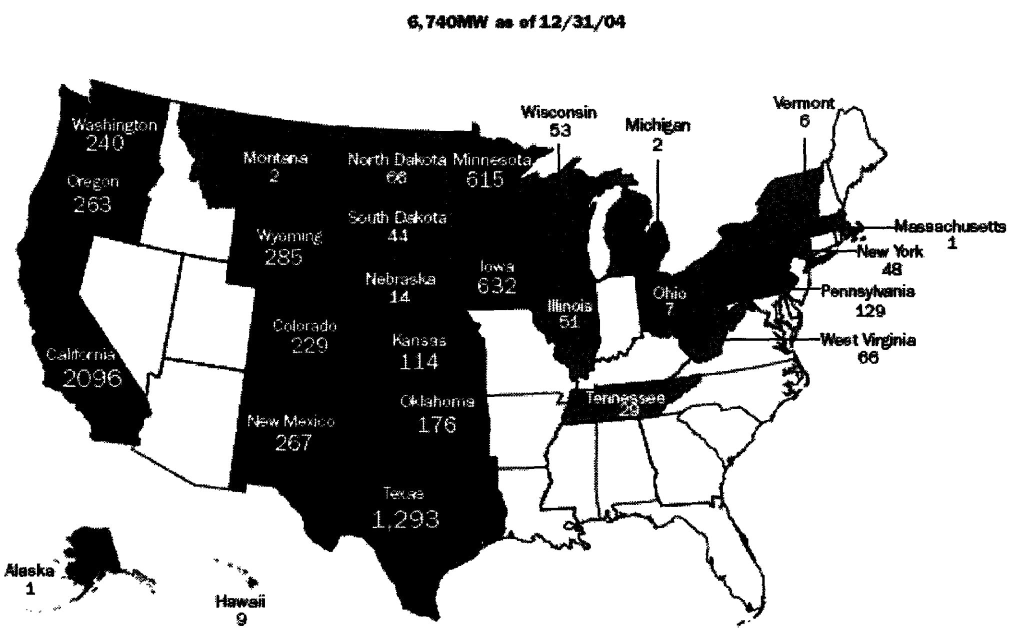



**Figure 4-2 United States Wind Power Capacity (MW) in 2004**[32]

**(1)Production Tax Credit**

The United States was one of the pioneers in wind energy development, with hundreds of turbines erected across the mountain passes of California during the 1980s. In recent years, however, it has been held back from realizing its full potential by the intermittent nature of the main federal incentive introduced to encourage development. First brought into force in 1992, the Production Tax Credit (PTC) currently provides a 1.9 cent per kilowatt hour credit for electricity produced commercially from a wind energy facility during the first ten years of its operation. In order to qualify, a wind farm must be completed and start generating power while the credit is in place. [1]

The justification for the credit is that it both recognizes the environmental benefits of wind energy and helps to level the playing field with the subsidies available to other fuels used for power generation. When the credit expires, however, as it has three times over the past six years, contracts are put on hold, investments trickle to a halt, and jobs are lost. During the period from the PTC's last expiry in December 2003 until its extension in October 2004, for example, thousands of jobs were lost and over US$2 billion in investment were put on hold. By the end of 2004, following the credit's renewal, the industry had brought into service only 389 MW of new capacity, well under what would otherwise have been installed. Renewal of the PTC is the main reason for the boom in construction activity during 2005.[1]

The American Wind Energy Association is continuing to lobby in and outside Congress for a longer term renewal of the PTC so that both financial stability and continuity can be maintained in the wind power industry.

**(2) Renewable Portfolio Standards**

A second factor which has encouraged wind energy in the US has been the introduction of a Renewable Portfolio Standard in a number of states. This lays down an increasing percentage of renewable electricity which utilities are expected to source within a prescribed timescale. Twenty states have now introduced some form of RPS, plus the District of Columbia. In Illinois, for example, the aim of the RPS is for renewables to reach a contribution to electricity supply of 8% by 2012.[1]

The introduction of an RPS in New York State has provided the impetus behind the largest wind park yet planned for any of the east coast states, where development has lagged far behind other parts of the US. The New York RPS calls for 25% of the state's electricity to be supplied by renewable energy in 2013, resulting in five power generators being selected in a first phase. [31] Among them is the Maple Ridge project for 120 Vestas 1.65 MW turbines to be erected on a site not far from the town of Harrisburg. The wind farm will eventually be expanded to a capacity of 240 MW.[1]

**(3) Utility Investment**

The rising cost of natural gas, which now accounts for about 20% of US electricity generation, has also encouraged some utilities to look more closely at the attractiveness of wind. Wind energy provides stable, affordable insurance against the risk of increases in the price of natural gas and other fuels. Wind energy development can also cut consumers' bills by lowering demand for natural gas — particularly during winter peak demand periods — and extending its supply. A growing number of energy companies have started to invest in the wind power business. Recent examples include AES Corporation, which acquired California-based wind developer SeaWest Wind Power, and Goldman Sachs, which bought Houston-based developer Zilkha Renewable Energy.[1]

Jobs are an important bonus of the US wind industry's increased level of activity. A major study released last autumn by the Renewable Energy Policy Project reported that boosting wind energy from 6,000 MW to 50,000 MW would create 150,000 manufacturing jobs. A number of companies have recently announced plans for new or expanded production in the U.S., including

Spanish turbine maker Gamesa, blade manufacturer LM Glasfiber, and turbine maker Vestas-American Wind Technology.[1]

The AWEA estimates, using growth projections of 3,000 MW installed every two years over the next four years, that the U.S. could reach 15,000 MW of capacity by the end of 2009. If the PTC were renewed on a continual basis, that figure could be substantially higher. Current AWEA estimates are that by 2020 wind power could provide 6% of U.S. electricity, from 100GW of wind, a share similar to today's contribution from hydro-electric plants.[1]

**(4) Unlocking transmission barriers**

In order to unlock the vast wind energy potential of America's heartland and transport that power to market, it is critical that wind generators be able to gain access to the transmission network on fair terms compared with other generation technologies. Fortunately, transmission barriers, which have slowed expansion of wind power in many regions of the US, are beginning to recede. Federal regulators have proposed a dramatic overhaul of the wholesale electricity market structure that includes fair treatment of wind energy in transmission pricing. Among other changes, this would eliminate all penalties associated with wind's variable output when that variability does not result in increased costs to the system.[1]

However, carrying out these changes will be difficult due to power struggles between federal and state authorities. Wind development also requires investments in bulk transmission capacity from the rural, sparsely populated but windy regions to markets in major population centers. In Minnesota, for instance, the state has authorized construction of the largest single transmission project in over twenty years specifically to tap the state's powerful winds.[1]

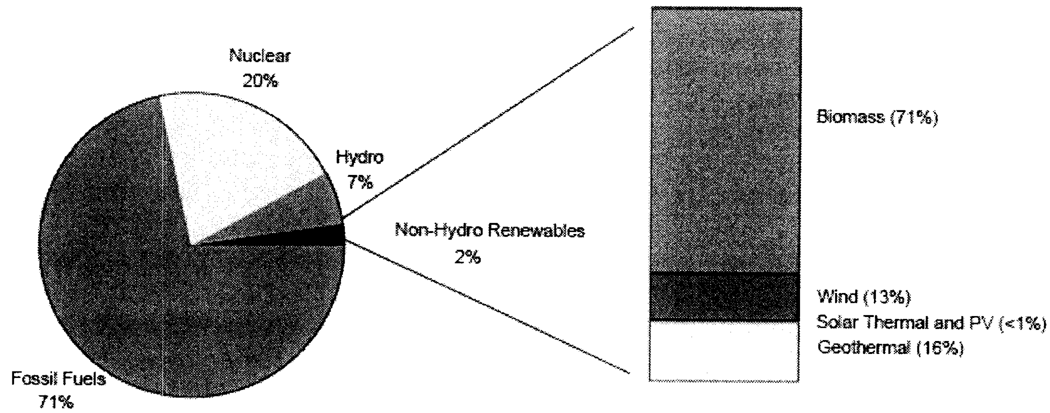
The United States still has far to go before wind power realizes its full potential - enough, according to federal studies, to meet more than twice the nation's electricity demand. The state of North Dakota alone has about fifty times the wind resource of Germany. But the pace of wind power development in the U.S. will depend to a large extent on the adoption of steady, supportive policies.[1]

## 4.1 Federal renewable policy[17]

### 4.1.1 Background

The United States has the largest economy in the world, with a population of 290 million in an area about two and a half times the size of Western Europe.[33] In 2003, the United States generated 3,883 billion kilowatthours (kWh) of electricity.[34] About 71% of United States electricity was generated from fossil fuels, about 20% from nuclear power, another 7% from hydroelectric facilities, and the remaining 2% from other renewables (Figure 4-3). Biomass (71%) was the predominant non-hydro renewable fuel for electricity generation in 2003, followed by geothermal and wind. Solar thermal and photo voltaics together accounted for less than 1% of U.S. non-hydro renewable generation.

In the United States, energy policies are the product of both individual state and federal policies. California is featured because it has been among the most active states in encouraging renewable energy.[35]




Source: Energy Information Administration, Electric Power Annual 2003, December 2004, Table 1.1, http://www.eia.doe.gov/cneaf/electricity/epa.pdf and Electric Power Monthly, November 2004, Table 1.1.a, http://www.eia.doe.gov/cneaf/electricity/epm/epm.pdf, accessed December 15, 2004.

**Figure 4-3 United States Electricity Generation, 2003**

### 4.1.2 Federal Non-hydro Renewable Energy Policies

Federal policies used to promote renewable energy have included financial incentives, regulatory measures, and research and development (R&D) programs.

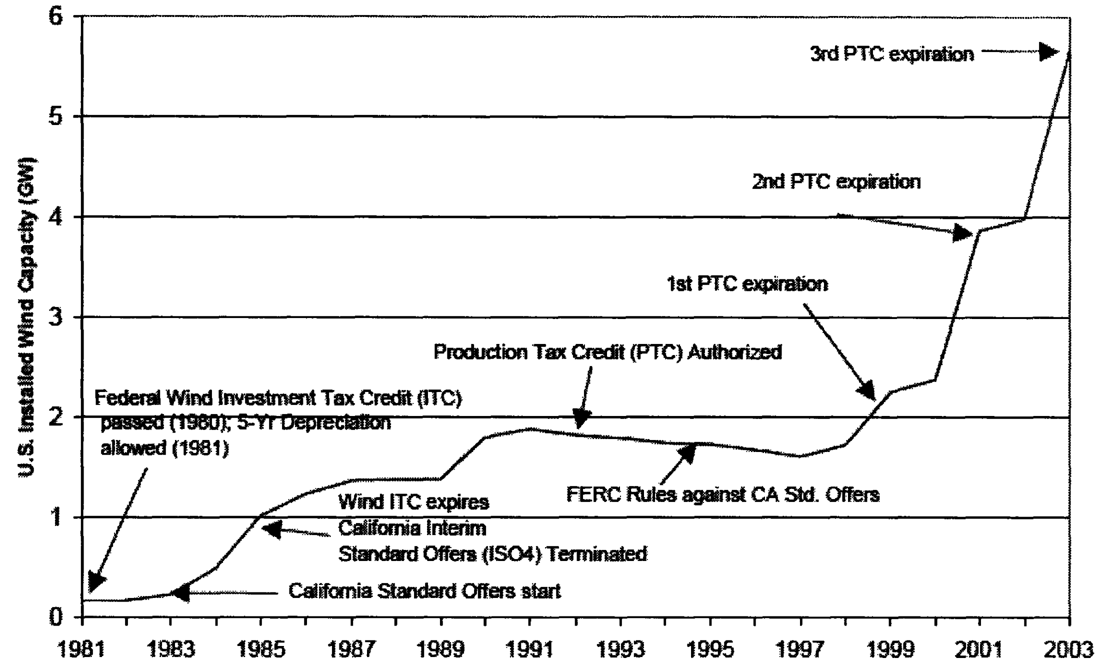
In response to energy security concerns of the mid-1970s, the United States passed the National Energy Act of 1978 (NEA), which sought to decrease the nation's dependence on foreign oil and increase domestic energy conservation and efficiency.[36] The Public Utility Regulatory Polices Act (PURPA) of 1978, part of the NEA with a stated purpose of improving energy conservation and energy efficiency in the utilities sector, also had a major impact on the development of renewable electricity.[37]

PURPA opened the door to competition in the electricity supply of the United States by requiring utilities to buy electricity from qualifying facilities (QFs), which are defined as nonutility facilities that produce electric power using cogeneration technology or renewable power plants with capacities of less than 80 MW. Utilities are required to purchase power from qualifying facilities at the utilities' "avoided cost." The interpretation of "avoided cost" was left up to individual states. This resulted in a number of avoided cost calculations on forecasts of natural gas and oil prices, which were higher than prices actually turned out to be, resulting in favorable investment conditions for renewable power.[38] However, in 1995, the Federal Energy Regulatory Commission (FERC) took responsibility for interpreting "avoided cost," directly linking it with the costs a utility would incur either generating the power directly or purchasing it from another supplier. This interpretation resulted in lower avoided costs than the interpretations of some states, including California.[39]

The United States has also used financial incentives to try to spur the growth of renewable energy. The 1978 Energy Tax Act (ETA), part of the NEA, included a 30-% investment tax credit for residential consumers for solar and wind energy equipment and a 10-% investment tax credit for business consumers for the installation of solar, wind, geothermal, and ocean thermal technologies. Although the level of these tax credits changed over time until their expiration in 1985, the fundamental policies were developed with the passage of the ETA.[40]

The most important law promoting renewable energy in the 1990s was the Energy Policy Act (EPACT) of 1992. EPACT established a 10-year 1.5 cents per kWh inflation-adjusted[41] production tax credit (PTC) for tax-paying privately and investor-owned wind projects and closed-loop biomass plants brought online between 1994 and 1999. The incentive expired in 1999, but was renewed twice, later in 1999 and 2001 before its expiration at the end of 2003. Late in 2004, it was extended again through 2005. This latest extension increased the number of renewable technologies that were covered by the incentive.

