EVIDENCE FROM INTERNATIONAL LOW-CARBON ELECTRICITY SYSTEMS

This paper presents analysis on those countries that generate more than 70% of their electricity from low-carbon sources, with a focus on how investment in low-carbon electricity capacity in these countries was delivered.

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1. INTRODUCTION

This paper presents analysis on those countries that generate more than 70% of their electricity from low-carbon sources. The paper focuses on how investment in low-carbon electricity capacity in these countries was delivered, and sets out how prices are set in each market.

This study looks at electricity systems in France, Slovakia, Switzerland, the Scandinavian countries (Norway, Finland, Denmark, Sweden which share one electricity market), Canada, Brazil, Peru and Venezuela. We note that Iceland, Costa Rica and Columbia also generate more than 70% of their electricity from low-carbon sources, however, due to a lack of available information, we have not carried out an analysis of these countries.

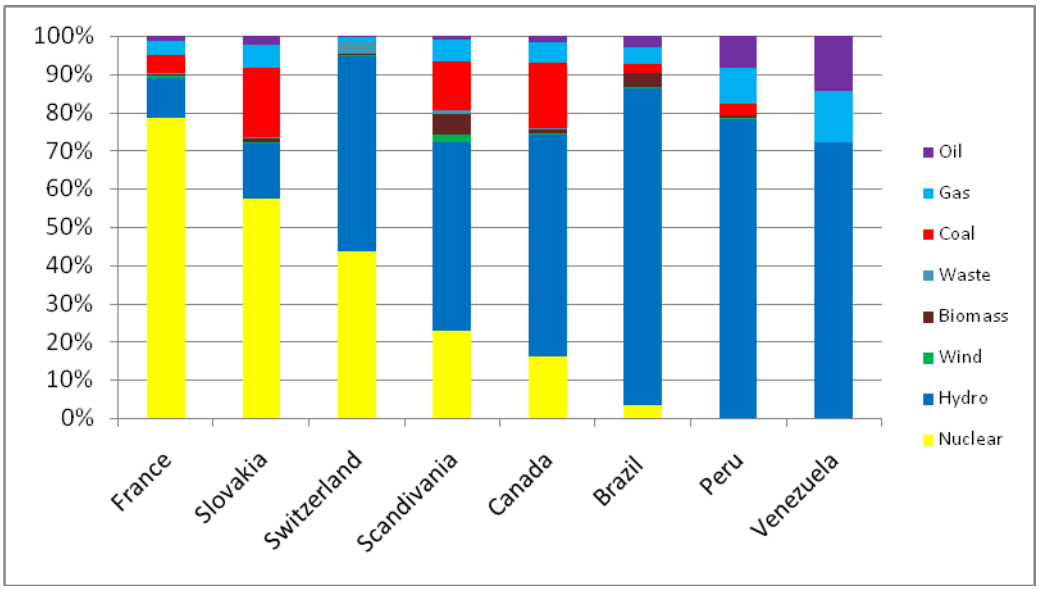
The structure of this paper is as follows:

- Section 2 shows the generation mix of different countries.
- Section 3 explains the drivers for investment in low-carbon generation including the current incentives offered to renewables.
- Section 4 briefly discusses how electricity prices are set in these countries.
- Section 5 discusses the challenges faced by these low-carbon systems.
- Section 6 provides some concluding remarks.

2. GENERATION MIX

The generation mixes in the low- carbon electricity systems covered by this appendix vary quite significantly (Figure 1).

Figure 1: Generation in systems with low-carbon mix



Source: International Energy Agency www.iea.org

Note: Data is for 2006.

