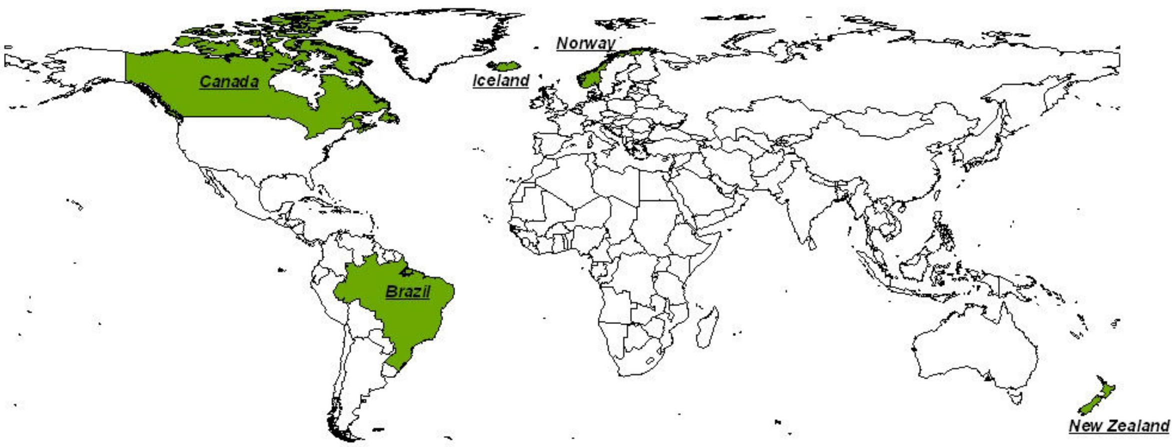
A Study of Five Countries that Generate Electricity from Renewable Resources



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Abstract

Electricity has a fundamental influence on global development. There are several countries currently generating their electricity mainly from renewable sources. Those countries, presented in this paper, are Iceland, Norway, New Zealand, Canada, and Brazil. This examination of the conditions, development and prospects for their electricity sectors is intended to provide assessments and conclusions applicable to all countries looking to expand their stake in clean electricity production.

The five included countries have harnessed mainly hydro power. A correlation between a country's development attributes and its electricity consumption has been found in many previous studies. However, no link was found between development and percentage share of renewable power. All countries are among the least settled in terms of population density, which appears to be a condition for harnessing hydro power, since large areas for reservoirs are needed.

All five countries started using their renewable resources around the turn of the 20th Century. The course of development was unique to each country, depending on their economic development after World War II, especially in the metals industry.

Energy policies amongst these countries also differ in detail, but common issues are regulation/deregulation, energy efficiency, energy conservation and the extension of green technologies. As large hydro projects are considered to have a significant negative impact on ecosystems and are threatened by potential future water shortages, four of the countries have expanded beyond large hydropower generation plants into wind, solar, and biomass.

Conclusions applicable to other countries: every country has renewable energy resources, and many have vast untapped potential. Each nation can tap the renewables that are abundant and feed them into their electric grids. Additional measures of energy efficiency and conservation are not only reasonable but necessary to secure a sustainable energy supply for mankind's future.

Introduction

In our modern society, electricity is the most important form of energy today and into the foreseeable future. In these times of depleting fossil fuels (peak oil) and climate change, some people still question whether it is possible for countries to generate their electric power predominantly using renewable energy sources. The examples of our 5 countries presented here demonstrate that it is.

There are currently, in fact, 18 countries that produce more than 50% of their electric power from renewable sources[1]. This paper will take a close look at five of those countries to illuminate the historic reasons, development, political and economic motivations, and their

[1] Information available at: http://www.iea.org/Textbase/country/index.asp

future plans for harnessing green power. The approach here is to emphasize the information that can be useful to any nation to increase its share of renewable energy generation.

The countries we focus on are Iceland, Norway, New Zealand, Canada and Brazil. This choice is based on the idea of examining countries of different size, population, location, and which have stable governments. The only developing country is Brazil, which provides an example of the possibilities of harnessing renewable energies for other developing countries.

Similarities and differences between the countries

To understand how the five countries have been successful in harnessing green resources to generate electricity, we will look more closely at parallels and distinctions between them. First we will look at the economy, development and electricity consumption, geography and climate, followed by the distribution of electricity generation.

Economy, development and electricity consumption

When comparing economic factors, electricity consumption and the Human Development Index (HDI[2]), connections become apparent (Table 1). The more developed a country is – in terms of the HDI – the higher the per capita GDP and electricity consumption. This makes sense because the developed countries produce more electricity and use more electric devices. It follows that these societies can afford the modern technologies (e.g. TV, computers, air conditioning, lighting, etc.).

Country	GDP per capita 2004 in US$[3]	kWh per capita consumed 2004[4]	HDI
Brazil	3,284	2,000	0.792
New Zealand	24,364	8,600	0.936
Norway	54,465	23,900	0.965
Canada	30,586	15,800	0.95
Iceland	41,893	26,000	0.96

Table 1: Correlation of GDP, electricity consumption and HDI

Nevertheless, there is no direct connection between the level of prosperity and commitment to renewable electricity generation in any of the considered countries. Brazil counts as a developing country (according to its HDI); still its share of electricity from renewable sources is higher than that of Canada or New Zealand.

So, if there is no correlation between the level of development and the portion of green electricity, is there any interdependence at all? Or are there other factors that dominate a

[2] Human Development Index. The HDI is a composite index that measures a country's average achievement in three basic dimensions of human development: A long and healthy life; Knowledge; Standard of living. A HDI less than 0.5 implies low development, higher than 0.8 is high development.