Figure 4-4 illustrates the relationship between wind capacity in the United States and the PTC. Although the graph depicts total installed capacity in the United States, nearly all the windpower capacity was in California until the 1990s. EPACT also created a Renewable Energy Production Incentive (REPI) for electricity generated from biomass, geothermal, wind, and solar from tax-exempt publicly owned utilities and rural cooperatives. Unlike the PTC, the funding available through REPI is subject to annual congressional appropriations, thereby making the availability and level of the credit uncertain.




GW = Gigawatts
FERC = Federal Energy Regulatory Commission
**Sources:** Wind Capacity, 1981-1989, California Energy Commission, Draft Final Report, "California Historical Energy Statistics," January 1998, P300-98-001; 1990-2002, Energy Information Administration, Annual Energy Review 2002, Table 8.7a; Policies compiled by Office of Integrated Analysis and Forecasting, Energy Information Administration.

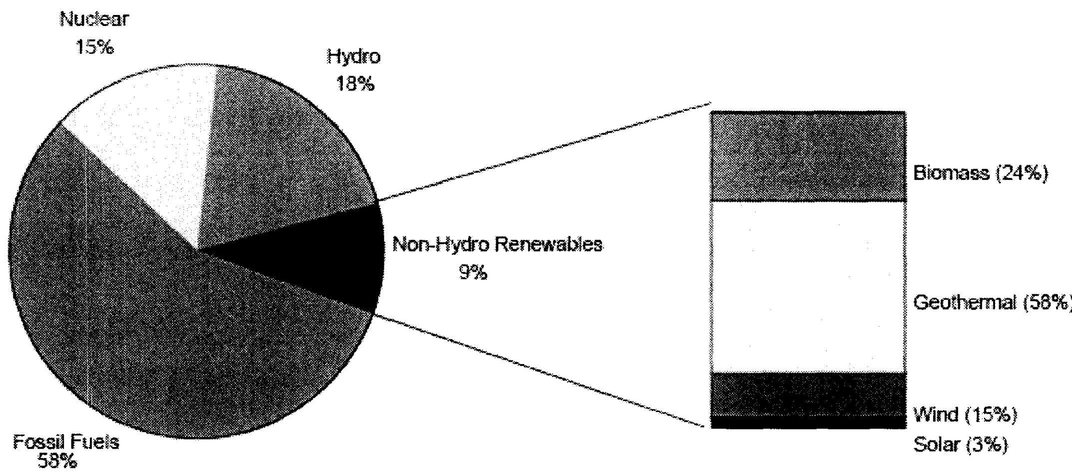
**Figure 4-4 Wind Capacity & Major U.S. and State Policies, 1980-2003**

### 4.2 California[17]

Until the early 1990s, nearly all growth in non-hydro renewable capacity in the United States took place in California. In more recent years, other states have begun pursuing policies to increase non-hydro renewable generation, and in particular, states are developing Renewable Portfolio Standards (RPS). However, most of these initiatives are still relatively new and their impact on non-hydro renewable generation is still unclear. For a review of current State RPS policies, renewables mandates and targets see "State Renewable Energy Requirements and Goals: Status Through 2003."[42] A comprehensive overview of state renewable energy incentives is provided in the Database of State Incentives for Renewable Energy.[43]Because this paper examines historical trends in non-hydro renewable generation, it is enlightening to examine California's policies that, along with Federal statutes, encouraged the development of non-hydro renewable energy there. Needless to say, the Federal laws described above—particularly PURPA and EPACT—have had a significant influence on the development of renewable energy in California. However, many laws enacted at the state level have also significantly affected the development of renewables in California.

#### 4.2.1 Background

California is the most populous state in the United States, with about 35 million people spread out over 150,000 square miles. California produced 277 billion kWh of electricity in 2003 and imported 22% of its electricity needs.[44]Of the electricity generated within the state, 58% was generated from fossil-fuel sources, 15% from nuclear power plants, 18% from large- and small-scale hydropower plants, and about 9% from other renewables (Figure 4-5). Most of the non-hydro renewable power was generated by geothermal energy, with smaller amounts from biomass, wind energy, and solar.[45]




**Source:** California Energy Commission, "California Gross System Power for 2003," http://www.energy.ca.gov/electricity/gross_system_power.html, accessed August 12, 2004.

**Figure 4-5 California Electricity Generation, 2003**

### 4.2.2 Non-hydro Renewable Energy Policies

California began providing tax incentives for installing renewable technologies—particularly solar energy devices—in 1976 with a 10-% investment tax credit.[46] Two years later, the amount of this investment credit was increased to 55%. The investment credit was consistently extended (though the periodic extensions did create uncertainty in the market) through 1986 for wind energy projects and into the 1990s for other renewable projects.[46] This state incentive was in addition to federal incentives for the construction and use of renewable energy technologies that were offered between 1978 and 1985. In 1978, California started the Wind Energy Program with a target of having 500 MW of wind capacity installed by the mid-1980s.[47] Although the federal government was also funding R&D for wind energy technologies at this time, the California Energy Commission (CEC) wanted to explore a wider range of designs than were eligible for the federal program. As such, it funded several turbine projects to determine the efficacy of different designs.[48]

In the early 1980s, California moved from funding strict R&D projects for wind energy to focusing on demonstration projects for wind turbines. These demonstration projects resulted in an improvement in design that helped to bring costs down for wind energy developers. Throughout this period, the focus was on relatively small machines compared to the multi-megawatt R&D efforts at the federal level.[47]

In 1982, California's Public Utilities Commission (CPUC) defined California's interpretation of the term "avoided cost" as used in PURPA. The interpretation was based on long-term avoided costs partially derived from forecasts of natural gas and oil prices. The price reverted to the actual avoided cost after the first 10 years. However, actual avoided cost turned out to be much less than contract costs because oil prices had fallen significantly during the mid-1980s. Thus, after the initial 10-year period, the price that wind producers were receiving dropped dramatically in what is sometimes called the "11–year cliff."[49] In 1982, the CPUC created the "Standard Offer" contracts to secure renewable electricity generation. The contracts were 10-year power purchase agreements for a price of 6.9 cents per kWh. The contracts were based on the notion that there should be no difference in electricity rates regardless of whether the electricity was generated by a utility or by a qualifying facility.[50]

The next year, CPUC authorized Interim Standard Offer Number 4 contracts (ISO4), which were granted for periods of 15-30 years, with prices guaranteed for the first 10 years. The majority of California's wind energy capacity was installed through this program, starting in late 1983. Wind energy projects began reaching the "11-year cliff" in 1992. The "cliff" reduced the profitability of California wind developments after their first 10 years of operation.

Nonetheless, by 1985, mostly via ISO4, California had installed 1,000 MW of wind capacity.[51] By 1990, this had increased to 1,799 MW of wind capacity, which was more than half the world's total at that time.[52]

In 1999, California began offering a 1.5 cents per kWh customer credit for purchasing renewable electricity. The rebate was reduced to 1 cent per kWh in 2000, with a ceiling of $1000 per year.[47] This incentive is similar to the demand-pull incentive (Ecotax exemption) used in the Netherlands, though it has not been as successful in increasing the demand for non-hydro renewable electricity.

In 2002, California introduced an RPS requiring utilities to purchase 20% of electricity from renewable generators by 2017. All non-hydro renewable sources are eligible, as well as small-scale hydropower and municipal solid waste if it is not combusted. To reach 20%, utilities are expected to increase the proportion of power they get from renewable generators by at least 1% each year through 2017.[53] The CEC estimates that by 2017 California will need to generate 30,610 billion kWh of non-hydro renewable generation in addition to the approximately 2,500 billion kWh of non-hydro renewable generation in 2003 to meet the RPS requirement.[54]

# 5. Wind power development in Europe

## 5.1 Germany[55]

With 2,000 MW of new installations, Germany accounted for almost half of the new capacity installed in the EU-15. The wind power capacity for the country totaled 16,600 MW in 2004. Germany remains the world's biggest market, in spite of a considerable, and anticipated, decline in its growth rate. In a typical wind year, Germany's wind farms generate enough to meet about 6% of the country's electricity needs, according to the German Wind Energy Association.[56]

The German wind energy industry currently employs 45,400 people. Wind power generation is concentrated in the northwestern regions of the country: Schleswig-Holstein, where the target of 25% of power to be generated from wind by 2010 has already been achieved; and other provinces in Northwestern Germany such as Mecklenburg-West Pomerania, Saxony-Anhalt, Lower Saxony, and Brandenburg.[56]

