# Carbon Dioxide Emissions Reduction Potential in Japan's Power Sector — Estimating Carbon Emissions Avoided by a Fuel-Switch Scenario


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**For WWF-Japan**


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# Executive Summary

In Japan, carbon dioxide ($CO_2$) emissions associated with the energy transformation sectors are estimated to account for over 30 percent (including indirect emissions) of the total $CO_2$ emitted by the national economy. Substantial efforts to reduce the emissions in the power sector—which produces over half of energy transformation emissions—could have a significant impact on climate change mitigation in Japan.

This report explores the potential for $CO_2$ emissions reductions from Japan's power sector by comparing the estimated quantitative impacts on $CO_2$ emissions, and the overall costs to Japanese society, of providing energy services through two energy pathways: a "Business As Usual" (BAU) scenario, in which current trends in the Japanese economy and power sector continue, and a "Power Switch" (PS) scenario, in which more aggressive transitions to non-fossil and low-carbon fuels are carried out in the Japanese power sector, accompanied by complementary aggressive implementation of energy efficiency measures geared to reduce electricity requirements. The Power Switch scenario is not a projection, but is meant to suggest the "potential" reduction of an "aggressive" but "realistic and achievable" approach.

Major differences between the PS and BAU scenarios include 1) stronger emphasis on substitution of natural gas for coal, 2) explicit emphasis on renewable energy implementation, natural gas-fired cogeneration and high efficiency natural gas-fired combined cycle generation, 3) a gradual nuclear phase-out (with "early" retirement of some nuclear units), and 4) the implementation of energy efficiency and energy conservation measures, mostly targeted at reducing electricity use, on a broad scale in the residential, commercial and industrial energy demand sectors.

This report demonstrates the environmental merits of these changes in the energy sector. Compared with power sector $CO_2$ emissions in the BAU scenario, overall emissions in the PS scenario are markedly lower, with year 2020 emissions in the PS scenario **20 percent** reduced relative to year 2000 emissions. Year 2020 emissions in the PS case are some **31 percent** lower than 2020 emissions in the BAU case. Relative to the BAU scenario, the PS scenario reduces Japan's GHG emissions by **94 million tonnes** of $CO_2$ equivalent per year by 2010, and by **190 million tonnes** per year by 2020. Overall GHG reductions in the PS scenario, relative to the BAU scenario, total nearly **2.0 billion tonnes** of $CO_2$ equivalent between 2000 and 2020.

The Power Switch scenario requires larger capital investments, overall, in the electricity supply and demand sectors, but these outlays are nearly totally offset by savings in fuel costs to Japan. In the power sector itself, in fact, the PS scenario avoids so much future capacity, that even with the addition of significant amounts of renewable generation, power sector capital and operating costs are **reduced** by some 14 trillion Yen between 2000 and 2020 relative to the BAU scenario. Another 0.5 trillion Yen is saved due to reduced capital and O&M costs in other energy transformation sectors. In the energy demand sector, the incremental capital costs of energy efficiency measures and of cogeneration and renewable energy (photovoltaic) generation installed in residences and businesses increase demand sector costs in the PS scenario by nearly 20 trillion Yen (2000 to 2020), but savings of 4.4

trillion Yen in imported fuel costs relative to the BAU scenario means that the net cost of the PS scenario to Japan is only about 1.1 trillion Yen over the period from 2000 to 2020.

Overall, under the Power Switch scenario, Japan could achieve 31 percent reduction in annual GHG emissions relative to the BAU scenario by 2020, at a net cost—factoring in both required additional investments and reductions in fuel import costs—of about 1.1 trillion yen over the study period, or about 57 billion yen per year. Expressed per unit of GHG emissions reduction, the net cost is 850 JPY/ tonne of $CO_2$ equivalent. Put in perspective, this cost is roughly equivalent, for example, to a 0.3 percent tax on electricity consumption. The net investment required, therefore, is extremely minor relative to the benefits to be gained.

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# 1. Introduction

Recent global temperature measurements indicate that the world's average temperature has increased at much greater than historical rates in recent decades[1]. Further, research strongly indicates that anthropogenic (human-caused) emissions of pollutants that help to trap heat within the earth's atmosphere are at least in part to blame for these temperature increases. A substantial portion of these pollutant emissions have their origin in the combustion of fossil fuels. As the world's need for energy services (services provided by the use of forms of energy) increase, and in the absence of an abrupt shift to non-fossil energy sources, global temperature rise, and its attendant impacts, are expected to become increasingly problematic over the coming decades. As one of the world's leading industrial economies, Japan contributes a significant share, and has accounted for a significant historical share, of the emissions that have led to global temperature increases. As such, it is imperative that Japan, as well as other industrial countries, adopt aggressive policies to reduce so called "greenhouse gas" emissions.

This report provides a quantitative comparison of medium-term (2000 to 2020) energy "scenarios" for Japan, with a focus on scenarios for the electric power generation sector. This report compares the estimated impacts on pollutant emissions, and the overall costs to Japanese society, of providing energy services through a "Business As Usual" scenario, in which current trends in the Japanese economy and power sector continue, and in a "Power Switch" scenario in which more aggressive transitions to non-fossil and low-carbon fuels are carried out in the Japanese power sector. The goal of this comparison is to indicate the changes that will need to be made to move the Japanese power sector toward environmentally sustainability, and to estimate the impacts of those changes.

## 1.1. Global Climate Change and the Role of Carbon Emissions

The entire global climate and ecosystem has 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 as agricultural and industrial practices, deforestation, as well as the burning of fossil fuels.

"Global warming", "climate change", and the "greenhouse effect" 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 impacts 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 global mean temperature will increase by 1.4 to 5.8º C with a doubling of carbon dioxide

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[1] "Northern Hemisphere Temperatures During the Past Millennium: Inferences, Uncertainties, and Limitations," Michael E. Mann and Raymond S. Bradley, and Malcolm K. Hughes, Geophysical Research Letters, Vol. 26, No. 6, p.759, 1999.

concentrations, relative to pre-industrial levels[2], with the temperature increase occurring within 40-100 years. Given current trends in emissions of greenhouse gases, this doubling—with its attendant increase in global temperatures—would likely happen in the middle of the 21st century. For reference, a global increase of 2º 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 5º C would exceed anything experienced in the last 3,000,000 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[3].

The combustion of all carbon-based fuels, including coal, oil, natural gas, and biomass, release carbon dioxide ($CO_2$) and other "greenhouse gases" to 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 greenhouse gases (or 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.

Warming of the earth may, in turn, have numerous secondary effects, some of which have potentially serious impacts of the well being of both humans and the plants and animals with which we share our planet. These effects include an increase in sea levels due to 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.

## *1.2. The Kyoto Protocol and Characteristics of Japan's GHG Emissions*

A milestone in the international effort to address the anthropogenic causes of clime 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 percent relative to 1990 levels. These emissions reductions are to be completed by a target year ranging from 2008 to 2012.

Japan ratified the Kyoto Protocol in 2002. Under the terms of the Protocol, Japan has agreed to reduce its GHG emissions by 6 percent relative to 1990 levels. Japan's GHG emissions in 2001 stood at 1,299 million tonnes of carbon dioxide equivalent[4], which was already 5.2 percent higher than Japan's 1990 emission levels of 1,235 million tonnes. More than 90 percent of the total GHG emissions in Japan, measured in carbon equivalents, are accounted

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[2] Third Assessment Report of the Intergovernmental Panel on Climate Change, 2001.

[3] Portions of the general discussion provided here were taken from M. Lazarus, D. Von Hippel, D. Hill, and R. Margolis (1995), A Guide to Environmental Analysis for Energy Planners, Stockholm Environment Institute--Boston Center. Many excellent recent compendia of climate change issues and impacts are available for the reader wishing additional details. A good starting point is http://www.gcrio.org/ipcc_docs.html.

[4] Greenhouse Gas Inventory Office of Japan, http://www-gio.nies.go.jp.

for by carbon dioxide emissions.[5] Figure 1-1 shows the pattern of carbon dioxide emissions by fuel type in Japan since 1950, showing both the substantial growth in emissions during the 1970s and 1980s (in particular), and a transition in fuels use from coal to oil to gas. Figure 1-2 shows Japanese $CO_2$ emissions by sector during the 1990s. As shown in Figure 1-2, the main $CO_2$ emissions sources in 2000 were the energy industries including the power sector (31 percent), other industries (33 percent), and the transportation sector (21 percent)[6]. 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.[7]

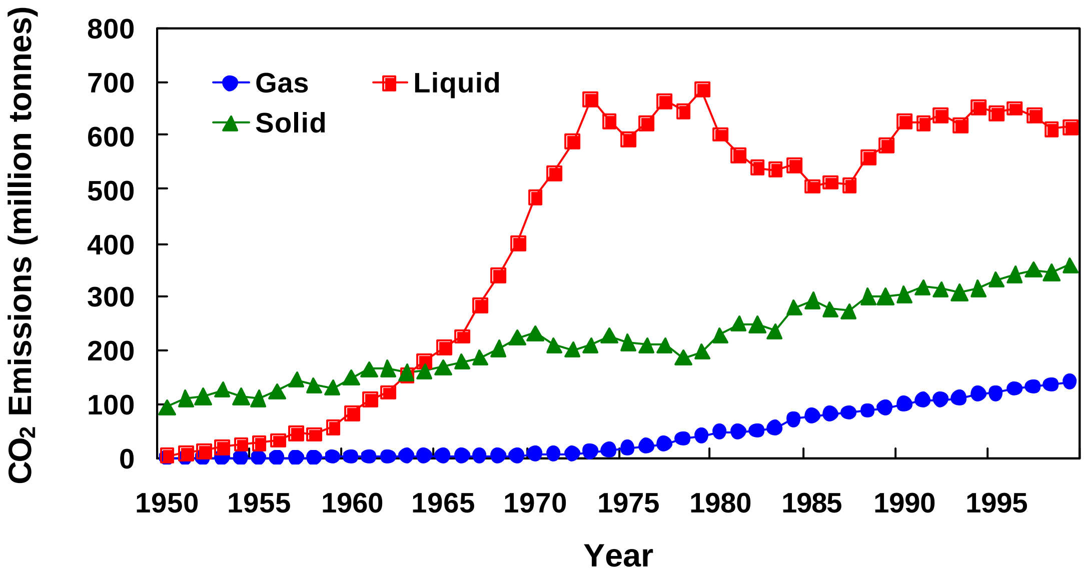


**Figure 1-1: Historical $CO_2$ Emissions in Japan by Fuel, 1950 to 2000[8]**

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[5] In this report, we express carbon dioxide emissions based on the full molecular weight of $CO_2$. Carbon dioxide emissions are often also expressed in units of "carbon equivalents", which measures the carbon content of a quantity of $CO_2$. For example, 1000 tonnes of $CO_2$ is the same as 1000 * 12 (the atomic weight of carbon)/44 (the molecular weight of $CO_2$), or about 270 tonnes of carbon equivalent (TCE).

[6] Note that data shown here are those of UNFCCC. Some of the definitions, calculation methods, and other parameters used by UNFCCC are different from those used by Japanese government organizations providing similar data.

[7] See, for example, http://cdiac.esd.ornl.gov/trends/emis/tre_coun.htm.

[8] Historical $CO_2$ Emissions in Japan by Fuel, 1970 to 2000, Gregg Marland and Tom Boden, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory.

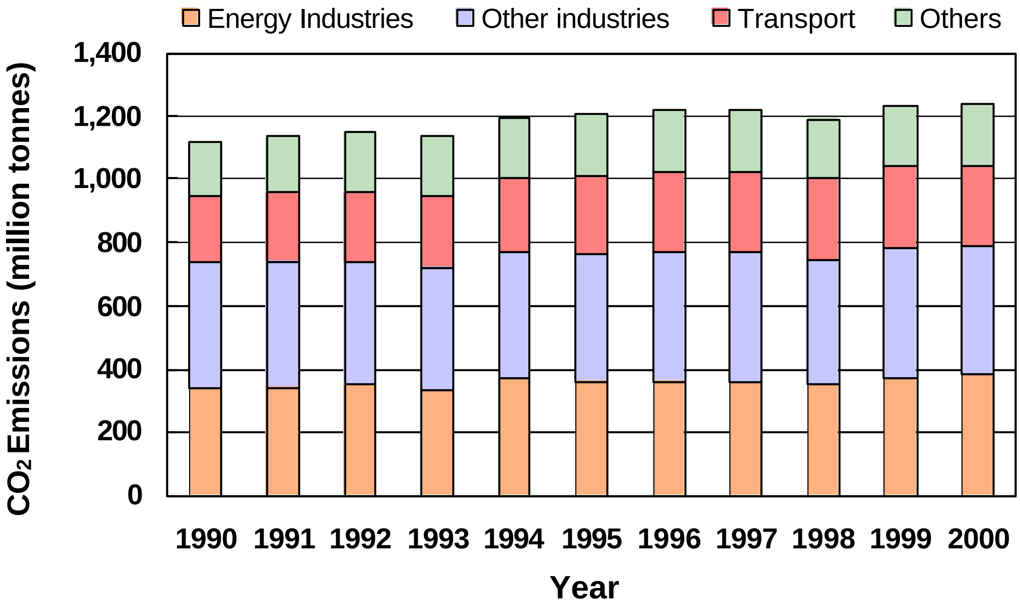


**Figure 1-2: $CO_2$ Emissions in Japan by Sector, 1990 to 2000** [9]

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 $N_2O$ (-0.5%), development of innovative technologies and further extensive efforts by the public (-2%), HFCs, PFCs and $SF_6$ (+2%), and sinks (-3.9%). Additional cuts necessary to meet the overall emissions 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.[10] 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. In fact, analyses of GHG emissions reduction potential prepared by WWF US as well as WWF Europe also demonstrate that energy conservation could most effectively reduce GHG gas emissions. 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[11]—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.

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[9] UNFCCC Greenhouse Gases Inventory Data Base http://ghg.unfccc.int.

[10] Guideline for Measures to Prevent Global Warming, http://www.kantei.go.jp/foreign/policy/ondanka/020319summary_e.html.

[11] International Energy Agency, http://www.iea.org.

### *1.3. Power Generation Sector*

Emissions associated with the energy transformation sectors alone are estimated to be over 30 percent (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 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 1-3, carbon dioxide emissions from electricity generation in Japan increased by 16.5 percent between 1990 and 2000. This increase is largely the result of an overall increase in electricity production in Japan (27.8 percent between 1990 and 2000), and has occurred even though there has been a small overall reduction in the fraction of total generation produced in thermal power plants. Figure 1-4 shows how the composition of electricity production has changed between 1990 and 2000.

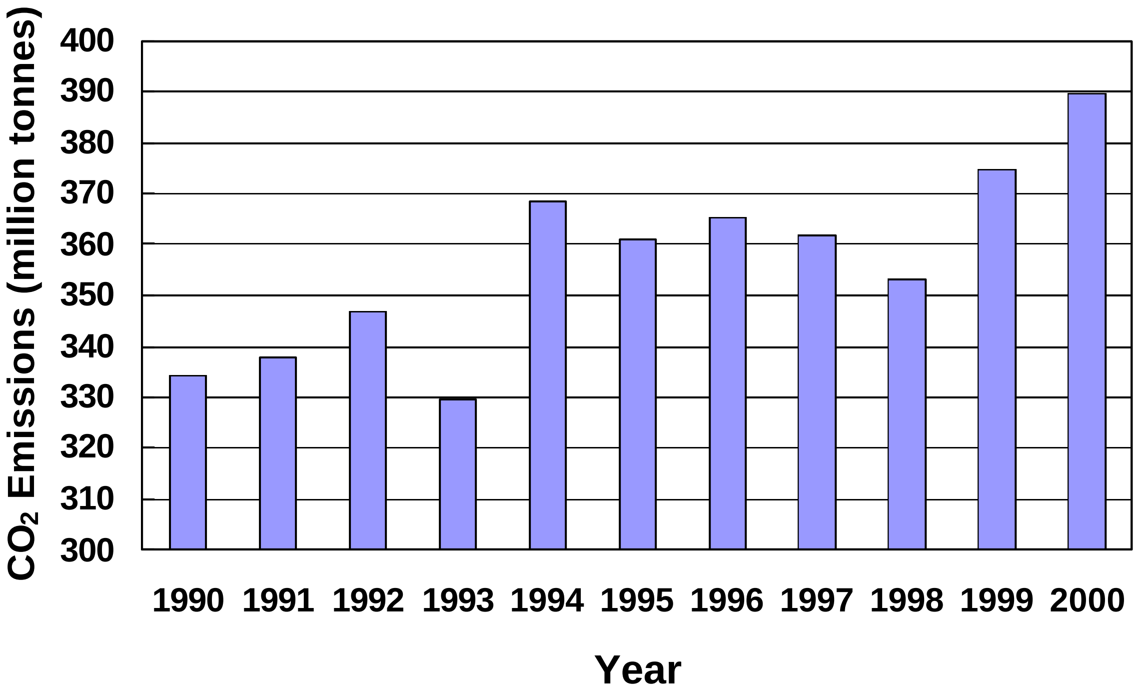


**Figure 1-3: Carbon Dioxide Emissions from Electricity Generation in Japan** [12]

[12] Handbook of Energy and Economic Statistics in Japan, Edited by the Energy Data and Modeling Center (EDMC) and the Institute of Energy Economics, Japan (IEEJ), and published by the Energy Conservation Center, Tokyo, Japan, 2002.

