

Renewable Energy Development and Utilization Cases of Three Countries, Japan, The United Kingdom and Canada from Three Continents

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1. My name is Toshi Takematsu, JICA Volunteer, working for Instituto de Estudios e Investigaciones Ambientales of UCES in Buenos Aires.

Professor Galloni, the Director of the Institute, is the coordinator of the Argentine branch of the GROBE Program, the world famous environmental organization and therefore, she has a long experience regarding environmental issues.

This professor thought that Argentina should adopt renewable energies which occurred abundantly in Argentina as their energies for the next generation after petroleum and natural gas which were said to last only another decade.

She thought it necessary to make people understand the necessity of sustainable and cleaner renewable energies for the Argentina in order to get their wide consensus.

That is the reason why she asked JICA to send an appropriate person to help her in this matter, and I am here now though I don't know whether I am an appropriate person or not.

2. What are the Renewable Energies ?

I don't know the precise definition of the renewable energy , but I am sure, it is not an energy like petroleum, coal or natural gas of which resources will be depleted by human consumption, but it is a natural energy like wind power, solar energy or biomass energy which does not deplete for ever as far as the solar system and the earth exist as in the same condition as they do now. Of course, secondary energy like electricity can be included in the renewable energy if it is produced by using renewable energies.

Besides above-mentioned representative renewable energies, there are hydraulic power, tidal energy and wave energy. If hydrogen is produced from water by electrolysis using renewable electricity mentioned above, it can be called renewable hydrogen.

Biomass can be burned to produce electricity, but it can be converted into bio-alcohol fuel or biogas by fermentation. They are also renewable fuel and gas

All these representative renewable energies are collected together in **Table 1** with their energy conversion technologies and types of consumption.

All these renewable energies do not emit or emit very little of contamination or GHG in the process of production and consumption or are carbon neutral, which means that they do not contribute to the increase of GHG content in the atmosphere.

As shown above, renewable energies are all environmentally friendly energies, and therefore, various countries are now making great effort to develop introduce them competitively.

3. Why we have chosen Japan, the United Kingdom and Canada ?

I have presented the Japanese experience in the development and utilization of renewable energies at the meeting of environmental experts and at the graduate class for the students specialized in environment in Buenos Aires.

These are a part of my duty as a JICA Volunteer, but for the Argentine people hearing my lecture, they can get only Japanese information. It is necessary for them to get information from various countries in order to choose their own future energy.

In a meeting of environmental experts, Prof. Galloni met a person from British Embassy. He said her that British Government had recently decided to produce considerable amount of renewable energies and introduced her a nearly-300-pages book describing on the program of renewable energies deployment towards 2020. He recommended her to use it as the information for Argentine people to decide their own renewable energies.

Consequently we have chosen Japan (Asia) and the United Kingdom (Europe). But as the professor needed a country from America, I recommended her to choose Canada which has a big land and a small

population like Argentina and is not a super country like the United States and she agreed.

4. Present situation and future plan of each country

4-1. Japan's situation

Two oil crisis during 1970s made Japan to exert tremendous efforts to develop new energies for energy diversification and later, when the environmental problem became a major issue of the world, Japan changed its direction of development from energy diversification to renewable energies.

In the early stage of 1970s, the Government focused its major efforts at coal liquefaction and gasification to produce oil substitute and gas substitute. But as the environmental problem was getting serious, it shifted its focus from coal to the development of solar cells and hydrogen energy and fuel cells.

Now we are going to look at Japan's present situation and future plans of the representative renewable energy projects.

4-1-1. Photovoltaic power

In Japan, from the early stage of popularization of solar panel installation, the Government supplied installers with subsidy to encourage installation.

That is the reason why Japan could keep the first place in the world in the installation capacity of solar panels until 2003 as shown in **Fig. J1**.

But in 2004, the Government abolished the subsidy and almost at the same time, Germany began to supply installers with subsidy much more favorable for the installers than that of Japan. Since then Germany keeps the first place in the world in the installation capacity of solar panels.

