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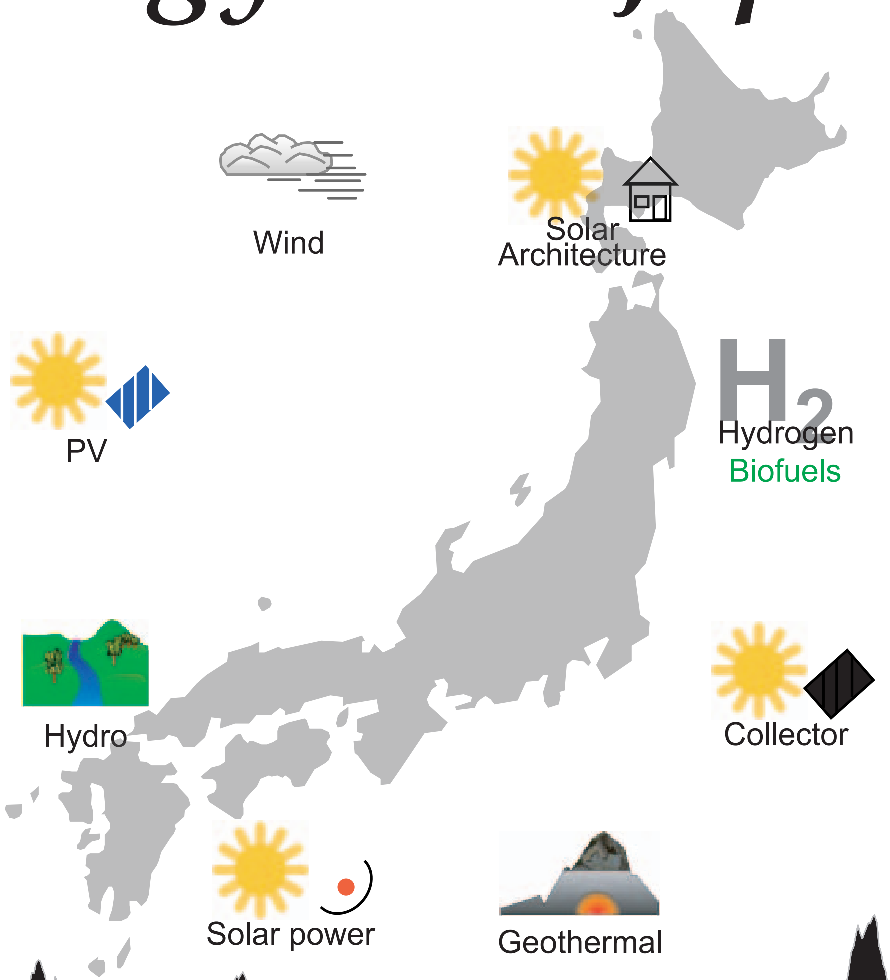
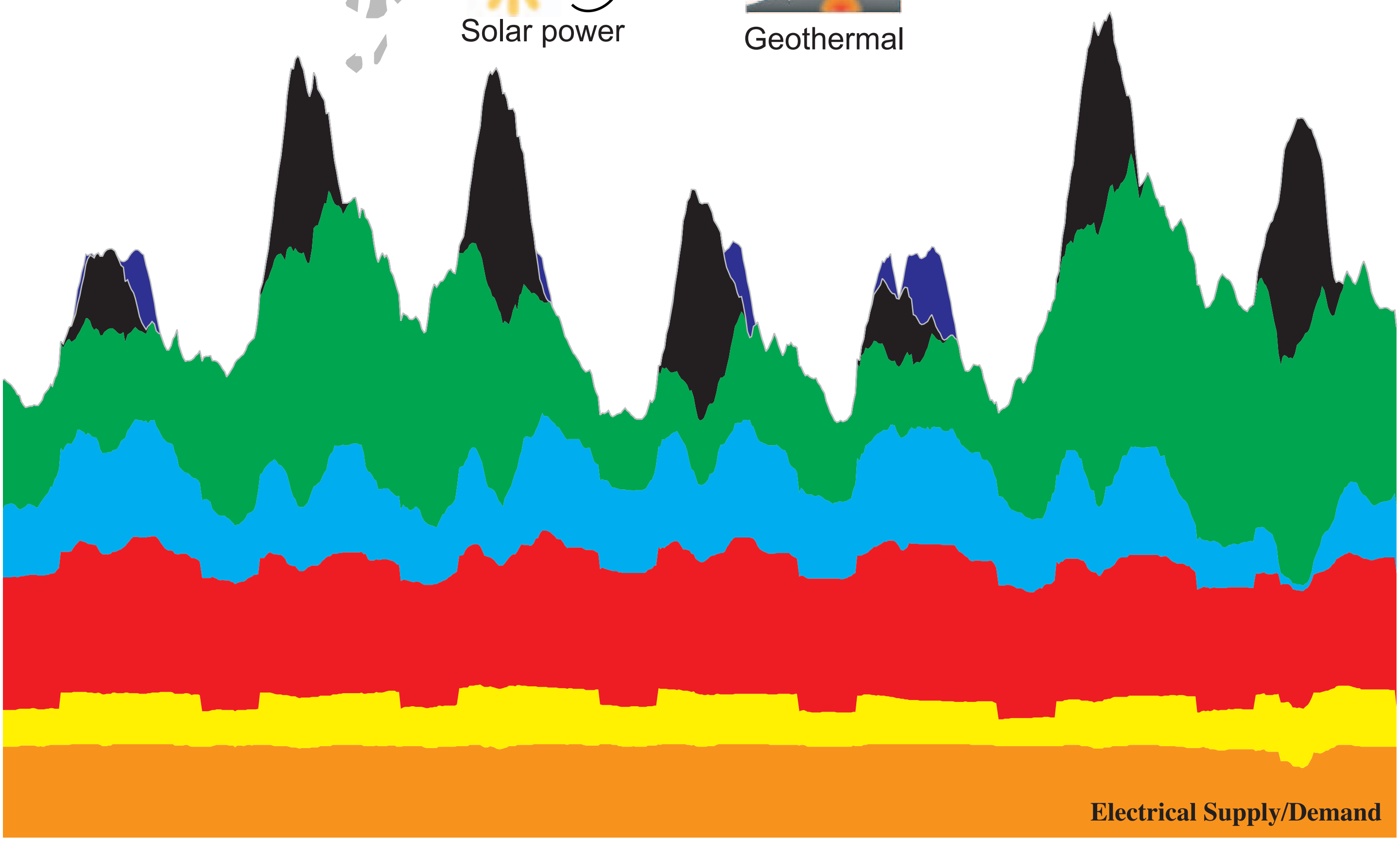
Energy Rich Japan





Energy Rich Japan

Published by : Harry Lehmann (hl@isusi.de)

Commissioned by Greenpeace International (Amsterdam) and Greenpeace Japan

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Content

1) Abstract

It has long been known that to protect people and the environment from both nuclear risks and dangerous levels of climate change, we must phase out the use of nuclear and fossil fuels, and switch to clean energy technology instead. Using Japan as a example, „Energy Rich Japan“ illustrates that the vision of a clean, green, energy-rich future is not only possible, but globally feasible.

Absatz aus Introduction : Renewable energy technologies using regional or global sources, coupled with a reduction in energy use by adopting energy efficient technologies, offer the only safe and proven option open to us for future energy needs. The objective of this study is to show that a region such as Japan is able to supply all of its own energy needs with this option, and to use the report to influence the discussion over the change from fossil and nuclear energy sources to a sustainable energy system.

Japan is a heavily industrialised country, with a population of 127 million living in a small island nation, yet in 1999 it was the world's second most powerful economy[1], with an industrial base that was recognised as one of the most energy efficient globally.

Japan was forced to become relatively energy efficient because it has very little domestic supplies of what are known as conventional energy sources. This industrial powerhouse meets the bulk of its energy demand by importing nuclear and fossil fuels, supplemented by a small amount of domestic oil and gas production, as well as some hydro and geothermal power. Japan's total primary energy consumption in 1999 stood at just over 22,970 Petajoules, (A Petajoule is a 1000 million, million joules). Of this, 18,500 Petajoules (80%) was imported as nuclear and fossil fuels.

Yet Japan could be independently rich in energy. Using baseline data from 1999, the „Energy Rich Japan“ report shows how a combination of the best energy efficiency technologies available today, and a massive investment in renewable energy, could ultimately provide Japan with 100% of its energy needs from renewables – including transportation fuels -without expensive and environmentally damaging imported fossil and nuclear fuels.[2] Rather than seeking „energy security“ through its hugely expensive and polluting nuclear program, for example, Japan could instead build its own renewable energy industry. As an energy-hungry and supposedly "resource-

1. SBS World Guide 8th Edition (2000) ISBN 1876719303.
2. The true expense of fossil and nuclear fuels is much higher then their purchase and import costs, which is often subsidised. Their long term pollution costs to society and the environment are currently not factored into their price.

poor" country, Japan could make this transition to clean, renewable energy without any sacrifice in living standards or industrial capacity.

The report takes Japan's current energy use, based on 1999 levels, and shows that demand could be reduced by 50% with energy efficient technologies that are already available around the world today. The „ERJ High Efficiency Demand Model" showed that using highly energy efficient technologies could save nearly 40% of today's energy consumption in the industrial sector, more than 50% in the residential and commercial sectors and about 70% in the transport sector.

It then shows how renewable energy could be used to meet that new level of demand, reducing and ultimately eliminating the need for imports. Six scenarios of how this might happen are outlined in the report, all of which can provide 100% renewable energy for Japan. Starting from a basic model (Scenario One) providing more than 50% of total energy needs from domestic renewable sources, each subsequent scenario provides variations or expansions on Scenario One, gradually reducing the reliance on imported energy, factoring in different population projections and expected improvements in renewable generation capacity and energy efficiencies, until by Scenarios Five and Six, no energy imports are required.

