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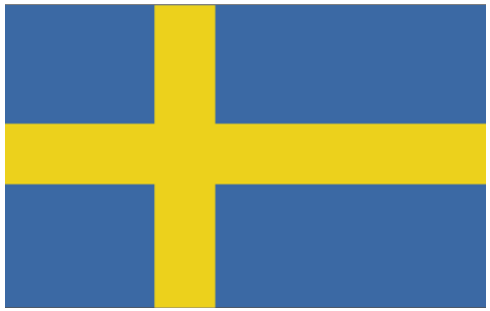
Can Sweden be powered by 100% Renewable Energy by 2020?



Summary:

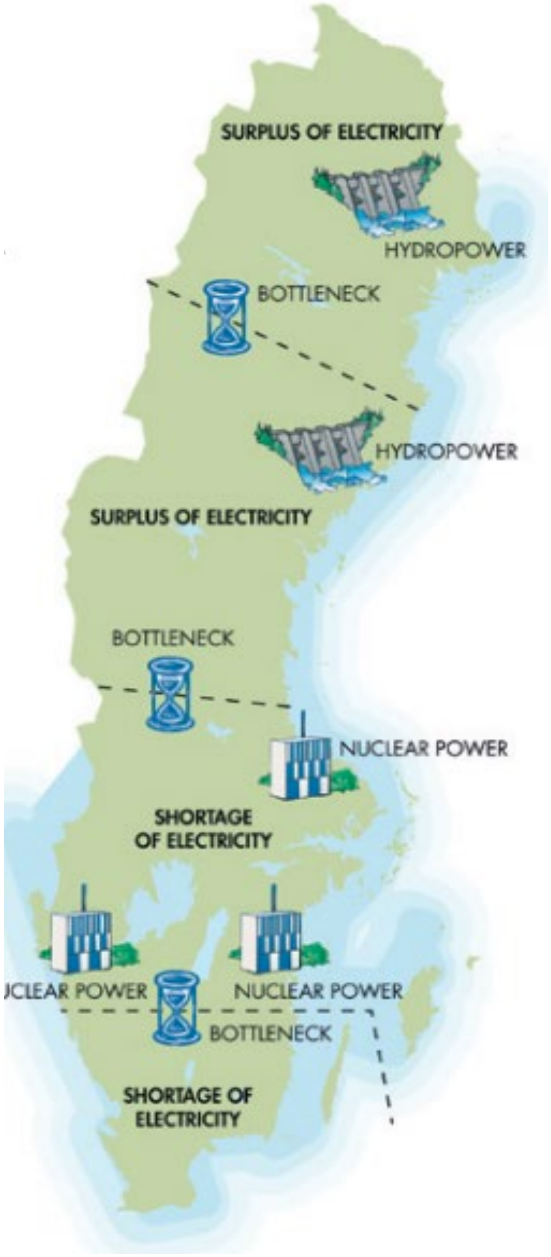
- Background
- Motivation
- History of energy mix and the current mix
- What do I propose for a transition to 100% renewable energy
- The Swedish Electricity Certificate System, pro's and con's
- Solutions
- 2020 estimates and projections
- What needs to be done to achieve the 100% scenario
- Acknowledgements