- France (78%) and Slovakia (57%) generate most of their electricity from nuclear. In addition, Slovakia has a significant amount of conventional fossil fuelled generation on the system, dominated by coal that contributes just below 20% of its generation.
- Switzerland generates 98% of its electricity using low-carbon sources. Most of its electricity is generated from nuclear (43%) and hydro (51%), which together make up around 95% of the electricity mix.
- The Scandinavian countries that make up Nordpool, taken together, have a much more diverse portfolio. While 72% of their electricity comes from a combination of nuclear and hydro, other renewables such as waste, biomass and wind contribute around 8% of the mix, and fossil fired plants the remaining 20%. The generation mix also differs significantly across the Scandinavian countries. Norway generates 98% of its electricity from hydro, and Sweden has a fairly even split between hydro and nuclear that together contribute around 90% of its generation. Denmark has no nuclear or hydro, but rather has an electricity mix dominated by fossil fuel plants along with 14% wind and 8% of waste and biomass. Finland has 28% nuclear, and 14% hydro and with 13% biomass has the highest proportion of biomass as part of its generation capacity amongst the countries that are part of Nordpool.
- Canada generates 58% of its electricity from hydro and 16% from nuclear. However, there are significant differences in the generation mix across the Canadian provinces.

While Alberta and Ontario generate a significant amount of their electricity from fossil fuel plants (coal, oil and gas); Quebec, British Columbia and Manitoba generate more than 90% of their electricity from hydro.

- The South American countries of Brazil (83%), Peru (79%) and Venezuela (72%) have an electricity mix dominated by hydro.

3. DRIVERS FOR INVESTMENT IN LOW-CARBON GENERATION

While the eight electricity systems analysed have different electricity mixes, a common feature is that the investment in low-carbon plant has occurred after extensive government intervention, either directly or through state-owned utilities. There has been a general move towards liberalisation of markets, however, in all the systems examined, the majority of the investment in low-carbon plant took place before significant liberalisation. In addition, even in the most liberalised systems, e.g. Nordpool, state-owned utilities continue to play a key role in investing in new generation capacity.

This section describes how investment in low-carbon generation assets came about in each of the markets considered, and sets out current ownership structures and support for renewables:

- **Investment in French nuclear power has been driven by the government through the state-owned EDF, with the aim of ensuring security of supply.** Until the 1970s, France was heavily reliant on imported oil. The oil price shock in the 1970s focused government attention on security of supply. The drive to ensure stable supplies of energy combined with the government's social objectives of low electricity prices, resulted in a renewed interest in nuclear power. Nuclear energy was seen as low-cost and would reduce reliance on imported oil.

  EDF's vertically integrated structure and market dominance meant that it was well placed to respond to the government's nuclear policy. State-owned EDF generated between 85-95% of the country's electricity, and had a monopoly in electricity transmission and foreign exports. EDF responded to the government's nuclear policy by building 37 reactors between 1973-1980, and a further 21 reactors in the period after 1980. All elements of the nuclear industry – manufacturing and technology, fuel cycle, nuclear plant orders and plant operation were synchronised to exploit economies of scale. The entire supply chain for the nuclear fuel cycle and reactor construction was developed in France to help support deployment. France now has a total of 59 nuclear reactors, with a total capacity of over 63 GW.

  Until 2005, EDF was completely owned by the French State[1]. Since 2005, the government continues to nominate EDF's CEO, and has a say in determining the company's broad development plans, investment, finance and fuel choice. In addition, the government continues to have a strong representation on EDF's board. This relationship between government and the industry helped ensure policies were pushed through.

  Currently, France uses feed-in tariffs (FITs) to stimulate investment in renewables. France recently introduced a tendering system for large projects, including wind, biomass, and biogas.

- **While the Scandinavian countries which make up Nordpool have recently focused on delivering their energy goals through the market, in the past it was**

[1] The Government sold a 15% stake in 2005

state-owned utilities that undertook investment in low-carbon generation. Norway, Denmark, Finland and Sweden have an integrated, common market called Nordpool. Most of the investment in low-carbon generation was undertaken before liberalisation, when the government directed investment through state-owned utilities. There has been a move towards liberalisation, with action taken to remove entry barriers and enable price signals to drive investment. However, a significant amount of current generation capacity continues to be owned either directly by state-owned utilities or through public-private partnerships.