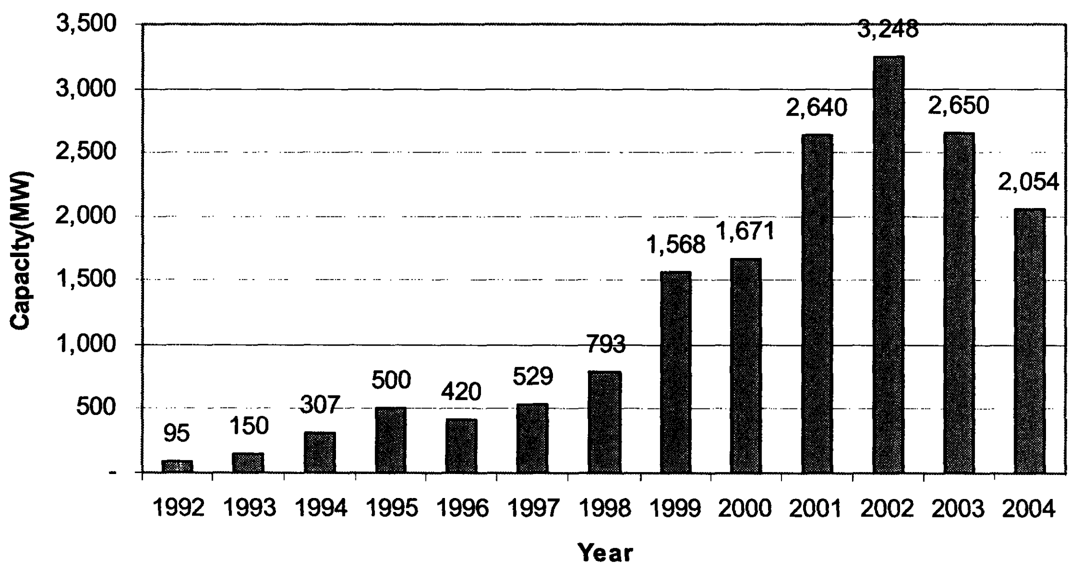



**Figure 5-1 Annual installed wind power capacity (MW) in Germany**

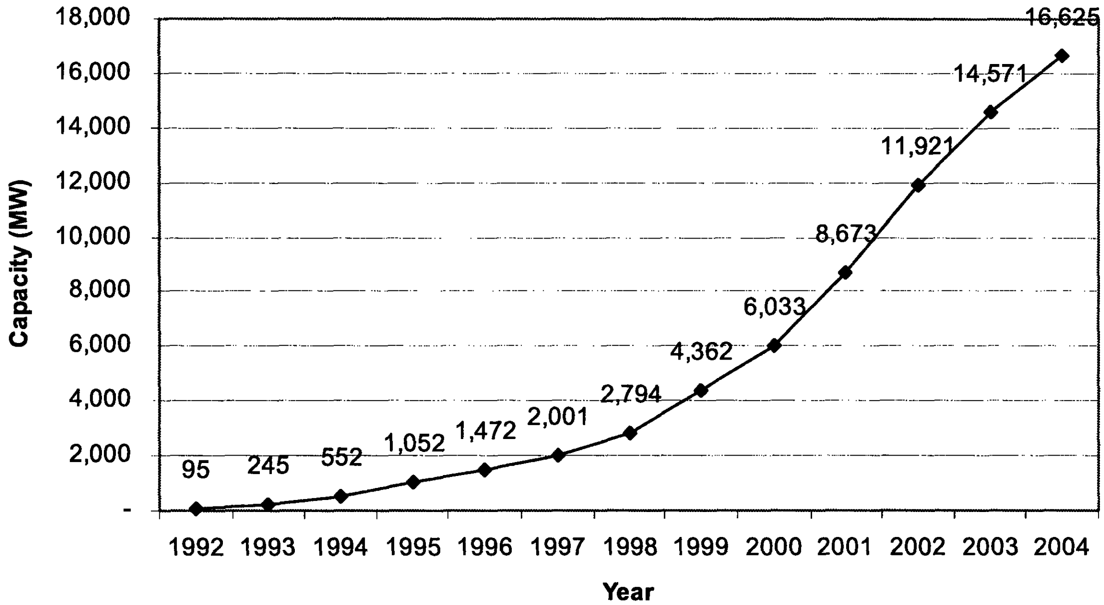


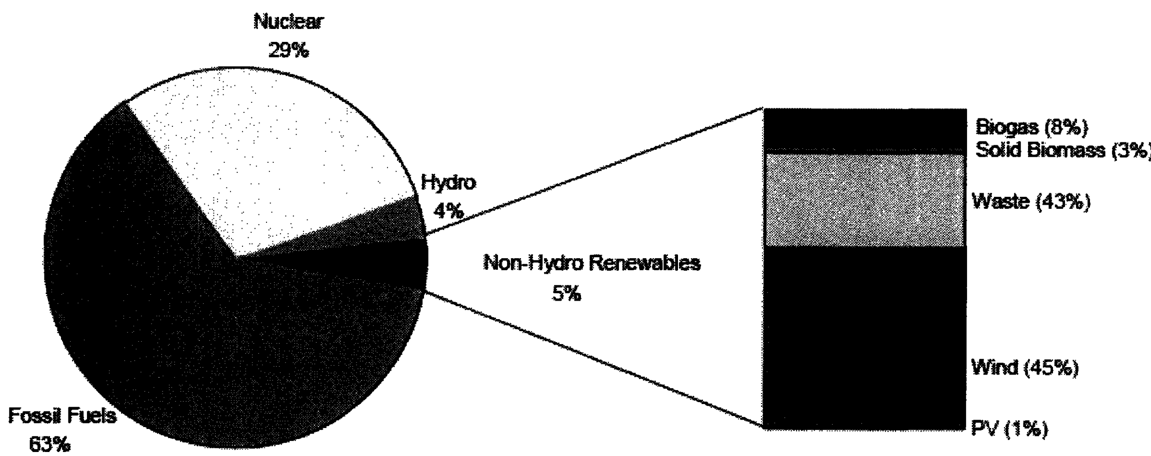

**Figure 5-2 Cumulative installed wind power capacity (MW) in Germany**

### 5.1.1 Background[17]

Germany has a population of 82 million in a land area slightly smaller than that of Montana.[57] Although Germany's economy and electrical grid are smaller than those of the United States, it is one of the largest economies in the world. Non-hydro renewable power generation in Germany decreased over the period 1980 through 1987, declining from 5.2 billion kWh in 1980 to 3.8 billion kWh in 1987. After 1987, however, non-hydro renewable generation has consistently increased each year, regaining 1980 levels in 1991. Installed non-hydro renewable electricity generation capacity in Germany was very small until the early 1990s, when installation of wind turbines and solar panels began to increase. Between 1987 and 1997, German non-hydro renewable generation grew at about 10% per year to nearly 10 billion kWh. During this time, the capacity of non-hydro renewable generation grew by a factor of 20, from less than 100 MW in

1987 to more than 2,000 MW in 1997.[58] Germany also had the greatest installed wind capacity in the world, with more than 14,500 MW at the end of 2003.[59]

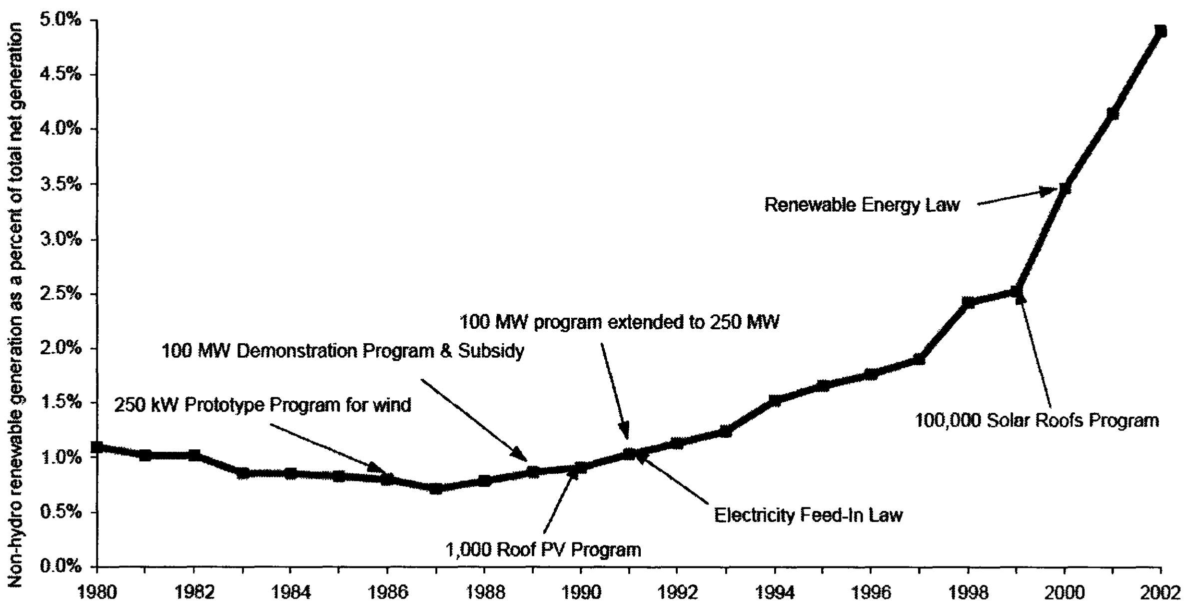
In 2002, Germany generated 72 billion kilowatt hours of electricity, of which about 63% was from fossil fuels. (See Figure 5-3) Germany generated about 29% of its electricity from nuclear power, about 4% from hydropower, and about 5% from non-hydro renewable sources.[60] The contribution of renewables has increased since 2001, mainly due to wind power. Over 3,200 MW of wind capacity were added in 2002, followed by another 2,600 MW in 2003, 2,000MW in 2004, bringing the cumulative installed capacity to 16,600 MW by the end of 2004.[61]




**Source:** International Energy Agency, Energy Statistics of OECD Countries, 2001-2002, OECD/IEA, 2004, Paris.

**Figure 5-3 German Electricity Generation, 2002**

Germany became interested in spurring the growth of renewable energy in the 1970s during the energy crisis brought on by the high cost of imported oil. Germany used a variety of policies to reduce oil imports, including subsidizing domestic coal, increasing the import quota on coal, expanding nuclear generation, and increasing research and development for new energy technologies (mainly renewables).[62] (See Figure 5-4)




kW = Kilowatts
MW = Megawatts
PV = Photovoltaic
**Sources:** Generation, Energy Information Administration, International Energy Annual; Policies, various sources compiled for and cited in this article by Office of Coal, Nuclear, Electric and Alternate Fuels, Energy Information Administration.

**Figure 5-4 Germany's Non-hydro Renewable Energy Policies and Growth, 1980-2002**

Although the development of renewable-generated power was initially driven by a desire to reduce dependence on foreign oil, current renewable energy policies are developed with the goal of reducing air pollution and carbon dioxide emissions. More recently, the German government announced its intentions to phase out nuclear power over the next 2 decades, a move that will probably continue to drive demand for renewable energy in the future.[63] Since 1998, the

Green Party has been part of the ruling coalition in Germany and has had a major role in affecting the country's energy and environmental policies.[64]

Germany and the United States enacted similar policies to promote the growth of renewable energy. However, Germany has surpassed U.S. installed wind capacity, despite the smaller size of the German grid.

**5.1.2 Research, Development, and Demonstration (1974-present) [17]**

Germany invests significant resources into the development of renewable energy. As in the others country, early R&D into wind turbines was completely government-funded and conducted by companies in the aerospace industry. From 1975 through 2000, Germany spent about $215 million (1995 dollars) on R&D of wind turbine technology. Funding levels for wind R&D varied from year to year, peaking at more than $28 million (1995 dollars) in 1980 and 1981 before declining and leveling off in the early 1990s at about $6 million (1995 dollars) per year.[64] While funding levels for wind R&D were higher in the United States, over the next decade, and then increasing beginning in FY 1992.[65]

Germany began the 250-kW Prototype Program for wind turbines in 1986. The program subsidized the first five turbines of a company after the prototype was constructed and tested. Although more than 50 commercial wind turbines were installed under that program, costs remained too high for market conditions in Germany at the time. In 1989 this was followed by the 100-MW Demonstration Program, which provided a subsidy of 0.08 Deutsche Marks (DM) per kWh (4.3 cents U.S.) for wind-generated electricity by turbines accepted into the program.[62] Participants could choose either this production subsidy, or a 60-% capital investment grant for the cost of the facility.[66] Due to its popularity, this program was expanded in 1991 to the 250-MW Wind Program.[67] By mid-year 1991, more than 2,300 applications for a proposed capacity of 520 MW had been received, and by 1998 more than 350 MW of wind-generated electricity had come onto the national grid.[68] These latter programs, with their focus on large turbines, mirrored the wind energy efforts in the United States. Therefore, the wind R&D programs in the two countries were very similar in their funding patterns and their focus.

### 5.1.3 Electricity Feed-In Law (1991) and Renewable Energy Law (2000)[17]

Germany's Electricity Feed-In Law, enacted in 1991, changed the market conditions for renewable electricity producers by mandating utilities to buy renewable electricity and by dictating the price that renewable electricity producers would receive for their power. Utilities were required to buy renewable power at 90% of the retail rate for electricity. This law did two important things for renewable electricity producers in Germany. First, it created a market for renewable electricity. Second, it guaranteed producers of renewable electricity a sustainable price high enough to cover their long-term costs. Both of these factors combined made renewable electric generating capacity a better investment.

In many ways, PURPA is similar to Germany's Feed-In Law. They both require utilities to purchase electricity from nonutility renewable producers, and they both define (if loosely, in the United States) the price at which the transaction will take place. A difference, however, is that in the United States, calculations of "avoided cost" tended to be lower and closer to market wholesale electricity rates than the higher fixed-price German utilities are required to pay to renewable electricity producers.[69] This means that in Germany, where the price paid to producers of renewable energy was higher, new renewable technologies became competitive earlier. Additionally, while the buyback rate for renewable power in Germany was linked to future retail prices in California, buyback rates for the first 10 years were linked to projections of future oil and natural gas prices. After 10 years, buyback rates reverted to actual costs, which were much lower, thereby decreasing the rates (premiums) paid to renewable power producers.

Another major difference between Germany's Feed-In Law and the U.S. PURPA is that the main purpose of the Feed-In Law was to promote the use of renewable resources, while the main purpose of PURPA was to promote energy efficiency. In the United States, before FERC interpreted the meaning of "avoided cost" in 1995, PURPA also promoted the development of renewables in states with favorable "avoided cost" calculations (like California). However, after FERC's interpretation of "avoided cost," the law became less favorable to renewable producers, but was still useful in its original purpose of promoting efficient nonutility electricity generation.