Background: Sweden

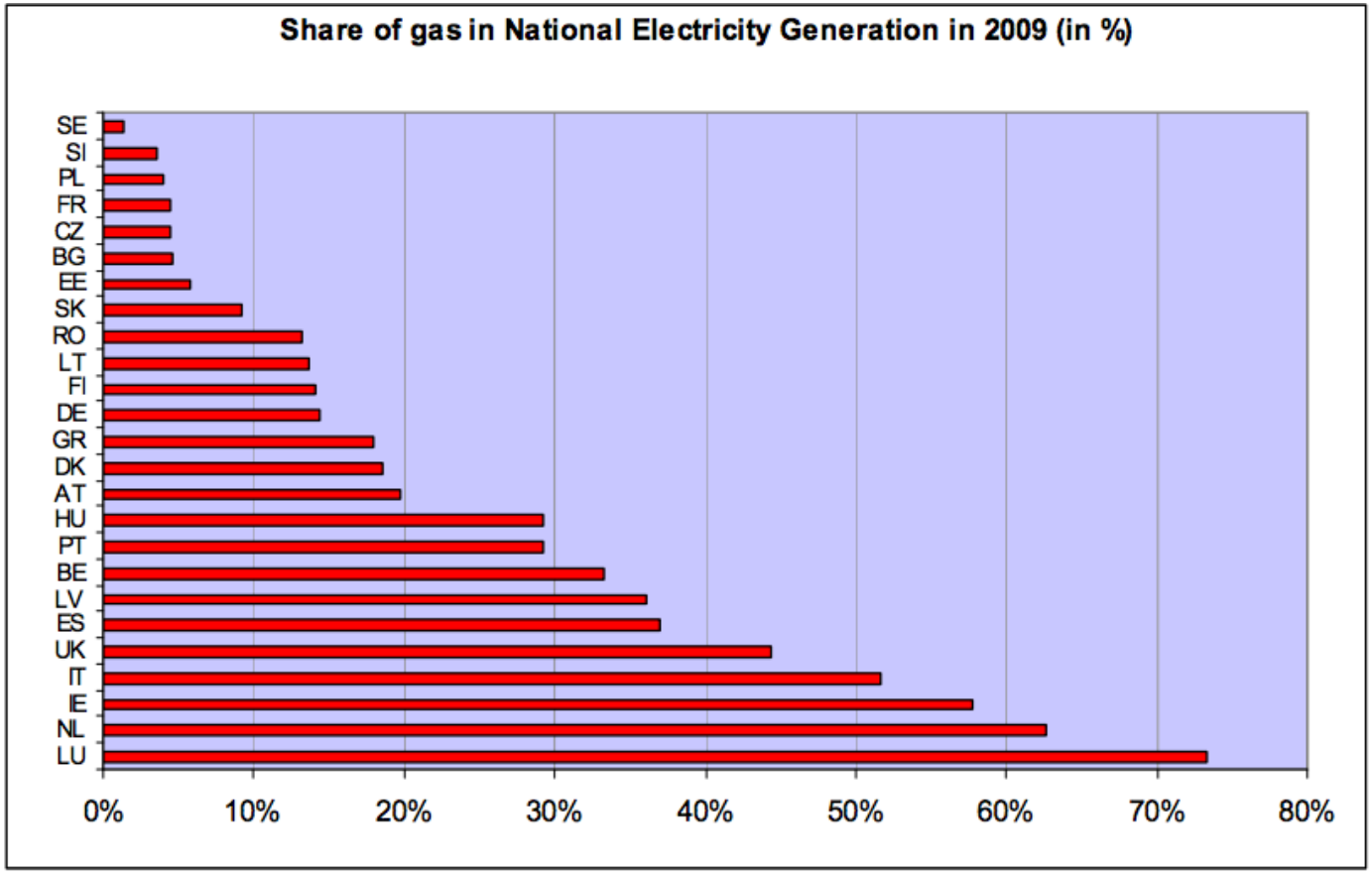
Area: Twice the size of Great Britain, about the same size as California.
Population: About 9 million.
Long coastline, rivers and lakes in the north. 20% of the population lives in the northern half of Sweden.

Motivation:

- What if Sweden decided to commit to transitioning to 100% renewable energy for its electricity sector by 2020, would that be feasible?
- The current energy mix: nuclear power and hydropower supply together the majority of Sweden's electricity. The hydropower facilities are in the North and the nuclear power plants are in the South.



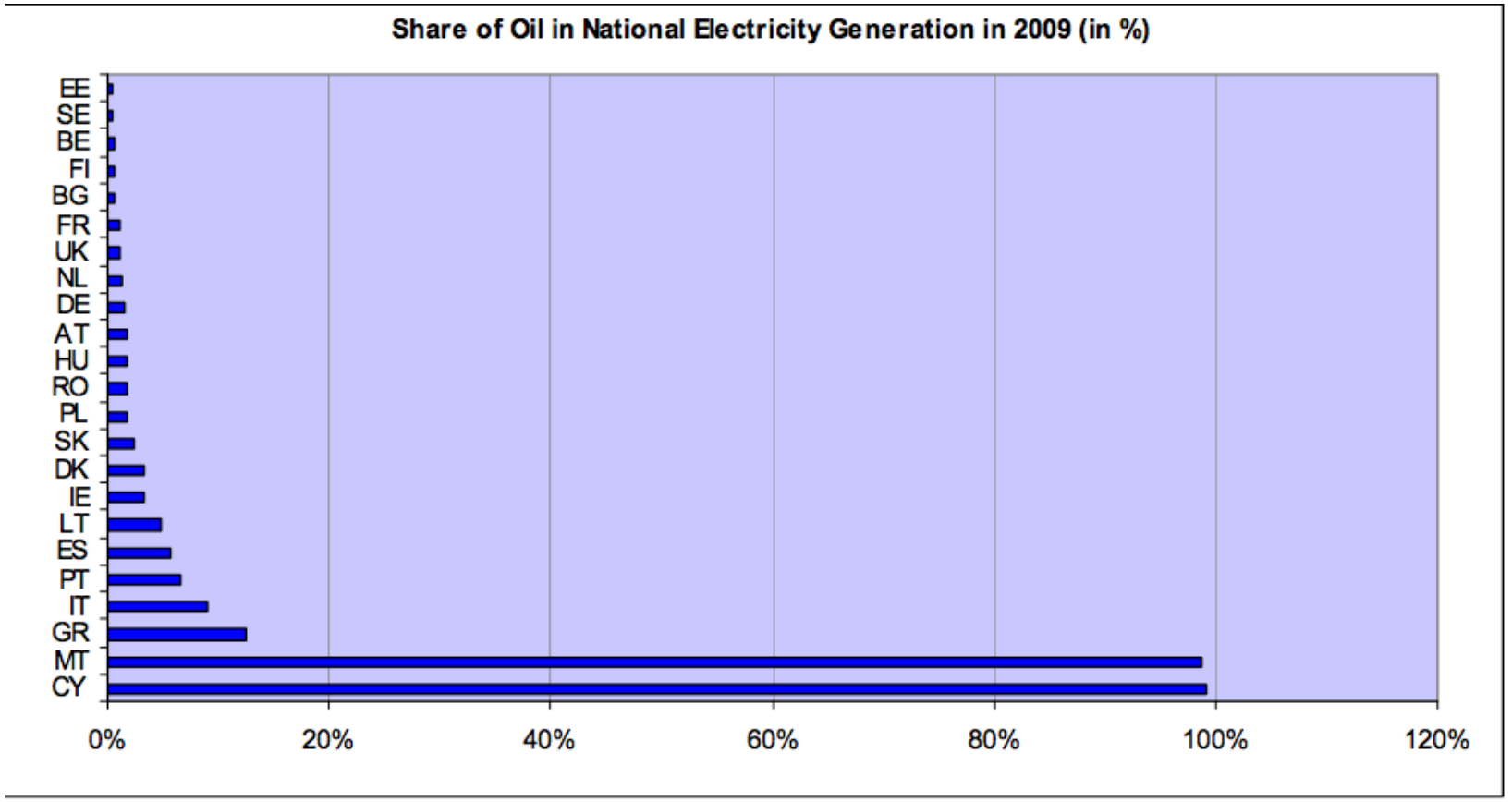
How did Sweden's energy mix evolve to the current state? Share of Gas (1%)