[3] http://hdr.undp.org/hdr2006/statistics/indicators/198.htm

[4] Source population 2004: http://www.prb.org/pdf04/04WorldDataSheet_Eng.pdf; Source electricity consumption: http://www.iea.org/Textbase/country/index.asp; consumption was divided by population and rounded

country's readiness to invest money and effort into renewable technologies? Or does a country need these factors at all and just adapts to their given circumstances, geography, and political leadership? These questions will be discussed in the following discussion.

Geography and Climate

In terms of size, there is a wide range for the different countries, from Canada, the world's second largest, and Brazil, the approximate size of the USA, to a small country like Iceland. Yet, similarities can be found. The population densities are among the lowest in the world. Brazil, with the highest density of the five nations discussed, is still rated 149th of 192 countries in the world (Table 2).

Country	Population	Size in km^2	Population density in people/km^2
Brazil	186,100,000	8,500,000	21.9
New Zealand	4,000,000	269,000	15
Norway	4,600,000	324,000	14.2
Canada	32,800,000	10,000,000	3
Iceland	300,000	103,000	3

Table 2: Population densities in examined countries[5]

Each of these five nations has abundant natural hydro resources, which are basically a function of their different, yet similar geographic conditions. The abundance of natural hydro resources seems to be a key factor in its extensive development as source of power. Norway and Canada are both relatively far north in the Northern hemisphere and rely on distinctive systems of glaciers and rivers to harness hydro power. Brazil is the only country with a tropical climate, possessing extensive river systems of the Amazon and Parana. These watersheds provide Brazil with abundant hydropower resources.

Iceland and New Zealand also exploit their other natural resources. Both are tectonically active and have access to abundant geothermal power. In addition, both countries have mountainous regions with glaciers (Iceland) and rivers (Iceland and New Zealand), allowing them to tap their abundant hydropower.

Is there a correlation between population density and the large share of hydropower in these countries?

The fact that hydropower plants need reservoirs to store a continuous power supply requires, as a precondition, the availability of large, uninhabited land areas. That means that if a country wants to exploit its hydro resources, it must have sufficient land area to build artificial dams. With the exception of New Zealand, the examined countries have low population densities and remote river systems. They can afford flooding regions for reservoirs and dams.

New Zealand's biggest problem with its existing hydro scheme is the lack of water storage capacity. While big reservoirs can store water for several years, the New Zealand lakes have

[5] http://worldatlas.com/aatlas/populations/ctydensityh.htm

water storage for just a few months. That makes the island very dependent on consistent precipitation and snow melt. Overdependence on a single renewable, like hydropower, can present a supply problem if there is a period of drought. Thus, it is important to develop a palette of renewable choices to meet the daily demand curve of a nation.

Nations with high population densities like Japan, Germany or the UK must plan their share of hydropower much more carefully, because their possibilities for installing large hydro facilities are much more limited. Newer run-of-river power plants will enable these nations to better utilize their hydro potential.

Which sources are tapped for electricity generation?

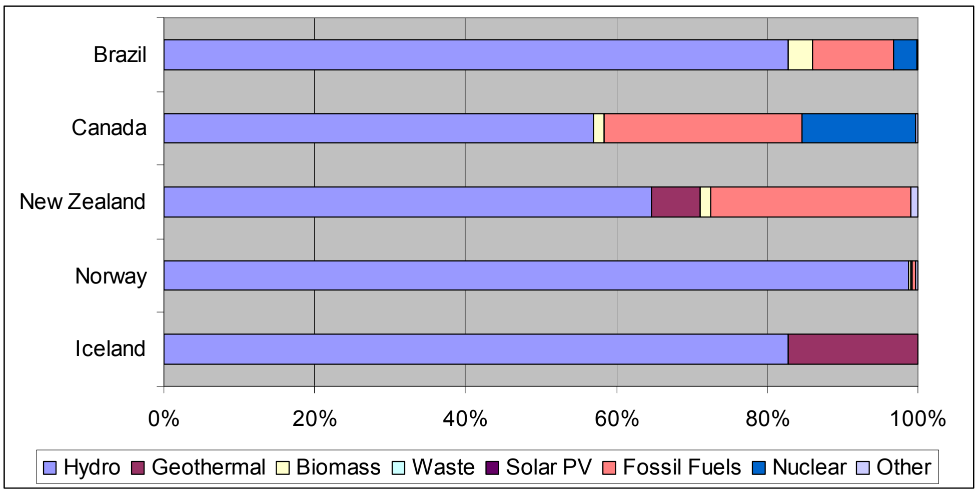

Figure 1: Electricity production by source[6]

As shown in Figure 1, hydropower is the dominant energy resource in all examined countries, ranging from a share of 57% (Canada) to almost 99% in Norway (Figure 1). Remarkable is the fact that all other renewable resources are barely harnessed. The only exception is Iceland, where the conditions for exploiting geothermal power are exceptional (see chapter "Geography and Climate"). Because of this disproportionate skew toward hydro, we will focus mainly on the aspects of this source of renewable power.

Development of the countries' energy mix

All five countries have in common that they started harnessing hydro energy early, around the turn of the 19th to 20th century. After World War II, new industries propagated with rapid economic progress, especially metallurgical production. These businesses were extremely energy intensive and, in those times, needed new sources of power. This dependence remains today. Figure 2 shows that in 2004, between 40% and 75% of the consumed electricity has been used for industrial purposes, with aluminum smelting being the dominant customer.