Since the U.S. net metering programs[70] obligate utilities to purchase renewable power, they can be compared to Germany's Feed-In Law. Although net metering allows consumers to sell excess electricity back to the grid, the policy is not analogous to Germany's energy policies, which obligate utilities to purchase renewable power from private producers, regardless of their size. The German law encourages much larger contributions to the grid from private renewable energy producers.

In 2000, Germany passed the Renewable Energy Law, which set specific prices that independent renewable power producers could receive for each type of renewable energy source, although for a limited amount of time. For instance, in 2000, a new wind turbine project would be paid 0.178 DM per kWh (U.S. 11 cents per kWh) for the first 5 years and then the rate would begin to fall. The decreasing nature of the prices is reflective of Germany's expectation that these projects would become increasingly cost-competitive. The buyback tariff rate for PV systems was € 0.51 per kWh (U.S. 45 cents per kWh) and was set to decrease by 5% annually.[71, 72] Finally, this law also dictates that the costs of grid connection for renewables projects are the responsibility of the utility, which can be passed on to consumers.[62] This new law, while still dictating the buyback rates paid by utilities, can more precisely target each renewable energy technology with a buyback rate designed to further its growth. Since each technology's cost of generation differs, the support necessary to make it competitive in the market varies.

It is clear that while the German Feed-In Law had a significant positive effect on the development of renewable electricity generation in Germany, PURPA did not have a similar effect throughout the United States. While some states, including California, did manage to install new renewable electric generation capacity, PURPA was a necessary measure, but not a sufficient incentive for investors to develop new renewable energy projects.[73]

One reason that PURPA did not have a similar effect as Germany's Feed-In Law could be the timing. The wind industry was significantly more developed, both in terms of technology and in terms of costs, in 1991 when Germany passed its Feed-In Law than in 1978 when PURPA was passed. Given that, subsequent development of wind turbines in the United States was undertaken with the relatively inefficient machines of the early 1980s, while post-Feed-In-Law wind turbines in Germany were both cheaper and more advanced. If the timing of PURPA versus Germany's Feed-In Law was the only consideration, one would have expected the U.S. market to begin to grow as technological advances in turbine designs brought costs down. However, even with the advances in turbine technology, PURPA did not begin to create the kind of market growth associated with the Feed-In Law in Germany until additional incentives (in the form of the U.S. Production Tax Credit, among others) were added in 1992.

## 5.2 Denmark

Denmark's total cumulative installed capacity for wind power topped 3,100 MW in 2004. In 2003, Denmark installed 220 MW. Most of the new capacity came from offshore projects: Rodsand/Nysted (158 MW); Samso (23 MW), and Frederickshaven (10.6 MW). Denmark generates some 20% of its power from wind. It is the nation that gets the highest percentage of its electricity from wind.[32] (See Figure 5-5, 5-6)

Denmark's wind power manufacturing industry is a major commercial success story. From a standing start in the 1980s to a turnover of more than € 3 billion, the wind sector has grown faster than any other business sector in Denmark and is bigger than the cement or steel industries. Danish wind turbines dominate the global market, and the country has forged itself a position at the head of the fastest growing energy source in the world.[31]

Over the past 15 years, the Danish wind turbine industry has grown into one of the heavyweights in machinery manufacturing. Alongside the two major turbine manufacturers-Vestas and Bonus - there are a score of large component companies and dozens of smaller suppliers. From a few hundred workers in 1981 the industry now provides jobs for over 20,000 people in Denmark – more than the whole electricity sector – and further thousands in manufacturing and installation around the world.[31]

The past decade in particular has seen a dramatic increase in the production capacity of Danish turbine manufacturers. Annual output, mainly for export around the world, increased from 500 MW in 1994 to over 3,100MW in 2004. Despite the emergence of competing manufacturing countries, 40% of the wind turbine capacity being installed globally today is of Danish origin. [31]

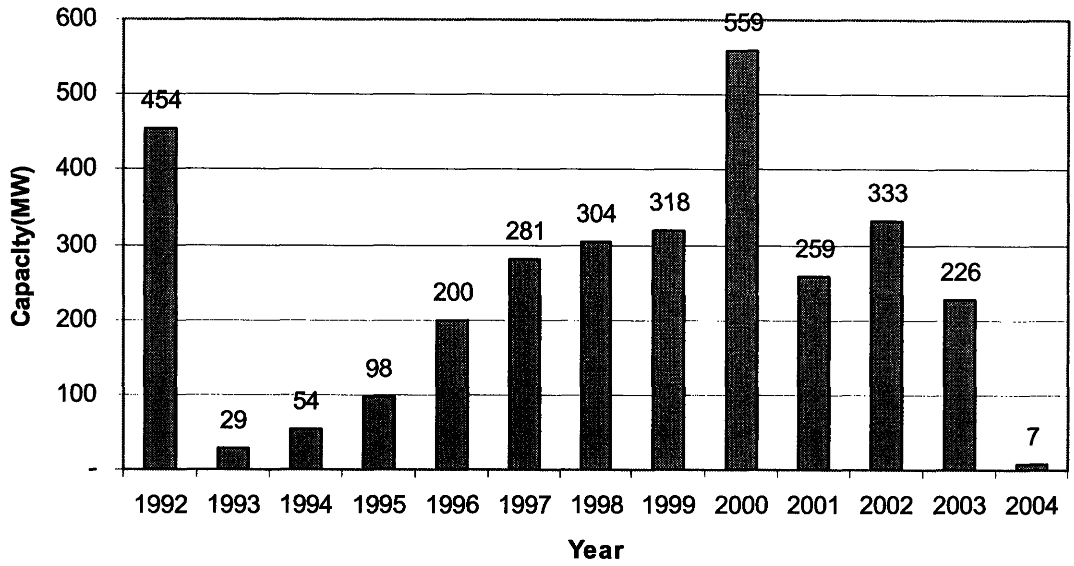



**Figure 5-5 Annual installed wind power capacity (MW) in Denmark**

(* The cumulative installation from its conception to 1992 was 454.)

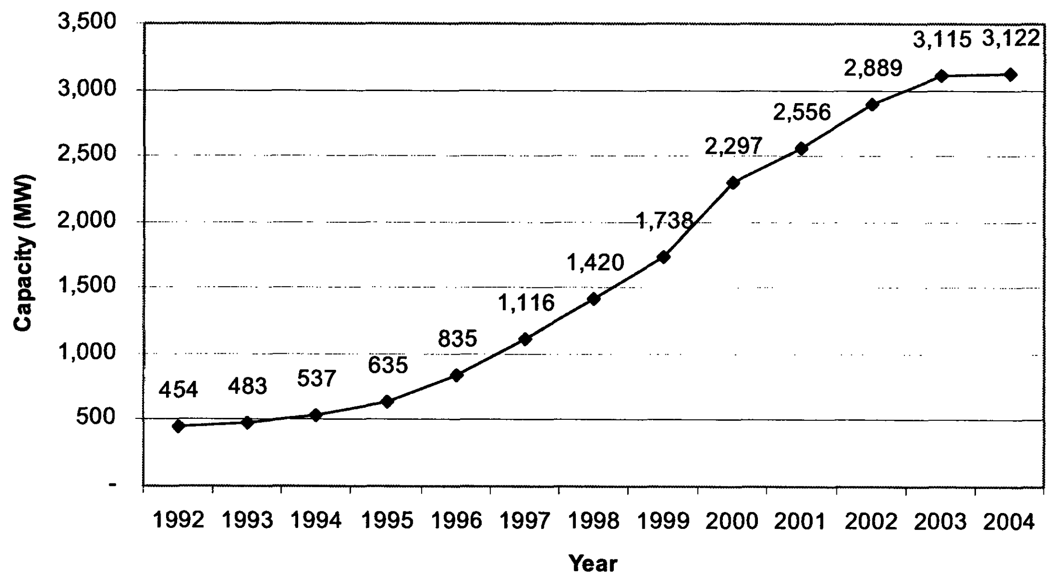



**Figure 5-6 Cumulative installed wind power capacity (MW) in Denmark**

**(1) Government commitments**[31]

One reason for the success in the Danish wind industry is the commitment from successive governments to a series of national energy plans aimed at reducing dependency on imported fuel, improving the environment, and moving towards greater sustainability. Nuclear power has been rejected as an option and there is a firm commitment to completely phase out coal as a fuel in power stations. No new coal-fired capacity will be installed. These domestic policies have in turn helped spawn a thriving export industry for wind turbines.

In 1981, the first Danish government energy plan envisaged that 10% of electricity consumption should be met with wind power by 2000. The government then expected that this could be reached by installing 60,000 wind turbines with an average capacity of 15 kW. The 10% target was in fact reached three years early with less than 5,000 turbines with an average size of 230 kW. In 2004, wind power accounted for more than 20% of Danish electricity consumption.[31]

Following a new agreement in parliament adding a total of 750 MW to existing installed capacity will, by 2010, increase the proportion to more than 25%. This is a higher proportion than any other country in the world.

By 2030 wind is expected to be supplying up to half of the country's electricity and a third of its total energy. To reach this level, a capacity in excess of 5,500 MW will need to be installed, a good proportion of it offshore.

**(2) Engineering innovation**[31]

Having already achieved more than 20% penetration, fresh challenges have emerged for wind power in Denmark, especially in the context of a new liberalized EU internal electricity market. The Danish authorities, transmission system operators, power companies and manufacturers are now working closely to find new market bases, as well as technical solutions for introducing even more wind power into the system.

An important element in the Danish success story has always been technological innovation. At a time in the 1980s when wind turbine design was locked in a "biggest is best" approach, the Danes went back to basics, using skills partly from agricultural engineering to construct smaller, more flexible machines. From the outset, the focus was customer-oriented and on making machines that produce electricity at the lowest possible cost per unit. The familiar three-bladed design with the rotor and blades set upwind (on the windy side of the tower) is now the classic concept against which all others are judged.

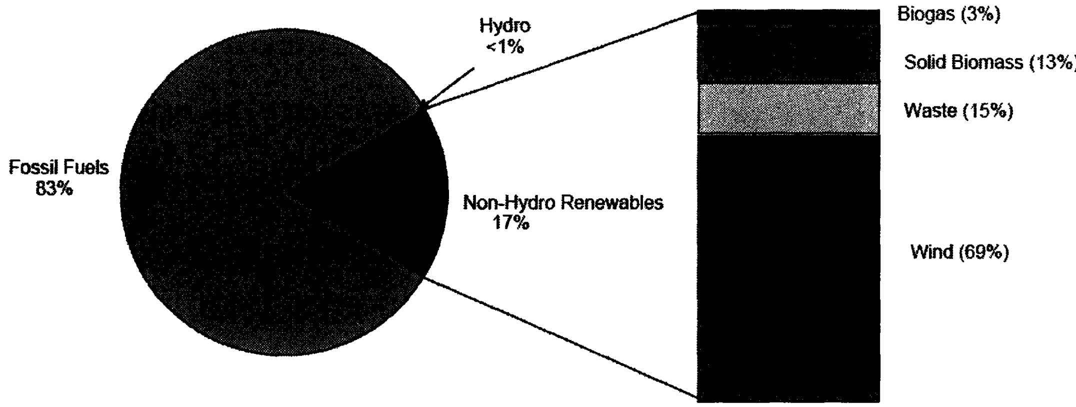
More recently, Denmark has led the world in the development of proposals to build large wind farms of turbines in its coastal waters. The first of these, at Horns Rev in the North Sea (160 MW) was built during 2002; the second, off the coast from Nysted at Roedsand Banke (158 MW), was completed in 2003. In 2007 and 2008 two new offshore wind farms of at least 200 MW will be completed. A succession of further large offshore wind farms is expected to be announced in the coming years.

Another feature of Danish development is that historically most of the turbines erected have been owned by individuals or specially established wind co-operatives. Over 150,000 Danish families now either own the firms themselves, or have shares in wind energy schemes. Even the large 40 MW Middelgrunden wind farm in the sea just outside Copenhagen is partly owned by a co-operative with 8,500 members.

### 5.2.1 Background[17]

Denmark is a small country compared with the United States, which has a population of just 5.3 million spread over a land area about twice the size of Massachusetts.[74] Although it is interconnected with the larger European electric system, its own electric grid is small relative to that of the United States. Denmark generates about 20% of its electricity from renewable sources—the largest percentage in the world.