But in the case of solar panel production, as shown in **Fig. J2**, Japan is possibly keeping its first place in the world still now.

In **Table J1**, shown a target plan to improve conversion efficiencies of various kinds of solar cells towards 2030.

Among different kinds of solar cells, the major development focus is put on the "Thin-film silicon" in the aspect of cost reduction and Germanium based "Ultra-high efficient type" in the aspect of high efficiency.

4-1-2. Wind power

Japanese Government and power companies were not positive to develop and introduce wind power generators because they recognized that there were no places in Japan suitable for wind power generation except for the both northern and southern ends of the land.

Actually, there are not so many flat and uncultivated lands suitable for wind farms. Most places where wind conditions are better for wind power generation are in the mountainous area like these **Photos J1** and **J2** where transportation and installation cost of the equipment are very high.

Moreover there are lots of lightnings and typhoons in Japan which could destroy generators and towers. Actually in 2003 at Miyako Island, one of our southern islands, 5 wind turbines were destroyed by a 252 km / h wind of the typhoon.

In **Fig. J3**, actual installation capacities are shown. The installed capacity in 2007 was 1,675 MW which is smaller than those of the UK and Canada for the corresponding year.

Our plan and targets for wind power generation are shown in **Table J2**.

In this, the Government will shift its focus to Off-shore wind where direction and speed of wind will be more stable than those of On-shore.

Photo J3 shows first 2 Off-shore wind turbines which Japan introduced for the first time.

Our target installation capacities (3,000 MW for 2010; 6,020 MW for 2030) seem to be too modest compared to those of the UK and Canada, being shown later.

4-1-3. Biomass Energy

Among various biomass energy projects, the project given highest priority by NEDO is now the production of ethanol for automobile fuel from wood waste instead of using food materials like corn and soybeans.

One of the demonstration plants is shown in **Photo J4**.

Now in Japan, about 26 million kLoe waste biomass resources occurs every year. Only 27 % of that (7.14 million kLoe) has been used and the rest has been discarded because of high cost of collection and transportation. To raise the ratio of utilization of the waste biomass resources and promote fuel production from woody waste are the major objectives to develop now and in the near future in Japan.

4-1-4. Renewable Hydrogen Energy

Hydrogen produced from biomass by partial oxidation or steam reforming processes and Hydrogen produced from water by electrolysis using electricity generated by solar cell, wind power or hydroelectric power can be called “Renewable Hydrogen”.

Hydrogen is said to be the cleanest energy on earth except for electricity.

If it is burnt in oxygen, it emits only water. If it is burnt in the air, it emits a small quantity of nitrogen oxides besides water.

But if it is introduced into PEFC (Polymer Electrolyte Fuel Cell) and reacts with air, it will generate electricity emitting only water. This is due to the low temperature oxidation of the fuel cell, too low to produce nitrogen oxides. This is the reason why fuel cell is said to be the cleanest power generator in the world.

PEFC can be operated at the temperatures between 80 and 120 degree C and has a compact size enough to stay in a passenger vehicle as a driving force. Therefore, it has a wide range of use including the energy source of vehicles and domestic houses.

In Japan, there are about 50 passenger FC cars and buses are driving around Tokyo and Osaka area for performance tests of vehicles and fuel cells. And to refill the vehicles with hydrogen fuel, there are 12 various types of hydrogen refilling stations located in both cities. One of the stations in Tokyo area is shown in this slide (**Photo J5**).

In this picture, the other side of the concrete wall is the site to produce hydrogen from gasoline (now not renewable source because of experiment) and to store it in high pressure cylinders up to 300 bars as shown in this picture (**Photo J6**).

The performance test of the PEFC for domestic use is also conducted using ordinary houses where ordinary families are living in different environment. **Photo J7** shows one of them. In this photo, FC is in the smaller box, in the larger box, there is a small plant called “Reformer” which converts city gas or LPG into hydrogen to be fed to the FC.