[6] Solar PV: Solar Photovoltaic; Fossil Fuels: Oil, Coal and Gas
http://www.iea.org/Textbase/country/index.asp

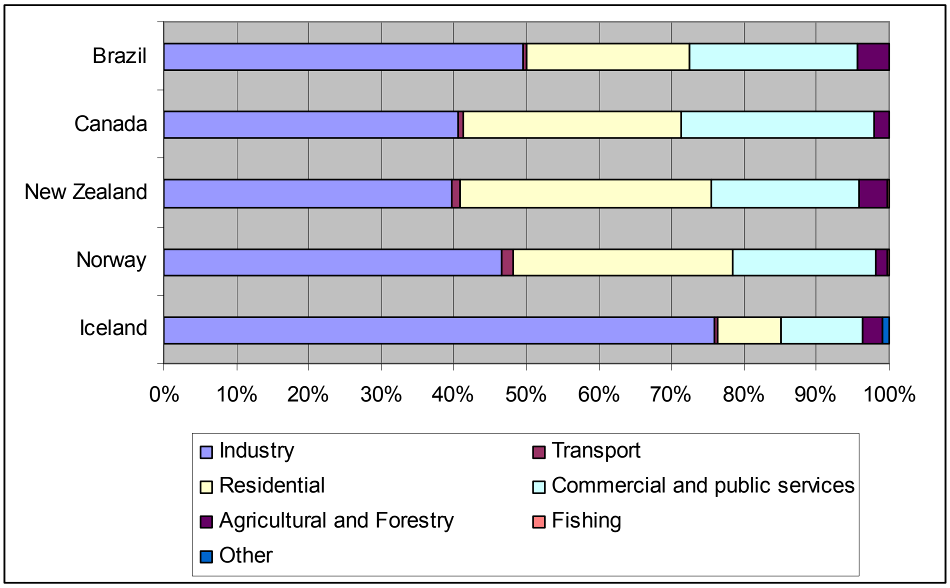

Figure 2: Distribution of power consumption 2004[7]

Iceland has always been deficient of fossil fuel resources. The island nation started importing oil as early as the 1860s. Consequently, other possibilities for acquiring electricity had to be found. The first hydropower plant started production in 1904.

In 1923, the government of Iceland began to research and further exploit its hydro and geothermal power. Iceland's electricity sector has gone through a rapid enhancement in the last 35 years (see Figure 3); the installed capacity of hydro and geothermal power multiplied almost 20 fold. During that same timeframe, the electricity consumption in Iceland doubled between 1987 and 2002.

The high share of power consumption by industry stems from aluminum smelting. The low share from residential electricity use stems from the fact that heating and hot water are derived almost entirely from their abundant geothermal energy.

[7] http://www.iea.org/Textbase/country/index.asp

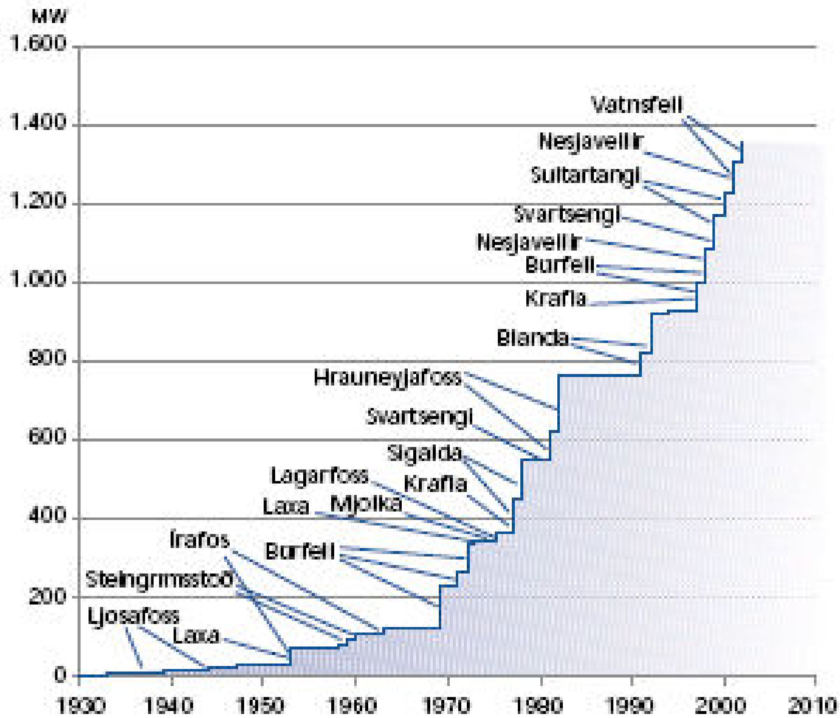

Figure 3: Total installed capacity of hydro and geothermal power plants in Iceland[8] (names represent location of the hydro installations)

Norway, as does Iceland, lacks its own coal resources. So, in order to keep pace with its rapid industrialization, the Norwegian people quickly found ways of harnessing hydropower. Most famous was the electrification of the city of Hammerfest in 1890. In the following years, more and more hydropower plants were installed, of both large and small capacities, the latter mainly for small industries like sawmills. At the beginning of the 20th century, all the generation plants were unified by the national government, and the first electric company started supplying the general population.

After WWII, Norway gained considerable expertise in hydropower generation by conducting systematic studies regarding small and large generation plants. They found that by installing small generators in remote areas, every household could have access to the electric grid. Concurrent with these studies, a highly expanded development of hydropower ensued from 1960 – 1985 (Figure 4). This research, which provided assessments of the economic, ecological and technical issues of hydro projects, culminated in the Norwegian Master Plan in 1982.