In 2002, Denmark generated 39 billion kilowatt hours of electricity, of which 80% was from fossil fuels.(See Figure 5-7) Denmark has less than 10 MW of hydropower capacity, so the remaining 20% is from other renewable energy sources, primarily wind.[75]



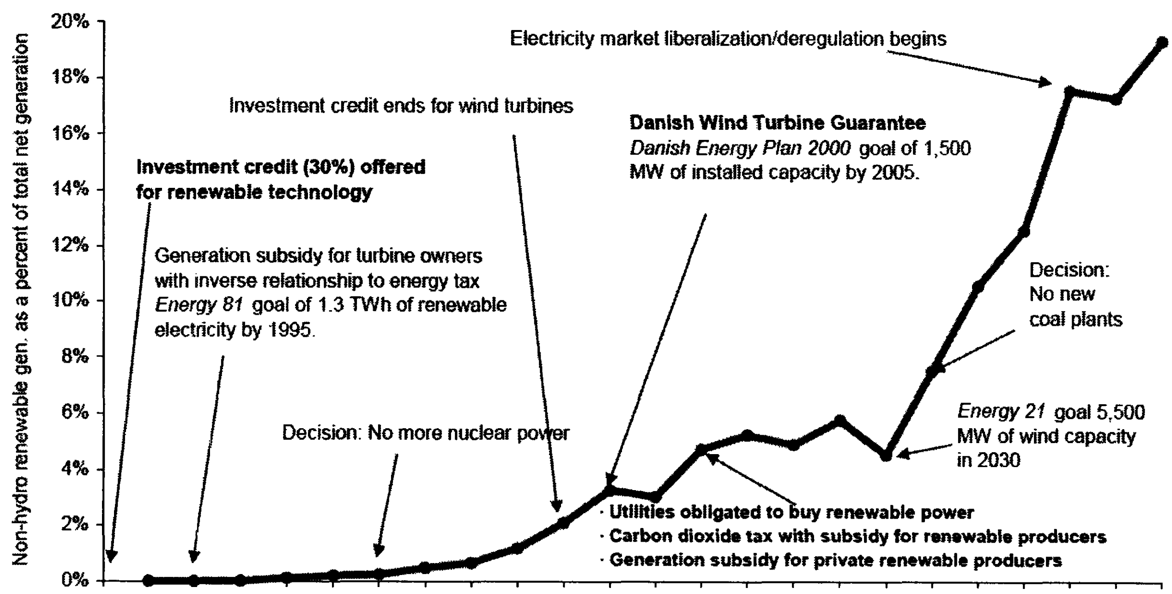

**Source:** International Energy Agency, Energy Statistics of OECD Countries, 2001-2002, OECD/IEA, 2004, Paris.

**Figure 5-7 Danish Electricity Generation, 2002**

Denmark began pursuing renewables as a source of energy in the mid-1970s as a response to high prices for oil imports. The program began with funding for research and development, but turned more toward developing the industry when, in 1979, the government began offering an investment subsidy for up to 30% of the cost of wind turbines, biogas digesters, and solar panels.[76] Although reducing Denmark's dependence on foreign oil is still relevant, this has taken a back seat to measures enacted by Denmark to protect the environment. Particularly important has been the goal of reducing carbon dioxide emissions to comply with Denmark's commitments to the European Union (EU).

Since the 1970s, the Danish government has been consistent in passing and funding its renewable energy policies, thereby fostering an environment of relative certainty for developers. Two factors drive this consistency in policymaking. First, Danes have an environmental consensus that has led them to develop energy in what they consider to be a more sustainable manner. Second, the wind industry in Denmark is developed with a system of cooperative ownership of turbines, which gives farmers and nearby landowners an interest in projects. Individuals or local cooperatives own about two-thirds of land-based wind turbines in Denmark.[77] Cooperatives have reduced local opposition and generated a voting public with a stake in the wind industry.

Denmark pursued five main policies (in bold in Figure 5-8)[78] to encourage the development of renewable energy between 1975 and 2000. In addition to these policies, Denmark also made more general energy policy decisions, such as the 1985 decision not to pursue nuclear power, that have also had implications for the development of renewable energy in Denmark.



TWh = Terawatthours
MW = Megawatts
**Sources:** Generation, Energy Information Administration, International Energy Annual; Policies, various sources compiled for and cited in this article by Office of Coal, Nuclear, Electric and Alternate Fuels, Energy Information Administration.

**Figure 5-8 Denmark's Non-hydro Renewable Energy Policies and Growth, 1979-2002**

### 5.2.2 Investment Subsidy (1979-1989)[17]

Denmark's investment subsidy allowed individuals to be reimbursed for capital costs of wind turbines, solar panels, and biogas digesters. The subsidy was available from 1979 to 1989 and declined gradually over that period from 30% to 10%.[76]

Denmark used a direct subsidy reimbursing a fixed percentage of the investment. Denmark's direct investment subsidy was successful in building its wind industry. With a properly calibrated investment subsidy, investors develop renewable energy projects to promote renewable energy rather than to save money on taxes—a major factor in the level of commitment to the efficiency of wind turbine operation.[76]

### 5.2.3 Production Subsidy and other Direct Support Mechanisms (1981 and 1992)[17]

In Denmark, the first production subsidy was introduced in 1981. It was designed to offset the energy tax for wind energy producers. In 1992, a flurry of legislation was passed which significantly benefited the wind industry. First, utilities became obligated to purchase renewable energy from private producers at a fixed price of between 70% and 85% of the retail price of electricity (a price higher than the wholesale price of privately-generated fossil fuel-fired electricity). Second, the 1981 energy tax was replaced by a carbon dioxide ($CO_2$)-based tax system and the original subsidy became a $CO_2$-related subsidy for all renewable energy technologies. The subsidy amounted to 0.10 Danish Kroner (DKK) per kWh (about 1.6 cents per kWh in 1992 or 1.2 cents per kWh in 2000) for both private producers and utilities. The net effect of this system is to increase the cost of $CO_2$-emitting generation, thereby reducing the relative cost of non-emitting renewable generation. Third, an additional production incentive was enacted for private producers of wind-generated electricity in 1992. This production incentive was an additional payment of 0.17 DKK per kWh (about 2.8 cents per kWh in 1992 or 2.1 cents per kWh in 2000). Thus, between the $CO_2$-related subsidy and the production incentive, private wind energy producers could expect 0.27 DKK per kWh (4.4 cents per kWh in 1992 or 3.3 cents per kWh in 2000) in addition to the guaranteed price paid by utilities.[76]

Although in 1992 these three policies were enacted separately, it is impossible to attribute growth in wind capacity in Denmark to any individual policy. Taken together, however, their passage in 1992 probably strongly contributed to the 30-% annual growth in wind capacity in Denmark between 1996 and 2001. The basic guaranteed pricing and utility purchase obligations in Denmark are very similar to those enacted in Germany, but the additional incentives for renewable energy producers in Denmark help to make renewable technologies more economical.

The U.S. PTC/REPI system enacted under EPACT in 1992 differs from Denmark's production subsidy in a number of crucial ways. First, the PTC has had to be renewed by Congress periodically. The original law applied to facilities constructed between 1994 and 1999. After a brief expiration period, the PTC was renewed in 1999 for 2 years, and again in 2001 for 2 years. The uncertainty about the future of the PTC is a major factor inhibiting consistent development. However, once a qualifying plant is built, the tax credit is certain for the next 10 years, even if eligibility for new plants expires. The REPI is subject to annual congressional appropriation, which has limited its effectiveness because public utilities cannot rely on revenue from REPI for financing renewables projects even for those plants that have already been built.[79]

The REPI and the PTC have certainly succeeded in increasing the installed capacity of wind turbines in the United States, from less than 2,000 MW in 1994 when the program started, to more than 5,500 MW in 2003. However, the uncertain nature of the PTC has created a boom-and-bust cycle for wind development in the United States, as large amounts of capacity are built in the year prior to the expiration of the PTC, and virtually no capacity is built when the PTC is not available. By contrast, Denmark's production subsidy remained the same from 1992 through 2000 enabling more consistent growth, and some would argue, a stronger domestic wind industry. Some changes are expected in Denmark's subsidy regime with the new green-certificate trading program that began in 2003.

An additional difference between the U.S. PTC and Denmark's generation subsidy is that while Denmark's production subsidy is a direct payment, the U.S. PTC is a tax credit. Assuming the value of the direct subsidy (after taxes) and the tax credit are the same, the tax credit scheme will favor larger, more diverse businesses if the value of the tax credit is greater than the tax liability on eligible generation. For instance, if a wind operator gets paid 3 cents per kWh for the electricity produced, pays taxes at a 33-% rate (1 cent), and is eligible for a 1.8-cent-per-kWh tax credit, the amount of the tax credit exceeds the operator's tax liability by 0.8 cents per kWh. But if the company is more diverse and is taxed on additional income from other sources, then the company is in a position to take advantage of the full tax credit.[80] In this way, the U.S. PTC puts smaller companies at a disadvantage. Denmark's generation subsidy did not have the same effect of favoring larger, more diverse companies. In fact, most wind turbines in Denmark are owned by small cooperatives. Also, contributing to local ownership were very favorable feed-in tariffs (rate paid for electricity going into the grid) and the availability of flexible financing terms provided by Danish banks.[81]

### 5.2.4 Domestic Market Support (1990-2000)[17]

In 1990, the Danish Wind Turbine Guarantee established government-guaranteed long term financing of large wind projects that used Danish-made turbines. The program significantly reduced the financial risk of building large wind projects with Danish turbines and thereby encouraged local manufacturing of wind turbines and turbine components.[82] Danish companies manufactured almost all of the wind turbine capacity installed in Denmark.[83]

In 1994, the government issued a directive to municipalities requiring them to plan for future wind turbine siting, although the directive did not create installation quotas for municipalities.[84] At the same time, the Danish government sought to reduce the public's resistance to wind turbines by subsidizing the removal of older, inefficient, or loud turbines with new machines. Finally, in 1994 and again in 1996, Parliament reduced the restrictions on which individuals can be in a wind turbine cooperative. The restrictions were originally designed to encourage many individuals to buy small shares in wind cooperatives in their neighborhoods. The loosening of the regulations reflected investors' desires to own more shares in cooperatives throughout Denmark. By 1996, Danish adults could own shares in wind cooperatives of up to 30,000 kWh.

After a slight decrease in non-hydro renewable capacity between 1990 and 1991, modest steady growth in both non-hydro renewable capacity and generation continued until 1996. Generation increased from 1 billion kWh in 1991 to 2.3 billion kWh in 1996 with a corresponding increase in capacity from 343 MW to 619 MW.[85] After 1996, however, the industry grew much more rapidly—at more than 30% per year—until at least 2002. During this period of rapid growth, no major new policies came into force, and the growth is probably due to the industry taking advantage of the incentives initiated in the early 1990s.

In the late-1990s, Denmark revealed a new energy strategy called *Energy 21*, which affirmed the 1996 targets for both carbon dioxide and wind generation capacity, but also set targets on a longer planning horizon for 2030. By 2030, Denmark wants 5,500 MW of wind generation capacity with 4,000 MW being offshore. This target corresponds to 50% of total Danish electricity demand in 2030. As of year-end 2003, wind energy supplied 21% of the Danish electricity demand.

Since 2000, Denmark has begun to turn away from guaranteed pricing and has introduced tradable green electricity certificates. Their new goal is to create a market for green power via these certificates, though the policy has not been in place long enough to evaluate the efficacy of the scheme. As a result, developments of wind power have been decreasing because of business risks. Denmark has not yet introduced the RPS system.

The dominance of Danish turbine manufacturers continues. In 2002, the two largest manufacturers of wind turbines worldwide were Vestas and NEG Micron, both Danish companies. Together they accounted for 36% of the new installations globally in 2002 and had a total accumulated installed capacity of 12,000 MW.[86] Early data indicate that the two Danish companies combined for 32% of new installations globally in 2003.[87] Vestas and NEG Micron merged in late-2003 and have continued to be major players in the world wind turbine market.[88] Another important factor in the development of the Danish wind industry was the consistent domestic market for wind turbines throughout the 1980s and 1990s.[89] Taken together, all this information suggests the policies pursued by Denmark nurtured the Danish wind industry and created companies with the ability to be dominant players in the world turbine market.

Although this program seems successful for Denmark, replication elsewhere might be difficult. The program was initially promulgated in 1990, prior to the formation of the EU. The EU determined that the Danish Wind Turbine Guarantee program created unfair competition and the scheme is no longer available within the EU.[90]

## 6. Comparison of policies in various countries that support wind power

In general, policies to promote renewables energy in Germany, Denmark, and Japan have tended to be coordinated and consistent. In the United States, many policies are enacted at the state level and may not be synchronized with federal policies, which are subject to periodic reauthorization and/or appropriations legislation.