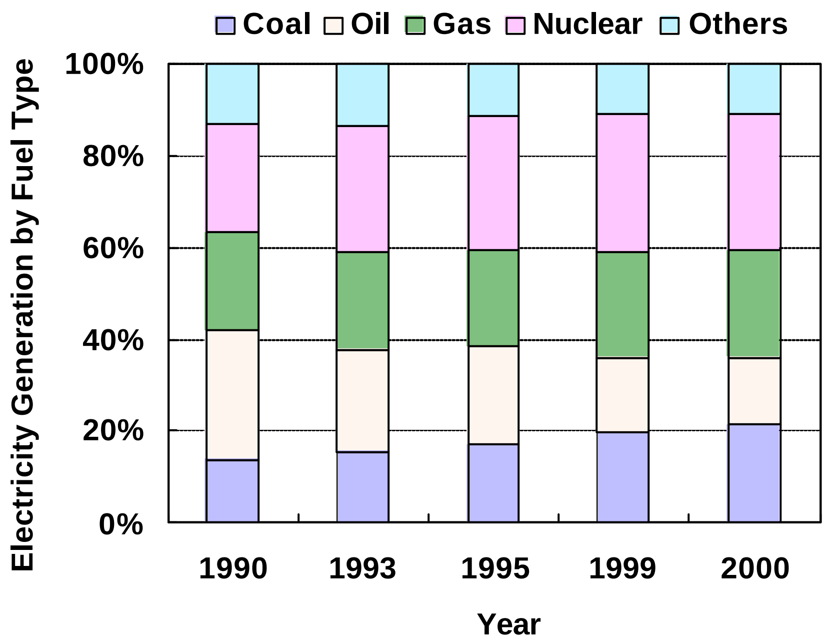


**Figure 1-4: Electricity Generations in Japan by Fuel Type, 1990 to 2000**[13]

The major fuel-switching options for electricity generation that are currently under consideration by the Japanese government to reduce GHG emissions reduction, 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[14] 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 percent annually through 2010. This assumption implies continued increase of energy consumption and 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 only 1.6 percent of Japan's primary energy by 2010 in the METI's business

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[13] Japan Energy Statistics 2001, Agency for Natural Resources and Energy, 2001.

[14] Japan's Energy Policy in the Future, Ministry of Economy, Trade and Industry (METI), Committee for Natural Resources and Energy, July 2001.

as usual case, increasing to 3 percent by 2010 in a "fully implemented" case. All other $CO_2$ emission reduction scenarios that comply with the government energy outlook unsurprisingly 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 $CO_2$ emissions reduction target. Japan has little indigenous fossil fuel energy resources. Japan stringently regulated all domestic energy markets, and put its strongest energy policy emphasis on securing a stable energy supply. The government had 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 now promotes market liberalization. The Japanese public has in recent years 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. If, as a result, nuclear power plant development does not occur on the time scale projected by METI, the reduction of Japan's $CO_2$ emissions to meet the target set by the Kyoto protocol will be even harder to achieve.

Market liberalization will likely increase the use of coal for power generation in Japan; in fact, the METI projects high growth in coal usage in the coming years. Under liberalized, competitive market conditions, the power sector would tend to avoid high-risk investments such as nuclear power stations, and would also try to improve efficiency and cut costs by using cheap fossil fuels such as coal. Worldwide reserves of coal are also greater than those of any other fossil fuel, and stable supplies of coal are available from a number of exporting countries. The availability of cost reduction measures such as these could also, in a competitive environment (and in the absence of additional incentives to pursue environmentally-friendly generation options), cause power sector investors to avoid investments in more costly hydroelectric and other renewable energy power facilities. Low energy prices would also reduce the economic attractiveness of energy efficiency improvements and energy conservation efforts. These trends, taken together, will likely cause an increase in $CO_2$ emissions from the Japanese power sector. In addition and in the absence of targeted policies to the contrary, market liberalization could lead to less government control through policies over environmental issues.

# 2. WWF Japan Power Switch Project

## *2.1. Project Outline*

The WWF launched the Power Switch Campaign in 2003. In the Power Switch Campaign, the WWF challenges one of the major GHG emitters, the power sector, to take action to make significant emission reductions and to make a rapid transition from coal-fired power stations to clean power sources.

In order to implement the campaign, WWF Japan launched Japan's Power Switch Energy Scenario Project to explore the maximum potential for $CO_2$ emissions reductions from

Japan's power sector, and to create a "Power Switch" alternative scenario that offers a significant, but achievable and realistic, departure from the official Japanese energy outlook.

The major goal of this study is to demonstrate and evaluate an achievable "power switch" proposal for consideration by decision-makers in Japan. The study will be used to influence decision makers in the Japanese power sector and in the Japanese government, and to inform the public that an effective, practical lower-carbon alternative to "business as usual" does exist. It is hoped that this increased awareness will create demand for new policies and measures to be implemented. This study also incorporates the results of related studies done previously for WWF Japan: WWF Scenario for solving the Global Warming Problem, Index for 2010 and 2020, prepared by Dr. Haruki Tuchiya of the Institute for System Technology,[15] and the Renewable Energy 10% Potential in Japan done by the Institute for Sustainable Energy Policy (ISEP).[16]

## 2.2. Research Methodology and Tools

The preparation of an energy-sector model for Japan, and the analysis of the Power Switch scenario for the power sector, was carried out within the LEAP (Long-range Energy-environment **A**lternatives **P**lanning) software framework. LEAP, developed by the Stockholm Environment Institute—Boston Center, is a scenario-based energy-environment modeling tool. Scenarios in LEAP are based on a comprehensive accounting of how energy is consumed, transformed and produced in a given region or economy under a range of alternative assumptions for future changes in population, economic development, technology, prices and other parameters. With its flexible data structures, LEAP allows for analysis as rich in technological specification and end-use detail as the user chooses. LEAP is not an optimizing model, rather it is a "bottom-up" (demand-driven) model in which users create quantitative descriptions of current and future energy demand and supply—energy and environmental scenarios—and evaluate the degree to which those scenarios meet specific criteria (such as cost, fuel diversity, or environmental constraints). Other software, such as MS Excel™, was used to supplement and document the elaboration of LEAP databases and the analysis of different energy scenarios.

The Project Team gathered and assembled as much energy data as possible on energy supply and demand in Japan, with a special focus on the energy transformation sector in general, and the power sector in particular. We also collected data on activities affecting energy demand, including data on historical, current, and (when available) projected industrial output, demographics, transport infrastructure, agricultural production, and other similar "drivers" of energy requirements. The Project Team then developed quantitative descriptions of the "base year" (2000, the most recent year for which complete data were available) energy demand and supply situation, of a Business as Usual energy scenario (based in part on existing projections by Japanese government agencies), and of a "Power Switch" scenario in which aggressive measures are applied to reduce power sector $CO_2$ emissions in Japan. Note that the PS scenario is not a projection, but one of the "achievable" alternative energy pathways that

[15] WWF Scenario for Solving the Global Warming Problem, Index for 2010 and 2020, Haruki Tsuchiya, Institute of System Technology, July 2001.

[16] "Renewable energy 10% potential in 2010 in Japan," Institute for Sustainable Energy Policies (ISEP), March 2003.

Japan could take. Excel workbooks that include much of the base year and projections data used to prepare the Japan LEAP model is attached as Annex[17] to this report.

Once the Business as Usual and Power Switch scenarios were complete, LEAP was used to estimate the GHG (and other pollutant) emissions implied by each of the scenarios, and was also used to determine the relative costs of the two scenarios. Further details of how these scenarios were formulated, and a summary of scenario results, are provided in sections 3 and 4 of this report.

# 3. Business as Usual Scenario

## *3.1. BAU Scenario Assumptions*

The Business as Usual (BAU) scenario represents the energy pathway that is implied if current energy policies and supply and demand trends in Japan persist. We developed the BAU scenario to match as closely as possible the BAU scenarios outlined by the Ministry of Economy, Trade and Industry (METI) and the Institute of Energy Economics, Japan (IEEJ). The projection period for the scenario is 20 years and starts from a 2000, the "base year"— the most recent year for which reasonably complete energy data are available. Base year energy data were obtained from various sources, with the principle source being the EDMC Energy Handbook[18] and Japan Energy Statistics, both published by IEEJ[19]. Assumptions and energy data projections for the Business As Usual scenario were for the most part obtained from the METI and IEEJ publications[20]. Projections through 2010 were based on projections and policies adapted from those assembled by METI.[21]

Both METI and IEEJ outlined two scenarios, "BAU" scenarios and "Target" scenarios. In this study, we use the METI and IEEJ BAU forecasts, with minor modifications, as the "base case" for analyzing future trends. The METI and IEEJ "Target" scenarios were used to inform the Power Switch scenarios, in combination with the ISEP study[22], WWF Scenario for Solving the Global Warming Problem, prepared by Prof. H. Tsuchiya for WWF Japan,[23] other work by WWF Japan and other research groups, as well as the Project Team's own assumptions as to future trends in Japan's energy sector.

[17] The Annex will be published separately later and will be made available on the WWF Japan's website (http://www.wwf.or.jp).

[18] Handbook of Energy and Economic Statistics in Japan, Edited by the Energy Data and Modeling Center (EDMC) and the Institute of Energy Economics, Japan (IEEJ), and published by the Energy Conservation Center, Tokyo, Japan, 2002.

[19] Japan Energy Statistics, 2001, Agency for Natural Resources and Energy, 2002.

[20] Long-Term Energy Outlook in Japan - Energy Outlook by 2020 under the Environmental and Market Constraints, Koukichi Ito, IEEJ Nov. 20, 2002.

[21] We have used the latest METI projection. However, Japan's official government scenario does not follow the current trend and actually posits a higher growth projection in terms of energy consumption and $CO_2$ emissions. The official scenario will likely be revised soon. Therefore the current trend may result in lower $CO_2$ emissions than the government scenario would.

[22] ISEP, op.cit.

[23] Tsuchiya, op.cit.

For overall projections of economic and demographic trends, the Project Team relied largely on the publication Long-term Energy Supply/Demand Outlook (hereafter referred to as "Energy Outlook"), by the Ministry of Economy, Trade and Industry (METI) Advisory Committee for Energy and Resources, July 2001. METI publishes reviews of Japan's energy policy every several years. The 2001 version of the Energy Outlook is the latest edition available of METI's review as of this writing. The METI outlook includes some projections that appear to run counter to trends over the last decade or more. The METI assumptions that appear questionable include 1) economic growth will continue at an annual growth rate of 2.0% until 2020, but energy consumption and $CO_2$ emissions will stay at very low levels, 2) energy conservation will be accelerated drastically, (recent trends show minimal if any improvement in energy efficiency in most sectors[24]), 3) there will be no or little siting difficulties for nuclear power plant construction, 4) domestic energy prices will be stable at very high levels, and 5) agriculture and the construction materials industry will grow steadily. IEEJ modified METI's energy outlook with by modifying several assumptions. For instance, in the IEEJ report, GDP annual growth rate is 1.5 percent per year until the year 2010, and is 1.1 percent annually from 2010 to 2020. These rates are lower than METI's projections, but are still higher than the current trend (Japan's GDP grew by an average of 0.7 percent/yr between 1997 and 2002[25]).

Given the current situation (the annual GDP growth rate 0.4 percent in 2001, and 0.2 percent in 2002), we modified the GDP assumption in this report taking into account other research groups' projections.[26] In the report, GDP growth is 0.5 percent annually until 2005 reflecting recent economic trends in Japan, and 1.5 percent after 2005, so that overall GDP growth from 2000 to 2020 is similar to the GDP growth projected by IEEJ. It is highly likely that the real GDP by 2020 would be lower than that reflected in the BAU scenario as modified for the current study. In order to avoid the underestimation of future energy consumption by estimating too low a rate of GDP growth, however, in this study we used figures as close as possible to those in IEEJ's report for GDP growth and for other economic assumptions.

### 3.1.1. Electricity Demand

Key assumptions in the electricity demand sectors for the BAU scenario include 1) current trends in electricity consumption continue, 2) no extensive additional energy conservation measures are imposed, and 3) no drastic policy changes are implemented. As a consequence, even though the energy efficiency of electricity-using technologies will continue to improve incrementally, overall energy consumption will continue to increase due to a combination of higher activity levels, increases in ownership rates for appliances, increase in the size of appliances, increases in the average number of hours that an appliance is used annually, and other factors. This trend in increasing consumption continued since 1986, a year in which energy prices declined significantly.

#### ***Residential Sector***

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[24] The Energy Conservation Center, Japan, http://www.eccj.or.jp.

[25] Economic and Social Research Institute, Cabinet Office, Government of Japan, http://www.esri.cao.go.jp/en/sna/menu.html.

[26] Handbook of Energy & Economic Statistics in Japan, The Energy Data and Modeling Center, IEEJ. Also the Central Research Institute of Electric Power Industry published their own projection at http://criepi.denken.or.jp/eng.

The key underlying activity in the residential sector is the number of households. Though population in the BAU scenario reaches its peak in 2007 (at just under 128 million people), declining slowly thereafter to slightly over 124 million by 2020, total households increase until 2010. The number of households are assumed to remain stable after 2010 (at 50.3 million), as declines in population are made up for by decreases in the number of people per household (continuing a trend of decreasing household size).

Energy efficiency improvements in the residential sector are assumed to continue at t roughly the same rate as during the 1990s. Large home appliances such as refrigerators and televisions tend to be larger in size, and the number of appliances per household (the ownership ratio) will increase, but at the same time the per-unit electricity consumption of these home appliances will decrease as they will become more energy efficient through technological innovation. Multiplying these countervailing factors together, the overall energy consumption for refrigerators and televisions will decrease on a per household basis. Conversely, the number of air conditioners, electronic high-tech toilets, dishwashers/dryers, clothes dryers, and personal computers per household will increase much faster than the rate of efficiency improvement, meaning that total energy consumption per household for these appliances will continue to increase.

## ***Commercial Sector***

The commercial sector has been and will be the fastest growth sector in Japan, both in terms of economic performance and in terms of energy consumption. An increase in retail and other commercial floor space, in the use of air conditioning per unit space, and an increase in the use of office appliances such as computers and copy machines contribute to giving the commercial sector the fastest growth of electricity consumption among the Japanese electricity demand sectors. In the BAU case, commercial floor space is assumed to increase by over 40 percent between 2000 and 2020 (to 2.35 billion square meters), an average annual growth rate of 1.77 percent. Of the major end-uses of energy in the commercial sector, the energy intensity of cooling and cooking (measured per unit of total commercial floor space) are assumed to increase during the modeling period, while the energy intensity of space heat and water heat decline. Electricity used for "motive energy and other", including, for example, pumps, fans, refrigeration, lighting, and electronics, increases to 2005, remains stable through 2010, then declines slowly through 2020.

## ***Industrial Sector***

In the industrial sector, physical output in the paper and chemicals sub sectors is assumed to increase between 2000 and 2020, while output in the ceramics (including cement) and steel sectors continue to decline slowly. Output in the non-ferrous metals and metals finishing industries is assumed to rise throughout the modeling period, while output in "other manufacturing" declines, and output in the food processing and textile industries rise for a few years after 2000, then slowly decline through 2020. Output in the agriculture and forestry, mining, and fishing industries declines considerably between 2000 and 2020, but output in the construction sector, after declining slowly until 2005, is assumed to increase very modestly thereafter (at an average of 0.2 percent annually).

Fuel use in the industrial sector is assumed to continue to shift from coal, cokes, and oil products (particularly heavy fuel oils) to electricity, resulting in an increase in industrial electricity consumption. The industrial sector arguably has the potential to improve its energy efficiency and to conserve energy more than other sectors of the Japanese economy, in part because METI could impose energy-efficiency policies on the Industrial sector more easily than similar policies could be imposed on other sectors. In addition, in the next two decades the trend of lower-energy intensity industries becoming more dominant in the economy relative to more traditional "heavy" industries will likely continue. Both of these factors argue for an overall decrease in the use of most fuels in the industrial sector. Historically, in the Japanese industrial sector, energy consumption per unit of activity decreased dramatically through 1986 as the energy efficiency of manufacturing technology was improved. Since 1986, however, energy consumption in the industrial sector has been slightly increasing until 1997, and there have not been significant improvements in industrial energy intensities since that time.

In the BAU case for industrial energy demand, assumptions as to future changes in energy intensity vary for different fuels and different sub sectors, but in general the intensity of coal and heavy oil use tends to decline fairly rapidly, while the use of natural and municipal gas increases, and the use of electricity either declines modestly or increases (on a per unit of output basis).

## ***Transportation Sector***

The main transport sector activities that drive energy demand are passenger kilometers traveled, which is assumed, in the BAU scenario, to increase at an average of 0.8 percent annually from 2000 to 2020, and freight (portage) tonne-km transported, which increases at a slower 0.5 percent per year.

Transportation sector energy consumption in Japan was relatively stable until 1986, but has been increasing ever since. Though the fuel economy of family cars has been improving significantly[27] , other factors that increase fuel consumption have become dominant, and as a result fuel consumption per vehicle has increased very substantially[28].

In the BAU scenario, the fraction of passenger transport using private vehicles, and the passenger-km of air travel, are assumed to increase gradually between 2000 and 2020, with a reduction in the fraction of passengers transported by other modes, particularly by train. The energy intensity per passenger-km of most passenger transport modes is assumed to remain the same or increase slightly over the modeling period, with the exception being "Eco-type" private vehicles (with more twice the fuel economy of standard vehicles by 2020) and jet transport, both of which are assumed to have substantial efficiency improvements over time. BAU scenario freight transport is assumed to shift toward road transport and away from ship transport. The energy intensity (per tonne-km transported) of freight transport is assumed to decrease for road and air freight, remaining the same for rail and water-borne freight.

In 2000, electricity consumption in the transport sector was dominated by rail transportation (electric trains). The railway sector will continue to gradually shift from diesel to electric locomotives, and the energy intensity of both types of passenger trains is assumed to also slowly increase (0.5 percent annually). The energy intensity of freight trains is assumed to remain constant. Despite the development of electric car technology, the total population of electric vehicles is assumed to remain insignificant throughout the study period in the BAU scenario, and as a result the amount of electricity consumed by electric cars is assumed to

[27] Japan Automobile Manufacturers Association, Inc. http://www.jama.or.jp/lib/jamagazine/200208/05.html

[28] Some of the factors that increase transport sector fuel consumption are an increase of activity (number of people x km), an increase in vehicle weight and size, an increase in the use of private vehicles, a decrease in the number of passenger per vehicle.

remain negligible. As a result of these assumptions about electricity use in the rail and road sub sectors, electricity use in the transportation sector, which is modest in the base year (as shown below) grows over the forecast period, but does so relatively slowly.