  - The state-owned Vattenfall generates nearly 50% of Sweden's electricity. Ownership of the nuclear power facilities is dominated by Vattenfall, and Sydkraft (in which E.On has a majority stake, with the Norwegian government owning 43.3%).
  - In Norway, the government still owns 87% of generation capacity. The state-owned Statkraft is the largest generator, with a market share exceeding 40%.
  - The Finnish government has a majority stake in Fortum, the largest utility in the Finnish market. In addition, Fortum owns a 27% stake in TVO, the company that is currently building the Olkiluoto nuclear plant.
  - The Danish electricity sector continues to be dominated by the government through municipal non-profit organisations.

Current incentives for the deployment of renewable technologies differ across the Scandinavian countries:

  - Sweden has adopted a system of tradable green certificates and electricity suppliers must source a target proportion of their power from renewable sources, and pay a penalty price if they fail to meet their targets.
  - Norway uses investment subsidies and partially funds up to 25% of investment costs.
  - In Finland, a subsidy is available for up to 40% of investment costs in renewable technologies such as wind and solar. In addition, the government uses tax rebates and FITs for certain technologies.
  - In Denmark, a premium above the market price is paid for most renewables, and FITs are used to encourage investments in solid biomass and biogas (under certain conditions).

- **Most of Brazil's low-carbon (hydro) plants came onto the system when the electricity sector was under government ownership.** In the past the government has actively invested in hydro power. Brazil introduced liberalisation policies in the 1990s with the intention of increasing efficiency. However, the government still controls half of generation capacity and continues to play an active role in setting the technology mix, while allowing the private sector to bid for new generation capacity. Box 1 provides a synopsis of the market reforms introduced in Brazil.

In Brazil, there are several support schemes for renewables, including soft loans to firms wishing to invest in renewable technologies.

Box 1: Market reforms and a transition towards a more liberalised electricity market

Brazil introduced market reforms in the 1990s, liberalising its markets and allowing the private sector to compete alongside state-owned utilities. Half of generation capacity is still under the direct control of the State. In spite of market reforms to boost private sector investment in the 1990s, installed capacity increased only 28% between 1990-1999, while electricity demand increased by 45%. The insufficient expansion of supply capacity was exacerbated by depleting water reserves resulting in an electricity crisis in 2001(see Section 5).

Brazil's second wave of reforms in 2004 was a direct response to the energy crisis in 2001, and aimed to ensure security of supply and improve the incentives offered to thermal plants. Central to the second set of reforms was the creation of a 'Pool' designed to match supply and demand through long-term contracts. The government retained control over defining the technology mix through a new institution. A 'free' market also exists in parallel to the Pool that is used to balance short-run supply and demand and allow large consumers (>10 MW) to buy electricity directly from generators. Distributors can buy electricity in the 'free' market if actual demand exceeds projected demand, or sell electricity if actual demand falls short of projections.

The government introduced capacity payments for thermal generators to address concerns of an electricity system dominated by hydro generation and thermal plant running for a very small proportion of the time. It has been argued that these payments were set too low for generators to recoup infrastructure investments and that they have not attracted the level of private sector investment needed in Brazil.

- **The Swiss electricity market is characterised by strong government intervention, both through the direct ownership of utilities and price intervention.** In 2005, 81% of the Swiss electricity sector was under public ownership, with the government owning three of the five largest firms. The 2008 Law on Electricity paved the way for market liberalisation that included the set up of an independent regulator and giving consumers more freedom in choosing their suppliers.

  At present, the Swiss government uses FITs to stimulate investment in renewables. In addition, the government is investing in R&D, and training/retraining workers in renewable technologies at vocational schools and universities.

- **Most of Slovakian low-carbon capacity was brought on the system as a result of heavy government intervention through the state-owned utility, SE.** SE had been under direct government control until 2006 when the government sold a 66% stake to a private utility. SE owns almost all generation assets over 100 MW, and generates around 85% of the country's electricity. In addition, SE owns and operates

all the country's nuclear plants. Most of the country's large hydro plants came on the system during the 1950s and 1960s as a result of extensive government investment, and the last large hydro plant was approved in 1993, when the electricity sector was still under government control.

In addition to tax exemptions for renewable energy, the Slovak government introduced FITs in 2005 to incentivise investment in renewables.