Although Japan has enacted laws similar to successful legislation in other countries, Denmark, Germany, and the United States have increased the market penetration of wind power to an extent not yet seen in Japan. Some of the differences in outcomes for the installation of wind power are related to varying resource endowments, political and economic systems, cultural traditions, and electricity prices, but two other factors may also be important: political commitment and policy mechanisms.

### 6.1 Political Commitment

At a general level, Denmark and Germany both displayed an extraordinary level of political commitment to renewable energy that was both consistent and well funded. Additionally, Denmark, Japan, and Germany enacted policies expressly for the purpose of promoting renewable energy—something the United States did not do until 1992 with the passage of EPACT.

Renewable energy targets are most effective if they are based on a percentage of a nation's total electricity consumption. Denmark and Germany set highly the Renewable Source Target for 2010. Setting targets does not in itself lead to any expansion of wind power and other renewable energy sources. But, as very well demonstrated by the indicative targets, they serve as a very important catalyst for governments to take action and develop the necessary regulatory frameworks to expand renewable energy.

One outward manifestation of the political commitment displayed in Denmark was the setting of ambitious goals for renewable energy—but, more importantly, the government enacted policies to enable the industry to meet its goals. For instance, Denmark's first renewable energy goal, set in 1981 when the government began subsidizing production from wind turbines, called for the production of 1.3 billion kWh of electricity from renewables by 1995, a goal that was met by 1993. In 1990, the Danish government again set a renewable energy goal, this time of installing 1,500 MW of capacity by 2005, a goal met in 1998. The 1990 goal, articulated in the *Danish Energy Plan 2000*, was supported by generation subsidies, $CO_2$-related subsidies, and guaranteed pricing policies introduced in Denmark in 1992. The structure of these subsidies further confirms Denmark's commitment to renewable energy as the subsidies are guaranteed over the long-term and do not need to be regularly reviewed by the government. Finally, in its *Energy 21* policy unveiled in 1996, Denmark set a goal of 5,500 MW of renewable capacity by 2030 and had achieved more than 3,100 MW by the end of 2003. The consistency with which Denmark has met its goals ahead of schedule gave confidence to wind industry developers and financiers that the government was committed to encouraging the development of renewable energy.

Germany set few goals expressly for developing renewable energy but did begin setting $CO_2$-related goals in 1990 and generally articulated a commitment to renewable energy as a way of reaching $CO_2$ reduction targets. This text from a Cabinet Decision on November 7, 1990 illustrates this commitment: "The Federal Government reaffirms its call for the longer-term economic potential of renewable energy sources to be tapped as rapidly as possible in light of the contribution they could make to $CO_2$ reduction…the Federal Government will continue to work towards making it easier for renewable energy sources to gain a foothold in the market." Germany followed up this $CO_2$ goal with the 1991 Feed-In Law, which was successful in significantly increasing the installed renewable capacity in Germany.

Japan's political commitment to renewables has been strong and consistent over time. The Japanese government introduced a Renewable Portfolio Standard (RPS) law in April 2003 with the aim of stimulating renewable energy to provide 1.35% of total electricity supply in 2010.

However, the law has a number of weaknesses, including a very low target (almost one tenth of Germany's), the inclusion of electricity generated by waste incineration as " renewable," and insufficient market incentives.

Overall, based on these two examples, the country that displayed the most success in meeting its goals, Denmark, gets a high percentage of its electricity from renewable sources, and Germany, a country that has displayed its political commitment in other ways, has the highest installed wind capacity in the world. These two countries are located in areas conducive to producing wind power efficiently. In addition, their governments have shown support by having consistent policies that involve renewable energy. Japan's success at installing PV capacity in the 1990s is also likely related to the government's political commitment to both R&D and market support mechanisms, but its ability to achieve its recent renewable energy goals may have been hampered by political and regulatory inconsistency.

### 6.2 Policies Affecting Wind power

The manner in which each country views renewable energy affects the way its policies are structured. The EU and Japan treat renewable energy as a strategic interest, creating numerous inter-related policies designed specifically to encourage the development of renewables. In Denmark and Germany, the stated purpose of the Feed-In-type laws enacted to support the development of wind power was to encourage the growth of renewable energy. PURPA, the U.S. counterpart to these policies, was less narrowly focused on renewables, as its original stated purpose was to encourage energy conservation and efficiency in the electric utility sector.

A second element to a policy's structure is its method of implementation. Germany and Denmark dictated the price that utilities were required to pay for renewable energy. Germany and Denmark also used a variety of financial incentives in addition to this command-and-control approach. The United States also turned to financial incentives with the PTC and REPI in 1992.

The method of implementation is crucial for how policy is enacted—voluntary programs, which cannot be enforced, are more difficult to implement.

A clear market for wind generated power must be defined in order for a project developer to enter. As with any other investment, the lower the risk to the investor, the lower the costs of supplying the product. The most important measures for establishing new wind power markets are therefore those where the market for generated power is clearly defined in national laws, as well as providing stable, long term fiscal measures, low investor risk and a sufficient return on investment.

In order to attract wind power companies to establish manufacturing facilities, markets need to be strong, stable and reliable, with a clear commitment to long-term expansion. A number of mechanisms have been introduced in different countries to further these aims.

Overall, there are two types of incentives to promote deployment of renewable energy:

1. **Price-Based Systems** where the government sets the electricity prices (or premiums) paid to the producer and lets the market determine the quantity.
2. **Renewable Quota Systems** (in the USA and Japan referred to as Renewable Portfolio Standards) where the government sets the quantity of renewable electricity and leaves it to the market to determine the price.

There are many variants of the price-based system. The term is rather misleading as not all of them actually fix the total price per kWh paid to the producer but for analytical purposes it is valuable to make a distinction between fixed prices and fixed quantities: Investment Subsidies, Fixed Feed-in Tariffs, Fixed Premium Systems, and Tax Credits.

Two types of renewable quota systems have been employed in national wind power markets: Tendering Systems and Green Certificate Systems.

At a national level, Japan and the United States are currently somewhere in between with its dual system of fixed prices and fixed quantities systems, while a majority of countries on the European Continent lean towards fixing prices. In Japan, the investment subsidy is a price-based system and the RPS is fixed quantities system. In the United States, the federal tax credit is a fixed price-based system and renewable quotas are fixed quantities systems at the state level.

### 6.2.1. Price-Based Systems

#### (1) Investment subsidies

Usually, investment subsidies are given on the basis of the rated power (in kW) of the generator. If used in isolation, these systems can be problematic because a subsidy is given whether or not production is efficient. In some countries investment subsidies have in the past resulted in poor siting of wind turbines, and manufacturers followed customer demands to use larger generators than necessary for optimal production of electricity. It improved project profitability but reduced production, because the turbines were not optimally designed.

Systems that base the amount of support on generator size rather than on electricity output are problematic because they lead to less efficient technology development. Any incentive should be related to efficiency of producing power rather than efficiency in completing the construction phase. For wind energy, the global trend is to reject investment subsidies as the only means of encouraging wind power investments.

However, investment subsidies can be effective if combined with other incentives as in the UK. In order to take account of the current higher cost of offshore wind power compared to the more mature onshore market, the British government offers investment grants to offshore projects to complement the ROC (Renewable Obligation Credits) system (a renewable quota system).

In Japan, to promote the introduction of the wind power energy, the Japanese government subsidized the developers. For the construction cost of new wind power stations, the government would subsidize 25% of the construction cost for private companies and 50% for municipal corporations.

**(2) Fixed feed-in tariff systems**

Mechanisms based on fixed feed-in tariffs (FIT) have been widely adopted throughout Europe and have proved very successful in expanding wind energy in Germany, Spain and Denmark. Operators of wind farms are paid a fixed price for every kWh of electricity they feed into the grid. In Germany, legislation fixes the price of electricity from renewable energy in relation to the generation costs of renewable technologies. The price will decrease 2% each year. A key characteristic of the price-based system is that the government sets a price on the societal value of generating a significant share of renewable energy in the electricity system.

As production costs decline, for instance as a result of improved technology and economies of scale, lower wind speed sites become profitable, expanding wind power further. Fixed feed-in tariff systems encourage competition among wind turbine manufacturers, pressuring them to produce ever more cost effective turbines and thus lower the cost to society of expanding wind power.

The most important advantage of Price-Based Systems is that they enable investors to plan ahead for new renewable energy plant. The main benefit of fixed feed-in tariffs is that they are simple and often encourage better planning.

They are not associated with a formal Power Purchase Agreement (PPA) and have no definite term. In principle, therefore, the level of the tariff can be changed at any time or removed by repealing the Law. The disadvantage is the political uncertainty that may arise over how long the system will continue, which means that investors must calculate a risk premium in case the price falls during the life of the project. Germany has been able to reduce much of the political risk by guaranteeing tariffs for 20 years.

**(3) Fixed premium systems**

A "Fixed Premium" or "Environmental Bonus" mechanism is another variant of the price-based system. Rather than fixing the total price paid, the government fixes a premium to be added to the electricity price. In principle, a mechanism that is based on a fixed premium/environmental bonus that reflects the external costs of conventional power generation could establish fair trade, fair competition and level the playing field in the Internal Electricity Market between renewable energy sources and conventional power sources.

Together with taxing all power sources in accordance with their environmental impact, fixed premium systems are theoretically the most effective way of internalizing external costs. In reality, however, fixed premiums for renewable energy technologies are based on estimated renewable electricity production costs and comparison with the electricity price rather than the environmental benefit of the renewable energy source compared to conventional power technologies.

**(4) Tax credits**

A tax credit is another variant of the price-based system. Whether an incentive is given in the form of a tax credit or a cash payment does not make a big difference from a socio-economic or investor perspective. But politically it can make a difference whether an incentive is paid by the electricity consumer or by the taxpayer. The largest wind power market to make use of a tax credit is the United States. The United States market is driven by a federal Production Tax Credit (PTC) of approximately 1.8 cents per kWh. It is adjusted annually to take inflation into account.

### 6.2.2. Renewable Quota Systems

#### (1) Competitive bidding, tendering

Tendering systems or competitive bidding has been/are used to promote wind power in France (for wind farms larger than 12 MW) and the UK. Japan has also made use of the mechanism since 2003 and the Danish government is finalizing a tender procedure for the future development of offshore wind power.

Developers of wind farm projects are invited to bid for a limited wind energy capacity in a given period. The companies that bid to supply electricity at the lowest costs win the contracts to do so. Usually 15 to 20-year power purchase agreements are entered into. The difference in price between these contracts and the price of conventional power represents the additional costs of producing green electricity. Allocation of development rights is usually achieved by letting the suppliers of electricity from renewable energy sources (the wind turbine owners) compete for the power purchase agreements.

The system removes much of the political risk for investors as the price is agreed upon for a defined period, and the power purchase agreement is enforced under civil law. However, investors are faced with another risk element under tendering. All developers who enter a bid risk losing the planning costs if the bid is not accepted or if planning permission is not given on the location in question.

Therefore, the model may be better suited for large projects than small ones. Furthermore, the method tends to only encourage development of the most economic (windy) sites. From an electricity systems integration point of view, a reasonable geographical spread of wind power is a clear advantage, as it reduces the balancing costs of the system.

One of the major drawbacks of the tenders made so far, e.g. in the UK, has been that they have encouraged ‘gaming’ of the system. Renewable energy technologies get cheaper over time. Therefore, a contract holder will wait as long as possible to build a project. Partly because of this inherent flaw, the British NFFO (Non-Fossil Fuel Obligation) tender system did not result in many projects being built. Another flaw of the NFFO model was that it did not penalize developers if they failed to install the capacity for which they had secured a power purchase contract.

Therefore, the model should be combined with a performance bond and meaningful penalties for failing to meet the contract. Tendering systems with high penalty clauses appear to be economically efficient, but they are probably only workable for large investors, and not smaller operators such as cooperatives or individual owners, at least not unless they are part of a larger risk-sharing arrangement through a joint project organization. Experience has shown that the aggressive competition created for lowest price leaves only small margins that will deter investors and force developers to use only the highest wind resource sites.

**(2) Tradable green certificates**

A tradable Green Certificate Systems (TGC) is, in principle, the same as the tendering system described above. The main difference is that the price for the power and certificates are settled on a daily basis on the electricity market alongside a separate market for tradable certificates (tendering systems are typically based on 15-20 year power purchase agreements). With daily settling of prices the TGC model is more risky for the investor unless an effective market for long-term certificates contracts (probably financial futures or options) is developed.