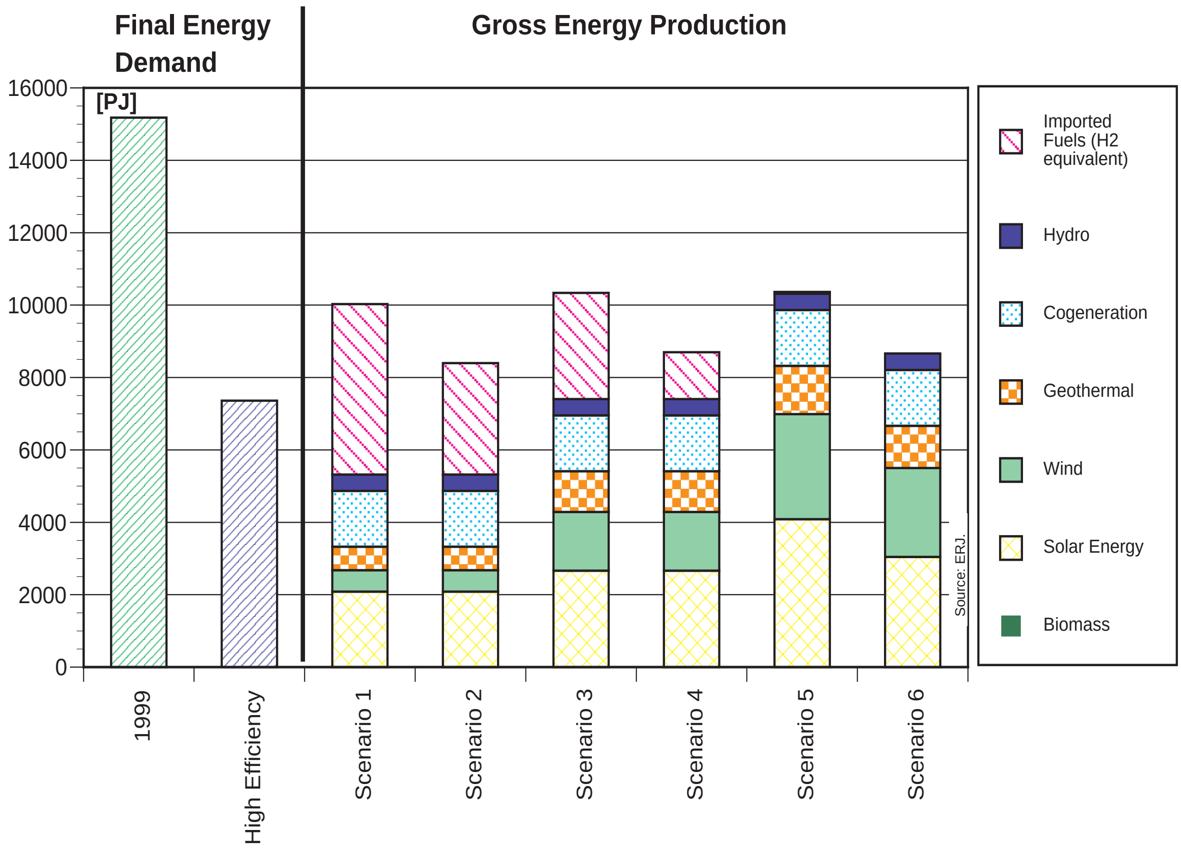


Figure 1 : Demand 1999 and the High Efficiency Model. Six Supply scenarios with different dependance from imports (Imported Fuels). Scenarios 2,4 and 6 assume a decreased population of Japan.

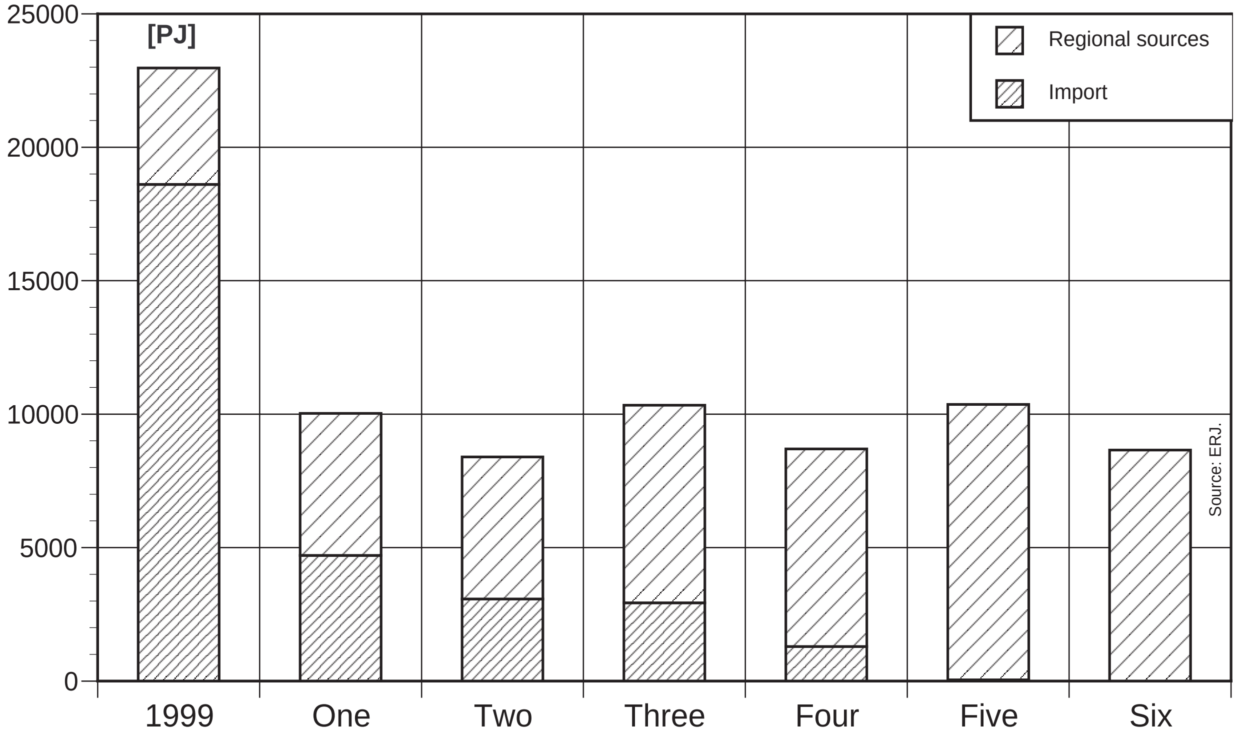


Figure 2 : Overview of the ERJ Scenarios showing primary energy supply and the share of domestic production. Scenarios 2,4 and 6 assume a decreased population of Japan.<3>

As supply reliability is most acute in the electricity sector where supply and demand must be fully matched in time, a simulation of the Japanese electrical power system and part of the heating system with the computer programmSimREN was done (see Figure 3 on Page 5).

This study does not attempt to answer two key questions: How quickly can such a system be implemented and how much will this system cost? To demonstrate the possibility of a solar energy supply for Japan, it is not necessary to specify the costs and the timeframe such a development will require.

The systems described here provide a framework for a debate about the restructuring of the Japanese energy economy. However restructuring with renewable energy does not need to be limited to the ideas described in this report. Other systems that can supply Japan with renewable energy are also possible.

All of the scenarios are able to be met in Japan, both in technical terms and in terms of natural resources, such as wind, solar radiation and geothermal capacity. The decisive factors will be public acceptance, priorities set by national policy in terms of energy security and international com-

3. Primary energy is the amount of energy that must be fed into the supply system to produce the final energy, calculated with certain statistical methods which include conversion efficiencies. Final energy demand is the amount of energy that is required at the place of energy consumption, i.e. fabrication plants, households, etc. The gross energy production of the supply system is the total amount of produced energy by the different technologies.

mitments and the future development of renewable energy technologies. „Energy Rich Japan“ is an ambitious concept, yet conservative in its methodology. Admittedly its implementation would involve considerable investment in infrastructure and far reaching changes to the way Japan designs and builds its future industrial, residential, commercial and transport sectors. Compared to the environmental dangers faced globally by climate change and nuclear accidents, the costs of not developing sustainable energy systems, be they in Japan or anywhere around the world, are potentially far greater.

How to achieve to a sustainable energy system is the question we hope we have addressed with this study. What we need now is the desire and will to make it happen.

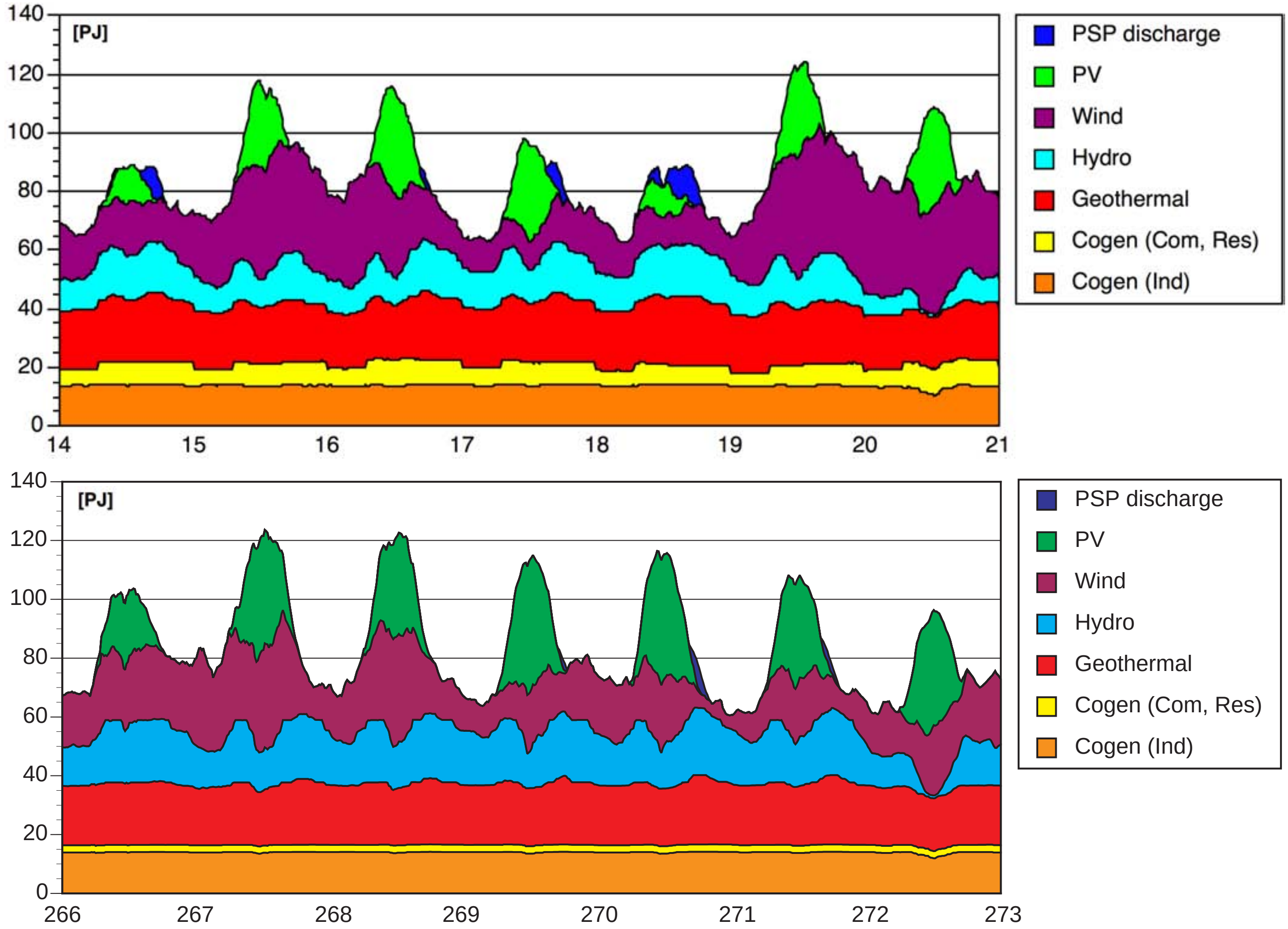


Figure 3 : The figures show the dynamics of electricity generation for 2 weeks of the year. The supply-system always produces enough electricity to cover the demand. If there is low electricity production of windenergy and photovoltaics at the same time, pumped storages get used to guarantee full supply (see days 14, 18, 19 and 271).