### 3.1.2. BAU Electricity Demand Projections

Figure 3-1 shows business-as-usual electricity demand simulated by LEAP using the METI and IEEJ assumptions described above. Electricity consumption in the BAU scenario is projected to increase from 968 TWh in 2000 to 1168 TWh in 2020. This result indicates that if current trends continue as modeled, electricity consumption will grow by an average rate of 0.9% annually over the study period, though growth in the 2000 to 2010 period is somewhat more rapid than in the 2010 to 2020 period. Among the different sectors of the Japanese economy, electricity consumption in the services (commercial) sector shows the strongest growth (averaging 1.7 percent/yr over the study period), followed by the households (residential) sector, at 0.9 percent annually, the industrial sector at an average of 0.5 percent/yr, and the transport sector at 0.3 percent/yr.

Electricity demand grows faster than overall fuels demand in Japan in the BAU scenario. Overall demand for end-use fuels increases by an average of 0.56 percent annually over the study period, and the fraction of end-use fuels demand provided by electricity increases from 22.6 percent in 2000 to 24.4 percent by 2020. Of the other major fuels used in the Japanese economy, the use of municipal gas grows the fastest, at an average annual rate of 1.8 percent/yr.

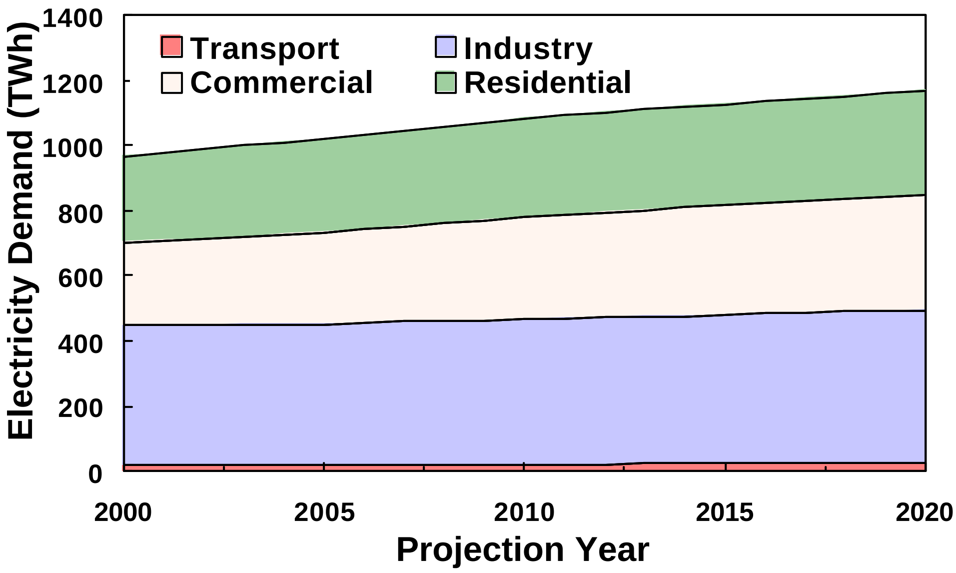


**Figure 3-1: BAU Electricity Demand Projection**

### 3.1.3. Electricity Supply and Other Fuel Transformation: BAU Scenario

In addition to the simulation of demand for electricity and other fuels described above, the LEAP model for Japan includes a rough model of the system for transforming resources (domestic and imported) into end-use fuels. Different transformation "modules" simulate the equipment and operations necessary to produce different fuels or move them from one place to another. The modules used in the LEAP model for Japan include:

- Electricity and municipal gas transmission and distribution
- District Heat production
- Electricity generation
- Municipal gas production
- Oil refining
- Coke production
- LNG imports
- Coal mining
- Natural gas extraction
- Oil extraction

Where appropriate, additions to production capacity are modeled over time so that the amount of fuel produced matches the amount of fuel consumed in the demand sectors. As this report focuses primarily on electricity, details on the assumptions underlying BAU changes in electric generation capacity are described below. Additional detail on assumptions used in modeling BAU electricity generation, as well as on assumptions used to model other transformation processes, can be found in the Annex to this report.

## ***METI and IEEJ Assumptions***

In preparing a LEAP simulation for an electricity supply scenario meeting the Business As Usual scenario electricity demand calculated as described above, the Project Team started with electricity generation fuel portfolio for assumptions based in part on reports by METI (which provided scenarios through 2010)[29] and IEEJ (scenarios through 2020)[30]. Table 3-1 shows IEEJ historical data and future projections for electricity output by fuel for public utilities. Discussions of specific policies and BAU scenario assumptions for nuclear power and for electricity generated using renewable resources are provided below.

[29] Japan's Energy Policy in the Future, Ministry of Economy, Trade and Industry (METI), Committee for Natural Resources and Energy, July 2001.

[30] Long-Term Energy Outlook in Japan - Energy Outlook by 2020 under the Environmental and Market Constraints, Koukichi Ito, IEEJ Nov. 20, 2002.

**Table 3-1: IEEJ Projection of Electricity Generation by Public Utilities**

| (TWh) | 1980 | 1990 | 2000 | 2010 | 2020 |
|---|---|---|---|---|---|
| Coal | 25 (5%) | 75 (10 %) | 170 (18%) | 213 (20%) | 246 (22%) |
| LNG | 78 (15%) | 165 (22 %) | 246 (26%) | 301 (29%) | 319 (28%) |
| Oil | 231 (45%) | 203 (27 %) | 84 (9%) | 64 (6%) | 50 (4 %) |
| Others | 16 (3%) | 21 (3%) | 23 (2%) | 23 (2%) | 23 (2%) |
| Nuclear | 82 (16%) | 201 (27 %) | 321 (34%) | 351 (34) | 404 (35%) |
| Hydro, Geothermal, etc. | 86 (17%) | 87 (12 %) | 90 (10%) | 95 (9%) | 98 (9%) |
| Total | 518 | 753 | 936 | 1047 | 1139 |

These numbers show only the electricity generation by the Public Utilities. Electricity is also generated by auto-producers (non-public utilities) — industries and other consumers who generate their own electricity on-site. In METI's report, current trends of increases in electricity generation and generation capacity by auto-producers are assumed to continue into the future. Total thermal generation capacity used by auto-producers in 2000 was 28 GW, and the fuel types used to power of thermal auto-producer generation capacity were oil (18 GW), coal (10 GW), municipal solid waste (or MSW 1 GW), and NG (0 GW). Total electricity generation is 151 TWh in 2000.

**Nuclear**

National policy with respect to nuclear power development has the most significant impact on Japan's potential to reduce $CO_2$ emissions from the power sector. Nuclear plants in Japan have historically been used to provide base load power, and have been run at annual average capacity factors of sometimes more than 80 percent.[31] [32] The addition of one nuclear power plant of about 1 GW capacity therefore increases annual nuclear output by almost 6-8 TWh, and as a consequence the number of nuclear power plants placed in service in coming years really has a marked bearing on how much GHG reduction can be expected in the power sector. Table 3-2 shows three projections of future nuclear capacity compiled by different governmental and semi-governmental organizations in Japan. Since it is uncertain how to solve the increasingly contentious problem of siting new nuclear capacity, even in a BAU scenario (let alone in a scenario where nuclear capacity additions are accelerated), there are wide variations in the projections.

[31] http://www.atom.meti.go.jp/siraberu/atom/05/index01s.html, or www.nisa.meti.go.jp/text/kokusai/030404-c.pdf.

[32] The "capacity factor" of a power plant is a measure of fraction of time that the plant operates at full capacity. Thus a capacity factor of 80 percent indicates that a plant annually generates power equal to its rated capacity times the number of hours in a year (8760) times 0.80.

**Table 3-2: Projected Business as Usual nuclear capacity**

| Year | 2002 | 2010 (# of new units) | 2020 |
|---|---|---|---|
| METI | | 61.85 GW (+13) | |
| IEEJ | 45.91 GW | 51.90 GW (+5) | 61.50 GW (+7) |
| Ministry of Environment[33] | | 53.25-59.7 GW (+7-13) | |

In this report, for the BAU scenario, no nuclear plant retirement is planned, although some existing plants should be retired before 2020 if the operating lifetime of nuclear plants is assumed to be 40 years. We assume, for the BAU scenario, that the Japanese government will use a target operating lifetime for existing of nuclear power plants that could be extended up to 60 years.[34] As a consequence, none of the 45.91GW of nuclear capacity currently operating will be retired, in the BAU scenario, until the year 2020 or later (Japan's oldest commercial nuclear power plants were put into service in the late 1960s and early 1970s). In IEEJ's scenario of business-as-usual nuclear power development, three nuclear power units now under construction are completed, and the scenario includes two additional units, which would be built by the year 2010. Installed nuclear capacity would therefore rise to be 51.90 GW by 2010 in IEEJ's scenario. IEEJ projects that seven more nuclear units could be built between 2010 and 2020, raising total operating nuclear capacity to 61.50 GW. METI projects the addition of 10-13 plants by 2010, leaving generation capacity in that year at 61.85 GW (23.2 percent of total national capacity) by the end of that year. In this study we largely adopt IEEJ's assumptions about future increases in nuclear capacity.

### Renewables

The $CO_2$ reduction potential of switching to renewable fuels and renewable energy technologies in the power sector in Japan has tended to be neglected in spite of the considerable technical, environmental, social, and political difficulties associated with further development of nuclear, and even fossil-fueled, power options in Japan. The lack of credibility of renewable energy technologies among power sector decision makers in Japan stems from the belief that renewables-based power systems cannot cost-effectively provide enough power to support Japan's projected high economic growth.

In contrast with the case of future nuclear power capacity estimates, there are few discrepancies among the projections of the output of renewable energy systems among various groups. In IEEJ's projection of future energy supply, energy generated from renewable sources estimates to total 4,000,000 kl of crude oil equivalent by 2010 and 5,000,000 kl by 2020. Projections by METI and NEDO (New Energy Development

[33] Report of GHG reduction scenario meeting in 2000, Reduction potential from the energy transformation sector, Ministry of the Environment, March 2001 March http://www.env.go.jp/earth/report/h12-03/6-1.pdf

[34] Nuclear power plants originally had a design lifetime of up to 40 years, but recent engineering assessments of nuclear plants has established that many can operate longer. Therefore, the operating lifetime of nuclear plants would likely be extended in Japan. http://www.world-nuclear.org/info/inf17.htm.

Organization) are on the same order of magnitude. Table 3-4 provides a summary of renewable-based electricity generation capacity included in IEEJ's business-as-usual projections[35].

**Table 3-3: Renewable Electricity Generation Capacity Projections**

| GW of: | 1999 | 2010 | 2020 |
|---|---|---|---|
| PV[36] | 0.21 | 2.54 | 3.65 |
| Wind | 0.08 | 0.78 | 1.23 |
| MSW[37] | 0.90 | 1.75 | 2.19 |

**Other assumptions**

The cogeneration capacity is projected to grow at a rate of 2.3 percent annually through 2010 and 1.5 percent/yr between 2010 and 2020. Both IEEJ and METI project the use of fuel cell technologies grow at a relatively high rate of 10.1 percent annually, which we use as the growth rate of fuel cell capacity addition through 2020.

### 3.1.4. BAU Scenario Results: Electricity Sector

The growth in electricity demand projected in the BAU scenario requires a corresponding increase in electricity generation, and in generation capacity. The following paragraphs show the implications of demand growth and of BAU assumptions as to the types of power plants likely to be added, on the mix of electricity generation capacity and output over the study period, and summarize the implications of BAU-case electricity sector development on the emissions of greenhouse gases from the electricity sector.

#### ***Generation Capacity and Electricity Output***

Figure 3-2 shows the trends in generation capacity by type of power plant in the BAU scenario. The bulk of the total new capacity added between 2000 and 2020 (a total of about 69 GW) is made up by a combination of coal-fired, nuclear, and natural gas-fired power plants. About 19 GW of existing oil-fired capacity is retired, resulting in a net capacity addition of about 50 GW between 2000 and 2010. More modest additions of pumped-storage hydroelectric power plants (to provide peak power) and small amounts of renewable energy-based electricity are also added. Because the year 2000 capacity of fuel cell generation is only 12 MW, even the growth rate of over 10 percent annually assumed as above leaves total year 2020 fuel cell capacity at less than 100 MW, which is a small fraction of a percent of year 2020 total national BAU generation capacity of nearly 310 GW.

[35] Long-Term Energy Outlook in Japan - Energy Outlook by 2020 under the Environmental and Market Constraints, Koukichi Ito, IEEJ Nov. 20, 2002.

[36] "PV" denotes solar photovoltaic power systems.

[37] MSW is not considered to be a renewable energy source in the Power Switch Scenario. MSW is discussed more in the later section.

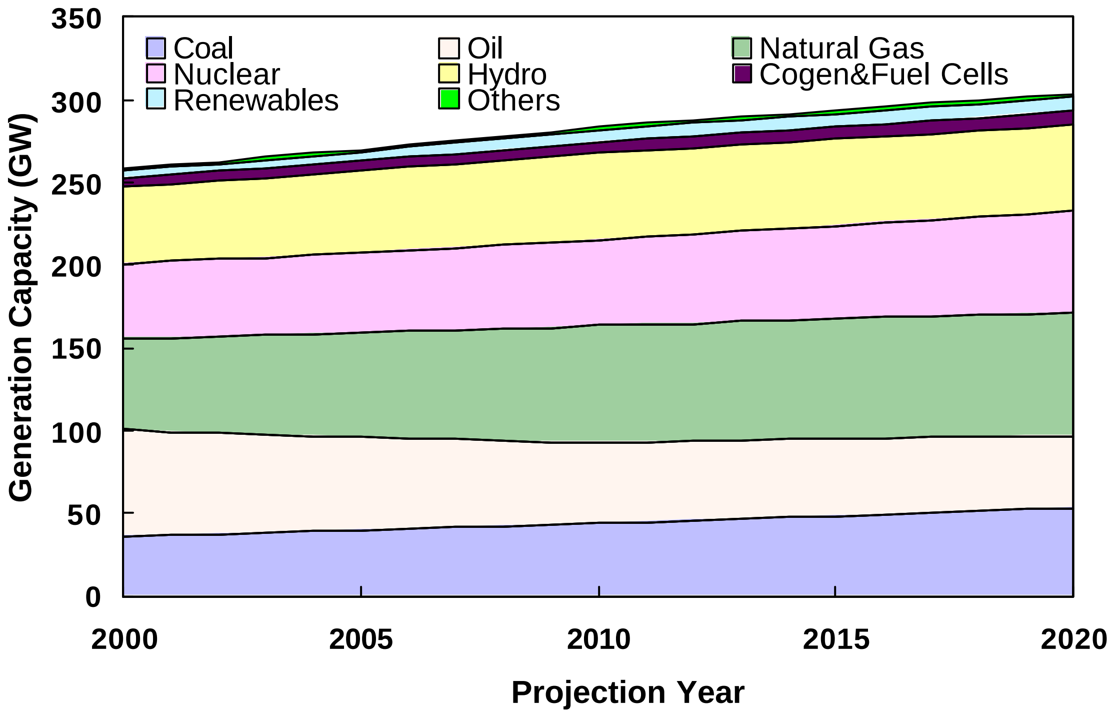


**Figure 3-2: Generation Capacity in Business as Usual Scenario**

Figure 3-3 presents the distribution of electricity output by different plant types in the BAU scenario. The pattern of output does not change radically over time, but the fractions of total electricity output provided by coal-fired, gas-fired, and nuclear plants each increase between 2000 and 2020.

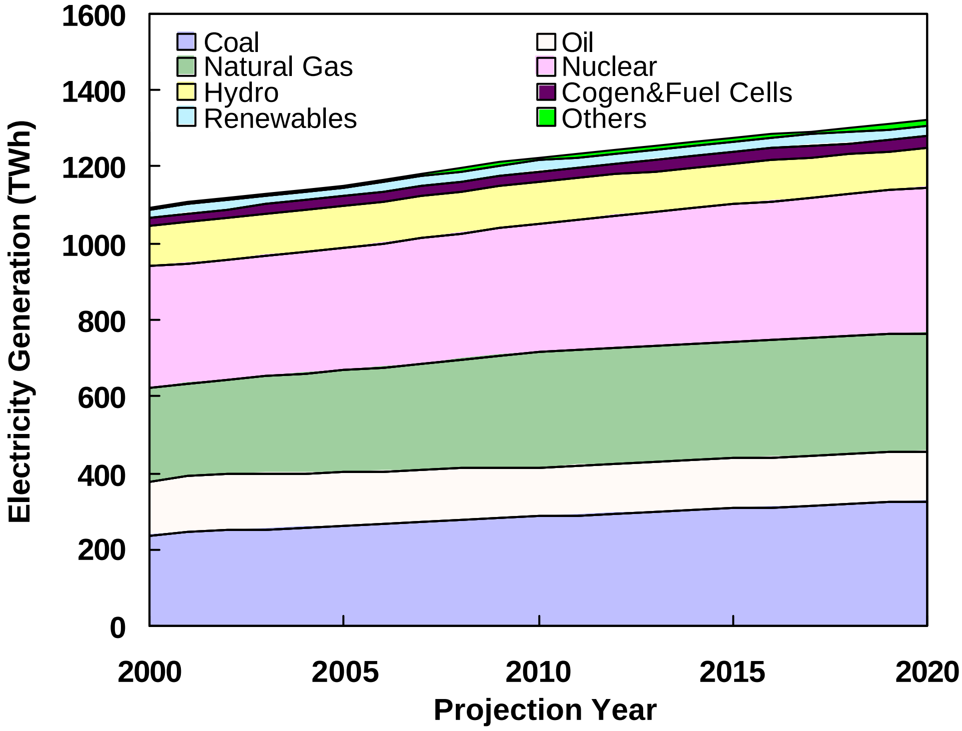


**Figure 3-3: Generation Output in Business as Usual Scenario**

In the BAU scenario, electricity generation must rise to 1320 TWh by 2020 in order to meet BAU electricity demand (plus transmission and distribution losses), implying an average annual growth rate of just under 1.0 percent per year from 2000 to 2020. Primary energy consumption (all fuels) in the electricity sector was 2667TWh (9596 PJ) in 1999, and is projected to rise, under the BAU scenario to 3430 TWh (12340 PJ) by 2020. By 2020, the generation fuel mix in Japan under the BAU scenario will be 36 percent nuclear, 22 percent natural gas, 24 percent coal, 10 percent oil, and about 8 percent fuel for generation based on other indigenous resources, including hydro, geothermal, and biomass wastes.