Under a TGC system, the government sets a specific and gradually increasing quantity – or minimum limit – for the amount of renewable electricity in the supply portfolio. An obligation is placed on either the electricity suppliers or end users of electricity. The generators (producers), wholesalers, retailers or consumers (depending who is obligated in the electricity supply chain) are obligated to supply / consume a certain percentage of electricity from renewable energy sources. At the settlement date, they have to submit the required number of certificates to demonstrate compliance.

The TGC mechanism is more complex in nature than other payment mechanisms. Wind turbine operators will have to be active in two interrelated financial markets: one for TGCs and one for power. One of the challenges in developing such systems is that there seems to be an asymmetry between the demand and the supply side in the markets. Wind turbine owners would prefer to have as long contracts as possible to minimize risk, while the electricity companies on the demand side seem to prefer short contracts. Another aspect to consider is whether all renewables technologies should be included in a single "umbrella certificate" or whether a certificate for each technology is the answer. One certificate only ensures development of the cheapest renewable energy technology, while several certificates will result in markets with dangerously low liquidity, at least in the beginning of development.

As with the auction / tender model, it is important to introduce penalties for not purchasing green certificates that are sufficiently high to deter non-compliance.

One drawback of a system with fixed quantities of renewables is that the speed with which they are introduced into the electricity supply system is largely independent of technical progress and the increasing efficiency of using renewables, and hence could become a cap on development.

## 7. Issues hindering the promotion of wind power in Japan

There are differences in how renewable energy is promoted because of the various policies as discussed in Chapter 6. To promote the development of wind power in Japan according to the 2010 schedule, there are three major issues that need to be resolved.

First is an issue of present policies, and second is an issue of capacity limits when transmitting power from the wind farm to utility companies because of intermittency, and third is an issue of Japan being a densely populated country.

### 7.1 Issues regarding present policies in Japan

In Japan, "The Special Measures Law concerning the Use of New Energy by Electric Utilities" (Renewable Portfolio Standard (RPS) law), which is the fixed quantity type, has been enforced since April, 2003. Even though this law was supposed to promote renewable energy in Japan, it has, in actuality, hindered the whole process.

The fixed-price policies, which have been introduced in Germany and Denmark, have promoted the popularity of renewable energy. However, the fixed-quantity policies, which have been introduced in England and Japan, have hindered the promotion of renewable energy in those countries. The reasons why this situation has occurred in Japan are as follows:

(1) The target is very low: According to the law, different types of renewable energy must provide 1.35% of the total electricity supply by 2010.

(2) Only 10 utility companies dominate over 99% of the electric power market, therefore there isn't any "liquidity of the market "at all in Japan. Each company controls a different geographical area in Japan which eliminates any chance for competition among the companies in this monopoly-like environment.

(3) The RPS law includes electricity generated by waste incineration as to be labeled "renewable energy"; most countries do not classify this type of energy as "renewables ".

(4) All renewable energy is lumped into one category and set at the same price even when the cost of producing different sources of renewable energy varies.

### 7.2 Issues of the Grid in Japan

In Japan, the accumulated capacity of wind power has reached almost 1,420 MW, including the capacity that has already been negotiated in PPAs . There are three regions that have purchased 75% of this energy. The three regions are Tohoku, Kyushu, and Hokkaido. These areas are prone to higher winds, and as a result, wind farms have been concentrated in these regions. Recently, these three utility companies have mentioned that there is a limitation of acceptance of wind power because this type of energy is intermittent. This is hindering more development of wind power in those regions.

Moreover, the electricity from renewable energy sources is categorized as a privately negotiated transaction. Therefore the decisions of the connection have been entrusted to the electric utility companies that own the system. Because the utility companies are so big and powerful, they end up making the final decisions during such negotiations.

A uniquely characterized transmission network system and pricing methodology are critical issues for Japan's electric power industry. Unlike the EU transmission network, which is structured geographically, with hubs and spokes connecting all points on the network grid, the Japanese network is like a belt extending down a long, narrow strip of land, connecting independent service regions from north to south. Figure 7-1 shows how the Japanese grid is unique in its belt-like transmission lines. The black dots indicate the connecting points of the different utility franchise. The gray lines show where two or more utilities are connected. Each EPCO's franchise region is strongly independent, and adjacent regions are connected by one AC interregional connection line and one supplemental DC connection line.

One of the most notable challenges concerns the weakness of the interregional connections between adjacent EPCOs' franchise regions. Since networking inside each franchise is tremendously strong and independent, and the annual power exchanged over interregional connection lines is very small (6 – 7% of the total power generated), transmission capacity on the interconnection lines is currently adequate. The weak connections could become a serious problem, however, if many new generation plants are constructed by IPPs such as wind power companies to more vigorously import and export energy between regions.

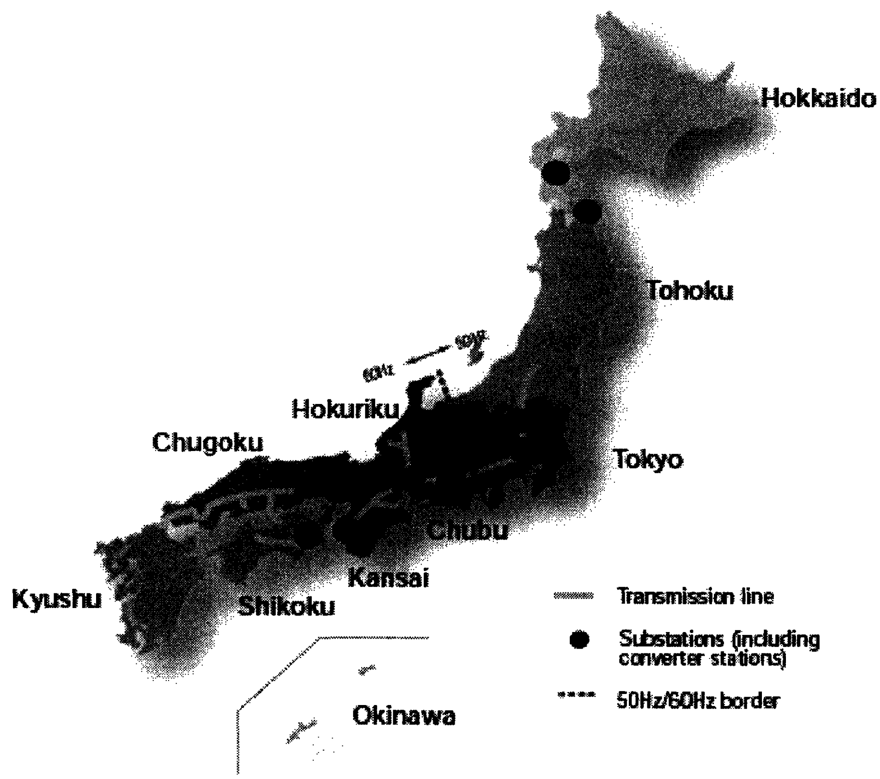



**Figure 7-1 Regional utility service areas and connected transmission grids in Japan**

As for the wind power, the output changes depending on wind condition. In addition, there are areas where transmission ability of a power transmission line is small even if wind condition is good. It is necessary to solve a problem with grid connection of wind-generated electricity to plan large-scale introduction. There are two issues that affect the acceptance of wind power in Japan. One is a technical limitation involving the capacity of each grid. The other involves the monopoly-like structure of the 10 utility companies (EPCO).

### 7.3 Issues of the densely populated country

Most areas that have optimum wind conditions are densely populated so this limits the construction of new wind farms. Due to the success that European nations have had with off-shore wind farms and the projected future growth in this market, Japan needs to think about how to enter this market in order to increase production of wind power. Japan has to realize that offshore wind farm construction must happen if wind power is going to make an impact on overall electricity consumption in the future.

## 8. Conclusion -Proposals for promoting wind power in Japan

After reviewing many policies in other countries regarding wind power and considering Japan's situation, there are ways that Japan can promote wind power that would meet the proposed targets that were decided on by the Japanese government. There are many different perspectives when analyzing renewable energy, but there are two key issues that Japan needs to take into consideration. The first is support schemes for renewable energy promoted by the government that would ultimately encourage new wind power companies to enter the energy market. The second is the improvement of grid issues specifically related to Japan. In addition, I would like Japan to consider using more off-shore wind power.

### 8.1 Components of a wind policy

The following suggestions are based on the review of wind power policies in other countries. My hope is that these proposals will initiate important discussion and ultimately the implementation of new ways to support and utilize wind power in Japan. With further research and analysis, these new ways of looking at and using wind power in Japan can change from being an idea on paper to being realized in Japan.

**Proposal 1: Introduce Fixed feed-in tariff systems into Japan instead of RPS**

As discussed previously, the issues concerning RPS have already been addressed. The target in RPS is very low and monetary risks are involved in future wind firm investments, therefore renewable energy has not been encouraged. If the fixed feed-in tariff system is introduced to Japan, many new wind power companies would be able to establish wind farms because these companies would be able to estimate future revenue. With the current system, wind power companies have to negotiate in Power Purchase Agreement (PPA) with one of the utility companies. The utility company ends up having leverage over the wind power company and has a stronger voice in issues such as price, amount of accepted wind energy, and the cost of connecting to existing transmission grids.

On the other hand, Germany and Denmark, leaders in the wind power, have introduced the fixed feed-in tariffs (FIT) system. As a result, the production and sale of wind power has dramatically increased. The success of this increase is based on FIT, and after reviewing the logistics of this system in European countries, it seems feasible for Japan to adopt this policy.

Mechanisms based on fixed feed-in tariffs (FIT) have been widely adopted throughout Europe and have proved very successful in expanding wind energy in Germany, Spain and Denmark. Operators of wind farms are paid a fixed price for every kWh of electricity they feed into the grid. In Germany, legislation fixes the price of electricity from renewable energy in relation to the generation costs of renewable technologies. The price will decrease 2% each year. A key characteristic of the price-based system is that the government sets a price on the societal value of generating a significant share of renewable energy in the electricity system.

As production costs decline, for instance as a result of improved technology and economies of scale, lower wind speed sites become profitable, expanding wind power further. Fixed feed-in tariff systems encourage competition among wind turbine manufacturers, pressuring them to produce ever more cost effective turbines and thus lowering the cost to society of expanding wind power. The most important advantage of Price-Based Systems is that they enable investors to plan ahead for new renewable energy plants. The challenge in a price-based system is fixing, or setting, the "right" price.

The main benefit of fixed feed-in tariffs is that they are simple and often encourage better planning. They are not associated with a formal PPA, so terms do not have to be negotiated. In principle, therefore, the level of the tariff can be changed at any time or removed by repealing the law. The disadvantage is the political uncertainty that may arise over how long the system will continue, which means that investors must calculate a risk premium in case the price falls during the life of the project. Germany has been able to reduce much of the political risk by guaranteeing tariffs for 20 years. If Japan follows the model Germany has been using, this disadvantage is no longer a major problem.

**Proposal 2: Strategies to improve grid connections**

There are two issues that affect the acceptance of wind power in Japan. One is a technical limitation involving the capacity of each grid. The other involves the monopoly-like structure of the 10 utility companies (EPCO). Because of this tight system, and the policies they follow regarding wind power, it is very difficult for these new companies to enter this closed market.

A uniquely characterized transmission network system and the system of setting prices for electricity are two critical issues for Japan's electric power industry. In order for wind power to increase in Japan, these issues have to be addressed and changes need to take place. Unlike the U.S. transmission network, which is structured geographically, with hubs and spokes connecting all points on the network grid, the Japanese network is like a belt extending down along, narrow strip of land, connecting independent service regions from north to south. Each of the EPCO franchise region is strongly independent, and adjacent regions are connected by one AC interregional connection line and one supplemental DC connection line. Because of the unique nature of the grids in Japan, they are much smaller than those in Europe or the US. The small grids are limited when it comes to accepting intermittent electricity such as wind power. If too much fractured electricity is accepted into a grid at one time, the output of electricity is compromised.

Utility companies in three regions of Japan have mentioned this aspect of fractured electricity. The total cumulative wind power that was produced in Japan was 900MW. There were three regions that purchased 75% of this energy. The three regions were Tohoku, Kyushu, and Hokkaido. These areas are prone to higher winds, and as a result, wind farms have been concentrated in these regions. Recently, these three utility companies have mentioned that there is a limitation of acceptance of wind power because it is intermittent. This is hindering more development of wind power in those regions.