2) Introduction and Foreword

*„Tell people something they know already and they will thank you for it.
Tell them something new and they will hate you for it.“ George Monbiot*

„Climate change is a problem with unique characteristics. It is global, long-term (up to several centuries), and involves complex interactions between climatic, environmental, economic, political, institutional, social and technological processes. This may have significant international and intergenerational implications in the context of broader societal goals, such as equity and sustainable development. Developing a response to climate change is characterised by decision-making under uncertainty and risk, including the possibility of non-linear and/or irreversible changes. This report confirms the finding that earlier actions, including a portfolio of emissions mitigation, technology development and reduction of scientific uncertainty, increase flexibility in moving towards stabilisation of atmospheric concentrations of greenhouse gases.” [4]

It was made clear in the Greenpeace report “Fossil Fuels and Climate Protection: The Carbon Logic”[5] that we need to drastically reduce our emissions of carbon dioxide to within tolerable levels, which must lead to a total phase out of the use of fossil fuels. The Carbon Logic report introduces the concept of a “carbon budget” which is the amount of oil, coal and gas that we can afford to burn if we are to avoid extensive damage to the environment caused by global warming. Just a one degree centigrade rise in temperatures over the next 100 years would cause significant damage. A temperature rise of more than one °C in that time would result in extensive damage. Greenpeace estimates that the carbon budget, which would keep any global temperature rise to within one °C, would be exceeded in about 30 years at present trends.

To stay within this budget, 75% of recoverable fossil fuel reserves must remain in the ground, never to be used as fuels. This will mean phasing out fossil fuels within this time period.

Without action to reduce emissions, 1500 billion tonnes of carbon will probably be released over the next 100 years, the majority of which will come from burning fossil fuels. This represents an enormous addition to the atmosphere of the potent greenhouse gas carbon dioxide, which began increasing significantly at the beginning of the industrial revolution. The resulting global warming would excessively raise global temperatures, increase extreme weather events, flood extensive areas of land, devastate ecosystems and accelerate extinctions. In Japan, 80% of beaches will disappear if sea levels rise by 65 cm and 90% will go with a rise of one metre[6].

4. Intergovernmental Panel on Climate Change (2001a).
5. Hare (1997).
6. Harasawa, H. (2001).

Rich, developed nations must take the initiative in order to make this switch because of their historical use of fossil fuels and their currently disproportionate percentage of emissions (Developed nations produce 80% of the world total greenhouse gas emissions from fossil fuels). In addition, developed countries are committed to assisting developing nations as a matter of equity and as part of their international agreements such as the Kyoto Protocol on Climate Change, aimed at reducing greenhouse gases globally.

In reality, our options for energy supply must be constrained by our impact on the environment. Fossil fuels can no longer be burned and nuclear power has proven to be dangerous and expensive and has had a disastrous impact on human health and the environment on a global scale[7]. The disaster potential posed by the nuclear industry with its associated problems of radioactive waste and the threat of terrorism or nuclear accident clearly indicate that this dangerous technology must be discontinued. The Kyoto Protocol climate conference in Bonn also agreed that nuclear power is not part of the Kyoto Protocol, having been excluded from the Joint Implementation and the Clean Development Mechanism[8]. With regard to fusion: In spite of decades of research and billions of dollars spent, nuclear fusion has not proved viable. Even if fusion will function one day it would also involve the production of radioactive waste. Renewable energies, however, offer us a sustainable solution.

2.1) Objectives of the „Energy Rich Japan“ Study

Renewable energy technologies using regional or global sources, coupled with a reduction in energy use by adopting energy efficient technologies, offer the only safe and proven option open to us for future energy needs. The objective of this study is to show that a region such as Japan is able to supply all of its own energy needs with this option, and to use the report to influence the discussion over the change from fossil and nuclear energy sources to a sustainable energy system.

The ongoing discussion regarding the potential of renewable energy and efficient design has been negatively influenced by a lack of facts about the availability and potential of these technologies. Showing that a region can provide its own energy today, purely from renewable sources will help to move us towards a fossil fuel- and nuclear energy-free system. Setting out a framework for a

7. The 1986 explosion at the Chernobyl nuclear power station has been described as "the greatest technological catastrophe in human history". The World Health Organisation (WHO) estimated that the accident released 200 times more radioactivity than was released by the atomic bombs dropped on Hiroshima and Nagasaki. In the first year after the accident 400,000 people had to be evacuated. Large tracts of Ukraine, Belarus and Russia remain heavily contaminated to this day, and even in the UK agricultural restrictions still apply as a result of radioactive contamination from the accident.
8. The COP was held from 16th to 27th July 2001 in Bonn, Germany.

100% renewable energy supply also provides the political and societal inspiration to make moves in the direction of a sustainable future as set out at the Earth Summit in 1992.

There is rapid development within the field of renewable energy and this study presents the best available options open to society today. Naturally, society needs to work further toward improving these technologies technically and economically.

Any energy system must fit with the limitations imposed by the biosphere on a long-term scale. So what are the controls that need to be observed when planning such a system? Among other things, a sustainable energy system must not involve any loss of species. It must promote the correct use of land. It must help protect ecosystems, such as forests, as interconnected and intact living systems, protecting species diversity. It must involve no emissions of persistent, bio-accumulative or toxic wastes, no radioactive wastes and it must embody the principles of equity and equality for the present and future generations[9].

Policies for a sustainable future promote an energy system as defined above. This means, among other things, that biomass has to be produced and used by sustainable methods. This means not degrading soils or displacing other essential uses of land such as forests, and not emitting greenhouse gases such as methane in biomass production. Biodiversity must be maintained and the energy balance of the whole biomass system must be positive. No genetically modified plants can be included in biomass production. Hydropower must not be used on a massive and destructive scale. Existing hydropower systems will be reviewed and assessed for their environmental impact. Any additional hydropower plans would promote small- and medium-scale hydro schemes on a case-specific basis. Reforestation programmes must be put in place to counter any clearances made for hydropower. Primary forest must not be sacrificed for such schemes. Photovoltaic production can involve problematic materials. Fuel cells are only emission-free when powered by clean hydrogen not acquired from fossil fuels or nuclear power.

As the saying goes, “There is no such thing as a free lunch”, but any impacts must be as minimal as possible in the total system.

This report clearly illustrates that a combination of renewable sources and energy efficient technologies can provide a solution that meets the above criteria.

The costs of such a system are lower than conventional sources when the total internal and external costs are factored, and they are becoming more price-competitive as they gain a greater per-

9. “At the most fundamental level, the principles of equity and equality must be integrated into all aspects of sustainable development. Sustainable development is in essence a participatory process, and problems of inequality, financial insecurity, etc. will tend to hinder the participation of some sectors of the community. A major goal of sustainable development must therefore be to tackle these problems.” Source: Action Towards Local Sustainability (UK).

centage of the energy market, as production prices drop considerably with increased mass production[10]. A truly renewable energy system will only become a reality if we begin to make moves in that direction now.

2.2) General Framework

Why did we select Japan as the subject for this study? The answer lies in the challenge: if it is possible to achieve a 100% renewable energy system in Japan using today's best available technology, it would be possible to transfer and adapt the results to many other locations even to cover the whole globe.

Japan, home of and signatory to the Kyoto Protocol on climate change, has been considered energy-poor with respect to fossil fuels and has become heavily dependent on energy imports. It has consequently adopted an extensive nuclear program, which is increasingly providing more problems than solutions. Despite its history of rapid industrial change, Japan does not have great preconditions for a rapid change to renewable energy, as it is highly industrialised and densely populated with a comparatively high-energy demand. Available land and water potential is also not well placed. Japan is a relatively remote island group with few options for energy exchange with other nations. However Japan is well placed for geothermal, wind and solar energy, which are also available in most parts of world. In rising to and meeting the challenge of a 100% renewable energy system for Japan, the study proves the viability of a truly sustainable energy system, which can be transferred to other regions.

A number of factors were identified as preconditions for the report. The first was that the study should fit into the Japanese system as it is, without any major changes in lifestyles. This entailed modelling an energy demand structure without proposing any changes in living standards. No predictions for economic growth or decreases are considered either. It was also assumed that the current transport infrastructure and traffic densities would not be altered to accommodate the energy system. In other words, the goal of the project was to show that a sustainable, renewable and efficient energy system is theoretically able to supply Japan's current needs. Conservative estimates were made in all areas of the study.

The power supply of Japan is presented in the six scenarios introduced here in this study. The electrical system of this innovative energy demand and supply system is simulated with a high temporal and spatial resolution, with the SimREN computer model using real weather conditions.

10. This is shown in Detail for Germany in the final Report of the Enquete Commission of the German Parliament „Sustainable Energy Supply against the Background of Globalization and Liberalisation“ (Source: Enquete Commission (2002)).

This is done to firstly optimise that system, and also to increase the plausibility of the energy scenarios described in this study. Three main scenarios are presented, ranging from a 50% domestic supply of energy from renewable sources to 75% and a 100% domestic supply, with variations on these three scenarios incorporating a predicted decline in the Japanese population from 127 million in 1999 to 100 million by the year 2050.

The systems described here provide a framework for a debate about the restructuring of the Japanese energy economy. However restructuring with renewable energy does not need to be limited to the ideas described in this report. Other systems that can supply Japan with renewable energy are also possible.

This study does not attempt to answer two key questions: How quickly can such a system be implemented and how much will this system cost? Both questions are often examined in energy scenarios. The majority of the project team were in agreement that answering these questions would go well beyond the scope of this study, which is meant to be a first step towards quantifying the resource. Giving answers to these questions would require an additional study.

To demonstrate the possibility of a solar energy supply for Japan, it is not necessary to specify the costs and the timeframe such a development will require. The energy system described in the ERJ Report entails a long process of developing and restructuring the present-day system according to future needs. The technological feasibility of the presented system can be proven based on present-day knowledge, applying the simulation system usedfor the first time in this study . Furthermore the uncertainty of future cost estimations and of introductory scenario studies would distract the discussion from the results of the study[11]. Namely that Japan is an energy rich country and that it can supply itself fully based on renewable sources.

However to give a sense of the order of magnitude for the time frame, existing scenarios and historical information from other regions would suggest that within 20 years at least a 30% increase in efficiency and at least a 30% provision by renewables is possible, but this is highly dependent on the availability of resources, the starting point and the political measures in the country in question.

From the basic desire to illustrate the feasibility of a ‘100% sustainable region’, Greenpeace International and Greenpeace Japan commissioned a scientific collaboration with institutions in Europe and Japan. The contributors included EUTech (Germany), ISEP (Japan), Wuppertal Institute (Germany) and ISUSI (Germany) with an international team. Close co-operation between the groups was ensured at all times.

11. More about this in: “Energy Rich Japan - Aspects of Costs and Timeframes“. available under www.energyrichjapan.info

The main emphasis of the work of EUTech lay on the analysis of efficient energy technologies especially in the industrial sector. ISEP concentrated on supplying data on Japan (e.g. the potential of renewable energies, data on electricity demand and weather data) and on formulating political goals and accompanying the development of the supply and demand models critically. The Wuppertal Institute's main emphasis lay on formulating the demand model. The international team of ISUSI provided the supply model, developed a Japanese version of the computer program SimREN, realised the simulation and co-ordinated the scientific work.

All meetings where done in Japan and the team worked together on all parts of the study. Such a study cannot always be realised without differences of opinion. Insofar as they could not be clarified in discussion, I accept the responsibility.

Prominent scientists from Japan and from Europe were consulted as independent external reviewers during the preparation of this report: Dr. Robert Gross (Imperial College UK), Dr. Jorgen Stig Norgard (Technical University of Denmark), Dr. Yasuhiro Murota (Shonan Econometrics), Dr. Hidetoshi Nakagami (Jukankyo Research Institute), Dr. Naoto Sagawa (Jukankyo Research Institute), Dr. Hermann Scheer (Eurosolar and alternative Nobelprize winner) and Dr. Jörg Schindler (L-B Systemtechnik).