Source: Eurostat May 2011

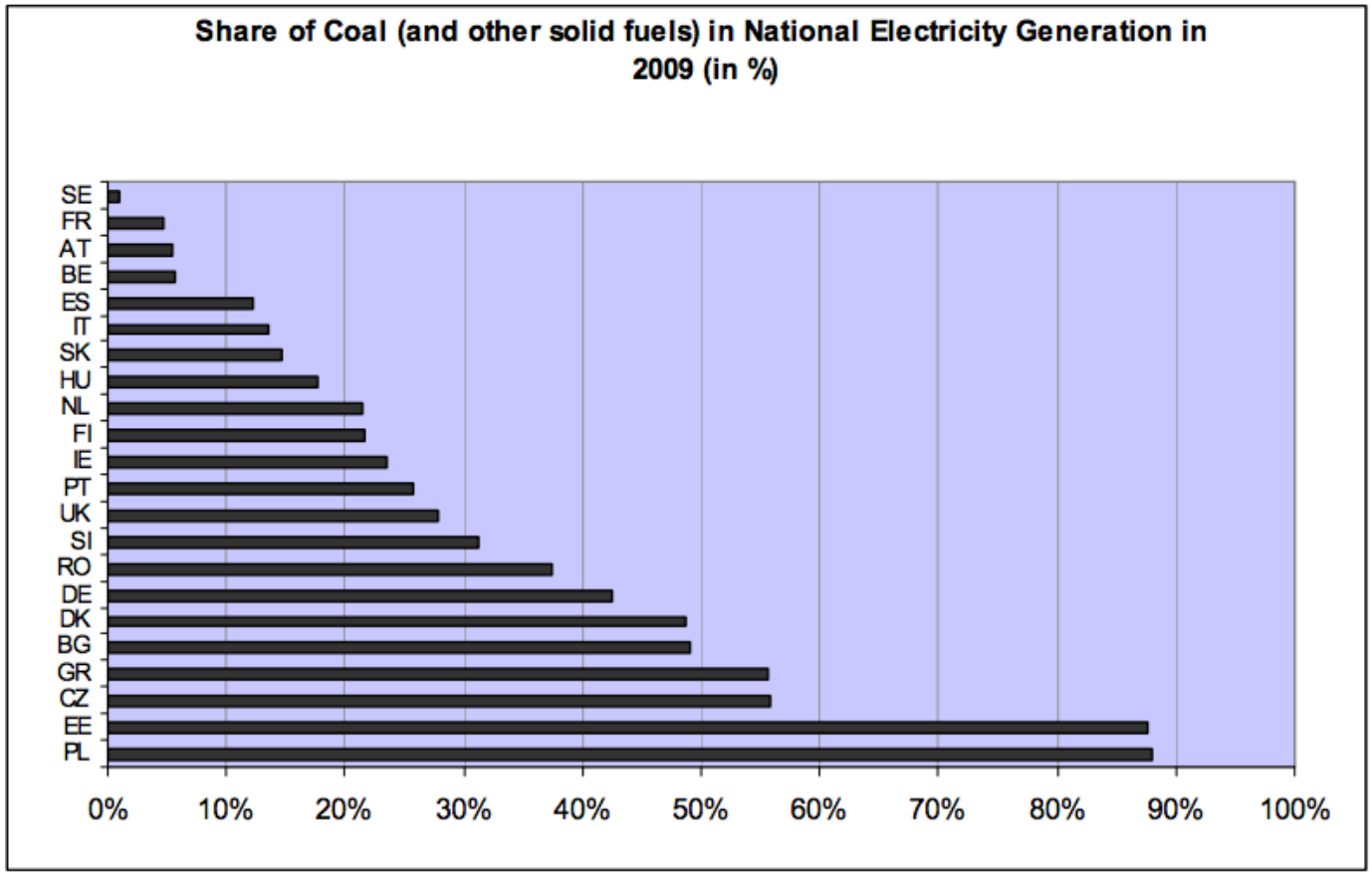
Market Observatory for Energy

Share of Oil (1%)