## ***Greenhouse Gas Emissions Projections***

Greenhouse gas emissions, expressed in $CO_2$ equivalents, from the electricity generation sector are projected to increase to 480 million tonnes of $CO_2$ by 2020, as shown in Figure 3-4,[38] an increase of 21 percent from the level in 2000. Of the total power sector emissions in Japan as of 2020, nearly 47 percent of the GHG emissions come from coal combustion, although electricity from coal fired plants accounts for only 24 percent of electricity generated.

[38] The coefficients used to convert fuel use in the electricity sector to estimates of greenhouse gas emissions are taken from a database of IPCC (Intergovernmental Panel on Climate Change) emissions factors. The Japanese government uses a different calorie calculation for some fuels, and thus uses slightly different emissions coefficients.

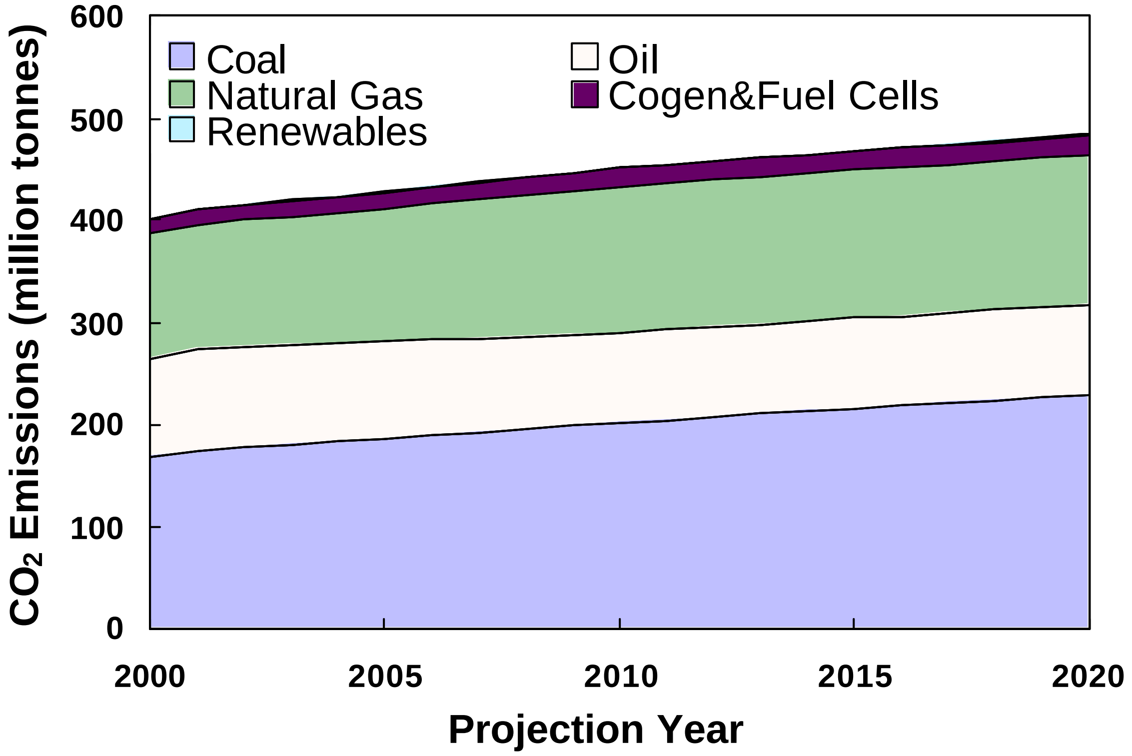


**Figure 3-4: Greenhouse Gas Emissions in the BAU Scenario**

# 4. Power Switch Scenario

The Power Switch (PS) Scenario demonstrates the savings in greenhouse gas emissions that Japan could achieve through a program of switching power generation technologies or fuels to low- or no-carbon resources, coupled with a timely and aggressive program of increasing energy-efficiency and demand-side generation.

## *4.1. Power Switch Scenario Assumptions*

The PS scenario differs from the BAU scenario in that it incorporates the following aspects: 1) stronger emphasis on substitution of natural gas for coal, 2) a gradual nuclear phase out ("early" retirement of some nuclear units), 3) explicit emphasis on renewable energy implementation, natural gas-fired cogeneration and highly efficient natural gas-fired combined cycle generation,[39] and 4) the implementation of energy efficiency and energy conservation measures, mostly targeted at reducing electricity use, on a broad scale in the residential, commercial and industrial energy demand sectors.

[39] Combined-cycle capacity is used in the Power Switch scenario as "endogenous capacity", a term related to the specification of the LEAP model that means that the model is set so that when more generation capacity is needed, LEAP adds gas-fired combined-cycle capacity.

In addition to the general overall characteristics just described, the Power Switch Scenario also incorporates the results of two WWF Japan studies conducted, respectively, by Dr. Haruki Tuchiya of the Institute of System Technology,[40] and by the Institute of Sustainable Energy Policies (ISEP).[41] Tsuchiya's study provides estimates of the $CO_2$ reduction potential of adopting energy-efficient technologies in the demand sector. The ISEP study assesses how much renewable energy implementation would be plausible by 2010. The Power Switch scenario in this study incorporates major elements of both studies. The goal of this scenario is to combine, describe and quantitatively evaluate WWF Japan's major perspectives regarding sustainable, clean and feasible energy scenarios. In so doing, the scenario projects a future that, WWF believes, is achievable through a combination of national will and aggressive policy measures designed to bring about changes in how energy consumed and supplied in Japan.

#### 4.1.1. Demand-side Energy Efficient Technologies (Tsuchiya Study)

For the purposes of the Power Switch scenario, we on the one hand focus on the energy transformation sector, and, in particular, on how the power sector could reduce its emissions of GHGs and other pollutants by switching fuels and changing technologies. Given the long life of power sector infrastructure, however, it is clear that the biggest potential reductions of greenhouse gas emissions from the power sector is to reduce the demand for power through energy conservation and efficiency improvement. Carbon dioxide emissions from the power generation sector in Japan increased 16.5 percent between 1990 and 2000 while electricity consumption increased from 766 TWh to 978 TWh, or 27.8 percent.[42] Given this rate of growth, and Japan's relatively limited energy resources, it clearly will not be easy to reduce greenhouse gas emissions by relying on electricity supply-side changes alone.

In fact, energy conservation has been shown to have very significant potential to cut $CO_2$ and other GHG emissions in other countries. In a study of the potential for GHG emissions reductions in the United States (the "WWF US study"[43]), energy efficiency measures entirely displace growth in electricity demand after 2005, and supply a similar reduction in $CO_2$ emissions from the electricity sector. Using a similar approach, a WWF-Europe report shows that electricity demand reductions of 27 percent could be achieved.[44] WWF-Japan also commissioned an extensive study (the "Tsuchiya study") that assessed the carbon dioxide emissions reduction potential available from measures in the demand sector that promote energy conservation and accelerate the adoption of energy-efficient technologies. Given that overall electricity consumption per capita in Japan is already half of that of the United

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[40] Tsuchiya, op.cit. .

[41] ISEP, op.cit.

[42] Handbook of Energy and Economic Statistics in Japan 2002, The Energy Data and Modeling Center, The Institute of Energy Economics, Japan (IEEJ).

[43] The Path to Carbon Dioxide-Free Power: Switching to Clean Energy in the Utility Sector, A study for World Wildlife Fund, prepared by Tellus Institute and The Center for Energy and Climate Solutions, April 2003. The results of the analysis showed the potential to decrease US emissions to 60 percent below current levels by 2020 without the per ton price going above $15 US.

[44] Low Carbon Electricity Systems – Methodology and Results for the EU, Mirjam Harmelink, Wina Graus, Kornelis Blok, and Monique Voogt, ECOFYS, March 2003.

States,[45] one might think that energy conservation and energy efficiency might not be as effective a means to cut $CO_2$ emissions in Japan as it would be in the United States, but the Tsuchiya study demonstrates that there still are significant CO2 emissions that could be reduced by adopting technologies that require less electricity.

Key energy-efficient technologies described in the Tsuchiya study are as follows:

- *Transformation sector*; amorphous-type transformers (improved pole transformers for electricity distribution).
- *Industrial sector*; inverter-controlled motors, improved factory transformers, introduction of high-efficiency motors, introduction of high-efficiency luminous lights, introduction of LED (Light-emitting diode) lighting.
- *Commercial sector*; high-efficiency transformers, cogeneration, introduction of non-filament street lights, LED traffic lights, replacement of incandescent lamps with LEDs, replacement of fluorescent lights with LEDs, replacement of emergency lights with LEDs, LCD (liquid crystal display) personal computer monitors (replacing cathode ray tube displays), reduction of standby electricity losses in office electronic equipment, digitalization of paper-based documents through IT (information technology) measures (reducing the use of paper, printing machines, and printing supplies), improvement of vending machine energy efficiency, energy-saving elevators, promotion of energy management systems for buildings,
- *Household sector*: LCD televisions, LCD personal computer monitors, high-performance refrigerators, fuel cell co-generation, reduction of standby electricity losses in home electronics.

To this list of technologies, the authors of this report have added an increase in household- and commercial-sector solar water heater use.

In addition, the Tsuchiya report includes, and the authors include in the Power Switch scenario, gas-fired cogeneration (internal combustion engine and combustion turbine) in the commercial sector, and gas-fired fuel-cell cogeneration in the household sector. Distributed solar photovoltaic generation in the industrial, commercial, and household sectors is also included. Cogeneration and distributed generation reduce the amount of electricity that utilities are required to generate both by supplying demand on-site and by reducing overall transmission and distribution losses, as less electricity needs to be transported from central power plants to consumers.

The estimated reduction of electricity demand based on the authors' interpretation of $CO_2$ emissions reduction results from the Tsuchiya study is summarized in Table 4-1

[45] 8.3 MWh and 13.8 MWh in 2000, International Energy Agency, http://www.iea.org.

**Table 4-1: $CO_2$ Emissions and Estimated Electricity Demand Reduction by Adopting Energy Efficient Technologies**

| | $CO_2$ reduction (Million tonnes $CO_2$) | | Electricity demand reduction (TWh) | |
|---|---|---|---|---|
| Year/sector | 2010 | 2020 | 2010 | 2020 |
| Transformation | 4.84 | 9.50 | 7.0 | 13.8 |
| Industrial | 20.2 | 43.1 | 27.1[46] | 59.3 |
| Transportation | 62.0 | 91.5 | 0 | 0 |
| Commercial | 26.7 | 55.6 | 46.6 | 93.9 |
| Household | 21.4 | 41.1 | 30.8 | 58.1 |
| Total | 135.1 | 240.8 | 111.5 | 225.1 |

Overall, the reduction in electricity demand obtained by adoption of the electricity-efficient and cogeneration/distributed generation technologies included in the Tsuchiya report (and additional demand-side technologies as noted above) is estimated at 114 TWh by 2010 and 238 TWh by 2020.[47] As a result, net electricity consumption in the PS scenario is 930 TWh in 2020, which is a 20 percent reduction relative to the BAU scenario. Relative to electricity demand in the year 2000, net electricity demand in the PS scenario increases virtually not at all through 2010, and then drops so that by 2020 net electricity demand about three percent lower than in 2000. Figure 4-1 shows the pattern of net electricity demand in the Power Switch scenario. An additional savings of about 7 TWh in 2010 and nearly 14 TWh in 2020 is achieved by the accelerated implementation of amorphous transformers (improved "pole" electricity distribution transformers). When these savings are factored in, the result is that the requirements for electricity generation in the PS scenario are **less**, by a bit more than four percent, in 2020 than they were in 2000.

It should be noted that neither the Tsuchiya report nor the PS scenario even begins to exhaust the potential for electricity demand reductions through energy efficiency measures. For example, no industrial process improvements (other than motor and motor system improvements) are included in the Tsuchiya report, nor is commercial air conditioning equipment or refrigeration equipment (except vending machines). In the household sector, improved-efficiency air conditioning, home insulation improvements, and lighting measures, among others, are not explicitly included in either the Tsuchiya report or in the PS scenario considered here. This suggests that there remains considerable untapped energy-efficiency potential even beyond the substantial potential savings noted above.

[46] Industrial estimates do not include modest electricity savings from reduction of paper and cement manufacture achieved through the "digitalization of paper" and "house renovation rather than replacement" measures.

[47] These numbers of the total demand-side savings include distributed generation – both cogeneration and PV, which is why they are higher than in Table 4-1.

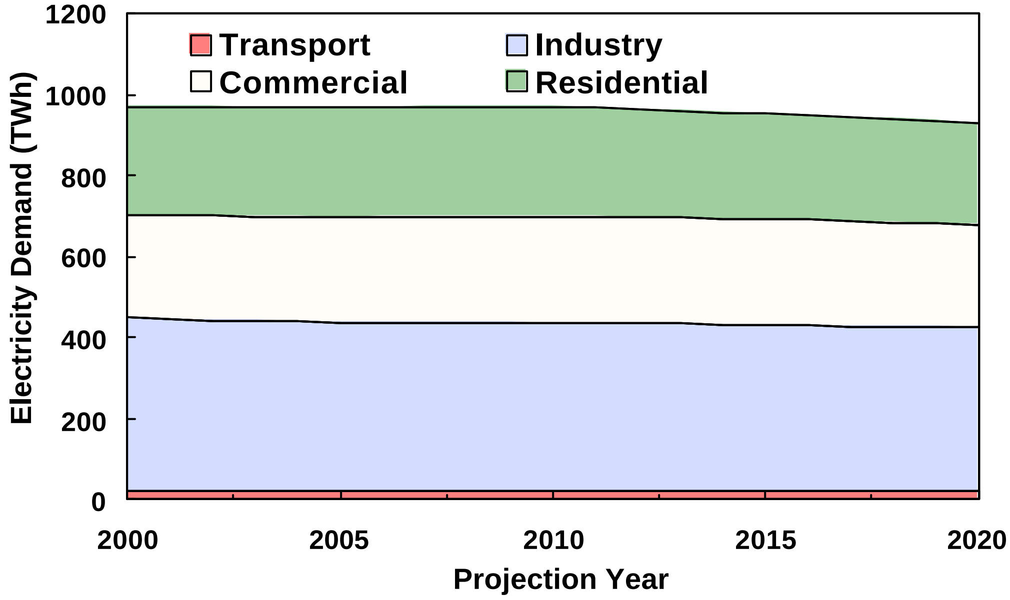


**Figure 4-1: Net Electricity Demand in the Power Switch Scenario**

### 4.1.2. Power Sector Scenario Assumptions

Although demand-side energy efficiency and distributed generation measures are crucial elements to the reduction of electricity-sector greenhouse gas emissions, particularly in the medium term, a key focus of this study is on changes that can be made in the Japanese power sector to markedly reduce greenhouse gas emissions. Below, we discuss several central elements on the "supply side" of the PS scenario. These include a shift away from coal use in the power sector, a similar shift away from the use of oil, an aggressive effort to implement renewable energy technologies for electricity generation, a gradual nuclear phase-out, an increase in the use and efficiency of gas-fired power plants, and an increase in the use of distributed generation and cogeneration (in addition to that noted above).

***Fuel Switch Away from Coal***

Coal-fired power plants arguably represent the most carbon-intensive generation option among those available to Japan. In the BAU scenario, electricity generation from coal in 2020 produces 46 percent of total $CO_2$ emissions from the power sector, even though coal accounts for only 24 percent of the electricity generated. Switching fuel from coal to natural gas and other cleaner fuels, and making a transition from polluting and inefficient coal-fired plants to efficient and cleaner plants, are steps that are necessary in order to significantly reduce power sector GHG emissions. The recent trend of coal use in the power sector, however, has been the reverse. Coal imports to Japan have increased dramatically in recent years, rising by over 50 percent in just the last decade (see Figure 4-2) as domestic coal needs have increased and the domestic coal production industry has been phased out. A large fraction of the coal imported to Japan is used for energy transformation and particularly for electricity generation. 149 million tonnes of coal was imported to Japan in 2000, of which

130 million tonnes were used in the energy transformation sector, including the 67.6 million tonnes (45 percent of total imports) used for electricity generation. Domestic coal production in 2000 same year represented only 2 percent of total coal consumption in Japan.[48]

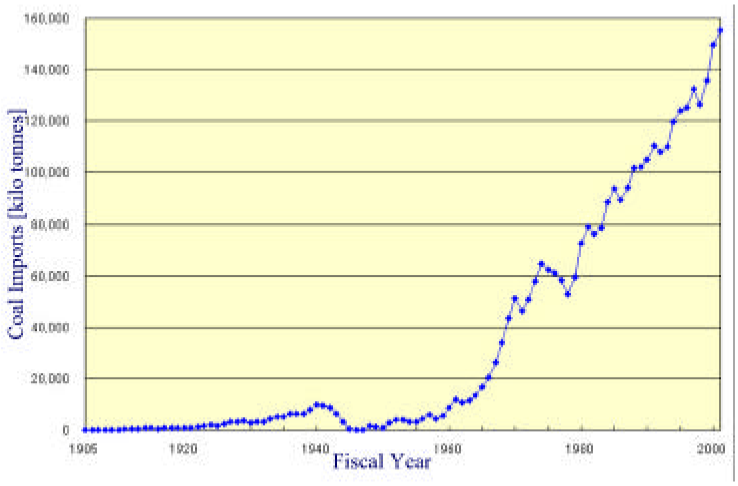


**Figure 4-2: Volume of Japanese Coal Imports, 1905 to 2000[49]**

Historically, Japan's major energy policy priority has been to maintain a secure supply of the fuels that its economy needs. From the perspective of the energy supply security of an importing nation like Japan, coal is an attractive natural resource. In terms of global reserves, coal is the most abundant of fossil fuels, and unlike crude oil, where most of the world's reserves are located in the politically volatile Middle East, the major coal exporters that sell to Japan are located in relatively politically stable regions. As of 2000, 60 percent of Japan's coal was imported from Australia, followed by China and Indonesia.[50]

While it would be ideal, from the perspective of domestic energy security, for Japan to rely on indigenous energy resources such as hydro and other renewable forms of energy as much as possible, the abundance and low price of imported coal compared to the costs of harnessing indigenous energy resources make coal-fired power hard to beat from a purely economic perspective.