I wish to thank them for their work, their criticism, contributions and support towards publishing this study. We have included the in some points contradictory suggestions in the study as far as possible. I would like to thank Jörg Schindler for his contribution to the hydrogen part of the report. Many thanks to Hermann Scheer for the support the "World Council for renewable Energies" (WCRE) gave the report during publication.

Lastly I wish to thank Greenpeace International, Greenpeace Japan and especially Lynn Goldsworthy for the support with this study, without which this report would never have been realised.

How to achieve to a sustainable energy system is the question I hope we have addressed with this study. What we need now is the desire and will to make it happen.

Harry Lehmann

Scientific Coordinator of the
Energy Rich Japan Research Team/Study

Head of Institute for Sustainable Solutions
and Innovations

3) Methodology

Standard Energy Demand Assessment

To accurately analyse energy consumption, a demand model was built to reflect the actual demand in Japan in detail, by identifying all areas and sectors where energy was consumed. Sectors included were industrial, commercial, residential and transport. Japanese energy demand data was taken from the year 1999, chosen as the reference year for the Energy Rich Japan Demand Model.

„High-efficiency“ Energy Demand Model

To ensure the credibility and value of the study, the report examines the possibilities of reducing demand without making any changes to the level of industrial production, and without involving any reductions in the current standard of living or lifestyle alterations. Reductions in demand were based on today’s best-available technologies in each of the demand sectors, all of which could be implemented without having to restructure society or industry. Two approaches were employed to model demand reduction. Firstly a bottom-up approach was used, in which identified devices and processes were replaced by best available technology and the savings aggregated. The „Energy Rich Japan“ report details the application of high-efficiency technologies to all aspects of process-by-process energy demand. Secondly, a top-down approach considered the performance of a process as a whole, for example steel production was compared to best practice performance in other countries.

Demand reductions in the population-change scenarios assumed a linear decline in demand, although a smaller and older population, for example, would have a far more complex effect due to smaller households and changes to production levels from a reduced workforce.

Renewable Energy Supply Model

In order to meet this new Energy Rich Japan demand, a supply model was devised to cover electricity, heat and fuels including fuels for transport sourced from renewable energy. The supply model incorporated a wide variety of the latest renewable energy technologies. The model was designed to supply energy in the form of electricity, heat and fuels at anytime throughout the year, to all identified demand locations.

To accommodate time and seasonal variations, fluctuating sources, such as wind and solar power, were combined with sources such as geothermal or combined heat and power from stored hydrogen or biofuels[12], which are able to supply energy on demand, regardless of weather conditions.

Surpluses in the electrical supply system were converted into hydrogen fuels, stored in pumped water storage for use later as hydropower or used for heating.

Figure 4 : Kiyomino Solar Settlement (Japan); Source : Hakushin Corporation, Saitama.

A Simulation of the Japanese Power System.

The SimREN simulation was developed to study the dynamics of an energy supply system consisting solely of renewable energy sources. SimREN was used to plan and optimise the supply system for Japan. The objective of this optimisation was to assure a reliable supply at all times and to supply Japan with electricity without importing energy from outside of Japan. The simulation calculates the deliverable energy from installed power plants using time-resolved methods. The installation of power plants was adjusted until the optimal amount of installed power plants was found.

The year 1999 was taken for the reference year of the ERJ Demand Model and therefore the time span that was simulated. A time span of a whole year had to be simulated in order to ensure that seasonal variations and critical weather situations were included and tested.[13] SimREN calculated the energy demand of a consumer group at a certain point in time using typical daily and yearly demand curves. The consumer groups were residential, commercial and industrial consumers.

12. The amount of fuels quoted in the ERJ Supply Models are calculated in hydrogen equivalent. Fuel needs can and will be covered by sustainably produced domestic biomass, but the exact amount of sustainable biomass available in Japan was unknown at the time of publication.

13. For the simulation Japan was divided into 12 geographical regions, which were able to exchange energy with each other. The modelling system was developed using very detailed meteorological data from 153 sites around Japan.The weather data was broken down into 15 minute intervals over the 24 hours each day in the 52 weeks, so that accurate information of both seasonal and daily variations in the energy supply were available.

4) Results

4.1) Energy Rich Japan High-Efficiency Energy Demand Model

One of the underlying assumptions of the report is that Japan's current energy demand can be substantially reduced using the best available energy efficiency technologies. By converting to or adapting these efficiency systems in the four sectors of industrial, commercial, residential and transport, substantial reductions in energy demand were identified. Under this model each of the four sectors is broken down into components and the most efficient technologies from around the world are applied.

By doing so, the Energy Rich Japan High-Efficiency Demand Model reduced the final energy demand by about 50% - from nearly 15,200 PetaJoules in 1999 to a theoretical level of under 7,500 PJ in the ERJ Demand Model [14].

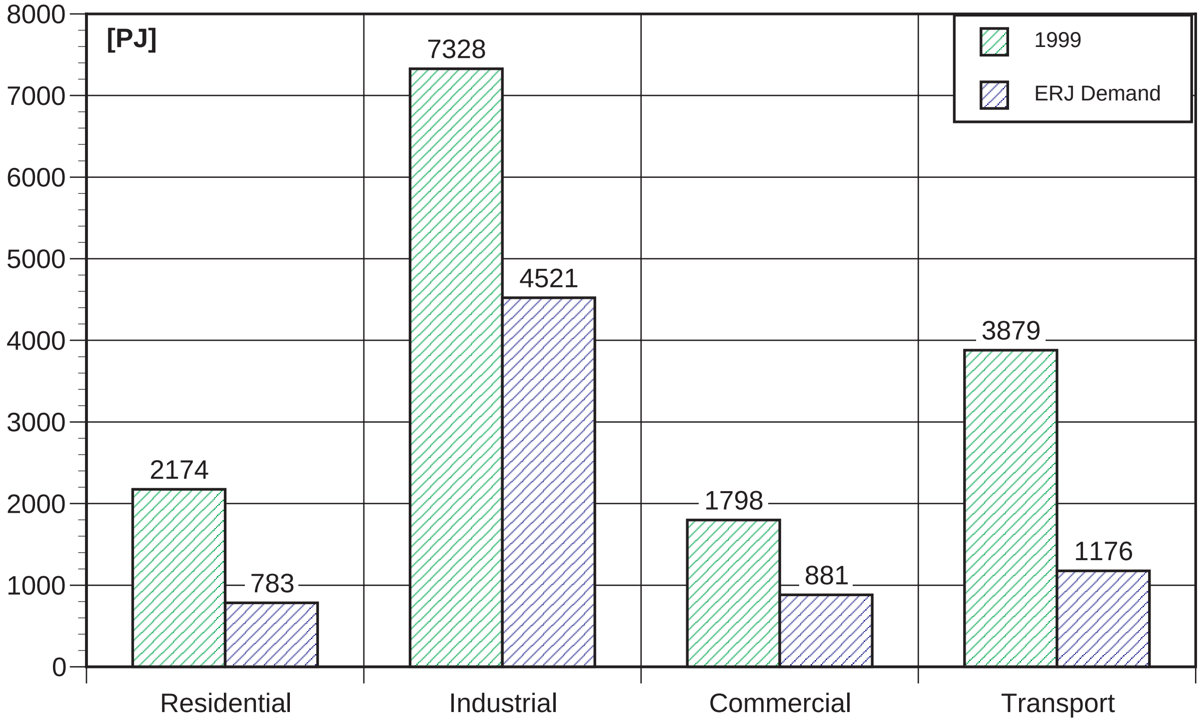


Figure 5 : Projected Japanese final energy demand according to the standard (1999) and the ERJ Demand Model

14. One Petajoule is one x10^{15} joules of energy. One kWh is equal to 3600 kJ.

The greatest absolute reduction in final energy demand of over 2700 Petajoules or 37% was seen in the industrial sector; In 1999 Japan's industrial sector used 7328 Petajoules of energy, making it the highest demand sector nationally. With best available technology it can be reduced to about 4650 Petajoules.

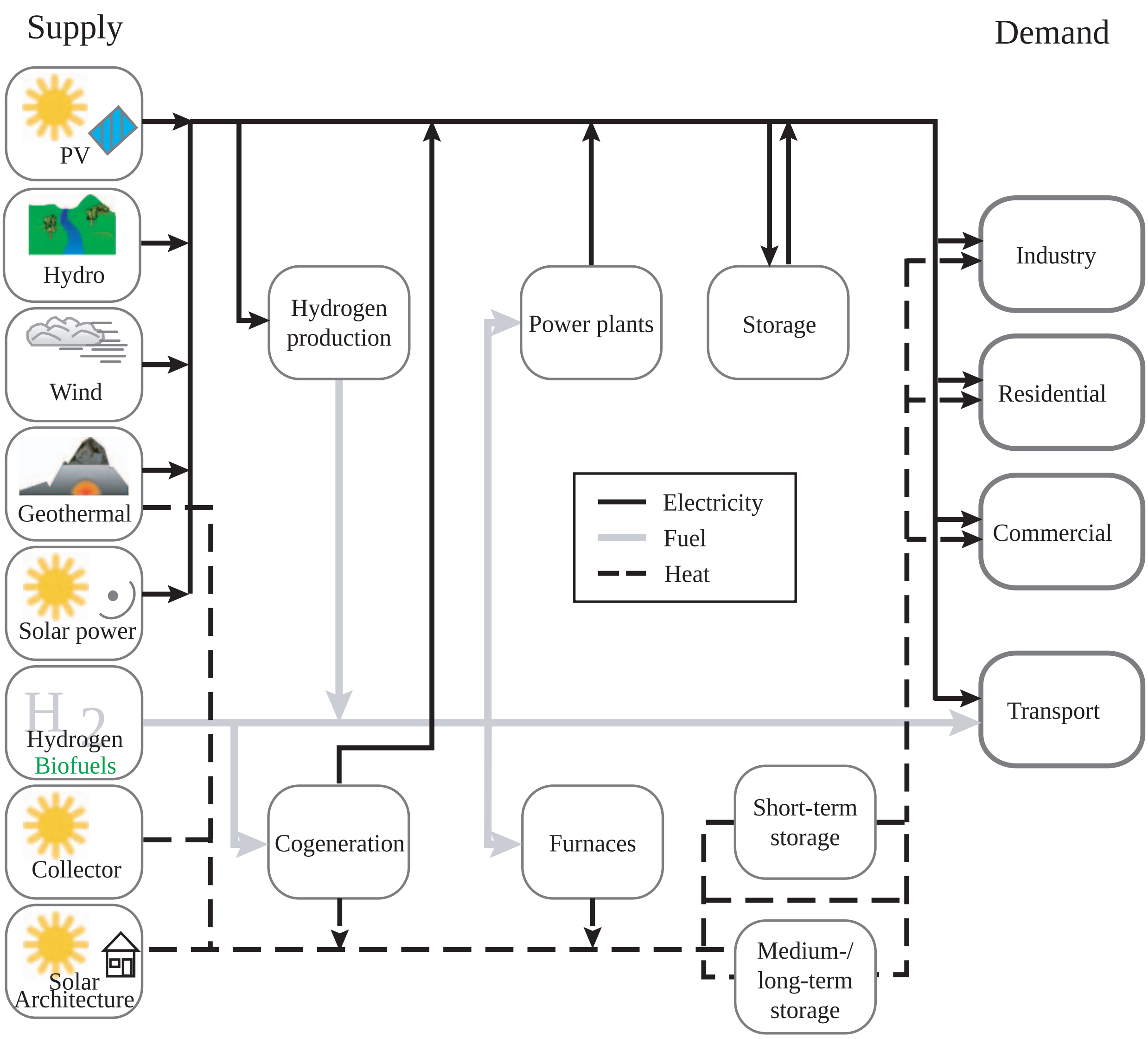
- The commercial sector in 1999 used 1798 Petajoules. By using the best high efficiency technology reductions in final energy demand totalled over 50% or 917 Petajoules
- The residential sector reductions in final energy totalled 64%, or nearly 1400 Petajoules respectively compared to the 1999 level of 2174 Petajoules
- A significant reduction of 70% or over 2700 Petajoules in final energy was seen in the transport sector – from 3879 Petajoules in 1999 to 1176 Petajoules using best available technology

4.2) ERJ Renewable Energy Supply Model

The challenge in designing a reliable fully renewable energy system was to find a combination of technologies where the pros of some types balanced out the cons of the others. A reserve capacity is necessary as a backup for fluctuating sources, especially in the electrical system. This capacity can be minimised by designing a combination of renewable technologies where fluctuations in production match a varying demand, such that any fluctuations in supply never lead to electrical production that cannot meet the demand.