Source: Eurostat May 2011

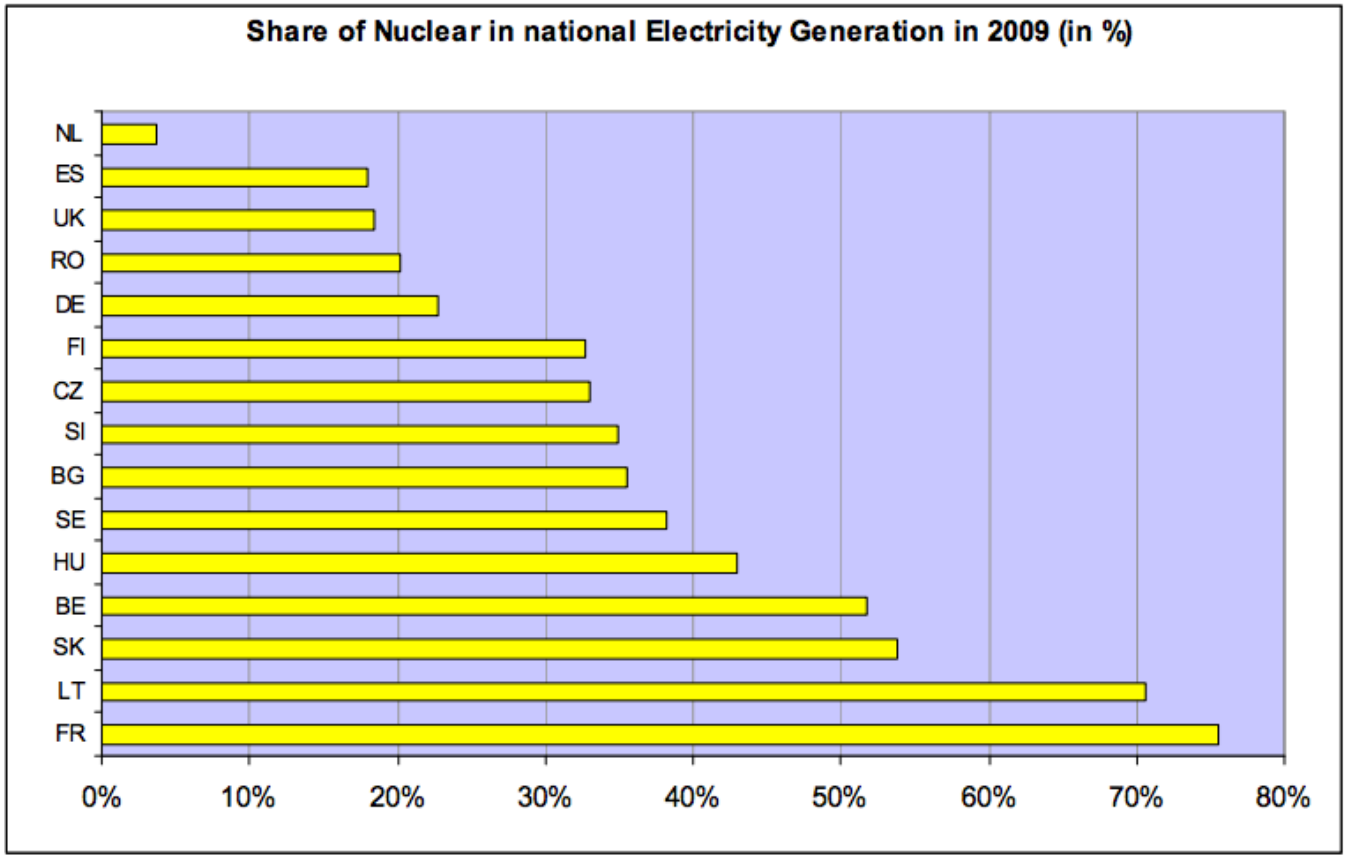
Share of coal (1%)
Sweden has a low-carbon economy



Source: Eurostat May 2011

Market Observatory for Energy

Share of Nuclear Power (38%). Nuclear power is considered cleaner than fossil fuels but it is not renewable!