The Power Switch scenario, however, includes a marked reduction in coal-fired generation capacity, and thus in coal use in the power sector. Power sector coal use must be reduced if $CO_2$ emissions from the power sector are to be reduced significantly. If, as in the BAU scenario, more coal-fired plants, it will be far more difficult to achieve Japan's reduction targets under the Kyoto Protocol. Reducing coal use in the power sector also yields reductions in the emissions of other important air pollutants. Reducing Japan's reliance on coal for power generation is likely to be beneficial from an energy security point of view as

[48] Handbook of Energy and Economic Statistics in Japan, Edited by the Energy Data and Modeling Center (EDMC) and the Institute of Energy Economics, Japan (IEEJ), and published by the Energy Conservation Center, Tokyo, Japan, 2002.

[49] Japan Coal Energy Center, http://www.jcoal.or.jp/graph/graphjp04.html.

[50] Japan Coal Energy Center.

well, in that reducing coal usage will provide an additional incentive to use indigenous energy sources such as renewable energy.

In order to reduce $CO_2$ emissions from coal-fired power plants relative to the BAU scenario, in addition to not adding new coal-fired plants, choices for the PS scenario are retiring existing plants, re-powering existing plants to combined-cycle operation, or adding new high-efficiency plants that use stringent air pollution control technologies.

**Retiring or re-powering of existing plants**

Power generation using older coal-fired power plants is generally inefficient. $CO_2$ emissions per unit electricity produced are greater than that of newer and more efficient power plants. Older plants also produce more of other types of air pollutants, including particulate matter, than newer plants, unless older plants are "re-powered" or refurbished. In general, re-powering integrates new power generating systems to the existing steam generation system (coal, oil, or natural gas-fired) in order to increase generation capacity and improve efficiency.[51] Typical re-powering is to add extra gas turbines and/or fluidized bed combustion facilities to old coal-fired boiler units; these modifications typically improve thermal efficiency by 14 to 28 percent while boosting output power by 20-40 percent, and reducing air pollutant emissions (but often with an increase in solid waste production).[52] Since re-powering builds onto an already existing facility, it can be completed on a shorter time frame than building new power plants. In addition, infrastructure such as transmission lines surrounding the plants already exists, and the intrinsic value of existing sites, which are already permitted and have established infrastructure such as power line and fuel access is maintained. As a consequence, re-powering can help to avoid the severe siting problems often faced by large new generation facilities.

The major problem with re-powering of power plants in Japan, and particularly of coal-fired power plants, however, is high cost. Re-powering costs are estimated 250,000 JPY per 1kW addition of gas turbine to convert a coal-fired power plant to Fully Fired Combined Cycle operation, and 150,000-200,000 JPY/kW for re-powering to Heat Recovery Steam Generator Combined Cycle.[53] [54]

There have been several cases in which LNG (natural gas)-fired power plants in Japan have been re-powered, but no case as yet in which coal or oil-fired power plants have been re-powered. Re-powering of coal-fired plants doesn't seem to be an option that is favored in Japan. First of all, most re-powering that is contemplated involves that the addition of gas-fired combustion turbine units, not (for example) coal-fired fluidized bed units feeding gas turbines, so that even re-powering of coal power plants could effectively be considered additions to natural gas-fired capacity. Second, Japan's Ministry of Environment has evaluated the potential to add re-powered generation capacity to those power plants that have

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[51] Research Report on Technologies of Greenhouse Gas Emission Reduction. Reduction Potential in the Energy Transformation Sector, Ministry of the Environment, March, 2001.

[52] See also, for example, US DOE, FBC Repowering Project Overview, http://www.netl.doe.gov/coalpower/combustion/FBC/APFBC/APFBCprojects.html.

[53] Ministry of the Environment, March 2001, op.cit.

[54] Re-powering costs in the report seems to be about 2 times higher than US cost quoted by DOE. See also footnote 37.

enough physical space to add re-powering units on-site.[55] Without regard to the cost of re-powering the Ministry of Environment estimated that there were 10 GW of potential re-powering capacity additions at existing oil-fired power plants, and an additional 8 GW at natural gas-fired plants. No opportunities for re-powering of coal-fired plants were identified. Third, since the cost of re-powering is high, and since re-powering begins with an inefficient, relatively old power plant, re-powering has no compelling economic or environmental advantage over building new natural gas-fired power plants. Re-powered plants do not necessarily emit less $CO_2$ per unit output than the average of emission rates of the old plant and of a new plant with capacity equivalent to the capacity added through re-powering. Fourth, since electricity consumption doesn't seem likely, under any scenario, to grow rapidly in Japan, re-powering is not likely to be necessary to increase generation capacity. The final important factor is that new technologies are being developed in Japan and elsewhere. More sophisticated options than re-powering with greater pay-offs in efficiency and capacity include Pressurized Fluidized Bed Combustion, Gasification Combined Cycle, Advanced Turbines, and Indirectly Fired High Performance Power Systems.[56]

Given the considerations above, the Power Switch scenario does not consider the re-powering option for coal-fired power plants. Old coal-fired plants are retired in the PS scenario. A total of 24 GW of coal-fired capacity is retired by 2020, with two-thirds of those retirements, or about 16 GW, taking place between 2010 and 2020. This rate of retirement is roughly consistent with retiring coal-fired power plants once their lifetime reaches about 40 years, and means that by 2020 the coal plants operating in Japan will all be relatively more efficient, relatively cleaner plants built after 1990. The capacity of coal-fired plants in last 30 years increased by roughly 1GW capacity annually[57], on average, between about 1970 and 1990, so the rate of retirement included in the PS scenario occurs at similar rate to the rate at which older plants were constructed. As a result of the accelerated retirement of coal-fired power plants, the efficiency of coal-fired power is assumed to increase (from a gross efficiency of about 40 percent in 2000 to 41 percent in 2010 and 43 percent in 2020), and the fraction of sulfur dioxide emissions captured by control equipment is assumed to increase to 90 percent.[58] The PS scenario includes no additions of new conventional coal-fired plants.

**High conversion efficiency technologies**

Advanced coal-fired power generation systems such as IGCC (Integrated Gasification Combined Cycle) and PFBC (Pressurized Fluidized Bed Combustion) have been researched and developed extensively, both in Japan and in other countries. These systems emit less $CO_2$

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[55] Ministry of the Environment, March 2001, op.cit.

[56] See, for example, "Integrated coal Gasification Combined Cycle; Technology development history and current status," Inumaru et. al, Central Research Institute of Electric Power Industry, http://criepi.denken.or.jp/jpn/PR/Review/No44/

[57] Data sources are the Ministry of Economy, Trade and Industry, and the Citizen's Alliance for Saving the Atmosphere and the Earth, http://www.netplus.ne.jp/~casa/index2.html.

[58] Note that the efficiencies provided here are gross generation efficiencies, and have therefore not been adjusted to take into account the approximately 6 percent of plant output that is used for in-plant use. Data in Experience Curves For Environmental Technology And Their Relationship To Government Actions, prepared in 2002 by E.S. Rubin, M.R. Taylor, S. Yeh and D.A. Hounshell for (apparently) the "Sixth International Conference on Greenhouse Gas Control Technologies", suggests that more than 20 GW of the 36 GW of coal-fired power plants in operation in Japan as of 2000 were equipped with $SO_2$ scrubbers. See http://www.rite.or.jp/GHGT6/pdf/C2-1.pdf.

per kWh of output than standard coal-fired power plants because of their higher thermal efficiency. In modeling coal plant energy efficiency in LEAP, we have assumed that the gross efficiency of existing coal-fired power plants stays at 40% until 2020 in the BAU scenario, and increases slightly over time as described above in the PS scenario. The thermal efficiency of new advanced coal-fired power plants will reach 45 to 50 percent by 2020.

These technologies, however, may not ultimately play a significant role in reducing $CO_2$ within the next 20 years in Japan. These advanced technologies are still in the testing stage. Several experimental pilot plants are now being operated. High capital cost is another reason to suspect that these technologies will not be widely used in the near future. In addition, while these technologies provide immediate benefit in the reduction of pollutants such as $SO_x$ and $NO_x$ relative to standard coal-fired plants, they do not reduce $CO_2$ emissions as effectively as switching to cleaner fuels.[59] Due to their cost and technological uncertainty, no plants of these types have been added in the BAU case. In the PS case, demand-side measures and $CO_2$-emissions consideration make additional coal capacity of any kind unnecessary and undesirable, respectively.

## ***Oil***

The capacity of oil-fired plants is projected to decrease in the BAU scenario. Existing oil fired generation capacity in 2000 was 63.95 GW, and is assumed, based on retirement of old units, to decrease by 2.8 percent annually through 2010, and at 1.0 percent annually thereafter. The Power Switch scenario calls for a somewhat more rapid phase-out of oil-fired generation, with capacity decreasing by 2.5 percent annually after 2010. The capacity of combustion turbine plants fueled with residual oil is assumed to stay at its 2000 level of 0.72 GW in both scenarios. The capacity of diesel oil-fueled engine-driven cogeneration plants are assumed, in the PS scenario, to increase following IEEJ's cogeneration projection in their target scenario, namely growth of 6.2 percent annually to 2010, with growth of 1.5 percent/yr between 2010 and 2020. Growth of diesel engine cogeneration capacity is thus more than twice as rapid as in the BAU scenario (2.3 percent/yr) between 2000 and 2010.

## ***Accelerate Renewable Energy Implementation***

Some argue that as other advanced generation technologies such as combined cycle gas power plants are improved, and as their capital costs decline, it will be more difficult for renewable energy sources to be economically competitive as "clean technology" options in the future. Given, however, the substantial uncertainties involved in fossil fuel markets, and the environmental and energy security benefits for Japan of boosting the fraction of its energy needs supplied by domestic and renewable resources, it is very important to explore fully the technological potential to reduce $CO_2$ emissions through the aggressive deployment of renewable energy technologies such as wind power, solar-thermal and -photovoltaic electricity, geothermal, small or medium hydro-electric power plants, and firing of sustainable-harvested biomass in new or existing power plants. Given the environmental and energy security benefits of renewable energy technologies, as well as their potential impacts

[59] Though there are several methods of "scrubbing" $CO_2$ from power plant stack emissions (capture and indefinite storage of $CO_2$ as carbon or in another form) under discussion and development, these technologies result in very substantial losses in net power plant efficiency, and are likely to be very costly. As a result, the $CO_2$ scrubbing option has not been considered in this study.

on local employment, it is a mistake to judge "renewables" solely on the basis of narrowly-defined "market competitiveness".

**ISEP Study**

WWF Japan commissioned the Institute of Sustainable Energy Policies (ISEP) to evaluate the extent to which Japan could adopt and use renewable fuels as primary energy sources by 2010.[60] The study group, led by Dr. Tetsunari Iida of ISEP, estimated that the share of renewable fuel resources could potentially be increased to 10 percent of the total primary energy in Japan by 2010 if Japan would adopt alternative renewable energy policies and measures.[61] In the ISEP study, "renewables" means wind, PV, geothermal, and small hydro (<10MW) power, biomass-fired electricity generation excluding generation using Municipal Solid Waste (MSW), and black liquor (a by-production of paper manufacturing). In the ISEP study, MSW is excluded because MSW can contain petroleum-derived products such as plastic bottles that, when burned to generated power in waste-burning plants, can potentially emit toxic gases such as dioxins. The ISEP study estimated the maximum renewable energy resources in Japan; its results are summarized in Table 4-2.

**Table 4-2: Renewable energy resources in Japan**[62]

| Area | Wind | PV | Biomass | Geothermal & Small hydro |
|---|---|---|---|---|
| Hokkaido | 11.80 | 5.34 | 3.54 | 8.59 |
| Tohoku | 4.17 | 10.99 | 6.51 | 17.98 |
| Kantou | 4.43 | 25.66 | 6.26 | 8.02 |
| Hokuriku | 1.05 | 2.89 | 0.86 | 9.84 |
| Chuubu | 1.53 | 10.83 | 2.36 | 20.93 |
| Kansai | 0.35 | 9.49 | 1.88 | 5.18 |
| Chuugoku | 1.52 | 6.40 | 2.32 | 5.27 |
| Shikoku | 3.11 | 3.40 | 1.18 | 3.54 |
| Kyuushuu | 2.43 | 11.61 | 4.24 | 9.26 |
| Total | 30.30 | 86.60 | 29.13 | 88.60 |

Unit: TWh

The ISEP study does not explicitly describe how much electricity could be generated from renewable resources. Therefore, for the Power Switch scenario, we have effectively applied a Renewable Portfolio Standard (RPS) that starts at 11.2 percent of total supply-side electricity generation in 2000,[63] increasing to 13.5 percent in 2010 and 18.1 percent in 2020.

[60] ISEP, op.cit.

[61] Based on the results of the ISEP study, WWF Japan recommended at the UN World Summit on Sustainable Development in 2002 that Japan could adopt a numerical target of 10% as the fraction of primary energy supplied by renewable fuels by 2010.

[62] Units are converted to TWh from PJ, figures shown here are rounded.

[63] For the purpose of counting generation as "renewable" or not in this report, we consider power generated from hydro resources (not counting pumped-storage hydro), wind, solar energy, and biomass including "black liquor" to be generation from renewable resources. Note that this definition is slightly different than that used in the

Renewable Portfolio Standard, a policy concept that is currently being used or contemplated in a number of countries, establishes a minimum amount of renewables-based power as a fraction of total electricity generation. The implementation of a RPS is designed to speed the introduction of renewable technologies into the electricity sector. In the PS scenario, additional generation from distributed PV systems accounted for on the demand side raises total renewable generation to 13.9 percent of total electricity output by 2010, and 18.9 percent by 2020[64].

In the electricity generation sector, the PS scenario builds on IEEJ's "Target scenario", which includes the renewable energy capacity. The PS scenario uses IEEJ's figures for generation capacity in 2010 and 2020 for supply-side PV systems (additional PV capacity is included on the demand side as well based on the scenario described in the Tsuchiya study). The Power Switch scenario, however, adds considerably more wind power capacity after 2010 than does IEEJ's Target scenario (to a total of 11.5 GW), reflecting the recent boom in worldwide wind energy capacity construction, and improvements in technology for capturing wind energy in offshore wind farms. Still, when the renewable capacities used in the PS scenario are calculated relative to the maximum potential resources estimated by ISEP in Table 4-2, only a fraction of total PV and wind potential is tapped by 2020.

In the Power Switch scenario, MSW is not explicitly considered as a renewable energy source, as some fraction of MSW is plastics, and thus not ultimately derived from renewable sources. We do, however, adopt IEEJ's "Target Scenario" projections regarding MSW capacity, but do not add MSW capacity beyond those levels. The WWF and majority of other renewable energy advocate groups do not count MSW as renewables. First of all, fuel for MSW contains many non-renewable components such as plastics, metal, and ashes. Second, the combustion of MSW generates toxic gases that are not necessarily removed by even the best pollution control equipment. In fact, although the METI's BAU projection includes MSW as a renewable energy source, the Renewable Portfolio Standard Law, which was enacted in 2002, excludes most industrial waste from renewables, and only the organic biomass component of MSW is currently counted as a renewable fuel. The government is scheduled to revisit this issue of the designation of MSW in three years.

### Photovoltaic Technology

The total generation capacity of photovoltaic (PV) power systems in Japan increased by a factor of four in recent years, rising from 55 MW in 1996 to 209 MW in 1999. The Japanese government has provided R&D (research and development) funding to the PV industry for many years. Despite substantial progress in the development of photovoltaic technologies, the domestic market for PV is not as strong as the PV industry had expected.

The biggest obstacle to the wider acceptance of PV power systems is high system capital costs. ISEP projected a cost reduction for PV systems from 900,000 yen/kW in 1998 to 300,000 yen/kW in 2010. Figure 4-5 shows the ISEP estimate of past and future (as projected by ISEP) trends in PV system capital costs.

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ISEP report. Note that the vast bulk (80 percent) of renewable generation in 2000 is from existing hydroelectric facilities.

[64] Note that this calculation includes both demand- and supply-side generation in both renewable generation and in total electricity output. Total electricity output therefore includes gas-fired demand-side (residential and commercial) cogeneration.

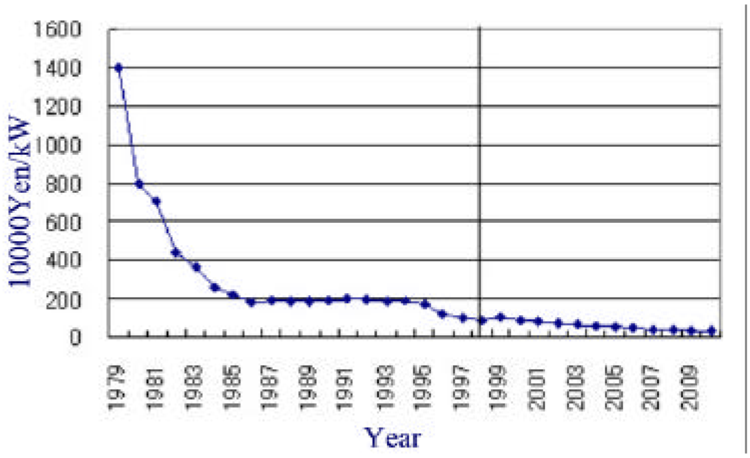


**Figure 4-3: Declining Price Trajectory for PV System Capital Costs (ISEP)**

**Wind energy potential**

Wind power is the most promising renewable energy prospect for commercial success. The main stumbling block for Wind energy's commercial success in Japan is likely to be energy policy and power transmission system-related issues rather than capital cost or technological maturity.

**Other renewables**

Conventional hydroelectric generation and geothermal generation capacities are assumed to stay at the current levels, largely because Japan has already developed water and geothermal resources to nearly the maximum extent practicable, and at least partially because additional development of these resources is likely to be politically difficult. The capacity of generation using most biomass fuels, including by-products produced during the pulping process ("spent liquor" or "black liquor"), digester gas from sewage or animal waste treatment, and industry waste would stay the same. The use of other biomass, including biomass grown on plantations but mainly using existing agricultural wastes is assumed to increase to 1 GW by 2010, 2 GW by 2015, and 4 GW by 2020.