In order to work around the limitation of the capacity of intermittent electricity that grids can hold, I propose that storage batteries be introduced and connected to the wind farms. If storage batteries are used in conjunction with the production of wind power, they will improve the fractured nature of wind-generated electricity and maximize the usage of wind power. If storage batteries are introduced, the wind farms avoid impacting the grid during times of low demand. As a result, the limitations that have been imposed by the utility companies could be lifted. No longer would fractured energy be an issue. Wind power could be delivered in a steady, reliable fashion. Now, the cost of storage batteries is still high, so they have yet to be used in Japan. The commercial use of these batteries is increasing, so many companies have entered this market and improvement of the product is on-going. If producers of wind power used these batteries, the cost of the batteries would go down. This same phenomenon has been seen with the wind turbines; price has gone down, while quality has improved.

The second major issue that the power industry has to face is that of monopolization. The nine utility companies in Japan have monopolized the power industry and because of the present structure, new companies, such as wind farms, have a difficult time entering this market. Because there is a lack of information that can easily be accessed, these new companies do not know how much wind power a particular utility company can accept.

I propose that this information be readily available to all stake holders, so there will be an element of competition that has yet to be introduced into these utility companies. If the guidelines and rules are standard for all of these independent, yet cohesive, utility companies, it will be easier for additional companies such as those that produce wind power, to negotiate with these giants. The utility companies should come together and publish information such as how much wind power a particular grid can accept and the cost of connecting to the grid. If these companies initially had this information, they would be able to evaluate more easily the feasibility of future projects. As it stands now, the wind power companies do not have this information, so it is hard for them to commit to future ventures. It is important for future projects to be in the works because of Japan's commitment to the environment through the Kyoto Protocol. Meeting the reduced $CO_2$ emissions target set by the Japanese government can only be attained if the commitment to renewable energy sources, such as wind power, becomes more commonplace than it is now. The utility companies need to revisit how wind power is developed and purchased and figure out a way to support these companies. If the information about each utility grid is easily accessible in book form, as previously mentioned, this will show the commitment the utility companies have to the future of renewable energy. In order for wind power to be successful, there has to be a healthy working relationship among the utility companies, wind farms, and the government.

**Proposal 3: Encourage more off-shore wind farms**

European nations are also leaders in the off-shore wind farm market. Offshore sites are the new frontier for the wind industry. In northern Europe alone, many thousands of megawatts of capacity are planned off the coasts of a dozen countries. Eventually, this new offshore business could challenge the oil and gas producers on their home territory.

The main motivation for going offshore stems from the considerably higher and more predictable wind speeds to be found out at sea. With average speeds well above 8 meters per second at a height of 60 meters, most of the marine sites being considered in northern European waters are expected to deliver between 20% and 40% more energy than good shoreline sites.

A second advantage is that placing wind farms offshore reduces their impact on the environment of residential areas.

It is currently more expensive to build wind turbines out at sea. Offshore wind farms require strong foundations which must be firmly lodged into the sea bed.

Many kilometers of cabling is required to bring power back to shore, and both construction and maintenance work must be carried out in reasonable weather conditions using specialist boats and equipment. Nonetheless, as demand for this new energy increases, the industry is beginning to substitute expensive specialized components in prototypes with cheaper standard components and facilities, driving down electricity costs, as has happened on land.

By the end of 2004 a total of almost 600 MW of offshore capacity had been installed around the coastlines and large inland waters of five European countries – Denmark, the UK, Sweden, the Netherlands, and Ireland. The largest of these, at Nysted in Denmark, has a capacity of 165.6 MW.

In the future, however, much larger offshore projects are envisioned, with total capacities rising to above 1,000 MW and with individual turbines in a size ranging up to 5 MW. These would benefit from economies of scale and would result in a reduction in unit production cost.

The targets set and licenses issued by a number of European countries show the expectation for substantial growth in the offshore market over the next 20-25 years. Among the eight leading nations with offshore plans, the aim is for a total of more than 50 GW of capacity to be installed over the next 25 years. The target set by the European Wind Energy Association is for 70 GW by 2020.

Due to the success that European nations have had with off-shore wind farms and the projected future growth in this market, Japan needs to think about how to enter this market so as not to be left behind. It would be beneficial for Japan to invest in this aspect of wind power for a number of reasons. The first reason is that Japan is surrounded by sea water, so using the ocean is easily accessible. Japan is very small, so land resources are limited and may be hinder the promotion of wind power. Building wind farms off shore would give companies a chance to increase production of energy while keeping in mind environment targets that have been set by the government. Another reason why Japan would benefit from off-shore wind farms is that many companies have expertise in working in and around water, such as constructing seaports and bridges, that all of the technical knowledge and resources are locally available. The off-shore wind farms would generate jobs for related companies. A third reason why Japan should consider this type of energy is that the off-shore wind farms are far from residential areas. When energy is being produced, it can be a noisy production. Having off-shore wind farms would separate the farms from residents.

Because of all the benefits of off-shore wind farms, I propose that off-shore wind farm development be promoted and encouraged.

### 8.2 Economic analysis of Japanese wind policies

Wind power generation is one kind of the renewable energy where the technology has reached a commercial level. The unit size of the generator has been developed to produce up to 2000kW, which has helped to reduce the generating cost. The potential capacity for the wind power development in Japan is estimated to be about 20,000MW by NEDO. Now, the cost for construction is 190,000yen/Kw. The generating cost per kWh is 8 to 10 yen/kWh for large scale development. At this time, the generating cost of wind power is still higher than that of conventional power such as thermal or nuclear. To promote the introduction of wind power energy, the Japanese government has given subsidies to the developers of wind power energy. For the construction cost of new wind power stations, the government subsidizes 25% of the construction cost for private companies and 50% for municipal corporations. NEDO estimates that the cost reduction for generating wind power can be achieved by a scaling up of the equipment and the expansion of production through technological development.

**Table 8-1 Cost estimates by NEDO**

| Year | 2004 | 2010 | 2020 | 2030 |
|---|---|---|---|---|
| Target capacity(MW) | - | 3,000 | 10,000 | 20,000 |
| Construction cost (yen/kW) | 190,000 | 150,000 | 120,000 | 100,000 |
| Generating cost(yen/kWh) | 10 | 8 | 5 | 4 |

In the following part, I will examine the generating costs and subsidies to promote wind power. A comparison of generating costs based on conditions set by METI is as follows.[91, 92]

**Table 8-2 Comparison of generating cost**

| | Life time (year) | Availability factor (%) | Capacity (MW) | Generating cost (yen/kWh) | $CO_2$ emissions ($g\text{-}CO_2/kWh$) |
|---|---|---|---|---|---|
| Wind | 17 | 30 | 30 | 10.0 | 29 |
| Hydro | 40 | 45 | 15 | 11.9 | 11 |
| Oil | 40 | 80 | 400 | 10.7 | 742 |
| LNG | 40 | 80 | 1,500 | 6.2 | 608 |
| Coal | 40 | 80 | 900 | 5.7 | 975 |
| Nuclear | 40 | 80 | 1,300 | 5.3 | 22 |

In the above comparison, the cost of LNG, coal, and nuclear energy are lower than the others. The generating costs of coal and nuclear energy are more stable compared to oil and LNG because the prices of the resources rarely fluctuate. This allows for a stable price when calculating generating costs. Therefore, the Japanese government has been encouraging the development of nuclear power because the cost is cheap and stable. In addition, the $CO_2$ emission is low. As mentioned before, however, the development of nuclear power has been delayed. Because of this, the promotion of renewable energy should become more important so that Japan can meet the 2010 target of the Kyoto Protocol.

I will compare the cost of wind power and coal thermal power. The comparison only includes coal thermal power because the cost is inexpensive and rarely fluctuates. There is a prediction that if the production of coal thermal energy increases, a $CO_2$ emission market will evolve. Here, I predicted that one ton of $CO_2$ emissions could be traded for 5,850 yen/t- $CO_2$ (the equivalent of about $50/t- $CO_2$) and 11,700 yen/t- $CO_2$ (the equivalent of about $100/t- $CO_2$). If this is the case, the production of coal thermal energy in Japan will end up costing much more than it does today. The additional costs will be 6 yen/kWh and 12 yen/kWh. Using the information in table 8-2, I came up with the costs in table 8-3.

**Table 8-3 Analysis of additional costs related to $CO_2$ emissions**

| | Generating cost (yen/kWh) | $CO_2$ emissions (g-$CO_2$/kWh) | Predicted price of $CO_2$ trading (yen/t- $CO_2$) | Additional cost with $CO_2$ trading (yen/kWh) | Total generating cost (yen/kWh) |
|---|---|---|---|---|---|
| Wind | 10.0 | 29 | 5,850-11,700 | 0 | 10.0 |
| Coal | 5.7 | 975 | 5,850 | 5.7 | 11.4 |
| Coal | 5.7 | 975 | 11,700 | 12.0 | 17.7 |

If the $CO_2$ market evolves, and the generating cost of coal increases because of its $CO_2$ emission, wind power energy will no longer be the most expensive energy source.

The following are additional costs to the Japanese economy related to my proposal for promoting wind generated power in Japan to meet the 2010 targets set in the Kyoto Protocol. The target capacity of wind power is set at 3,000 MW by 2010. Right now, the cumulative capacity is 900 MW. In order to meet the intended goal, 2,100 MW still has to be generated. The table 8-4 shows the amount of additional monetary support the wind power developers would need from the Japanese government to spur the speedy development of new wind farms. Right now, there are many obstacles hindering the development of wind power. If wind power developers could see a solid commitment from the Japanese government in the form of subsidies, this would encourage more investment in the wind power sector.

**Table 8-4 Analysis of additional subsidy (2005-2010)**

| | Subsidy of the construction cost (25%) (million yen) | Subsidy of the generating cost (4 yen/kWh) (million yen) | Subsidy of the additional cost of Batteries (6 yen/kWh) (million yen) |
|---|---|---|---|
| Remaining capacity - 2,100 MW | 78,750 | | |
| Calculated generating power-27,600 (GWh) | | 110,376 | 165,564 |
| **Total subsidy** | | | **354,690** |

The one subsidy that the government offers is giving 25% of the total construction cost, including transmission lines, to the wind power developer.

One additional subsidy that I propose the government establish is related to the fixed feed-in tariff system. The government should pay the electric utility company 4 yen/kWh. This will entice the utility companies to be more willing participants in the wind power arena. In addition to the subsidy of 4 yen/kWh, the utility companies will pay 6 yen/kWh which is reasonable price for comparing to the cost of coal thermal energy, for a total cost of 10 yen/kWh.

The other additional subsidy that I propose the government establish is related to the cost of the batteries which store wind energy producing a counter-measure for problem of intermittency. The subsidy should be 6 yen/kWh. With all of the costs taken into account, the final cost of wind generated power would be 17 yen/kWh if the two additional subsidies that I propose are realized.

The cost of coal thermal energy, when factoring in the $CO_2$ trade market, ends up being 18 yen/kWh in the case that its cost will be 11,700 yen/t- $CO_2$ (the equivalent of about $100/t- $CO_2$). Therefore, it is conceivable to estimate that wind power will end up costing less than coal thermal energy if the government can see the big picture and makes all of the necessary changes to the present-day situation of renewable energy.

Until now the Japanese government has encouraged the development of Monju, a nuclear power plant, by ear-marking annual monies for the initial construction and on-going operating and maintenance costs. One of the most famous nuclear power stations, Monju is Japan's only fast breeder reactor. Located in Tsuruga, Fukui Prefecture in Japan, construction began on the reactor in 1985 and the generation of power started in 1995. Monju is a sodium-cooled, MOX-fueled loop type reactor that has a maximum capacity of 280 MW. The Japanese government has spent 800 billion yen on this reactor so far. And as of 2006, Monju has been closed following a serious sodium leak and fire in 1996. It is expected to reopen in 2008. The necessary renovations needed in order to reopen the plant will cost an additional 18 billion yen.[93]

Compared with the 800 billion yen that has been spent on Monju, the total subsidies related to my proposal that wind developers would receive from the government amounts to about 350 billion yen, less than half the cost of Monju.

After 2010, the cost of wind power will go down if the production of technological development of wind power energy is promoted and off-shore wind power is introduced on a large scale. As this development becomes more widespread, the production and use of renewable energy will increase year after year once people see how beneficial wind generated power can be. Hopefully, the targets set in the Kyoto Protocol that Japan is required to meet will be the catalyst for big changes in the sector of renewable energy in Japan.

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