- **The Venezuelan electricity sector is dominated by state-owned utilities.** The State has played an active role in the electricity sector since the 1970s, redirecting profits from the petroleum sector towards investment in electricity generation, and providing subsidies to the power sector. The state-owned EDELCA generates around 75% of the country's electricity and owns 60% of installed capacity. In the past electricity tariffs have been subject to approval by the Council of Ministers.

  Venezuela has begun to introduce market reforms including the removal of entry barriers to enable the private sector to enter the market and stimulate competition. However, the government retains ownership of all large hydro plants and maintains the right to fix tariffs for generation, transmission, distribution and marketing.

- **Most of Peru's low-carbon generation capacity came on to the system as a result of government intervention through state-owned utilities.** Prior to liberalisation, most electricity generation capacity was controlled by the government through state-owned utilities. Peru embarked on a privatisation programme in the early 1990s with the aim of improving efficiency and expanding electricity access to a greater proportion of the population.

  While Peru has made significant progress in liberalising its electricity market, the government retains control over the electricity sector through 'golden shares' in recently privatised utilities giving it the deciding vote in decisions to shut down a company, incorporate new shareholders, register shares on the stock exchange or merge with another company.

  The government provides a guaranteed price and internal rate of return of 12% to investors in renewables.

- **A large portion of Canadian electricity is produced by publicly-owned utilities.** Canadian electricity markets are within the remit of provincial governments. Electricity markets differ significantly across provinces in terms of their electricity mix (partly due to differing endowments of natural resources) and the level of liberalisation, private participation and competition. Generally, there are a few dominant players in the market that maintain control over generation, transmission and distribution. Most energy utilities are owned by provincial governments. The federal government is responsible for nuclear power, and has driven investment through the state-owned Atomic Energy of Canada Limited (AECL). AECL is responsible for all aspects of nuclear energy, including the design, marketing, construction and servicing of nuclear reactors.

  Canada uses a range of schemes to stimulate renewable investment including FITs and green certificates.

4. HOW ARE ELECTRICITY PRICES SET?

This section discusses the different ways in which electricity generators are compensated, and the level of government intervention that determines electricity prices. While countries differ in the ways they compensate electricity generators, there is some form of government intervention in all the systems covered in this paper, with the exception of the Scandinavian countries[2].

- **French electricity prices are subject to government regulation.** Through contracts with EDF, the government states how much they expect prices to fall in real terms over a given time period. In addition these contracts set out goals, tariffs, debt levels, quality improvements, investment, export policies and public service obligations that EDF need to meet.

- **The Scandinavian countries compensate their electricity producers through a common market called Nordpool.** Nordpool consists of a spot market and a financial futures market. Supply and demand for the next day are balanced in the spot market, the futures market helps investors hedge against future volatility and each Nordpool country also operates a balancing market to address transmission bottlenecks and imbalances. The prices in the spot and futures markets are determined by demand and the marginal cost of generation.

- **In Brazil electricity prices are set through an electricity pool based on long-term contracts.** Based on demand projections, and the technology mix, distributors buy electricity in public auctions for contracts typically lasting three to five years. A free market runs in parallel to balance demand and supply in the short-run.

- **In Slovakia the government regulates prices.** Distribution companies are required to submit tariffs to the regulator for confirmation over a four year regulatory period. The regulator has the authority to set tariff conditions and maximum prices for the electricity sector.

- **The Canadian compensation mechanism varies across provinces.** With the exception of Alberta and Ontario, all Canadian provinces have adopted regulated prices, with a designated provincial authority in charge of setting prices. Electricity prices in Alberta and Ontario are set through the market. However, provincial governments have intervened in both markets in the past, through the introduction of price caps to protect consumers from volatile American gas prices feeding through to high electricity prices in Canada.

[2] Information on Switzerland, Venezuela and Peru was not available.

5. CHALLENGES FACED BY LOW-CARBON SYSTEMS

Though the systems covered in this paper have been successful in bringing on low-carbon, high-capital investment, the characteristics of some of the low-carbon technologies have led to these systems facing some challenges . This section sets out challenges faced by France, the Scandinavian countries and Brazil and outlines the varying government responses.