## ***Nuclear Phase Out***

Nuclear power generation has been considered by many policymakers in Japan to be the most important technological option Japan has had available to reduce national green house gas emissions. Although the international community still debates whether nuclear energy could be the solution to global warming, Japan has strongly promoted nuclear power as a clean source of energy which could help to reduce not only $CO_2$ emissions. Government plans to achieve the Kyoto protocol target have seemed impossible without relying more heavily on nuclear power. In addition to the benefits for GHG emissions reduction, nuclear power development has been considered a key to improving Japan's energy security. Both Japan's energy security policy and its climate change mitigation policy thus have tended to rely almost solely on the promise of nuclear power development.

Recent nuclear plant shutdowns, however, have caused new doubts in the mind of the Japanese public about nuclear reliability. It has long been argued whether Japan could significantly increase nuclear power capacity without solving technical and social problems associated with siting new power plants, as well as nuclear waste isolation/disposal issues. In recent years, however, the Japanese public has become increasingly aware of and educated about not only nuclear safety issues but also energy security and fuel diversity issues. In April 2003, Tokyo Electric Power Company (TEPCO) was forced to shut down all of its nuclear reactors for emergency inspections after admitting to a pattern of falsifying safety records at nuclear plants since the late 1980s. For the period of this inspection, TEPCO has been obliged to take 17.38 GW, or about 30 percent of its power generating capacity off-line. Although TEPCO promised to carry out its inspection program as quickly as possible, there was a fear of a supply shortage all summer, which was scrutinized as a "power crisis". The Japanese public has become aware of the urgent necessity for Japan to develop technologies to use alternative energy sources other than nuclear power to help address energy security and global warming issues.

Considering the numerous problematic issues regarding nuclear power development, the Power Switch scenario is based on a non-aggressive nuclear phase-out scenario. This implies that the use of non-renewable energy resources such as fossil fuels and uranium have to "eventually" be reduced to zero—a phase out of fossil fuel and nuclear power. The Power Switch scenario includes the beginnings of a gradual nuclear phase out pathway. In the PS scenario, the lifetime of nuclear power plants is considered to be 40 years, so that 10 GW of existing nuclear generation capacity will be retired by 2020, with most of the 10 GW retired after 2010. This implies that most of the plants built in the 1970s or before will be retired by 2020. Only those few plants currently being constructed or well into the planning phase, a total of 6.9 GW[65], will be added during the next 20 years under the PS scenario.

## ***Natural Gas***

Natural gas is the cleanest-burning of fossil fuels, and its utilization has increased dramatically in many parts of the world during the last two decades. In spite of uncertainties about future natural gas supply and price, the United States and Europe are also rapidly increasing their reliance on natural gas for electricity generation. Japan's power generation sector has also been shifting toward greater use of natural gas.

There are obstacles to the markedly expanded utilization of natural gas in Japan. These include:

- The relatively high cost of imported LNG (Liquefied Natural Gas) relative to other fuels (notably coal).
- The lack of natural gas infrastructure, including both LNG import terminals and, perhaps most importantly, the lack of natural gas transmission and distribution systems that are substantially interconnected between gas company service territories.
- High retail natural gas prices in Japan. Gas prices in Japan in 2000 were $450 per 10 billion calories for gas for industrial use, and $1300 per 10 billion calories for residential use. These prices were many times higher than those experienced in the United States—$170 for industrial and $300 for gas for residential use—and were over twice as high as

[65] The plants under construction or highly likely to be built include the Hamaoka5 ABWR, at 1,380 MW; the Higashidori1 BWR, 1,100 MW; the Onagawa3 BWR, 825 MW, the Shika2 ABWR, 1,358 MW; the Shimane3 ABWR, 1,373 MW; and the Tomari3 PWR, 912 MW.

gas prices in any other OECD country[66]. To the extent that gas supply does not keep up with demand (or grows more costly), the recent rapid increase in natural gas demand will likely help to bring about a large and continuous increase in the gas prices, which could in turn have a serious negative impact on the competitiveness of gas relative to other fuels. If natural gas prices stay high (and possibly become more volatile) in Japan, other energy forms, including renewable energy, will be seen as more economically attractive options, which will spur Japanese consumers and policymakers to seek those options.

Natural gas will play a significantly important role in the reduction of national $CO_2$ emissions for at least the next 20 years, but also considers natural gas, as well as nuclear power and other fossil fuels, to be only an interim means of addressing the problem of global climate change. In the long run, fuel shifts toward a newer generation of clean energy technologies based on renewable resources, and incorporating the use clean fuels such as hydrogen, will be required. Natural gas could also serve as a transition fuel in that it could be a source for hydrogen manufacture in the beginning of a switch from carbon-based fuels to hydrogen, but the primary energy resources used should ultimately be switched almost entirely away from fossil fuels to biomass and other renewable sources of energy.

In the Power Switch scenario, natural gas-fired combined cycle and natural gas-fired cogeneration, as well as renewable sources of electricity, are used to meet overall demand for electricity through 2020 as coal-fired, oil-fired, and nuclear generation capacities decline. The Power Switch scenario assumes that a fraction of existing natural-gas-fired steam-cycle plants (19 of about 56 GW) will be either retired or converted to combined-cycle operation (through re-powering), and that any new gas-fired power plants (other than cogeneration or fuel cell plants) will be high-efficiency combined-cycle plants to cost-effectively make the most of (mostly) imported gas resources while producing minimal pollutant emissions.

## ***Cogeneration and Other Distributed Generation Systems***

Cogeneration can nearly double the efficiency with which energy in fuel provides useful products by generating both steam (or, in some cases, hot water) and electricity. Cogeneration is useful in cases where the heat produced by a cogeneration system can be delivered and utilized efficiently, which usually means that the cogeneration system must be located at or near the site of heat demand. Heat demand in Japan, including process heat in industry and space and water heat in the commercial sector, is currently supplied in large part by combustion of residual oil and other oil products—as well as, in some industrial sub-sectors solid wastes and coal—in boilers and furnaces. If a substantial fraction of this demand could be provided through cogeneration, the reduction of overall GHG emissions by utilizing cogeneration heat would be large.

In addition, as cogeneration systems are typically located close to or on commercial and industrial sites where electricity and heat are consumed, the more cogeneration and other distributed electricity generation systems are implemented, the lower the requirements for transmission and distribution of electricity, and the lower transmission and distribution losses will be. This in turn reduces the net requirements for electricity generation.

[66] Gas price data from the US Department of Energy's Energy Information Administration (EIA) WWW site, web pages http://www.eia.doe.gov/emeu/international/ngasprih.html and http://www.eia.doe.gov/emeu/international/ngasprii.html.

At present less than 2 percent of all Japanese electricity is generated in cogeneration systems, but this fraction is expected to grow rapidly. In the IEEJ Target scenario, a growth rate of cogeneration capacity is set at 6.2 percent annually through 2010, and 1.5 percent between 2010 and 2020. For the Power Switch scenario, we assume this same level of growth for larger cogeneration systems (gas and diesel-fired engines, and gas-fired turbines) modeled on the supply (energy transformation) side. On the demand side, in the PS scenario, heat from cogeneration systems modeled on the electricity supply side displace some industrial heat requirements that would be (and are in the BAU scenario) provided by residual fuel oil consumption, and displace some combustion of oil fuels in commercial space heating and water heating end-uses.

Fuel cells are a promising on-site clean electricity generation technology. The thermal efficiency with which fuel cells and fuel cells coupled with gas turbines are expected to be very high. In the Power Switch scenario, we assume that fuel cell generation capacity for utility systems (or in large commercial or industrial applications) total 300 MW by 2010, and 2 GW by 2020. These fuel cells are modeled on the supply side, on the assumption that they would represent dispatchable capacity—utilities might, in fact, use them as reliable distributed generation systems and thereby help avoid costs of distribution infrastructure additions. These capacity figures are significantly less than the fuel cell capacity growth assumptions of IEEJ. IEEJ's Target scenario projections for fuel cell capacity both the residential and commercial sectors are 2.1GW in 2010 and 10.1 GW in 2020. NEDO's target is 2.2 GW in 2010. These capacities do not include the power of fuel cells used in automobiles in the future. As noted above, however, the PS scenario does include significant numbers of residential-sector fuel cell systems (derived from the results of the Tsuchiya study), which offset the need for utility grid power.

### 4.1.3. Results and Discussion of the Power Switch Scenario

Based on the assumptions described above, the WWF-Japan Power Switch scenario was simulated using LEAP. Wind, PV, Biomass, natural gas cogeneration and natural gas combined cycle generation are entered into LEAP as "exogenous" (externally specified) capacity in quantities such that electric energy demands are met, and capacity remains high enough to meet a reserve margin target of 20 percent (the same as used in the BAU scenario) by 2020.[67] Figures 4-6 and 4-7 present, respectively, the electricity outputs and generation capacity by type of power plant in the Power Switch scenario between 2000 and 2020. Striking features of these figures, relative to results for the BAU scenario, include a considerable reduction of coal-fired generation and capacity, an increase in natural gas combined-cycle output, and increases in wind, cogeneration, and photovoltaics capacity and output. In addition to the 16 TWh of utility PV generation, though not visible in these electricity supply-focused figures, there are 22 TWh of generation from PVs located on the premises of residential, commercial, and industrial customers, and over 50 TWh of generation from smaller demand-side (commercial and residential) cogeneration systems.

[67] The goal here is to model the BAU and PS scenarios on an even footing. As a consequence, both scenarios meet the same reserve margin target for 2020, and in both scenarios reserve margins fall from 2000 levels of about 24 percent to the 20 percent level by 2020. As PV and wind power, which have significantly higher capacity in the PS scenario than in the BAU scenario, are intermittent resources, their contributions toward the total capacity needed to meet peak demand plus reserve margin is discounted substantially relative to thermal power plants (which can theoretically be available to meet peak needs at virtually any time).

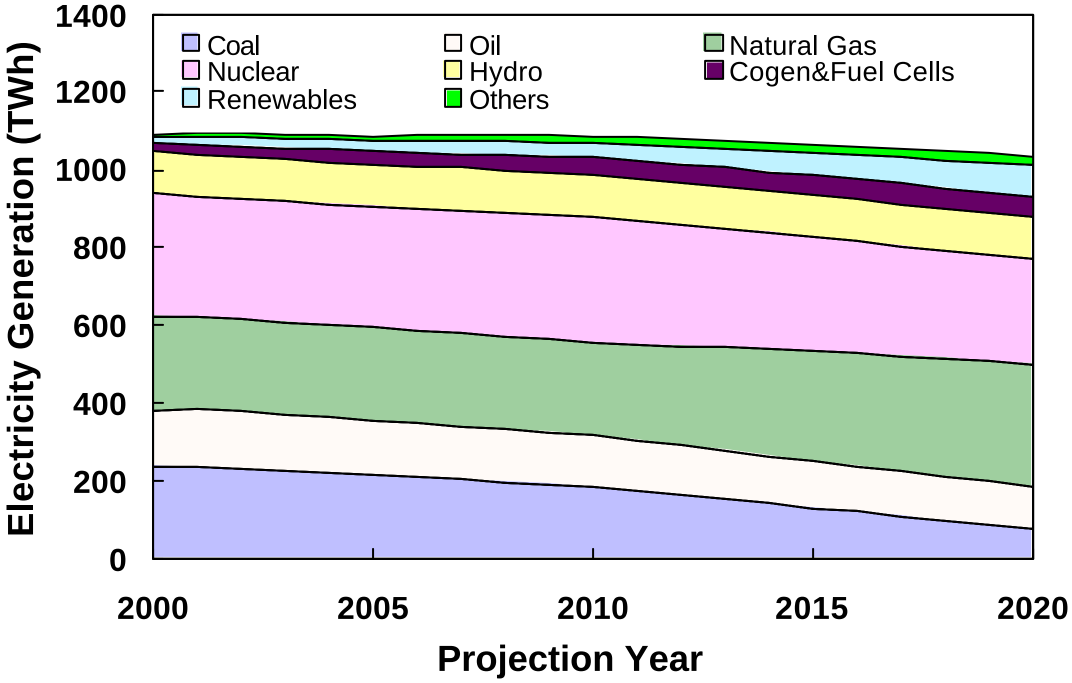


**Figure 4-4: Electricity Generation in Power Switch Scenario**

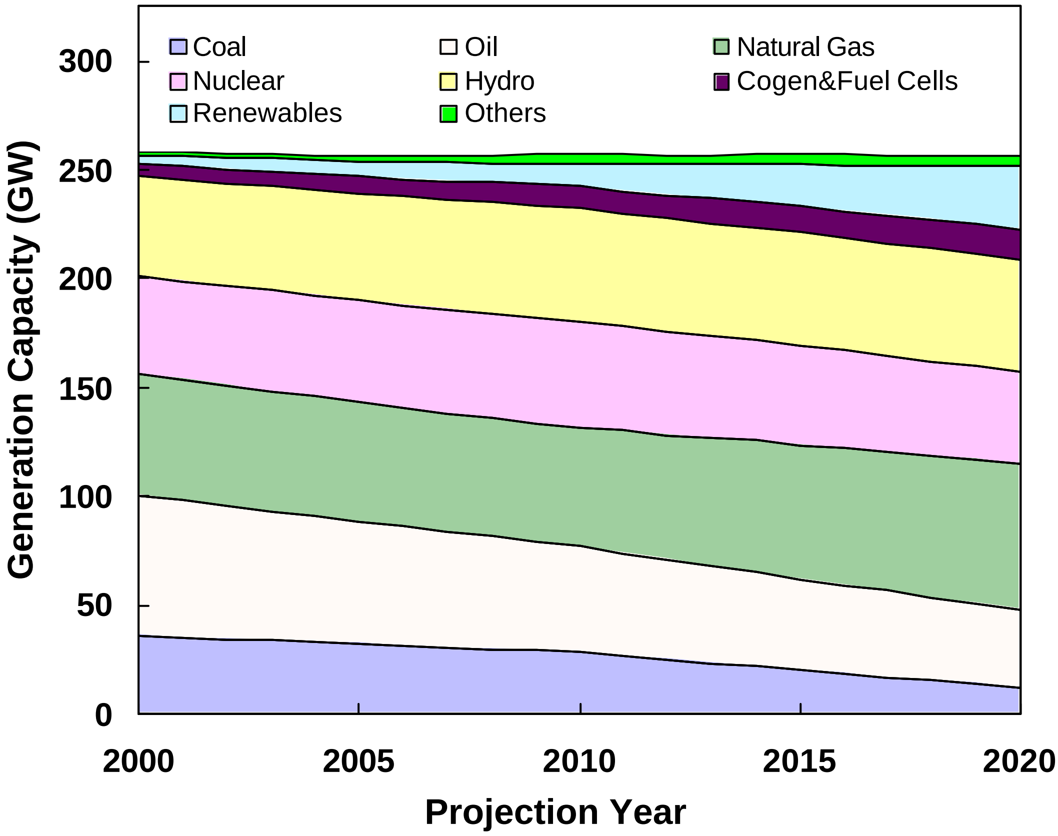


**Figure 4-5: Generation Capacity in Power Switch Scenario**

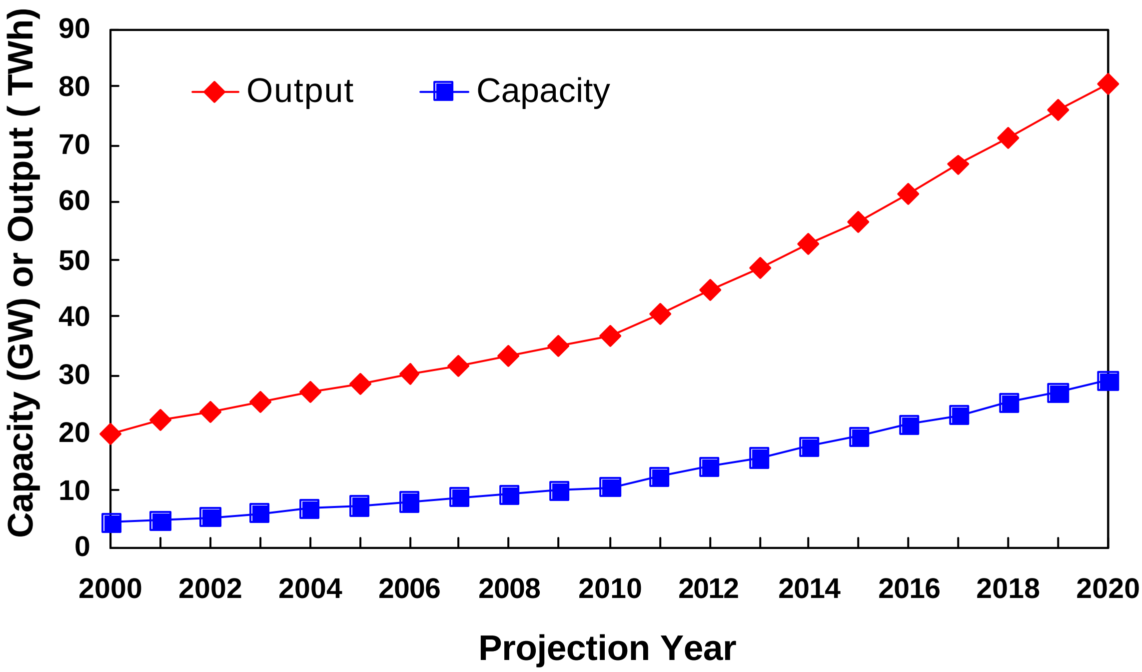


**Figure 4-6: Generation Capacity and Output by Renewables in Power Switch Scenario**

Figure 4-7 shows the heat output from "supply-side" cogeneration in the Power Switch scenario. Diesel-fueled engine-driven cogeneration and natural gas turbine cogeneration dominate the output of heat from the power sector. Overall, production of heat from cogeneration in the PS scenario is over 150 percent higher by 2020, than in the BAU scenario, when the additional production of co-generated heat counted in the demand sector is also considered.