The focus in designing the ERJ Supply Models was therefore on the electrical subsystem, as this is the most (time) critical component of supply. Fluctuating sources, such as wind and solar, were combined with adjustable "supply on demand" sources such as geothermal plants and hydro power to a reliable supply of energy throughout the year, regardless of seasonal or daily variations. Surpluses in the electrical supply system were converted into hydrogen that was used as a fuel for storage and conversion in various types of plants or stored in pumped water storage systems.

The electrical supply model was designed to deliver electricity throughout the year using domestic Japanese energy sources as much as possible. The heat and fuels supplying system was then designed.



Source : ISuSI.
Figure 6 : Structure of an energy system based on renewable sources.

The limitations in transporting heat necessitate that any generated heat has to be consumed locally, that is near to the production plant. The heat supply structure reflects this fact, as consumers themselves also produce heat. The ERJ Supply Models keep the focus on the self-sufficiency of consumers but switches heat generation from fossil fuels to renewable sources. Therefore the ERJ Supply Models use cogeneration plants, steam turbines, heating plants and solar-thermal collectors in the industrial, commercial and residential sectors.

Similar to fluctuating sources in electrical supply, the production rate of heat from solar-thermal collectors cannot be foreseen in terms of how much energy will be produced. Heat produced by solar-thermal systems has to be used immediately and sometimes heat production will far exceed heat demand. This is the point where heat storage becomes important. Short-term and mid-term storage, capable of storing heat for periods up to one week or one month, combined with adjustable suppliers can guarantee sufficient heat supply at every time.

Cogeneration plants in industry are operated in two different modes. If electricity is most important for the system, the cogeneration plants are controlled to meet electricity demand, while the simultaneously produced heat can contribute to the heat demand or be stored.

The ERJ Supply Models consider fuels in all sectors although only the transport sector is strictly dependent on fuels. Besides consuming fuels, the system itself produces fuels such as hydrogen by utilising surplus electricity from the supply system, and substitutes fuels that conventional systems need for warm water and heating by using heat from solar-thermal supplies. This approach has two major benefits: surpluses in electrical supply are not lost and the amount of fuels that must be applied from external sources is minimised.

The remaining demand for fuels (calculated as the total fuel demand, minus fuels substituted by solar-thermal systems and the system's hydrogen production) has to be covered by hydrogen or fuels from sustainably produced biomass. The amount quoted in the ERJ Supply Models represents the amount of hydrogen that is not covered by domestic sources in the different designs of the system. This fuels can be substituted by sustainably produced domestic biomass, but the exact amount of biomass available in Japan was unknown at the time of publication.

The ERJ Report produced six renewable energy scenarios, all of which can provide 100% renewable energy for Japan. They start from a basic model (Scenario One) which provides more than 50% of total energy needs from domestic Japanese sources of renewable energy, including fuels for transport. Each subsequent scenario provides variations or expansions on Scenario One, gradually reducing the reliance on imported energy, factoring in different population projections and expected improvements in renewable generation capacity and energy efficiencies, until by Scenarios Five and Six, no energy imports are required.

Scenario One: The first steps, with some reliance on imports.

In this scenario, domestic renewable energy sources could provide 53% of Japan's electricity and heat supplying system, and transport, after factoring in the reduced demand created by best efficiency practices. Another 4700 PJ of energy would still have to be found. This could come from imports of hydrogen or use of sustainable biomass for example.

This scenario uses more modest efficiency measures, turbine sizes and conversion efficiencies than in the later scenarios. In Scenario One the following renewable energy systems are installed:

- Wind: 27,000 wind turbines with an installed capacity of nearly 57,000 MW of electricity; This is nearly twice the number of plants and about 4.6 times the installed capacity in Germany by the end of 2003[15]
- Solar photovoltaic: 3.2m^2 of solar panels installed per capita on roofs. This would be approximately 400km^2 and represents less than half of the available south-facing area in the residential sector alone. It would have a capacity of over 60,000MW
- Solar-thermal systems: three square meters per capita is installed for heating
- Hydropower: improving efficiency of existing hydropower plants by 10%
- Geothermal: increasing existing capacity of geothermal plants from 547MW to 22,900MW. This would use 25% of the potential geothermal energy available
- Cogeneration plants provide heat and power from renewable energy sources

A note on biomass: Biofuels can also be derived from sustainably produced biomass. At the time of preparing the study there are significant uncertainties regarding the potential volume of sustainably produced domestic biomass in Japan. For this reason, details regarding the value of biomass in Japan were not incorporated in this study. Nevertheless, biomass will make an important contribution to a future energy supply.

Starting from the base case of Scenario One, the later scenarios incorporated various combinations of efficiency and generation, using:

- Increased levels of energy efficiency implementation
- Larger wind turbine size and technologies in line with current commercial prototypes and increased deployment in wind-rich areas for hydrogen production
- Higher solar conversion efficiencies in line with current laboratory cell performance and increased deployment on suitable rooftops and façades
- Increased deployment and full load use of geothermal plants
- Solar-thermal power plants (used for hydrogen production in scenarios Five and Six)

The main differences in Scenarios:

1. Scenario One: Electical supply based completely on domestic sources

This scenario covers 53% of energy use from domestic renewable sources. Japan would still need to import renewable energy to meet the shortfall. The mix of which renewable energies to import

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would be a decision for Japanese authorities to make, in this study they are calculated as if they would be only hydrogen.

2. Scenario Two: Population change

This is the same as in Scenario One, but a assumed decline in the Japanese population from 127 million in 1999 to 100 million results in a reduction in energy demand from nearly 7,500 PJ to under 6,000 PJ. Supplies of electricity and heat remain the same, but the supply of fuels from electrical surpluses almost doubles, coupled with a decline in consumption of fuels for heat production. This results in a higher share of domestic produced fuels and a resulting increase in supply to cover 63% supply of Japan's energy needs with 3,075 PJ of hydrogen or equivalent fuels to be imported. This is now 13.4% of the import share compared to 1999.

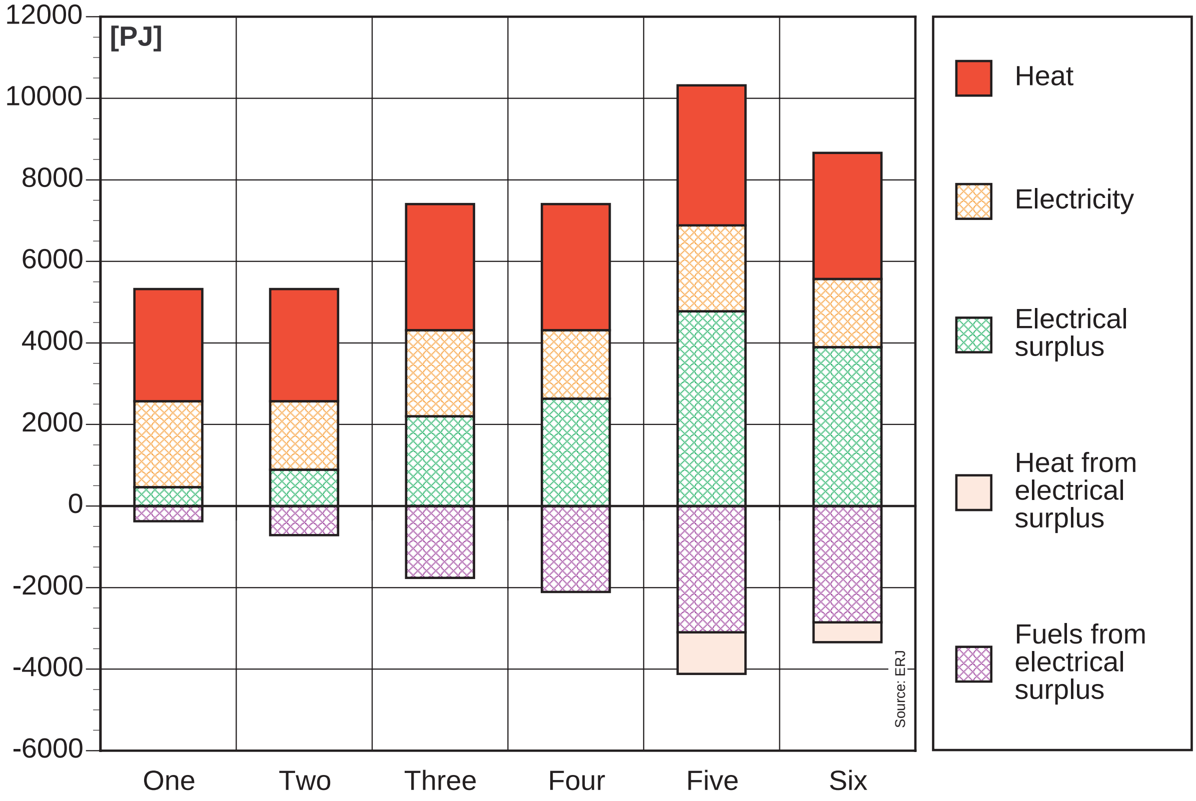


Figure 7 : Domestic electricity & heat production in all six "Energy-Rich Japan" scenarios. Electricity is divided into immediately used and surplus production. This surplus is used for heat and for fuel production

3. Scenario Three: Offshore Offensive

Energy supply is increased, mostly using offshore wind power. A number of measures are taken to increase energy supply from domestic sources including:

Photovoltaic: Installation increased by a factor of 1.5 to $4.8m^2$ per capita. PV's efficiency increased to from 15% to18%.

Heat supply in industry: The amount of solar collectors in industry doubled providing an additional 257 km^2.

Wind: Offshore installation four times the amount of Scenario One. All additional windmills are five MW plants. Average power of installed offshore-plants climbs from 2.6 MW in Scenario One to 4.4 MW in Scenario Three.

Geothermal: Increased to 35% of available potential, and the amount of full-load hours increased to 8,100 hours per year.

Use of electrical surpluses: The efficiency of hydrogen production set to 80%.

These measures raise the amount of energy produced from regional sources from 5,321 PJ in Scenario One to 7,403 PJ or 72% of Japan's energy needs. Another 2,932 PJ must then be supplied by imported hydrogen or regionally produced sources (e.g. sustainable produced biomass). This is under 13% of the 1999 import share.