[8] http://www.os.is/Apps/WebObjects/Orkustofnun.woa/1/swdocument/9701/Energy_in_Iceland_2ed_2006.pdf?wosid=false

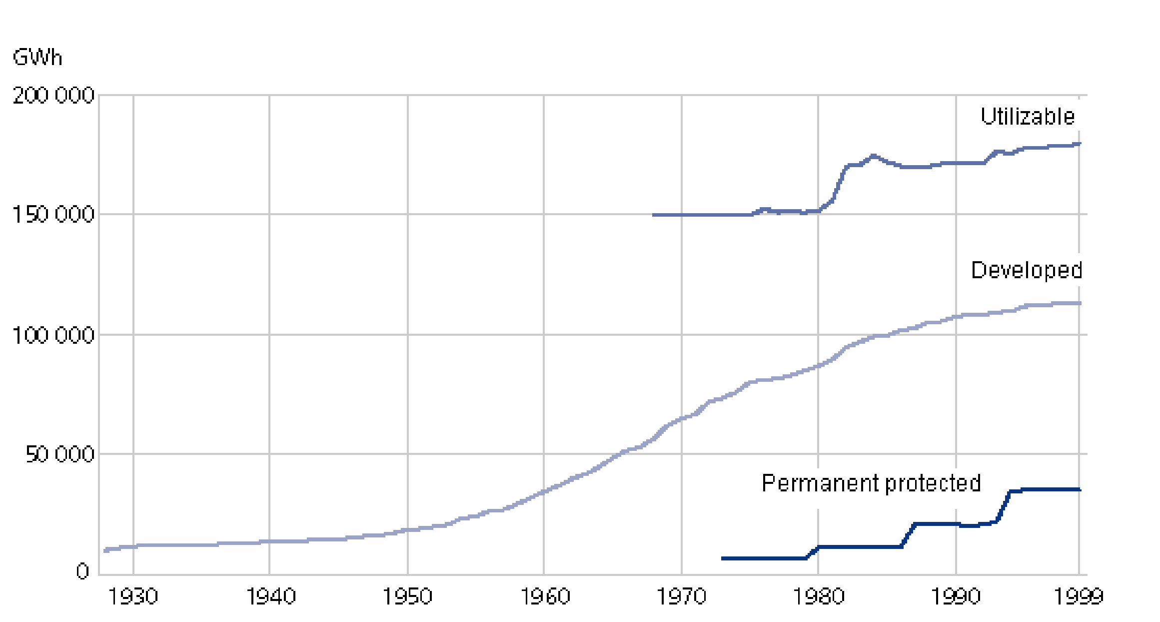

Figure 4: Development of hydro power in Norway[9]

A greater focus on renewable energy was heightened during the oil crisis of 1973, expanding the development of wind and wave power for ecological rather than economic reasons. Hence, the consciousness of environmental responsibility was inherent quite early in Norway.

Although hydro power in **New Zealand** was developed early, coal and oil were the first sources of electricity. The government began large hydro power projects in the 1920s and pushed its development in the 60s. Since the 1930s, hydro energy has been providing about 60% of all electricity in New Zealand.

From the 1980s onwards, oil fired generation has been virtually eliminated, and the main resource of fossil fuel has been natural gas from the Maui gas field.

The earlier mentioned problems of small water reserves for use in the power plants are shown in Figure 5. This variability in water resources led to diminishing hydropower supplies from 85% in 1980 to 55% in 2005. The gaps that arose from this have been filled with higher shares of natural gas. Consequently, New Zealand will remain dependent on its fossil fuel sources to reconcile the fluctuations in availability of water. Fortunately, natural gas is one of the cleaner conventional fuels.