France

Nuclear plants are usually run as baseload, and are unable to provide the flexibility needed to meet peak demand. Technological innovation, coupled with a good interconnection with neighbouring countries has enabled France to address the challenges faced by an electricity system dominated by nuclear.

One of the direct consequences of the French nuclear programme in the 1970s was excess generation capacity. In the 1980s, France began to export cheap electricity to its neighbours. In 2008, France exported 13% of its electricity, and is the largest electricity exporter amongst IEA countries. The plants have also been adapted to 'load follow' and match supply and demand.[3] However, excess capacity has resulted in French nuclear reactors having the lowest load factors (60-65% between 1986-1992) amongst nuclear plants in IEA countries.

Scandinavian countries

The Scandinavian countries faced an energy crisis in 2002-2003, partly due to the high proportion of hydro power in their generation mix, and the dependence of this hydro power on weather patterns. In July 2002, water levels were well above normal in Finland, Norway and Sweden. In order to make room for the expected water inflow in the autumn, generators began tapping into existing reserves and exporting electricity during August, September and October. However, as a result of a sharp fall in precipitation (likely to occur only every 100-200 years), water levels fell far below normal in October/November. The drop in hydro availability was equivalent to around 9% of Nordic electricity consumption.

As a result of the fall in hydro availability, wholesale prices rose considerably. At its peak the average daily price reached $130/MWh compared with an average spot price in 2002 of $31/MWh. The Nordic countries dealt with the crisis by ramping up generation from coal, gas and oil capacity and increasing imports from neighbouring countries, particularly Russia and Germany. Energy demand responses in some countries, for example in Norway, also helped reduce the impact of the crisis.

The governments chose to let the market handle the unexpected fall in generation supply from hydro. While prices rose sharply, the high levels of interconnection with neighbouring countries, the availability of Denmark's thermal capacity, and a common, integrated market ensured that the Scandinavian countries managed the crisis without the lights going out.

[3] A load-following plant is more flexible than a traditional nuclear plant and is able to adjust power output to meet demand.

Brazil

Brazil had an energy crisis in 2001, triggered by a particularly dry period combined with growing energy demand and insufficient thermal backup capacity. Reservoirs were at a third of their capacity, an amount that was insufficient to meet demand until the next rainy season.

In contrast to the Scandinavian countries, the Brazilian government strongly intervened in markets to tackle the crisis. The government responded to the crisis through high price penalties for excess consumption, and discounts for energy savings. This was combined with a large scale TV information campaign aimed at encouraging families to save energy. Following on from the interventions, energy consumption was reduced by 20% and a blackout was avoided. Energy saving during the crisis significantly contributed to reducing waste, as industries and households substituted towards more energy efficient appliances. In spite of the rationing being lifted in 2002, energy demand failed to pick up by 2003 and the drive during the crisis to increase capacity and reduce demand resulted in a system characterised by excess supply capacity.

The Brazilian crisis illustrates the challenges that may be associated with heavy reliance on a single technology, which in turn is dependent on weather cycles. Increased interconnection, and a more diversified capacity mix would be likely to reduce the risk of this kind of energy crisis.

6. CONCLUSIONS

This paper has examined eight low-carbon electricity systems from around the world. There are significant differences in the technologies they have adopted – France and Slovakia generate most of their electricity from nuclear; Brazil, Peru and Venezuela generate most of their electricity from hydro, while the other countries have a combination of nuclear and hydro as part of their generation mix.

A common feature is that the present low-carbon mix in these countries has followed on from extensive government intervention in the past, through state-owned companies or state directed investment. Moreover, state-owned utilities continue to play an important role even in countries that have liberalised their markets, for example in Canada, and the Scandinavian countries.

Even in liberalised electricity systems, governments continue to intervene to incentivise investment in renewables. This ranges from FITs and obligations, to direct subsidies to the capital costs of projects.

Though the systems covered in this paper have been successful in bringing on low-carbon, in some cases, heavy reliance on a single low-carbon technology has led to challenges. Interconnection, demand response, and the availability of diverse back-up technologies has helped deal with these challenges.

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