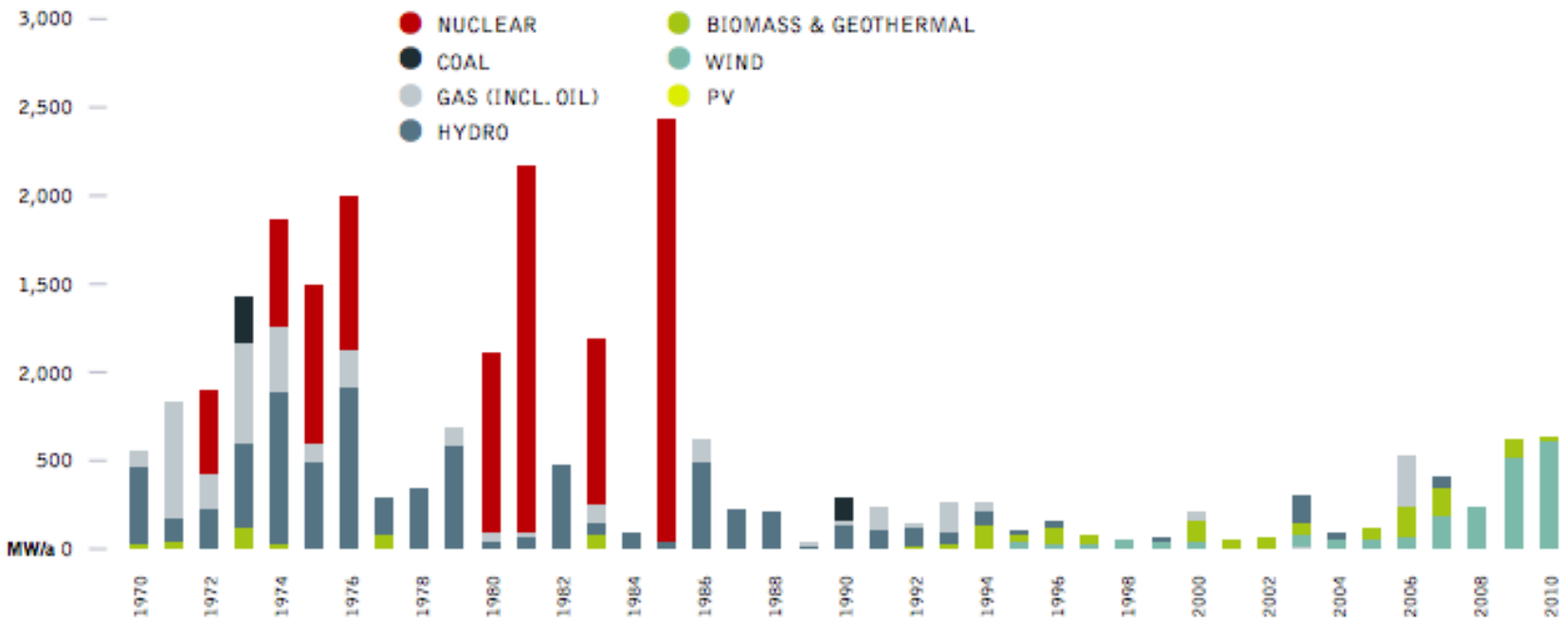


Source: Eurostat May 2011

Market Observatory for Energy

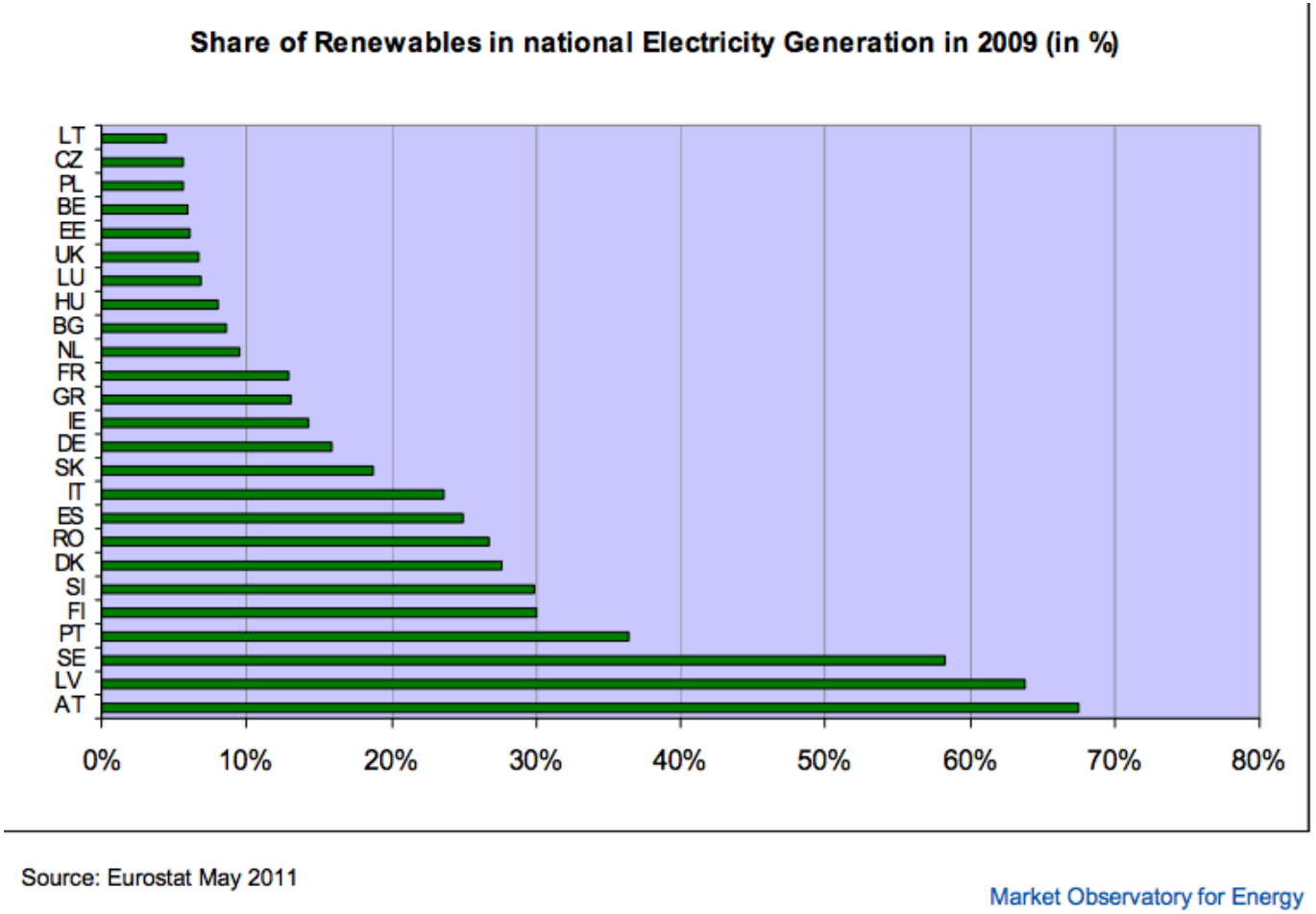
Annual power plant market