[9] http://www.statvoks.no/synergy/hydroel_no.doc

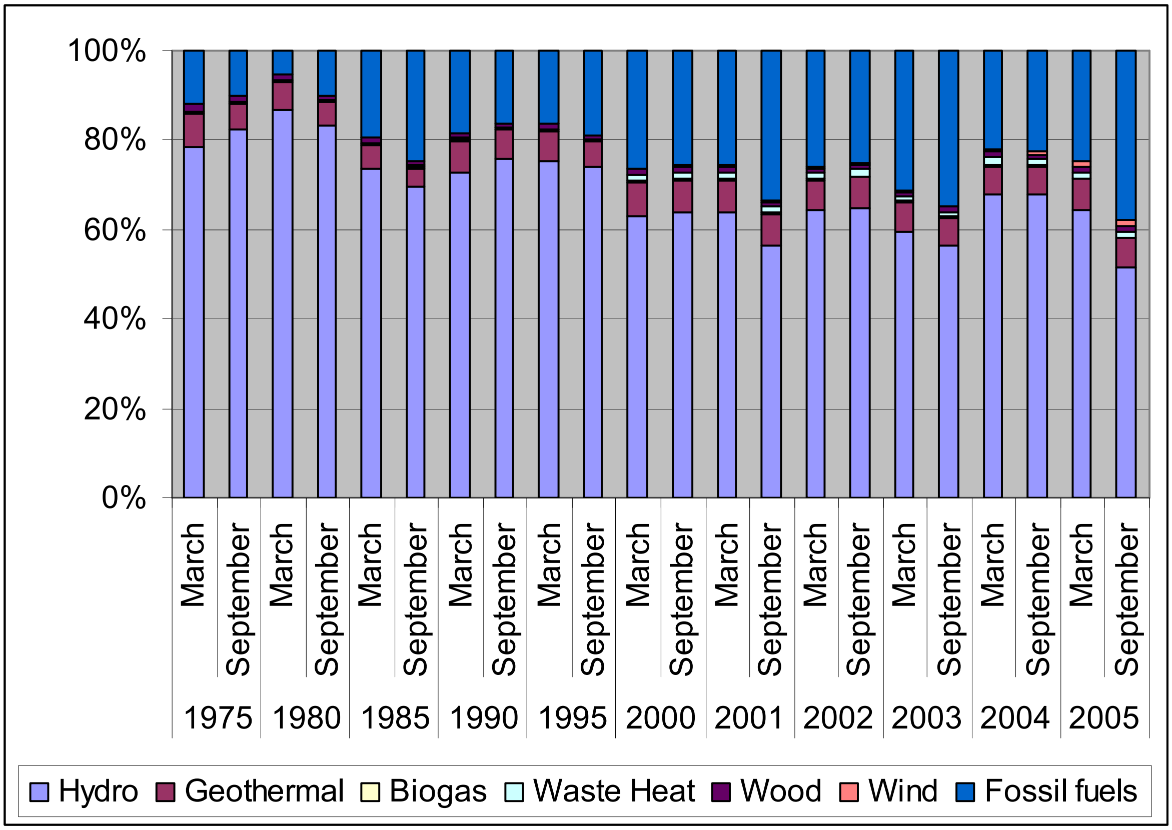

Figure 5: Electricity generation by fuel type New Zealand[10]

Due to rapid growth in population and towns in **Canada**, it became evident very early that small hydro plants were not suitable to supply sufficient energy[11]. At the same time, the technological advancement of harnessing hydro power led to a focus on large hydro power projects. In the last decade of the 19th century, Canada started one such project at Niagara Falls. In 1921, what was then the world's largest water generation plant started production. After WWII, most of the small generation plants were decommissioned or replaced by bigger facilities.

In the 1960s, the harnessing of nuclear and fossil fuels began and the first generation plants were built.

In 1974, the Churchill Falls facility in Newfoundland became the largest hydro power plant of the world with an installed capacity of 5,428 MW. The first installation of tidal energy took place in 1984, and from 1983 to 1993, the first wind farms were built, with a total capacity of 440 MW.

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[10] http://www.waterpowermagazine.com/storyprint.asp?sc=2039414
[11] http://www.canren.gc.ca/tech_appl/index.asp?CaID=4&PgID=31

Brazil started producing electricity with several companies supplying the regions[12]. In 1920, there were about 300 corporations with an installed capacity of 355 MW (276 MW hydro) that served 431 regions. By 1939, the number of companies almost tripled, to 1,176 with 738 hydro power plants and 637 thermoelectric generators. Around 85% (or 885 MW) of the installed capacity was sourced by hydro.

In 1961, the institution, Eletrobras, was founded under the jurisdiction of the Department of Mines and Energy and became politically responsible for the hydroelectric energy in Brazil. The institution had four subsidiaries which were regional in scope. Today, the company is financially owned by the Brazilian government and controls energy supply in all Brazilian regions through its subsidiaries. Even though nuclear power was introduced in 1968 with a 627 MW generator at Rio de Janeiro, hydropower has grown in subsequent years. The Itaipu hydro power station started production in 1984. Its capacity of about 12 GW is able to serve 20% of Brazil's electricity needs and about 95% of Paraguay's demand[13]. In 1995, the total electricity output was more than 55 GW, of which 50.7 GW (or 91.3%) stem from hydro sources. These numbers increased rapidly in the ten years that followed, and in 2005 the power plants in Brazil produced almost 92 GW of hydro based electricity from more than 2,000 generation plants[14].

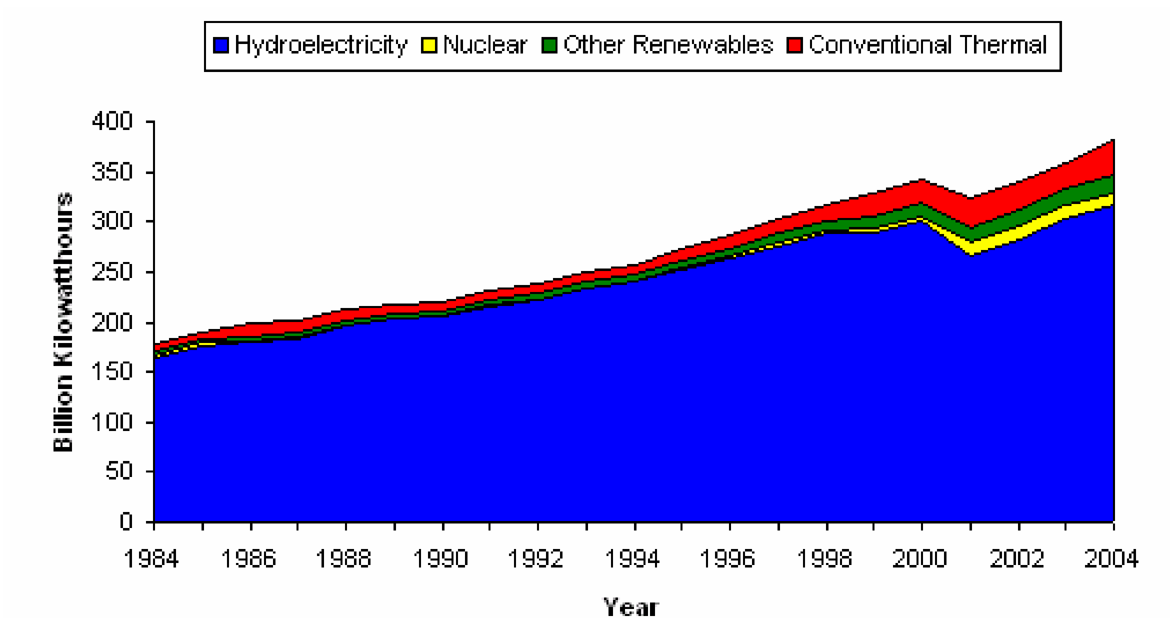

Figure 6: Electricity production by source 1984 - 2004 Brazil[15]