4. Scenario Four: Offshore Offensive combined with population reduction

Measures are the same as with Scenario Three with increased energy supply, but the population decline described in Scenario Two is adopted, resulting in an increase in the share of domestic energy supply to 85% and a reduction in imports to 1,294 PJ or 5.6 % of the 1999 import figure.

5. Scenario Five: Full Supply and Rational use of Electricity

Electricity not needed to cover the fuel demand of cogeneration and transport is used for heat production, rather than converting surplus electricity to fuels and then heat. A direct conversion to heat is 90% efficient. Further measures taken to increase energy supply from domestic sources include:

Photovoltaic: (PV) The area increased to $6m^2$ per capita rooftop installed. An additional $6m^2$ per capita was installed on façades of buildings, making a total of $12m^2$ per capita.

Heat Supply in industry: The amount of solar collectors for industrial process heat tripled giving an additional 514 km^2.

Solar-thermal plants: Installed 600 km^2 of solar-thermal power plants with an efficiency of 20%.

Wind: Efficiency was assumed to increase by one fifth.

Onshore installation increased by a factor of 2.5. Offshore installation increased by a factor of 4.5. All offshore plants are 5MW.

Geothermal: Increased use of geothermal potential to 40%, with an efficiency increased to 20%.

Use of electrical surpluses: The efficiency of hydrogen production was increased to 85%. Only a part of electrical surpluses is used for fuel production, after fuel demand of cogeneration and transport is covered. The remaining electrical surplus is used for direct production of process heat in industry (efficiency 90%). This reduces the need for heating plants.

This scenario provides over 10,000 PJ from domestic sources, equivalent to almost 100% of Japan's needs.

6. Scenario Six: Full Supply, Rational use of Electricity and Population Change

Again the projected population decline is employed and combined with Scenario Five. The main differences include:

Photovoltaic: Used area is 4.8m^2 per capita (1.5 times of Scenario One, but less than in Scenario Five). No façade mounted PV is included.

Heat supply in industry: The amount of solar collectors in industry was halved compared to Scenario Five.

Solar-thermal plants: Area of 410 km2.

Wind: The number of onshore windmills is a third greater than in Scenario One, but much less than in Scenario Five. Offshore is just under four times the amount of Scenario One (slightly less than in Scenario Five), using only 5MW plants (this differs from Scenario 3).

Geothermal: Used potential is 35%, with all plants using ORC. Full-load hours: 8,100 hours per year.

Use of electrical surpluses: The efficiency of hydrogen production was set to 85%. Only a part of electrical surpluses gets used for fuel production (fuel demand of cogeneration and transport are covered). The remaining electrical surplus is used for direct production of process heat in industry (efficiency 90%) This reduces the need for heating plants as explained in Scenario Five.

This is a 100% regional supply, producing over 8,600 PJ of energy, with no imported fuels.

Which Scenario offers the Best Solution?

All of the above scenarios are feasible in Japan, both in technical terms and in terms of natural resources, such as wind, solar radiation and geothermal capacity. The decisive factors will be costs, public acceptance and priorities set by national policy in terms of energy security and international commitments. In terms of costs and energy security, a mixture of regional sources including sustainably produced biomass, supplemented by imports of hydrogen represents the best solution to ensure a sustainable supply.

These scenarios provide a number of possible solutions, but these are in no way comprehensive as many variations are possible. The team have attempted to offer a wide spectrum of possibilities, but do not attempt to provide an “ideal” solution.

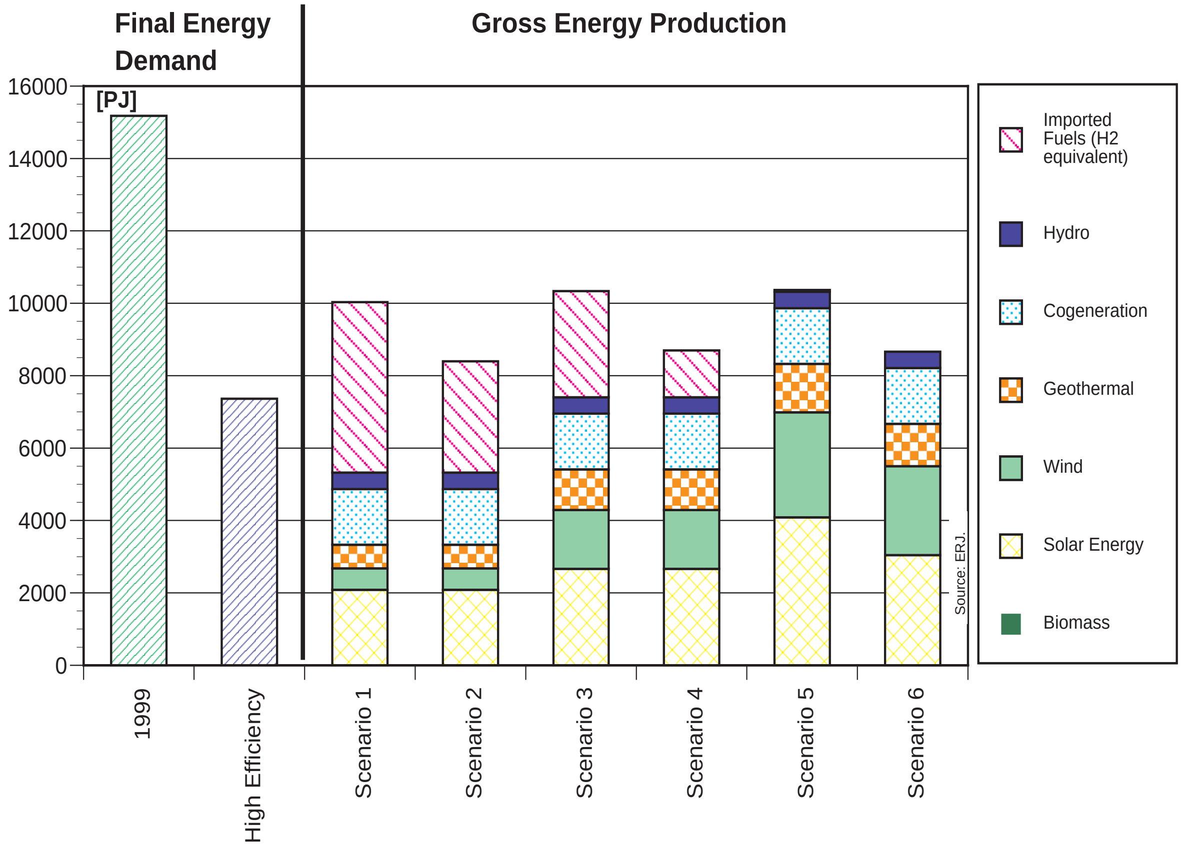


Figure 8 : Demand 1999 and the High Efficiency Model. Six Supply scenarios with different dependance from imports (Imported Fuels). Scenarios 2,4 and 6 assume a decreased population of Japan[16].

16. Primary energy is the amount of energy that must be fed into the supply system to produce the final energy, calculated with certain statistical methods which include conversion efficiencies. Final energy demand is the amount of energy that is required at the place of energy consumption, i.e. fabrication plants, households, etc. The gross energy production of the supply system is the total amount of produced energy by the different technologies.

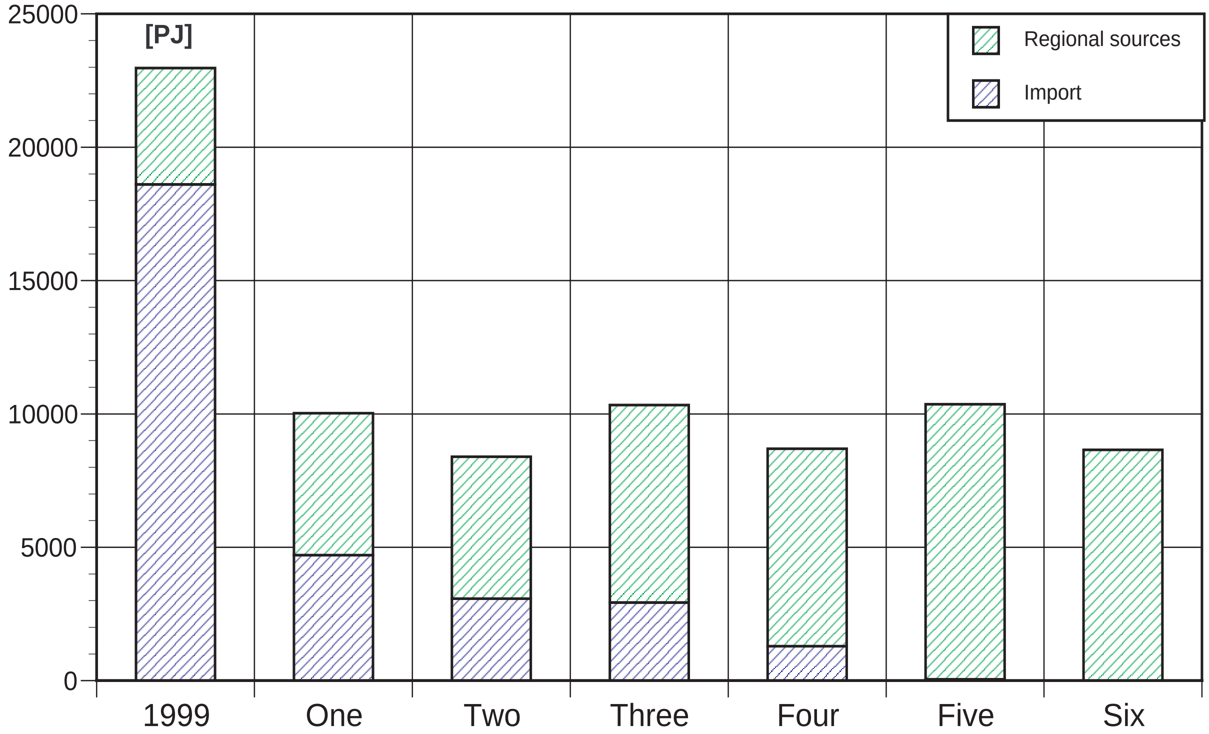


Figure 9 : Energy supply in PJ showing import share against domestic production.