The Ministry of Economy, Trade and Industry of Japan has a plan to introduce Hydrogen Fuel Cell Vehicles (HFCV) at the level of 5million units by 2020 and 15million by 2030. But for the time being, it is very

difficult or almost impossible for Japan to prepare hydrogen necessary for the demand for 2020 (17billion Nm³ / y only for the HFCVs) from renewable resources.

Therefore, the representatives of Hydrogen Energy System Society (HESS) of Japan have visited Patagonia a couple of times so far and had meetings with the representatives of Argentine Hydrogen Association and those of local Governments, and they are now confident that Patagonia has a vast wind power potential enough to supply 5 to 10 times more energy than the total annual energy consumption of Japan annually. **(Photo J8)**

The hydrogen associations of both countries have been discussing on the possibility of the production of hydrogen from water electrolysis using electricity generated from the wind turbines in Patagonia and transport it to Japan as the fuel for HFCVs.

If this idea could be realized, it will not only contribute to the large scale international trade of renewable energies but also will contribute to the economy of both countries.

This is the wind of Comodoro Rivadavia of Patagonia.

4-2. UK's situation

At the meeting of the EU in the Spring of 2007, a decision was made as the EU Directive that EU member countries must change 20% of their energy consumed into the energy which comes from renewable sources by 2020 and the share of contribution was shown to each country. **Table E1** shows UK's share of contribution.

According to this table, UK must use 10 times more energy from renewable sources from 1.5 % in 2006 to 15 % by 2020.

The planned share of renewables in the energy consumption in 2020 was proposed by BERR (Department for Business Enterprise & Regulatory Reform) as 32 % to electricity sector, 14 % to Heat and 10 % to Transport.

Now we are going to see the situation and future plan of the UK's major renewable energies.

4-2-1. Wind Energy

Recently and also towards 2020 target, the major sector of renewable energy to which UK Government pays attention is wind power.

In the year of 2006, total installed capacity of on-shore and off-shore wind power generation was 2.3 GW, and in 2008, it exceeded 3.3 GW.

And in 2020, the Government plans to increase installed capacity of wind power up to 28 GW as shown in this Figure (**Fig. E1**).

From these data, it is clear that in the renewable electricity generation sector, the majority contribution has been and will be made by wind power, especially in the future, by off-shore wind power.

In 2008, there were 165 working on-shore wind farm. If all these cases like that wind farms now under construction, planned and already permitted, and planned but before permission were to be realized, another 366 wind farms would be added with additional capacity of 10 GW shown in **Table E2**.

In **Photo E1**, a photo of a 5MW off-shore wind power generator under installation near the coast of Caithness, Scotland.

Another information : Denmark used to be the most advanced country regarding installed capacity of off-shore wind power. But in 2008, UK took over its position.

4-2-2. Biomass Energy

In the renewable energy composition in **Fig. E2**, second largest component is Biomass (Biomass / Waste, Sewage Gas and Landfill Gas) both for 2006 and 2020.

In 2006, the share of electricity from biomass sources in total electricity generated in the UK, was 2.3 % (about 2.5 GW). But in 2020, only Biomass / Waste based electricity generation will grow from 2006 level.

Landfill Gas based electricity generation has a clear tendency to shrink not only in the share but also in the absolute capacity.

Total biomass based electricity generation will grow twice larger in 2020 compared with that of 2006.

But when it comes to the Heat generation, as shown in **Fig. E3**, the share of biomass based Heat generation in the total renewable heat generation in

the UK in 2006 was more than 92 %.

Moreover, Bioenergy share in total renewable energy utilization in 2006 was 82 % as shown in **Fig. E4**.

From these two figures, it can be said that the share of biomass energy in all of the renewable energies now in use is overwhelmingly large in the UK.