Although the total share of renewable sources for electricity in Brazil has decreased in the last two decades (Figure 6), it is still around 85%.

[12] http://www.escelsa.com.br/aescelsa/historia-ee-brasil.asp
[13] http://www.itaipu.gov.py/
[14] https://www2.focusbrazil.org.br/siteusa/reports/Industry%20Reports/Brazil%20Market%20For%20Small%20Hydro%20Power%20Plants.pdf
[15] http://www.eia.doe.gov/emeu/cabs/Brazil/Electricity.html

Economy and Politics

Due to the fundamental importance of electric energy for a country, economic and ecological issues of power supply must be reconciled by the government through reasonable and tenable energy policies. The approaches of the governments represented here differ greatly, from total deregulation (Iceland) to a regulated market in New Zealand. Even so, all of the countries have developed strategies to implement sustainable and environmentally friendly energy provisions. These strategies contain three basic principles:

- **Energy efficiency:** Improving the technical efficiency of all energy using devices
- **Energy conservation:** Avoiding energy waste and reducing energy use
- **Renewable energy systems:** Reducing dependency from fossil fuels; reducing CO_2 emissions

Accordingly, Brazil, Canada, New Zealand and Norway have ratified the Kyoto Agreement[16], while Iceland has accepted, but not ratified, the protocol[17]. Since policies on sustainable energy vary amongst the countries, we will explain only a few examples; more information is made available using web links.

Iceland's government brought its "Master Plan for Utilization of Hydro and Geothermal Energy Resources" to life in 1999[18] with the objective of evaluating and comparing different options for proposed power development schemes. The impact on ecology, cultural heritage, and economy are also discussed in the plan. This instrument is intended to assess power generation plans in advance to avoid damaging impacts without sacrificing cost efficiency. As stated in the plan, the number of feasible hydropower projects is about 60, accompanied by about 40 geothermal projects. The power market in Iceland has been fully deregulated since January 1, 2007, to create a competitive environment for production and sales of electricity and for efficient and cost-effective transmission and distribution.

Norway deregulated its energy market with the "Energy Act 1990"[19]. The purpose was to secure economic efficiency, security of supply and a national equalization of electricity prices. However, around 87% of the electricity is still produced by public companies, with 13% by private businesses. This act was a model for other Northern European countries, and today Norway is one of the most open electricity markets in the world.

Due to decreasing precipitation and increasing electricity demands, the hydropower based electricity system in Norway has become vulnerable in the recent years. Actually, the present production is less than demand, so electricity has to be imported. Thus, the government is planning to develop a more robust electric system[20]. Short term national goals are the enhancement of heating water in order to relieve demand on the electric grid, and the establishment of wind farms with an energy output of 4 TWh by 2010. The government-owned

[16] International agreement to reduce Greenhouse Gas emissions in the future, signed 1997; more information available at http://unfccc.int/kyoto_protocol/items/2830.php

[17] http://unfccc.int/files/kyoto_protocol/background/status_of_ratification/application/pdf/kp_ratifcation.pdf

[18] http://www.landvernd.is/natturuafl/enska/master_plan.html

[19] http://www.ub.uio.no/ujur/ulovdata/lov-19900629-050-eng.pdf

[20] http://www.iea.no/oslo/iea-norge.nsf/Attachments/5F66E8488C28D399C12570920047B090/$FILE/Renewable+and+efficiency_Norway+2005.pdf

enterprise, EnovaSF[21], is responsible for achieving these targets. Enova is financed by a levy on the power distribution tariff and has introduced several programs involving renewable energy projects for wind power, heating, and other innovative technologies.

New Zealand's electricity market experienced remarkable success in the 1980s and 1990s after it was deregulated and the state-owned power generation was privatized, accompanied by the creation of a wholesale electricity market. However, because there were only a few market participants, regulation of the power market was reinstituted in 2003. The threat of market power abuse was the impetus for creating the Electric Commission in order to maintain government control over the power industry and to manage electricity reliability.

In **Canada**, responsibilities in the electricity market are split into a territorial and international segment[22]. The provinces and territories have jurisdiction over generation, transmission, distribution and pricing of electricity within their boundaries. The federal government is responsible for energy exports to the U.S. Consequently, the price for power varies from province to province, depending on demand, supply, and the general market setup. Canada is a net exporter of electricity to the USA, selling 42,930 GWh in 2005. Sustainable development in terms of green electricity is being conducted by the Renewable and Electrical Energy Division (REED)[23] which promotes projects like Purchase of Electricity from Renewable Resources (PERR)[24] and the Wind Power Production Initiative (WPPI)[25].