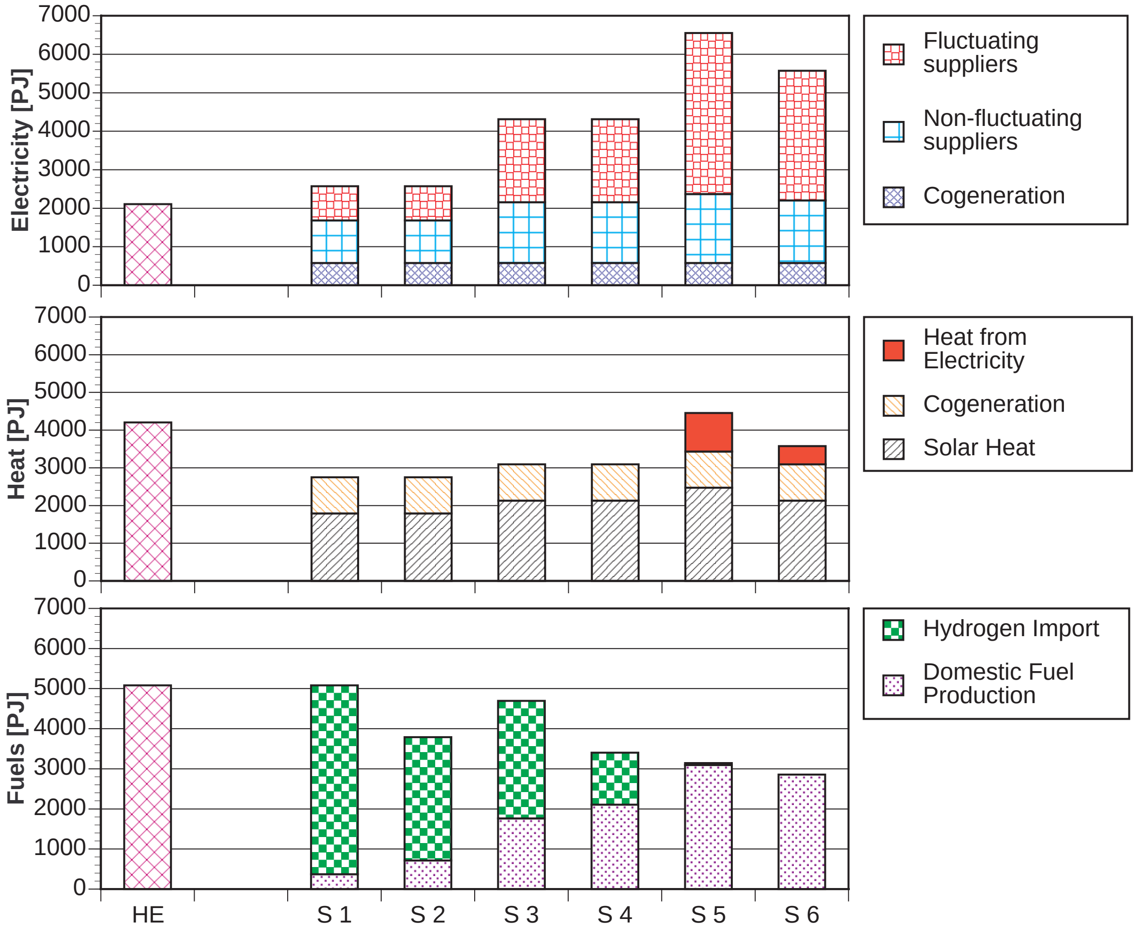


Figure 10 : Electricity, heat and fuel production in all six "Energy-Rich Japan" scenarios. Electricity surplus is used for heat and fuel production.

4.3) Scenario One and its dynamics through the year.

The year 1999 was taken for the reference year of the ERJ Demand Model and therefore the time span that was simulated. A time span of a whole year had to be simulated in order to ensure that seasonal variations and critical weather situations were included and tested. The Scenario One was simulated. If Scenario one was able to supply reliable electricity, heat and fuels all over the year, then the other scenarios (because of their higher installation capacities) would be also able to do so.

A well thought-out spatial resolution was also seen as important for the significance of the results, as all weather-dependent effects had to be simulated with a high resolution to be as realistic as possible. Consequently, all available weather data was taken into consideration for the SimRen Simulation for Japan. The information from 153 weather stations uniformly distributed over the whole country was available. The potential photovoltaic production was calculated using 66 of these stations, which also measured solar radiation.

Figure 11 : Onshore Windfarm, Keiko.

All the other data integrated into the model of Japan was available from the ten Japanese districts. Some regions were divided into two, because of differing meteorological and geographical characteristics. These were Hokkaido East and West, Tohoku East and West and Kyushu North and South. Thus the ERJ Electrical System Model has 12 regions as shown in the picture below. The energy consumption of Okinawa was only available combined with Kyushu and is therefore included in the Kyushu demand. Since most of the southerly islands cannot be integrated in the Japanese electrical grid, only the islands of Yakushima and Tanegashima were used. The more southerly islands can be used to produce hydrogen, because they have very high wind speeds and solar radiation but this was not included in the simulation.

For Japan, daily demand curves for spring, summer, autumn and winter, and a curve for public holidays were developed (hourly resolution). These curves differed from region to region and demand sector to demand sector. The final demand curve used in the simulation Program SimREN included a random fluctuation of five percent to reproduce more realistic consumer behaviour, as consumers are not entirely predictable.

The energy demand was calculated first. The energy demand of consumers is not adjustable by energy demand management[17]. The electricity production of fluctuating suppliers in every region was then determined and subtracted from the energy demand. The remaining demand had to be covered by adjustable suppliers and storages.

An energy manager was used in the simulation to control the adjustable energy suppliers. Cogeneration power plants consisted of motors for low temperature heat and steam turbines for high temperature heat. They supplied the industrial sector with enough heat for its processes. Two thirds of these cogeneration plants operated constantly throughout the day. The others were adjusted to meet the electricity demand in the regions. This mode of operation was possible as the heat could be stored in the industry and then consumed when heat was needed.

Firstly, the energy manager powered up the cogeneration plants in the industry in order to cover the remaining electricity demand. If their production did not meet demand, geothermal power plants were used to produce more energy. The hydropower plants were powered up last as their energy production depended on the water level in the dedicated river and was therefore restricted by the amount of usable water.

Figure 12 : High efficiency solar thermal vacuum collector systems;
Source : Paradigma, Ritter Energie und Umwelttechnik, Karlsbad, Germany

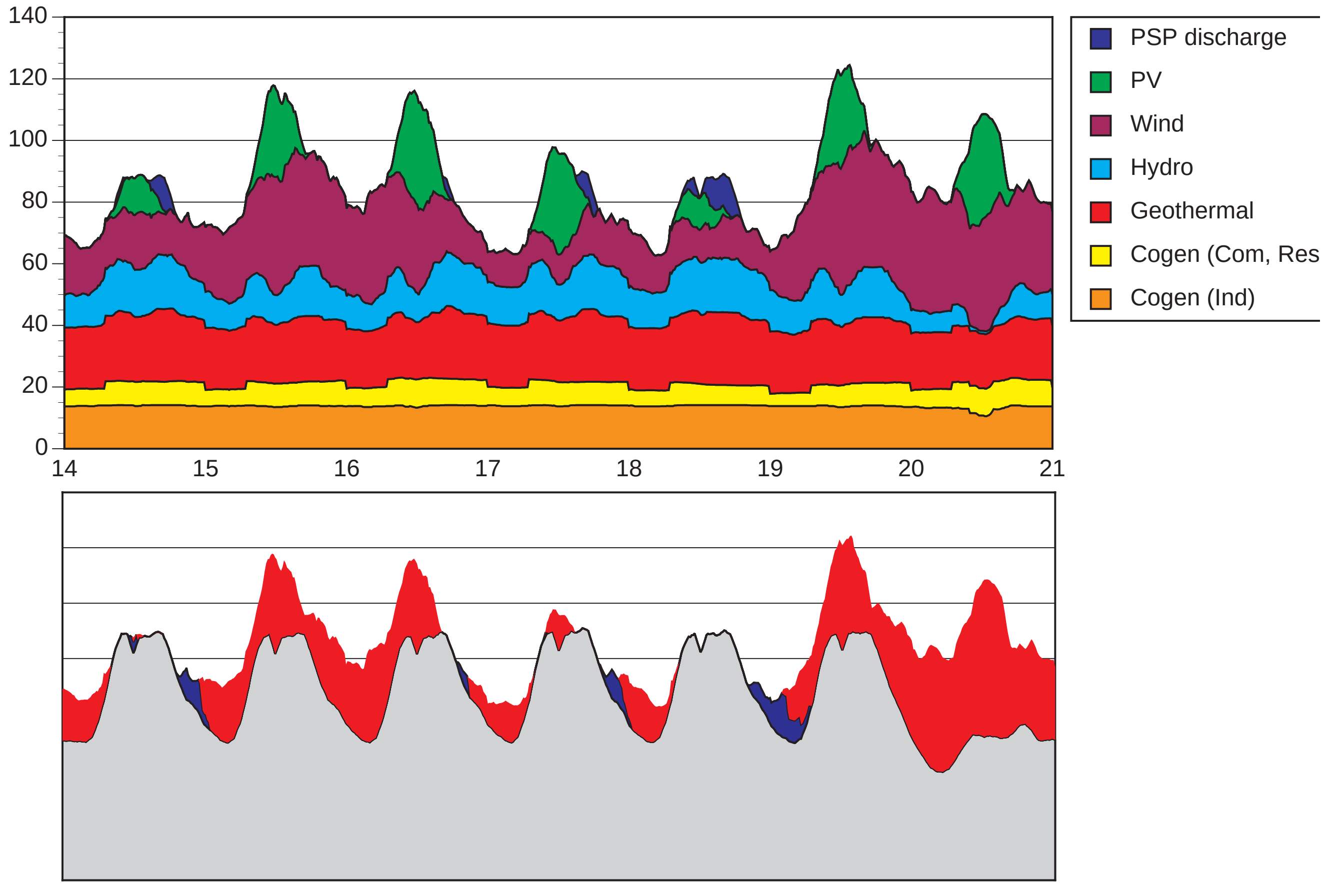
17. It would be possible to alter consumer behaviour by sending information to consumers about varying prices according to demand. But this kind of demand management is not included in this program version, although it would improve the energy system.

Regions with a high population density such as Kanto or Kansai are not self-sufficient in energy production. In these regions, the energy deficit is very high because of the large energy demand, with little space for windmills and other energy suppliers. Other regions with a very low population density have a large amount of windmills because of the available space and therefore can export energy to these densely populated regions. This energy exchange has to be managed.

The Import-Export Manager distributed the surpluses over the regions that lacked energy, until all the energy was used or all the regions were fully supplied. The Manager attempted to use the shortest possible distances in order to minimise transportation losses. If the electricity production was still insufficient, a fast reacting hydrogen power plant with one Gigawatt peak output was powered up. The Manager then emptied the pumped storage plants in order to produce more energy and finally another two Gigawatts of fast reacting hydrogen power plants could be powered up if required. The Manager could also command the energy managers in the regions to produce more energy than required for their own region in order to supply other regions. This ensured that all potentials were used up to a maximum to supply Japan with energy. After many simulation runs this strategy turned out to best meet the supply. This strategy had the advantage that pumped storages always contained some energy for critical times and fast reacting power plants did not burn too much hydrogen.

In this program version of SimRen, Japanese holidays were treated as normal working days, as integration in the simulation was not possible. During the optimisation process it became clear that the introduction of a summer time adjustment would be favourable as the electricity demand peaks would match the peaks in the solar radiation much better. That is why in the ERJ Electrical Supply Model a time shift of one hour between March 28th and November 31st is included.

Energy supply curves for certain weeks in 1999 were included below to illustrate the dynamic and reliable nature of the supply system.