figure 7.7: sweden: annual power plant market 1970-2010



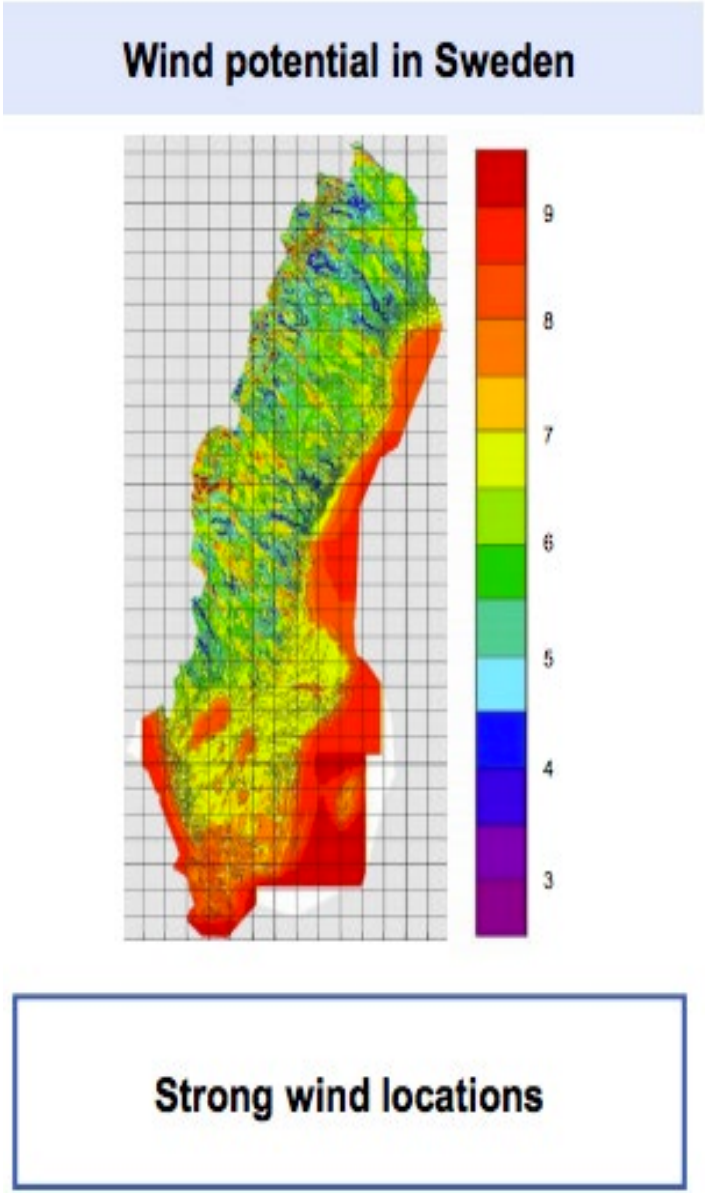
source PLATTS, IEA, BREYER, TESKE.

Renewable Energy (57%). For Sweden, this is mainly hydropower and biomass.