Fig. E5 shows share of the 4 renewable resources in two heat generation scenarios for 2020. In both 14 % and 11 % scenarios, the majority of the share will be allocated to Biomass energies, but the share of Solar Heat and Heat Pumps will be considerably increased up to 30 to 40 % even though cost of Solar Heat will be considerably higher than that of Biomass.

Table E3 shows the Government's biomass energy strategy towards 2020. **Read the slide.**

4-2-3. Tidal and Wave Energies

Potential amount of UK's Tidal and Wave energies are estimated as follows :

Off-shore Wave Energy :	50 TWh / year
Tidal Stream Energy :	18 TWh / year
Near-shore and Shore-line Wave Energy	8 TWh / year

Total amount of these energies corresponds to 15 – 20 % of total amount of electricity generated last year in the UK.

Though the Tidal Stream and Wave Energies are in their infant stage of technology, but it is expected that at most 2 % of total current electricity generation (about 2 GW) will be covered by these two technologies by 2020, because in December 2008, world first Tidal Stream type turbine manufactured by an English company, Marine Current Turbines Ltd., started its commercial operation at the capacity of 1.2 MW in Stranford Channel, north of Ireland. **Fig. E-14** shows the picture of the turbine.

Another tidal energy technology, Tidal Range is a proven technology, and since 1966, 240 MW Tidal Barrage has been working at Rance in France.

UK Government thinks it possible to generate electricity amounting to 5 % of total electricity consumed in 2020 by using this technology.

If the Government choose Severn Estuary (**Photo E3**) as the site to construct Tidal Barrage, only one longer barrage will cost 15 billion pounds and its power generating capacity will amount to 8,640 MW supplying 17 TWh electricity annually corresponding to 5 % of total electricity consumed in 2020.

The smaller barrage (Shoots Barrage) is estimated to have the capacity of 1,050 MW and possible to supply 2.75 TWh electricity annually and its construction cost is estimated to be 1.5 billion pounds.

This project will be permitted by the Government after 2 years feasibility study. Therefore, the operation is expected to start in 2022. But according to EU's draft Renewable Energy Directive, it will be applied exceptional provision only applicable for big projects over 5 GW.

4-3. Canada's situation

Canada is rich in water resources like Niagara Falls and hundreds of lakes. Therefore, it is well known as a big hydroelectric country of which hydroelectric production is 4 times bigger than that in Japan, although its population is only 1 / 4 of that of Japan. It is natural that the price of electricity is very low in Canada.

Now Canada produces hydrogen by water electrolysis using cheap electricity. A Canadian Government paper says that Canada must be the biggest per-capita hydrogen producing country in the world.

Canada is now famous also for PEM Fuel Cell which Vancouver based small company "Ballard Power Systems" developed which will be used as clean power source for vehicle and domestic use in the future.

This figure (**Photo C1**) shows a water electrolyzer for experimental use installed in the Hydrogen Experimental Facilities of Pico Truncado, Patagonia. It was presented by Canadian Government when the Facilities was built to produce hydrogen from water by using electricity generated by the wind turbines installed in the same site as the Facilities.

Canadian renewable energy policy is represented by the 14 year plan of eco ENERGY initiative, Renewable Power 1 Program (2007 – 2020).

This plan aims at generating electricity amounting to 14.3 TWh by wind

power, photovoltaic power, hydro power, biomass and tidal / wave power.

We will see the present situation and future plan of these energies.

4-3-1. Wind Power

Canada is located in the cold latitudes where climatic condition is harsh.

But even though, the installation capacity of wind turbines was rapidly increased from 683 MW in 2005, 1,856 MW in 2007, to 2,369 MW in 2008 and in 2012, Canada aims at 5,600MW, more than double of the capacity for 2008.

This rapid growth of wind turbine installation is due to the Government's strong incentive (C\$ 8.4 billion).

Though Canada has no experience of off-shore wind power so far, they considered off-shore has more advantage than on-shore in the aspect of wind speed, lower turbulence and direction stability and started the survey of off-shore wind characteristics.