In **Brazil**, electricity demand and supply is coordinated through a "Power Pool"[26]. The government purchases all electricity on behalf of all pool members. All distributors have to contract their entire estimated demand for the next 3 to 5 years. The institution, EPE[27], then allocates energy from the pool to the distributors. The price is calculated as the average of all long-term projected prices and is the same for all distribution companies. In parallel, there is a "Free Market" to reduce market volatility and to buffer lower or higher demands than projected.

The Brazilian government implemented the Program of Incentives for Alternative Electricity Sources (PROINFA[28]) in order to promote electricity generation from renewable sources. It will be conducted in two stages. Stage I was designated to be completed by the end of 2007, with an installed capacity of 3,300 MW from renewable sources[29]. Stage II: Once that 3,300

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[21] www.enova.no
[22] http://www.neb.gc.ca/energy/EnergyPricing/HowMarketsWork/EL_e.htm
[23] http://www2.nrcan.gc.ca/es/erb/erb/english/View.asp?x=68
[24] The Canadian government is committed to purchase 20% of its electricity needs from renewable resources
[25] http://www.canren.gc.ca/programs/index.asp?CaId=107&PgId=622
[26] http://www.oecd.org/dataoecd/12/11/34427493.pdf
[27] Empresa de Planejamento Energetico
[28] http://www.iea.org/Textbase/pamsdb/detail.aspx?mode=gr&id=1474
[29] I.e. wind, biomass and small hydroelectric

MW objective has been met, PROINFA will target increasing the share of electricity produced by three renewable sources (wind, biomass and small hydro) to 10% of annual consumption within 20 years. PROINFA is expected to create 150,000 new jobs and to enlarge private investments of about USD$2.6 Billion.

Future outlook

As environmental protection, climate change and greenhouse gases are crucial issues globally. Progress in the field of harnessing renewable energies is crucial for all countries. Thus, we will look at future plans for clean energy in our 5 countries.

In **Iceland**, the future of electricity generation is dependent mainly on the development of power intensive industries, aluminum smelting in particular. A yearly increase in electricity consumption is assumed. With the Master Plan (see p.12), the government has an instrument for economically and ecologically reasonable scheduling of their development. Most likely is the further progress of harnessing electricity from both hydro and geothermal sources[30].

Norway plans to introduce a mandatory market for green certificates for renewable energy in 2007. This is an incentive – even for private individuals – to invest money in renewable energy and is able to boost green electricity economically. Renewable Energy Certificates (REC) will be issued for production of wind, solar, small hydro, and geothermal power, as well as biomass and wave energy.

The future growth projections for renewable energy technologies in Norway have been examined in several studies[31]: electricity from hydro power is expected to increase only marginally, while wind and solar power are anticipated to grow significantly.

Ecologically, the Norwegian government is moving away from developing large hydro schemes and moving towards new generating capacity in the form of small hydro, wind power and gas fired power plants[32].

To meet the challenges of the Kyoto protocol, Norway has developed the following strategies:

- Harnessing wind power of at least 3 TWh/year by 2010
- Focusing on R&D to enhance gas thermal generation plants with no emissions of carbon dioxide (CO_2) or nitrous oxides (NO_2)
- Supporting a district heating system, to reduce dependence on oil and electricity for heating
- Continuing support for energy conservation technologies and schemes

30 http://www.os.is/Apps/WebObjects/Orkustofnun.woa/1/swdocument/9701/Energy_in_Iceland_2ed_2006.pdf?wosid=false

31 http://www.forskningsradet.no/servlet/Satellite?blobcol=urldata&blobheader=application%2Fpdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1175177851307&ssbinary=true, page 15

32 http://www.forskningsradet.no/servlet/Satellite?blobcol=urldata&blobheader=application%2Fpdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1175177851307&ssbinary=true

To secure a sustainable energy future, the **New Zealand** government implemented the "National Energy Efficiency and Conservation Strategy"[33] in 2001, to improve energy efficiency and to transition to renewable energy sources with these six goals:

1) Reduce CO_2 emissions through energy efficiency and renewable energy measures[34]
2) Reduce local environmental impact through energy efficiency and conservation and management of expanded renewable energy supplies
3) Improve economic productivity with cost effective energy efficiency
4) Promote industry development with new renewable energy projects
5) Improve economic resilience with sustainable systems of renewable energy
6) Improve health and welfare by provisioning adequate energy services in the communities

Like Norway, New Zealand is planning to move away from large hydro projects. Contrary to Norway, New Zealand is also moving away from gas; the main reason, and challenge, is the depletion of the Mauri gas field which still represents the second largest source of primary energy in the country. In order to satisfy the increasing electricity demand (estimated 2% growth per year), New Zealand will explore small scale hydro, solar, wind and geothermal energy in the near future.

Canada expects an annual growth in electricity demand of 1.5 to 2 percent. In order to meet this increase, new technologies must be developed and significant investments be made. Technologies vary depending on the provinces and territories and the potential is mainly dependent on the geophysical provincial characteristics. While in some provinces, wind power, small hydro and biomass are broadly available, others, such as geothermal, ocean energy and clean coal, are more limited.

The government's measures for securing electricity supply in the future are referred to as "Emerging Technologies[35]". These include wind power, small hydro, biomass, geothermal, photovoltaic, fuel cells, ocean energy and clean coal. Recent developments in the energy markets has created the conditions for rapid growth in these emerging technologies:

- The increase in fossil fuel prices in recent years
- Most of the low-cost hydro sites have been developed. There is also considerable public concern about further development of nuclear power
- A move towards more competitive generation markets in many provinces
- Increasing public concern with air quality issues and the long-term impact of greenhouse gas emissions
- The costs of many renewable technologies have been decreasing because of technology improvements

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[33] http://www.eeca.govt.nz/about/national-strategy/index.html
[34] According to Kyoto protocol at least 20% improvement in economy-wide energy efficiency by 2012
[35] http://www.neb-one.gc.ca/energy/EnergyReports/EMAEmergingTechnologiesElectricity2006_e.pdf

Furthermore, many of the emerging technologies have become economically competitive in recent years[36].