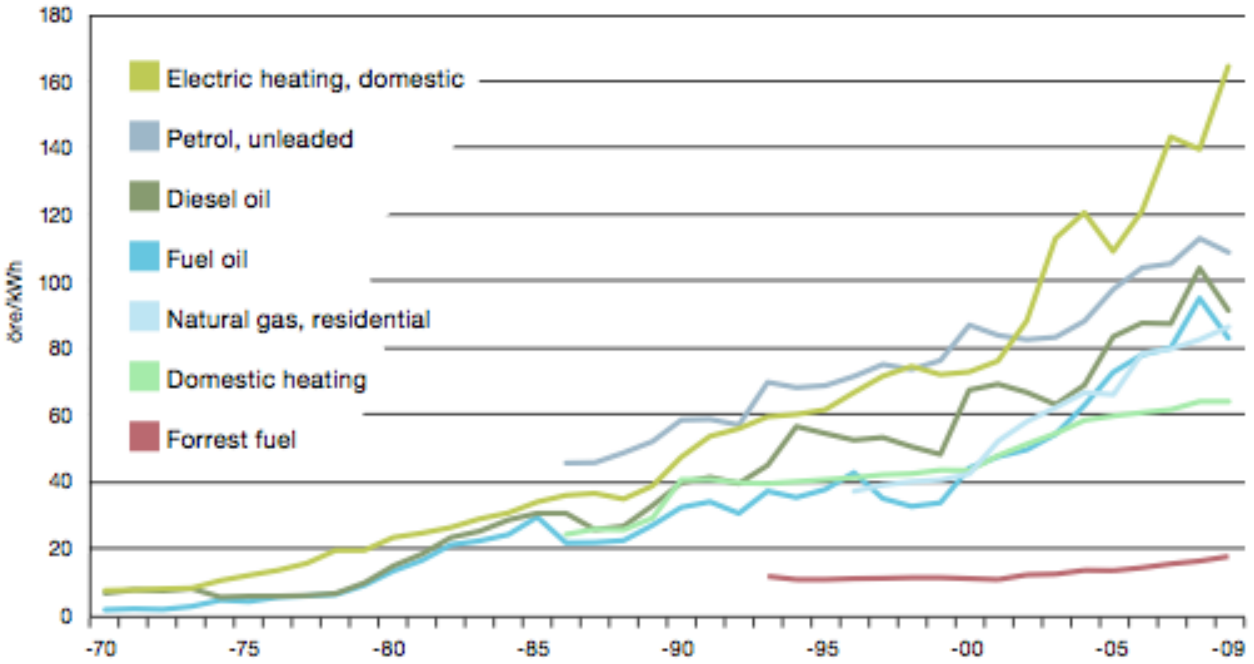
Proposed Path:
Wind power and Biomass

- For a transition to 100% renewable energy, fossil fuels are not he main obstacle.
- Biomass has been increasing quickly as a percentage of the national electricity generation.
- Sweden has great wind power potential.
- Wind power accounts for only a few percentage points of the national power mix, but the wind power industry has a promising future.



Timber! Forest fuel prices are stable. This is why bio-fuels have taken over the fuel market

Figure 43 Actual commercial energy prices in Sweden, including tax, 1970-2009



Source: Swedish Petroleum Institute, Statistics Sweden, Swedish Energy Agency and Eurostat.
Note: Unless outherwise stated, prices and taxes for 1993 are for supplies for non-industrial use. VAT is included in district heating, domestic electric heating and natural gas for domestic use.