I will introduce one of the special experiences a small island of Canada had so far.

Ramea Island of Newfoundland Province has so far supplied electricity generated by diesel generators and wind turbines. Recently three new wind turbines were installed additionally (**Photo C2**). Therefore, when electricity demand is not so high, it is not necessary to run diesel generators.

This is due to the addition of other equipments like water electrolyzer, hydrogen storage tank and hydrogen generator. As shown in this Figure (**Fig. C1**), these equipments can produce hydrogen from water using surplus electricity and store it, and depend on the necessity, operate hydrogen generator to generate electricity without emitting contamination.

4-3-2. Photovoltaic Power

In 1995, Canada had only 1.86 MW of solar panels installed, but after that, installation of them increased rapidly like 14 MW in 2004, 20.5 MW in 2006 and 25.8 MW in 2007. Canadian Government evaluated this rapid growth saying "Photovoltaic has steadily been gaining ground in Canada".

These rapid growth of photovoltaic installation is possibly be supported by the Government incentives such as "Modeling & Optimization of PV-hybrid and Mini-grid Systems" for cold latitude area and a research and demonstration project on low energy solar homes "Net-zero Energy Solar

Homes” as shown in **Photo C3**.

4-3-3. **Biomass Energy**

6 % of total energy consumed in Canada comes from Biomass Energy now. Among various biomass resources, Canada directs its attention at the moment at Wood Residue, Sawdust, Straw and Perennial Grasses as the most promising resources to extract bioenergies.

Canada has made an intense effort to develop the technology to convert lingo-cellulose contained abundantly in the above mentioned biomass waste into ethanol.

Now the Government intends to produce 1.4 billion liters of bioethanol which is needed to provide 5 % ethanol containing gasoline in Canada by 2010 by using above mentioned technology.

Another way to make use of above mentioned biomass waste is to burn them under very high temperature and oxygen-deficient atmosphere to produce fuel gas composed of carbon monoxide, hydrogen and small amount of methane. This gas mixture can be used as a fuel for gas turbine power generation.

4-3-4. Small Hydro power (1 – 50 MW)

As shown in **Table C1**, potential amount of energy resources of this type of hydro in Canada is about 15,000 MW. 3,400 MW of them have already been installed.

Among various types of small hydros, what Canmet ENERGY directs its major attention for development are Low Head Hydro and Fish-Friendly Turbine technologies.

1) Low Head Hydro is defined to have the head of water drop typically less than 15m. This technology development is conducted with University of New Brunswick focused on the development of the power converter for low head hydro application.

The identified potential capacity of this type in Canada is more than 5,000 MW. If turbine technology applicable for very low head (less than 5 m) is developed, the potential capacity will be expanded much larger.

2) Fish-Friendly Turbine technology development is conducted in three ways to develop three different types of turbines applicable for small hydro less than 1 MW and head height from 1.5 to 15 m in cooperation

with companies, universities and international partners.

The first of the three is on-site testing in France since 2007 showed excellent energy performance and fish-friendliness.

4-3-5. Renewable Hydrogen

Canada is one of the world's largest per capita producer of hydrogen and a global leader in the technologies making hydrogen and fuel cells.

Many Canadian advances are being made especially in the transportation area like development of :

Hydrogen Fueling Stations

Hydrogen Vehicles (**Photo C4**) such as – personal vehicles, forklifts,
buses and airport baggage-tuggers

Materials handling such as – micro FCs

portable FCs – laptops, cellular phones and
flashlights

At the beginning of May this year, Natural Resources Canada held world biggest Hydrogen Energy Exhibition at Trudeau airport in Montreal.

Though I could not find the contents of the exhibition, I believe the event raised the Canada's prestige as the world hydrogen leader.

This slide (**Photo C5**) shows the picture of the Minister of Natural Resources Canada making the opening address proudly at the Exhibition.