Due to its growing economic development, **Brazil**'s demand for electricity has steadily increased and is projected to increase in the future, especially as the aluminum industry enhances its stake in Brazil. Thus, the government is planning to dam the rivers Madeira and Xingu in the Amazon region to satisfy the energy needs of the mining industry. The biggest planned project is the Belo Monte Dam with an expected capacity of 11 GW and an investment of US$ 3 billion.

Large hydro power projects are not without dispute. The following section "Hydro power: Curse or Blessing?" will illuminate the threats that are inherent in large hydro generation facilities.

Building large dams, in this case, would be of no help to the impoverished people as it is unlikely that inhabitants will benefit from the newly installed generation capacity. The resulting conflicts between the rural population and the big landowners of industry have cost the lives of six people in the last years. Ademir Alfeo Federicci, one of the most prominent opponents of dam projects in the region, was killed in 2001.

Hydro power: Curse or Blessing?

As all of the considered countries derive the majority of their electricity from hydro power, a closer look at the ecological advantages and dangers is appropriate.

Technically, hydro power can be harnessed when falling water creates height differences; the bigger the difference (called head), the greater potential energy of the water. These level differences are either natural or artificial (e.g. by building dams), the latter having a certain impact on the ecosystems. In order to secure a continuing electricity supply, hydro generation plants require reservoirs that provide a constant water supply. The biggest impact on nature stems from installing these dams which flood huge areas. When flooding areas over vegetation, methane, a greenhouse gas that is 20x more damaging than CO_2[37], is produced by plants rotting without oxygen under water. Hence, hydro power plants in regions with large flora can massively influence nature and the climate. Accumulating water in barren areas is less dangerous to populations, flora and fauna, and produce much less greenhouse gas emissions.

In their article "Rueckkehr der Giganten" ("Return of the Giants")[38], the authors describe the political and ecological legitimacy of newly planned large hydro power plants with artificial lakes in the global Southern countries, like Brazil. At first glance, the facilities will ultimately reduce poverty and global climate change. Yet, the interests involved in installing dams and generators are economic, which in itself is not negative. However, they are being built to produce currency, especially for the aluminum industry that needs vast amounts of cheap

[36] http://www.neb-one.gc.ca/energy/EnergyReports/EMAEmergingTechnologiesElectricity2006_e.pdf, page xiii
[37] http://www.epa.gov/methane/
[38] http://www.irn.org/pdf/ard/Giganten2007.pdf (in German language)

electricity, and the governments of tropical countries often subsidize large hydro projects in order to attract investors. Thus the electricity does not go to illuminate the lives of impoverished people and provide the vehicle to lift them out of poverty.

According to the authors, in order to improve poor people's access to a power grid, large dams are not necessarily the appropriate solution. Most of the people without electricity live in rural areas that are not connected to the grid. Hence, these people cannot benefit from big hydro power projects. In these cases, an enhancement of the local power grid would be much more effective and reasonable.

Furthermore, it is often necessary to resettle people when creating large reservoirs, and most of the time, there is no compensation paid to those displaced. Also, tropical dams are not climate neutral as they are purported to be. They emit greenhouse gas, mainly methane (due to the rotting vegetation that has been flooded) and thus contribute to global warming. In the 1990s, the dams in the Amazon region emitted greenhouse gases that were 50 times what natural gas plants did with the same capacity.

Lessons learned

What conclusions for other countries can be drawn from this paper? Is there a "recipe" to enhance a nation's share of renewable energy without negative impact on the people, economy and the environment?

Basically, the five countries presented here harnessed electricity from their hydro (and some geothermal) resources for no particular reasons other than that it was readily available in abundance, and the technology existed to use it. The point here is not that hydro power is the only or best natural resource, and it is not available in all countries in any case. Historically, people simply utilized the natural resources available for their development, and in those early times, environmental protection was not the issue it is today.

The lesson is for each country to determine what natural resources they have that are abundant and sustainable -- and to be responsible for the environmental impacts. Unfortunately, Brazil seems to be tempted to boost its industry for economic reasons that might have a positive impact on the country's balance sheet for a short duration. It is seem that over-development of large hydro can negatively the impact the environment. Whereas people who need to be connected to the grid in rural areas are often bypassed, bringing no real improvement in overall human development.

Tapping renewable resources to generate more electricity is not the only possibility of improving the climate situation. There are two fundamental steps to consider first. Energy efficiency and energy conservation also have a significant influence on the balance between exploiting resources and meeting demand for more energy. Why produce more electricity when you can lower the demand with energy saving and efficiency measures? With technologies and a mindset that help control electricity demand, it is often possible to limit the required capacities that need to be added.

Regulating the electricity market is being handled in multiple ways by the examined countries. Most important in this regard is the extent of a country's need to supply all people with electric power. Developed countries seem to be able to deregulate their markets in order to promote competition. Developing countries might fair best by starting with a regulated market to ensure that the basic needs of the people are satisfied.

Energy is a global issue, influencing all countries, independent of their economic or development status. Hence, if a nation cannot tap domestic natural resources for any reason, international cooperation in research and development is crucial to map a strategy that enables all countries to benefit from electric power and still act with environmental responsibility.