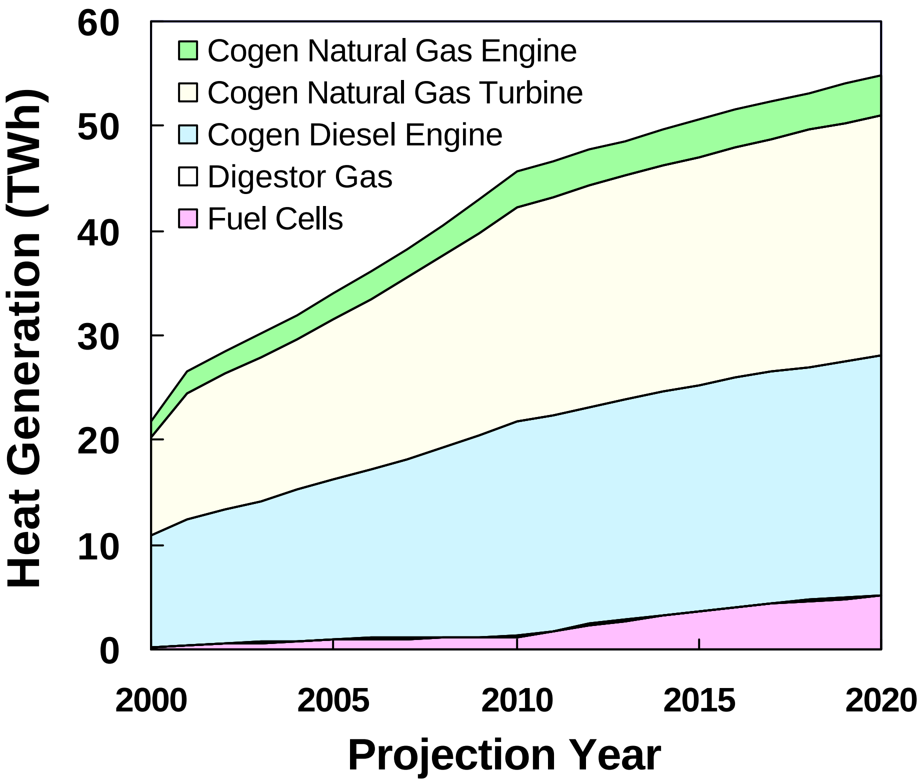


**Figure 4-7: Heat production by Cogeneration Systems in the Power Switch Scenario (supply-side only)**

# 5. The Power Switch Scenario, Benefits and Barriers

The Power Switch scenario outlined above offers a number of benefits relative to the BAU scenario. At the same time, the Power Switch scenario poses costs to portions of the Japanese economy that need to be taken into account, and there are barriers to implementation of the PS scenario that are not insignificant. Policy levers and approaches that might be used to help make the PS scenario, or one like it, a reality in Japan are also discussed below.

## *5.1. Comparison of Scenarios*

The BAU and Power Switch scenarios offer markedly different results, by 2020, both in terms of energy demand and supply, as noted above, but also in terms of their net greenhouse gas emissions, energy security and fuel diversity, and economic benefits and costs. In each case, comparisons of the BAU and PS scenarios are presented below.

### 5.1.1. Greenhouse Gas Emissions

The evolution of power sector greenhouse gas emissions, measured as $CO_2$ equivalents, is shown in Figure 5-1 for the Power Switch scenario. Compared with power sector GHG emissions in the BAU scenario (as shown in Figure 3-4), overall emissions are markedly lower, declining by 20 percent relative to year 2000 emissions. Year 2020 emissions in the PS case are some 31 percent lower than they are in the BAU case. Figure 5-2 summarizes the divergence in GHG emissions between the two cases over time. Major differences between scenarios include markedly reduced emissions from coal-fired, and to a lesser extent oil-fired power in the PS case, as well as slightly reduced emissions from gas-fired power plants (the $CO_2$ emissions output of the sum of all of the different types of gas-fired power plants, including gas-fired cogeneration is about 1 percent lower by 2020 than in the BAU case).

In addition to differences between the BAU case and the PS case in power sector GHG emissions, there are differences between the scenarios on the demand side. Reductions in boiler fuel use in the industrial and commercial sectors due to use of heat from cogeneration, plus reductions in fuel use in the residential and commercial sectors due to expanded use of solar water heat, are offset somewhat by higher fuel use due to expanded demand-side (smaller-scale) cogeneration in the household and commercial sectors. The net impact of these changes is that PS case GHG emissions from the demand sector by 2020 are approximately 5 million tonnes of $CO_2$ less than in the BAU case.

Overall, relative to the BAU scenario, the PS scenario reduces Japan's GHG emissions by 94 million tonnes of $CO_2$ equivalent per year by 2010, and 190 million tonnes per year by 2020. Overall GHG reductions from the PS scenario, relative to the BAU scenario, total nearly 2.0 billion tonnes of $CO_2$ equivalent between 2000 and 2020. Even more importantly, most of the infrastructure investments—as well as the industrial investments undertaken to produce the Power Switch infrastructure—will continue to provide GHG reduction benefits well beyond the time frame covered by this study.

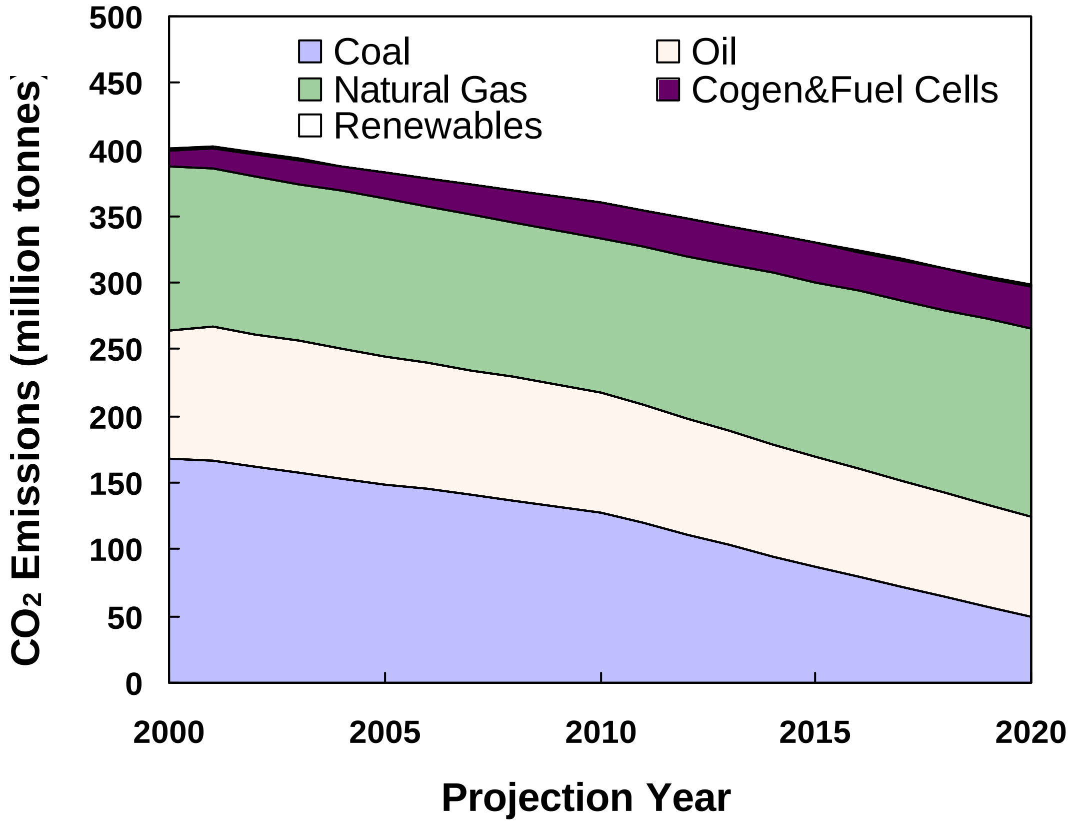


**Figure 5-1: Power Sector GHG Emissions in the Power Switch Scenario**

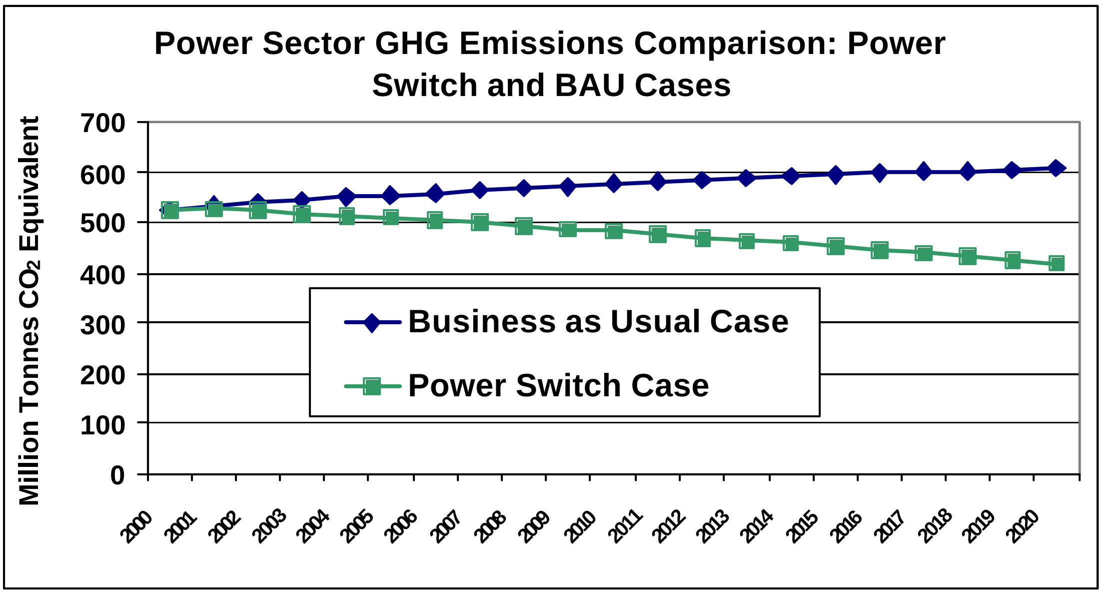


**Figure 5-2: Scenario Comparison, Power Sector GHG Emissions**

### 5.1.2. Energy Security and Fuel Diversity

Although a simple shift away from coal-fired to natural gas-fired power generation in Japan's power sector could reduce $CO_2$ emissions to some degree without major changes in energy infrastructure (for example, existing coal-fired power plants could be "re-powered" to use gas), or drastic energy policy changes, doing so arguably reduces fuel supply diversity. Leaning even more heavily on natural gas—the vast bulk of which, by 2020, would still need to be imported LNG—increases dependence on a single imported fuel, and does nothing to reduce overall fuel imports. Relying on imported fuels, including natural gas and uranium, reduces energy security in that an over-dependence on fossil fuels, natural gas in particular, leaves Japan vulnerable to fluctuations of fuel prices and supply availability. An increase in the use of indigenous energy resources, and especially of renewable sources of energy, would help to improve Japan's energy supply security. Although natural gas is the cleanest fossil fuel, it is important to move away from a heavy reliance on coal without an excessive increase of natural gas or nuclear generation.

Although the Power Switch scenario changes overall gas use for electricity generation very little relative to the BAU scenario, its marked increase in the use of power generation from renewable, domestic sources relative to the BAU scenario makes it improved in terms of fuel supply diversity.

In addition, the Power Switch scenario results, by 2020, in a reduction in coal imports of nearly 70 percent relative to the BAU scenario, and also results in decreases in annual imports of crude oil (3 percent), and nuclear fuel (20 percent). LNG imports increase, but only modestly (less than 2 percent). This means lowered vulnerability to supply disruptions, less reliance of Japan on imports and on imports from a particular region, and more reliance on domestic energy, including renewable generation at the point of end-use. Table 5-1 and Figure 5-3 provide comparisons of the electricity output by fuel type in the BAU and Power Switch scenarios in 2020. Note that although natural gas accounts for a greater share of electricity output by 2020 in the PS case relative to the BAU case, the quantity of natural gas used differs very little between the scenarios as shown in Table 5-1. Numbers in the table reflect only supply-side electricity generation. In the PS scenario, additional generation from distributed PV systems accounted for on the demand side raises total renewable generation to over 100 TWh in 2020.

**Table 5-1: Electricity Output by Type of Generating Plant in 2000 and 2020 for the BAU and Power Switch Scenarios**

| TWh | 2000 (Base Year) | 2020 (BAU) | 2020 (Power Switch) |
|---|---|---|---|
| Coal | 237.8 | 327.1 | 75.4 |
| Oil | 152.2 | 146 | 134.5 |
| Hydro | 103.2 | 103.2 | 106.4 |
| Nuclear | 319.5 | 379.5 | 267.8 |
| Natural Gas | 253.2 | 324.6 | 346.1 |
| Renewables | 19.6 | 27.7 | 80.7 |
| MSW and others | 5.2 | 10.7 | 24.4 |
| Total | 1090.7 | 1318.8 | 1035.3 |

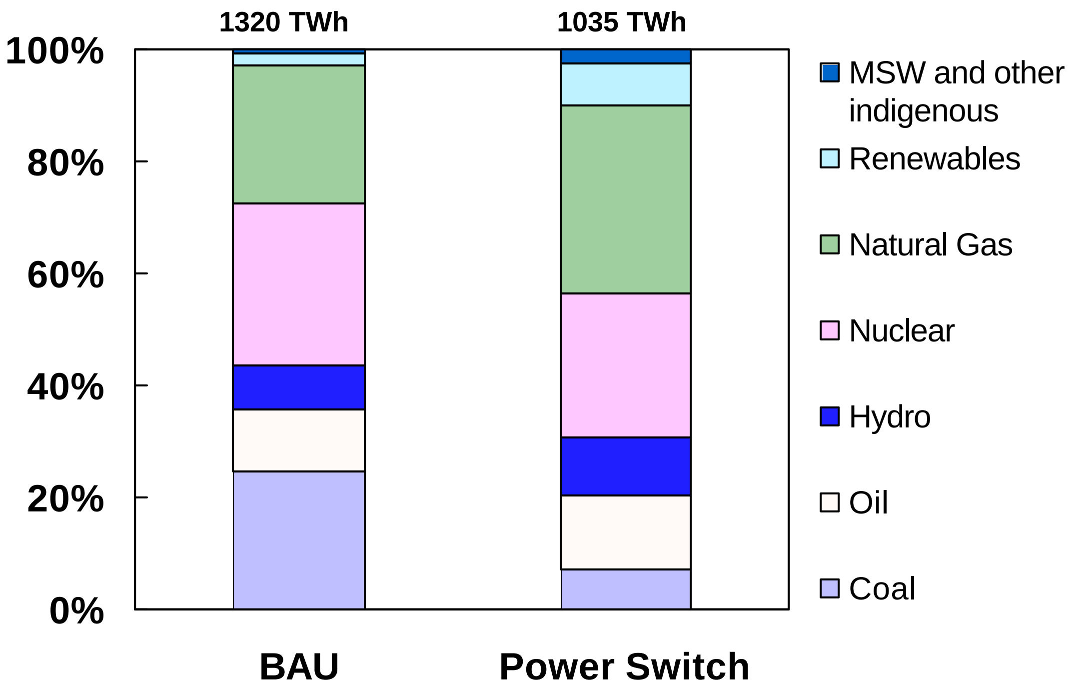


**Figure 5-3: Electricity Output by Type of Generating Plant in 2020 for the BAU and Power Switch Scenarios**

One quantitative measure of the relative diversity of fuel supply offered by different scenarios is a "diversification index", which can be applied to a pattern of fuel use, imports, or geographical source of imports within a fuel type to show the relative dependence of a country on sources of fuel supply. We applied an index described by Dr. Thomas Neff[68] to the fuels and resources supply for power generation in the Power Switch and BAU scenarios. The result, summarized in Figure 5-4, shows that while the diversification index changes little over time in the BAU scenario, the index decreases in the PS scenario, showing a **more diversified** fuel supply portfolio over time.

[68] T.L. Neff (1998), Improving Energy Security: Diversification And Risk Reduction, Fossil And Nuclear Fuels. Prepared for Nautilus Institute as a part of the study described in the footnote following this one, and available as http://www.nautilus.org/papers/energy/NeffPARES.pdf.

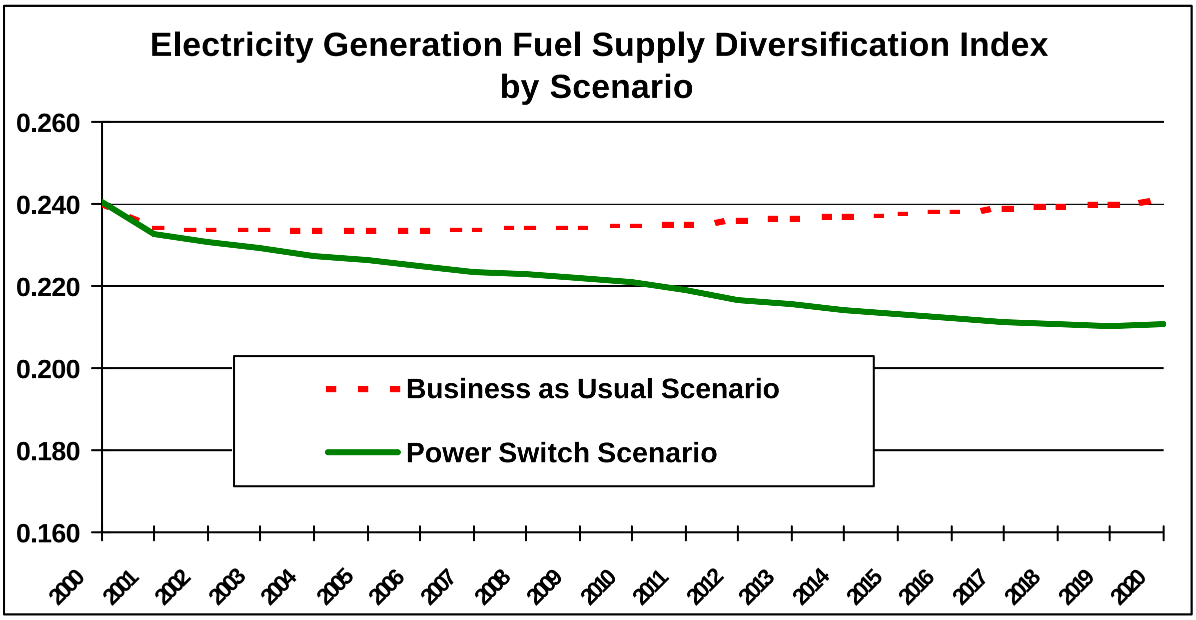


**Figure 5-4: Electricity Fuel Supply Diversification Index over the Study Period for the BAU and Power Switch Scenarios**

### 5.1.3. Relative Benefits and Costs of the BAU and Power Switch Scenarios

Historically, Japan's energy policy has tended to put less emphasis on cost effectiveness than on "energy security." Energy security as a concept in Japan has typically been narrowly focused on fuel supply security.[69] The priority of energy policy has always been to secure a stable and continuous fuel supply for the Japanese economy, as there are few indigenous fossil fuel resources in Japan. This energy security goal also provided the main reason for Japan's heavy investment in nuclear power development. Although uranium supplies and prices are stable compared to those of fossil fuels, however, nuclear development has other factors (as noted above) that influence nuclear policy, including domestic public opposition to nuclear technologies and the generally unfavorable international climate for nuclear power development. Over- investment in nuclear power and the distortion of real energy costs (through excessive government support for nuclear power) could become hugely risky in terms of energy security, particularly in the event of additional incidents involving the nuclear sector. It is therefore, and particularly now as the Japanese economy moves to a more competition-oriented approach to energy supplies, important to conduct "fair" comparisons of the costs of providing energy services.