140
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PSP discharge
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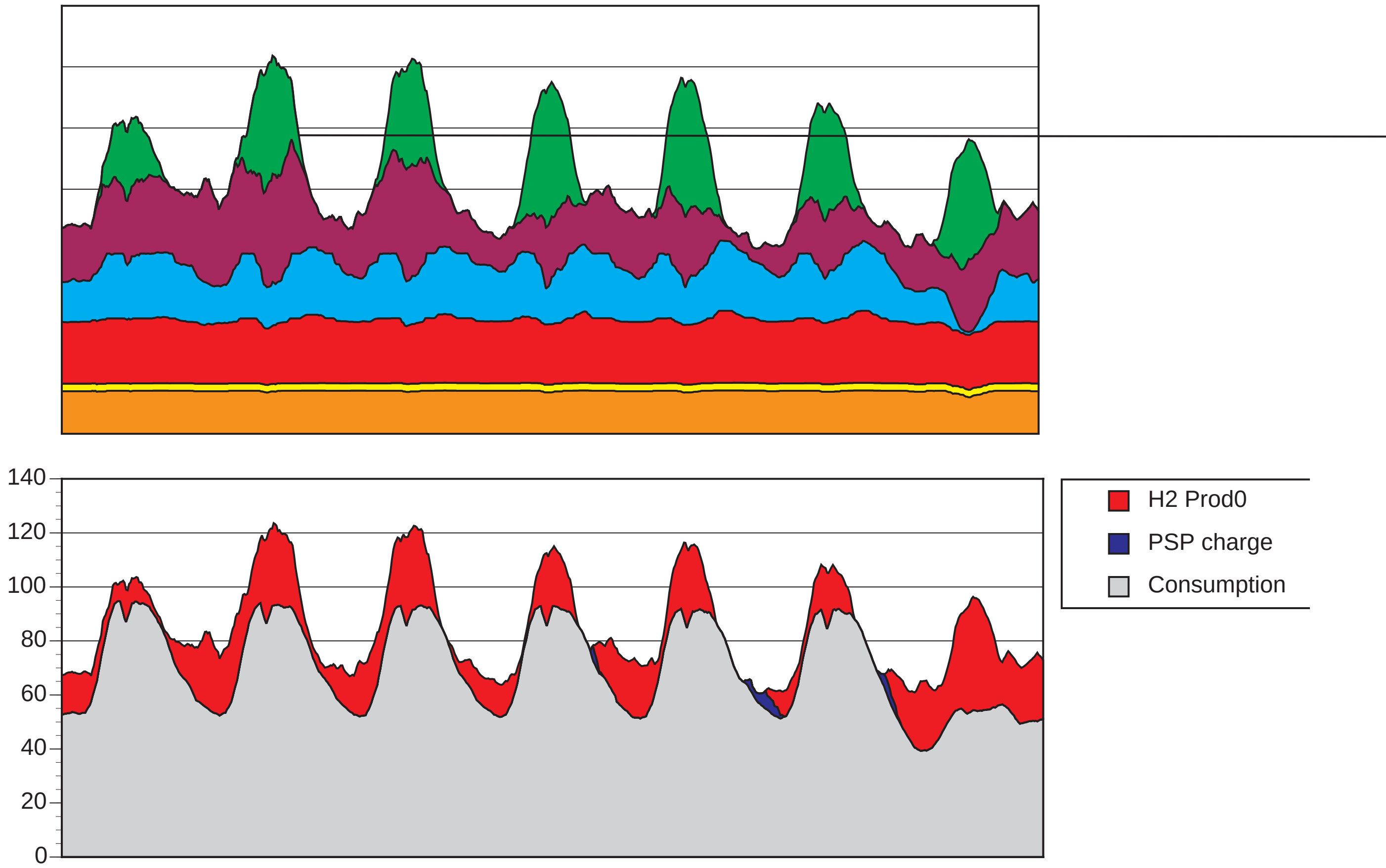

Figure 13 : ERJ supply and demand in gigawatts, showing the first week in January, third week in September and second week in November in Scenario One. Note that supply always meets or exceeds demand. Excess supply was used for hydrogen production or pumped water storage [18].

18. All the curves for 52 weeks of the simulation and an animation of the dynamics can be seen on: www.energyrichjapan.info.

5) Conclusions

The study shows that Japan can be transformed using today's best available technology to supply a reliable energy system, based on renewable and efficient energy technologies across the commercial, industrial, residential and transport sectors, and combined this with the harnessing of Japan's significant wind, solar, geothermal and hydroelectric resources.

The study shows that through detailed application of best available technologies, current final energy demand in the industrial, commercial, residential and transport sectors can be reduced to under 7500 PJ while maintaining or improving quality and reliability. This is half of current energy demand

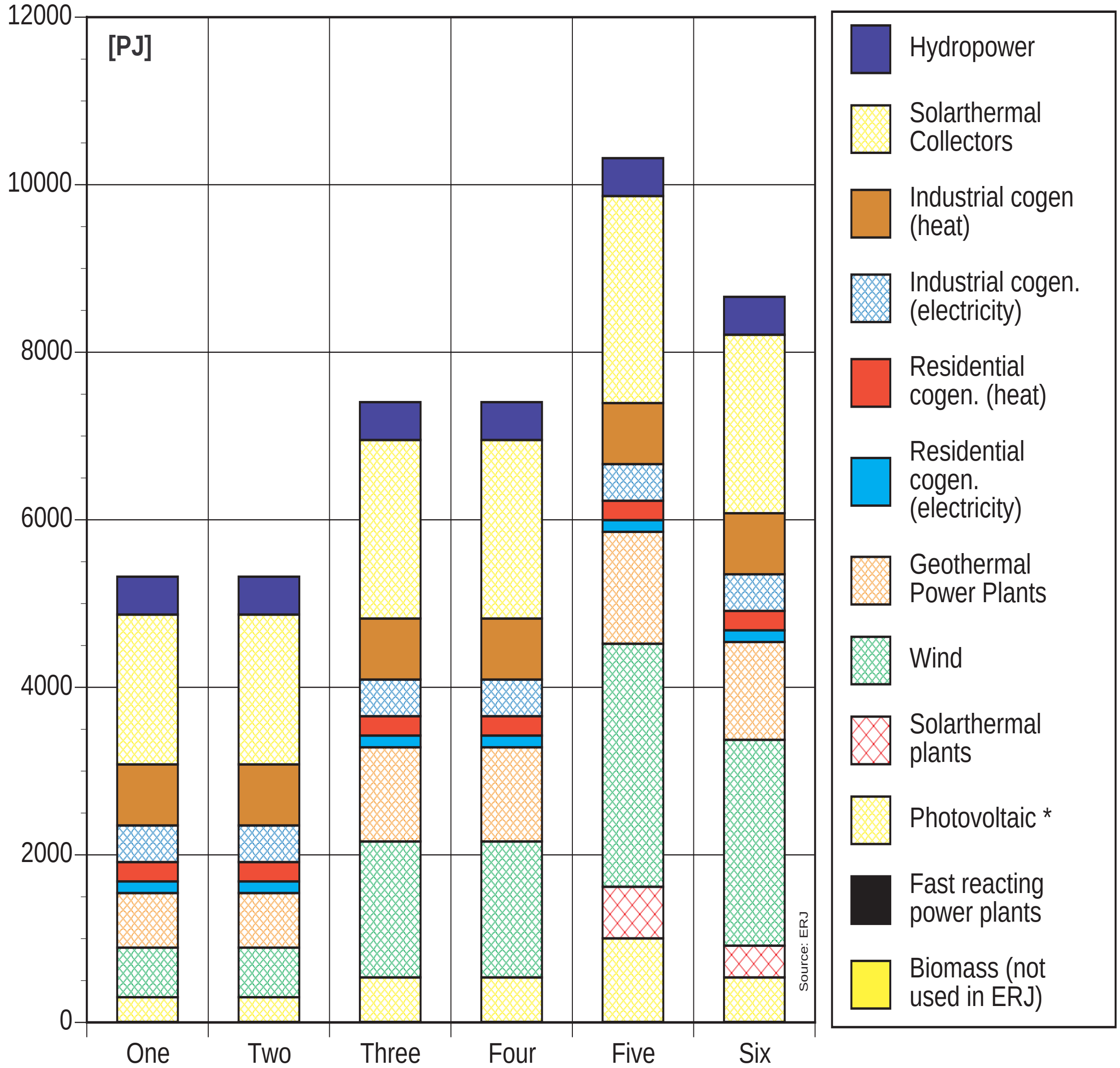

Figure 14 : Domestic gross energy production in petajoules using energy conversion technologies from renewable sources in Japan as used in the six scenarios[19]. This is the production of electricity and heat in the installed power plants. Biomass, although listed is set to zero because of the unavailability of the potential of sustainable produced biomass.

A number of six scenarios demonstrate the feasibility to supply Japans energy needs from renewable sources, using current state-of-the -art technologies. The presented systems reach from a 50% domestic supply up to domestic full-supply without any need for energy imports. Three of the scenarios consider foreseeable future developments, such as an increasing efficiency of renewable energy technologies and the predicted decline of Japans population, that are helpful in minimizing the effort to reach a sustainable enrgy supply. Biomass, although not considered in the study, will contribute to future energy supply, thus further lowering the need for energy imports or the supply systems extent.

The study also demonstrates that under these conditions, Japan's high standard of living and high industrial capacity can be maintained with a safe, sustainable and reliable supply base, either fully generated in Japan or making use of international trade in renewable fuels from low-cost production centres.

Figure 15 : An ORC power plant[20]; Source :Turboden, Brescia, Italy.

19. This is the gross energy production of the system in PJ (not primary energy).

20. Two geothermal power-plants using the ORC (Organic Rankine Cycle) technology are already in operation in Austria and Germany. The plant in Altheim, Austria from Turboden has a generating capacity of 1.000 kW. After a testing period of two years the plant is in normal operation since September 2002. The German plant in Neustadt-Glewe started operation in November 2003 and has a generating capacity of 210 kW. Sources: [Geothermische Energie 36/37 - Sonderheft Altheim, 10. Jahrgang/Heft 3/4, Juni/September 2002, Magazin of Geothermische Vereinigung e.V., Germany; 2002], [Erdwärme-Kraft GbR, Berlin, Germany; 2003].

6) Policy Recommendations

All of the scenarios are able to be met in Japan, both in technical terms and in terms of natural resources, such as wind, solar radiation and geothermal capacity. The decisive factors will be costs, public acceptance and priorities set by national policy in terms of energy security and international commitments. „Energy Rich Japan“ is an ambitious concept, yet conservative in its methodology. Admittedly its implementation would involve considerable investment in infrastructure and far reaching changes to the way Japan designs and builds its future industrial, residential, commercial and transport sectors. Compared to the environmental dangers faced globally by climate change and nuclear accidents, the costs of not developing sustainable energy systems, be they in Japan or anywhere around the world, are potentially far greater.

Without political support, even economically competitive renewable energy technologies remain at a competitive disadvantage as a consequence of distortions in energy markets created by decades of ongoing financial, political and structural support to traditional polluting technologies. Networks for power, heat, and transport have been developed over the course of a century based on use of fossil fuels and more recently for nuclear power. The switch to renewable energy will require strategic policy intervention to facilitate and accelerate the transition and political action will be needed to ensure full achievement of the economic and environmental benefits of renewable energy.

Efforts toward the introduction of a comprehensive market of renewable energy and efficient technologies include full-cost energy pricing, environmental regulations, tax incentives, codes and standards, public education. Specifically (but not comprehensive), the following areas of action are required:

Demand Policies

- Mandatory efficiency labelling and standards
- Economic incentives for efficient devices
- Minimum standards in new buildings, including insulation, solar-thermal and PV
- The retrofitting of existing buildings

Supply Policies

- Establishment of legally binding targets for renewable energy sources
- Creation and definition of stable returns for investors in renewable technologies (for example feed-in tariffs)

- Removal of market distortions
- Reformation of the electricity and fuel markets to accommodate environmental considerations

Transportation

- Taxation-based incentives for lower consumption vehicles
- Measures to increase the uptake of public transport
- Improved town planning

Hydrogen Economy Transition Policies

- Research and development
- Demonstration of the technology
- Hydrogen economy target dates
- Development of hydrogen infrastructure

Figure 16 : Offshore Windpark, Horns Rev in Denmark; Photo: Elsam A/S.