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[69] A broader definition of "energy security" would include elements of economic, environmental, and military security, as well as incorporation of consideration of a number of different types of risk. For a definition and application of energy security in the broader sense, see T. Suzuki, D. F. Von Hippel, K. Wilkening, and J. Nickum (1998), Pacific Asian Regional Energy Security: Frameworks for Analysis and Japan Case Study. Synthesis Report for Pacific Asian Regional Energy Security (PARES) Project, Phase I (available as http://www.nautilus.org/pares/PARES_Synthesis_Report.PDF.

In this section of this report, we compare the overall costs of BAU and PS scenarios. These costs include the cumulative capital costs of the different power sector and other transformation sector investments, the variable operating costs of energy infrastructure, and the fuel costs (focusing on the costs of fuel imports). On the demand side, incremental capital and/or operating and maintenance costs of the measures included in the PS scenario are also included in order to present a complete picture of all relevant costs that are different between the two scenarios. The relative non-monetary costs and benefits of the two scenarios, and those monetary costs and benefits that cannot be estimated in quantitative terms, are also discussed in this section.

## ***Cost Assumptions***

In the energy demand sectors, costs were entered for all of the electricity end-use and other relevant devices where changes were made between the BAU and PSE scenarios. Cost, expressed either as costs of saved energy or costs per device, were entered for those measures (energy-efficiency, distributed generation, and other measures) described in section 4.1.1, above. In most cases, the costs for these devices were either derived from available Japanese data or, more frequently, estimated based on US costs for similar measures, but including a "mark-up" of 50 percent over US costs to account for generally higher costs in Japan. A full recounting of all of the cost assumptions used on the supply side is too lengthy to provide here, but some key assumptions are as follows.

- In the Residential sector, the Cost of Saved Energy (CSE) used for measures that save electricity varied from 6 to about 35 Yen per kWh, depending on the measure.
- Annualized cost for residential cogeneration (fuel-cell cogeneration) installations were assumed to fall from about 50,000 Yen/kW-yr in 2000 to about 20,000 Yen/kW-yr in 2020, taking into account the different vintages (ages) of systems present in any given year.
- Annualized costs for residential solar PV installations were assumed to fall from about 100,000 Yen/kW-yr in 2000 to about 38,000 Yen/kW-yr in 2020, again taking into account the different vintages (ages) of systems present in any given year.
- In the Commercial sector, the CSE estimates used for measures that save electricity varied from -2.5 (these measures result in net saving through their reduction in operating and maintenance costs) to about 18 Yen per kWh, depending on the measure.
- Generation costs for commercial cogeneration (using engine- and turbine-driven systems) installations were estimated at 5 to 6.5 Yen per kWh, exclusive of fuel costs.
- Annualized costs for commercial solar PV installations were assumed to fall from about 95,000 Yen/kW-yr in 2000 to about 35,000 Yen/kW-yr in 2020, again taking into account the different vintages (ages) of systems present in any given year.
- In the Industrial sector, the CSE estimates used for measures that save electricity varied from 0 to 4.3 Yen per kWh, depending on the measure.
- Annualized costs for industrial solar PV installations were assumed to fall from about 80,000 Yen/kW-yr in 2000 to about 30,000 Yen/kW-yr in 2020, taking into account the different vintages (ages) of systems present in any given year.

In the Transformation sector, costs were estimated for improved electricity transmission and distribution (through use of amorphous transformers), for power plant capital and operating and maintenance costs, for refining costs, and for LNG terminal capital and operating costs.

In general, transformation costs were assumed to remain fixed over the study period, with the exception of costs for utility solar PV power plants, which decline in cost from 870,000 Yen/kW (total installed capital cost, not annualized cost) in 2000 to 150,000 Yen/kW in 2020, wind power costs which decline at 2 percent annually for the study period, and fuel cell costs, which decline by somewhat less than a factor of two between 2000 and 2020. LNG terminal capital costs were estimated using a combination of Japanese data to be about 360 Yen per GJ of gas handled annually, or about 20,000 Yen per tonne of annual LNG handling capacity.

The major assumptions as to resource costs have to do with the import prices of coal, crude oil, and natural gas (LNG). Starting with reported average Japanese import prices for "steam" and coking coal (4730 and 5360 Yen/tonne, respectively), we applied a price projection from the US Department of Energy's Energy Information Administration that shows coal prices declining by 0.71 percent annually through 2025.[70] Based on International Energy Agency (IEA) price projections and recent Japanese oil import costs (about 3200 Yen/bbl in 2002), we projected crude oil prices to fall at 5.6 percent annually through 2005, remain constant until 2015, and rise thereafter at 3.5 percent annually. LNG prices, starting at about 520 Yen/GJ, are assumed to follow the same trajectory as oil prices. Nuclear fuel is assumed to cost approximately 120 Yen per thermal GJ produced throughout the study period.

## ***Cost Comparison***

Because less power (both energy and capacity) is required in the Power Switch scenario, overall transformation infrastructure costs are lower than in the BAU scenario, even when relatively high capital costs for expanded renewable generation capacity is included. The Power Switch scenario's transformation costs over the period 2000 to 2020 are 14.5 trillion Yen **less** than the costs of the BAU scenario[71]. Considerable additional costs are required for energy-efficiency measures and on-site generation in the Demand-side, however. These costs total about 20 trillion Yen over the 2000 to 2020 period, of which more than half are costs of distributed photovoltaic and cogeneration systems. On the other hand, fuel costs are considerably lower, overall, in the PS case than in the BAU scenario. Japan avoids 4.4 trillion yen in import fuel costs by 2020 in the PS scenario, relative to the BAU scenario. Overall, under the Power Switch scenario, Japan could achieve 31 percent reduction in annual GHG emissions relative to the BAU scenario by 2020, at a net cost—including required additional investments and reduction in fuel import costs—of about 1.1 trillion yen over the study period, or about 57 billion yen per year. Figure 5-5 shows these overall cost and savings results.

[70] USDOE EIA (2003), Annual Energy Outlook 2003 with Projections to 2025. Data from Table 1.from http://www.eia.doe.gov/oiaf/aeo/tbl1.html.

[71] Total costs as presented are discounted at a rate of 3 percent per year, and are denominated in year 2000 Yen.

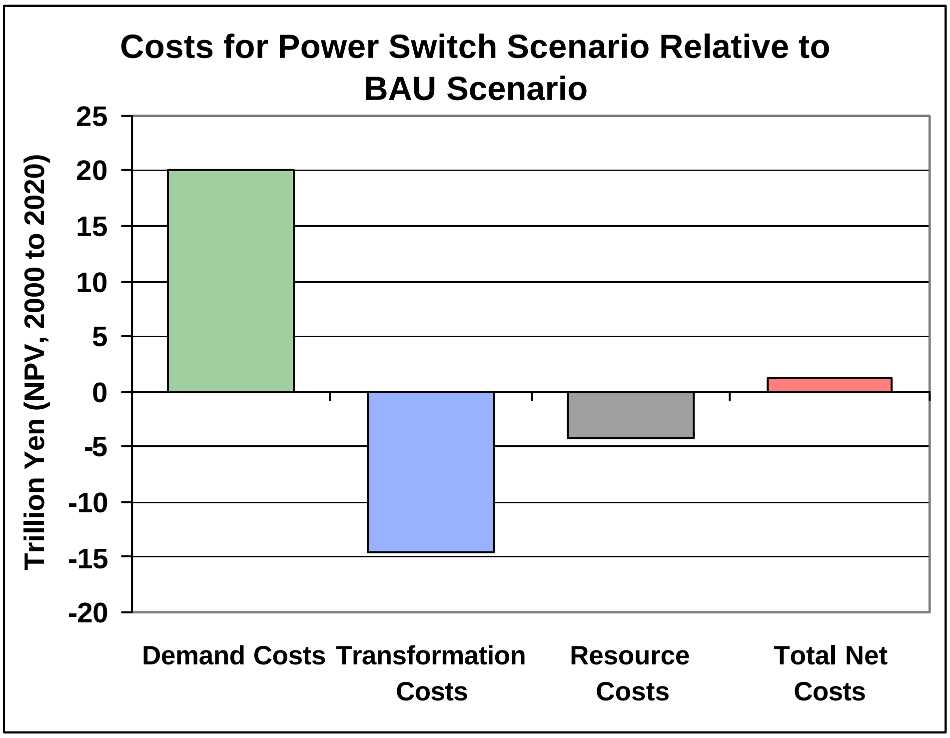


**Figure 5-5: Overall Net Present Value (NPV) Cost Comparison--Power Switch versus BAU Scenario**

Expressed per unit of GHG emissions reduction, the net cost is 850JPY/ tonne of $CO_2$ equivalent, which is equivalent, for example, to a 0.3 percent tax on electricity consumption. The net investment required, therefore, is extremely minor relative to the benefits to be gained.

Note that the above cost/benefit analysis does not ascribe or take into account any particular value to the 2.0 billion tonnes of $CO_2$ equivalent avoided by the Power Switch scenario relative to the BAU scenario. If a cost per tonne of carbon dioxide equivalent is included--perhaps as a stand-in for a carbon tax, the Power Switch scenario quickly becomes the less expensive of the two options. Figure 5-6 presents an exploration of what happens when an "environmental adder" for avoided GHG emissions is included in the analysis of the overall net costs of the Power Switch scenario. After the $CO_2$ value rises above 850 Yen per tonne, the Power Switch scenario quickly becomes the less expensive of the two scenarios considered. Similarly, if fuel prices rise higher than the forecasts used in this analysis indicate, or technical breakthroughs cause the costs for renewable power systems to be lower than we have estimated in the future, the Power Switch scenario also quickly becomes more cost-effective than the BAU scenario.

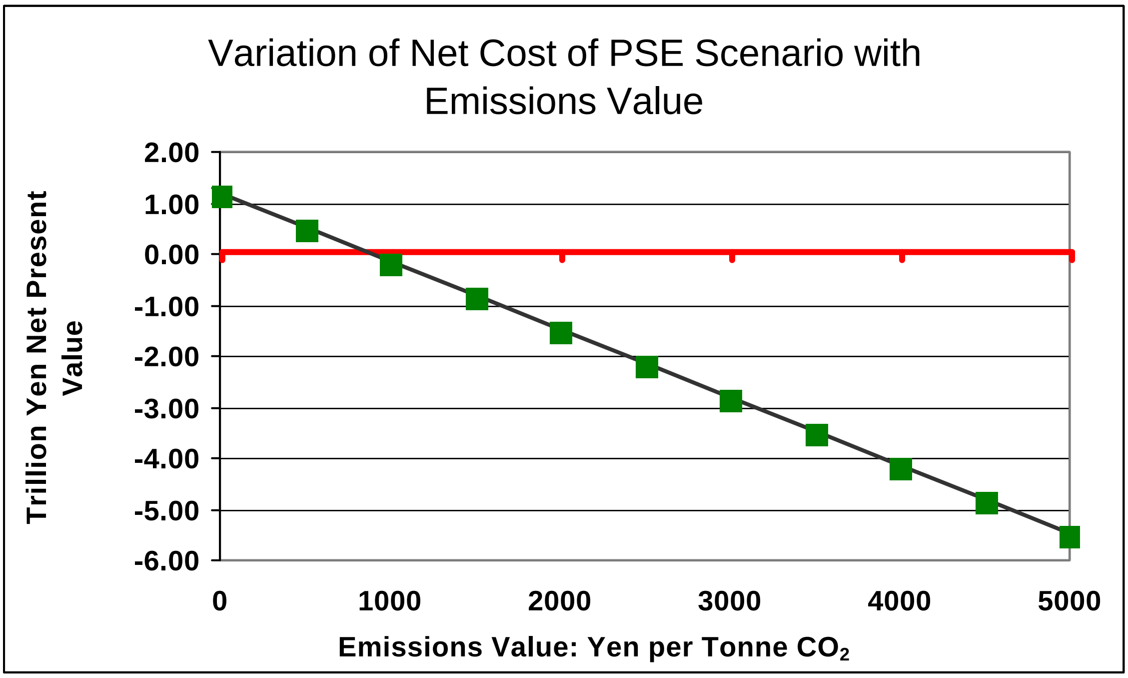


**Figure 5-6: Sensitivity of Net Cost of Power Switch to GHG Emissions Value**

## ***Additional Benefits of the Power Switch Scenario to Japan's Economy***

Some benefits and costs of the Power Switch scenario, considered relative to the BAU scenario, cannot be easily converted to monetary values. For instance, one of the major benefits of renewable energy in terms of cost and energy security is that the use of renewable power sources protect electricity consumers from fuel price (especially natural gas and oil) instability and volatility. Most renewable power sources—particularly solar and wind power—have zero fuel costs, thus once the infrastructure is purchased, the cost of generation (averaged over time) is essentially fixed. Other probable advantages of the PS scenario include:

- Improvements in domestic investment through reduction of money spent on imported fuel.
- A boost to the renewable energy industry in Japan, resulting (in all probability) in a reduction in the costs of renewable energy systems manufactured in Japan, and an increase in the competitiveness of Japanese firms in the global renewable energy business.
- An overall increase in domestic employment, as the use of renewable energy systems and energy-efficiency measures is likely to create more jobs than the number of jobs lost through reduced use of other power sources.[72]
- A reduction in coal ash and nuclear waste to be disposed of.
- A reduction in the emissions of nitrogen oxides and other air pollutants.

[72] Will Ratification of the Kyoto Protocol Result in Economic Loss?, Yasuhiro Murota and Kae Takase, WWF Japan and Shonan Environmental Research Force, 2001. The paper is available at http://www.wwf.or.jp/scripts/download/dfile/climate/motarasukaji.pdf.

The Power Switch scenario implies slightly higher energy costs for Japanese citizens. This could result in the most modest of reductions in overall economic growth and income, although the investments required on the demand side, displacing exports of funds to pay for fuel imports, may help to spur economic growth in the Power Switch scenario relative to the BAU scenario. The Power Switch scenario may also imply additional aesthetic impacts, mainly due to aggressive addition of wind generation capacity (though these impacts will be offset somewhat nationally, if not locally, by the reduction in construction of coal and nuclear capacity).

### 5.2. Barriers and Limitations of Power Switch Scenarios

Key barriers and limitations to the implementation of the Power Switch scenario could include:

- The existing institutional structure of the electric and gas utilities sectors, including the lack of integration between service territories, regulations and practices that may discourage on-site generation, lack of competition, and lack of knowledge on the part of utility managers about renewable and other generation alternatives.
- Lack of information about demand-side measures among electricity consumers.
- Lack of information about the climate change problem—and opportunities for solutions—among Japanese consumers.
- Lack of funding for demand-side measures and for renewable power development, particularly relative to research and development funding (and other explicit or implicit subsidies) for well-established generation alternatives.
- Entrenched interests and expertise within the government and utilities that favor a "BAU" approach to future energy sector development.

Some of other barriers to the implementation of each fuel or technology choice are also mentioned in the section 4.1.2.

## 6. Conclusion and Ramifications of Results

In this study, we have developed the Power Switch scenario, which is not a projection, but a "achievable" alternative energy pathway that Japan could take. The scenario, including aggressive implementation of energy-efficiency and demand-side generation measures, widespread adoption of renewable sources of energy for utility generation of electricity, the use of natural gas as a fuel for most new non-renewable electricity supply, and a gradual reduction in nuclear generating capacity, can provide:

- Absolute reduction of 20 percent of GHG emissions from a 2000 base year by 2020
- A 31 percent reduction in emissions for the Power Switch scenario compared to the BAU scenario by 2020

Analysis of the net costs of the Power Switch scenario, taking into account costs differences for demand-side measures as well as transformation infrastructure and resources use, indicates that the Power Switch scenario will just over 1 trillion Yen more than the BAU scenario over 20 years. This net cost could easily be negative (that is, a net benefit) if fossil fuel prices rise or costs of renewable generation technologies fall faster than estimated. This cost, spread over the electricity generated in Japan over the period amounts to about 0.3

percent of electricity costs, about 0.07 Yen per kWh, or about 350 Yen per year per household in the residential sector.

Clearly, the Power Switch scenario represents an extremely affordable investment in energy security and in the environment for the Japanese people. A number of policy tools are available, and will be needed, to bring the Power Switch scenario about. These range from efficiency standards and codes, to tax, utility or direct government incentives for energy efficiency and renewable energy, to emissions targets and caps. National resolve to address the climate change issue, however, will be the key ingredient in the success or failure of a Power Switch or similar initiative, as will be thoughtful consideration of climate change issues into overall planning as Japan's power sector undergoes institutional reorganization.