Interconnected grid between Nordic countries and Northwestern Europe

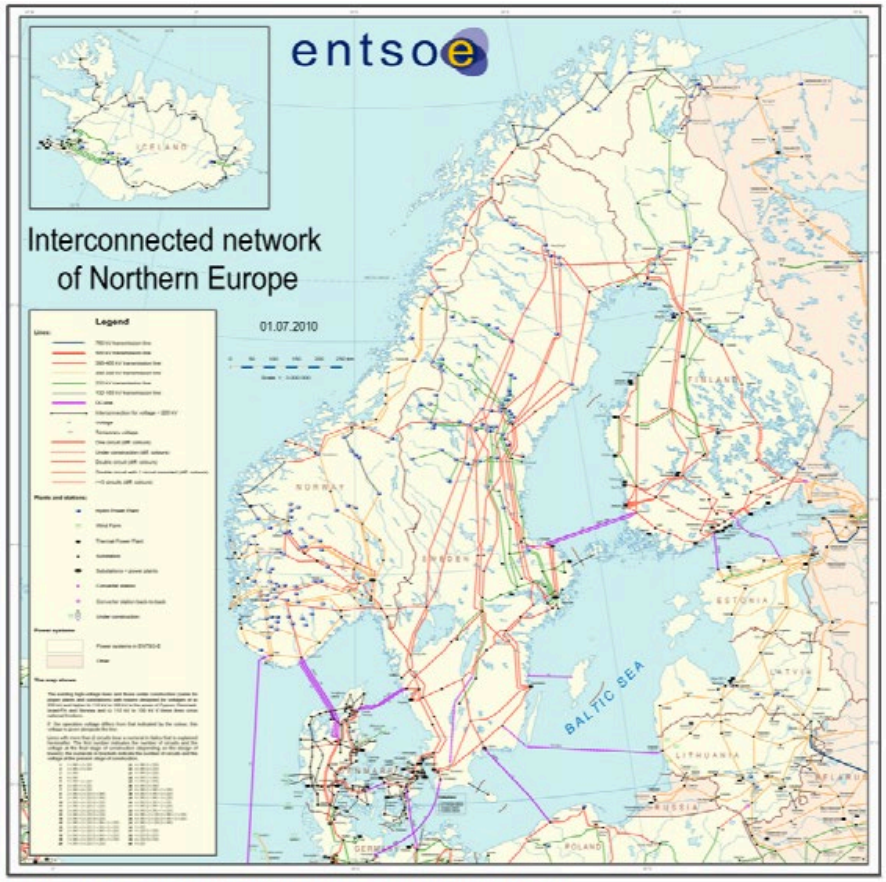
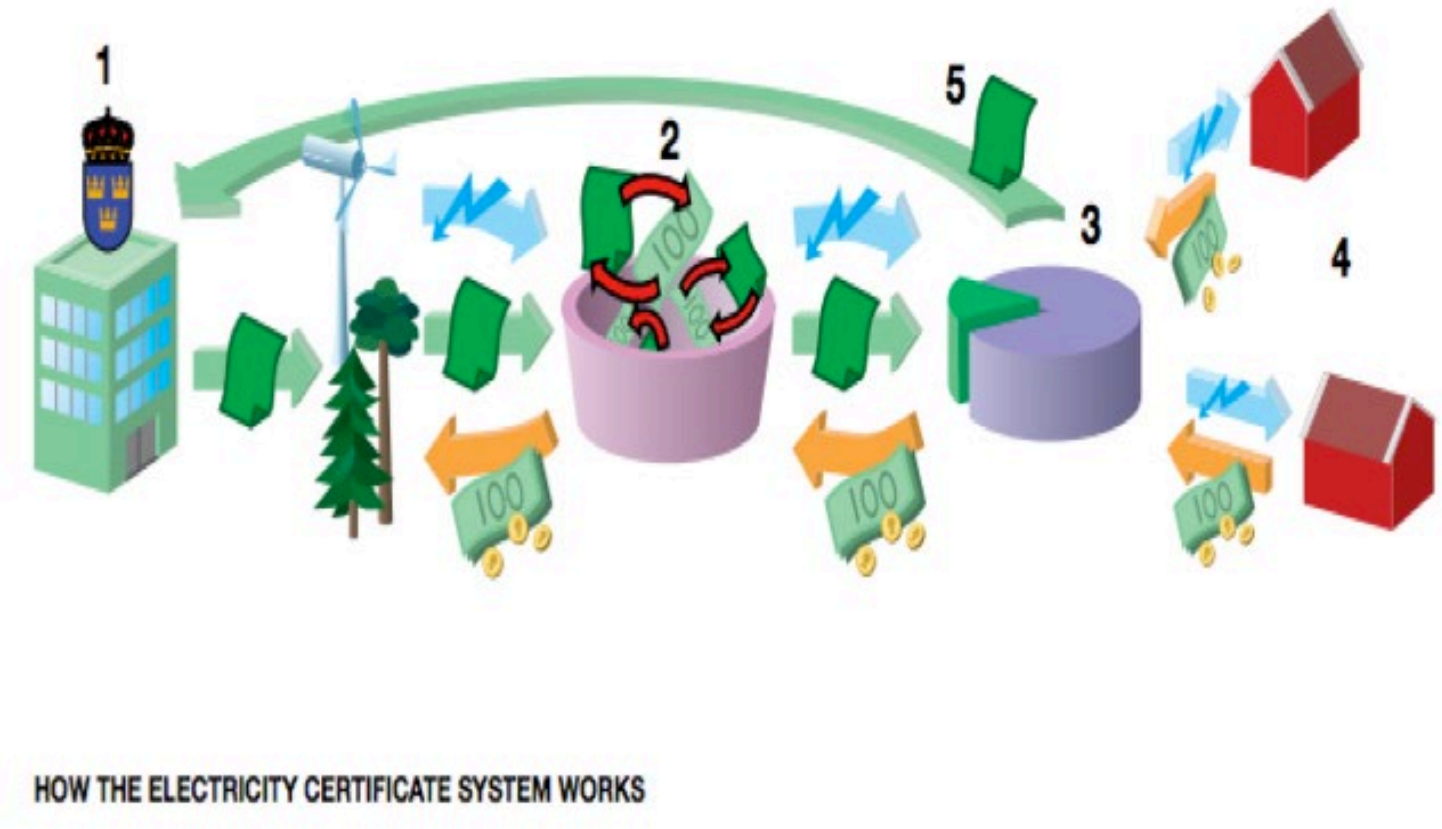


Figure 13 Transmission network in north-western Europe

Source: Svenska Kraftnät

Electricity Certificates, "similar" to feed-in tariffs, but not quite!



HOW THE ELECTRICITY CERTIFICATE SYSTEM WORKS

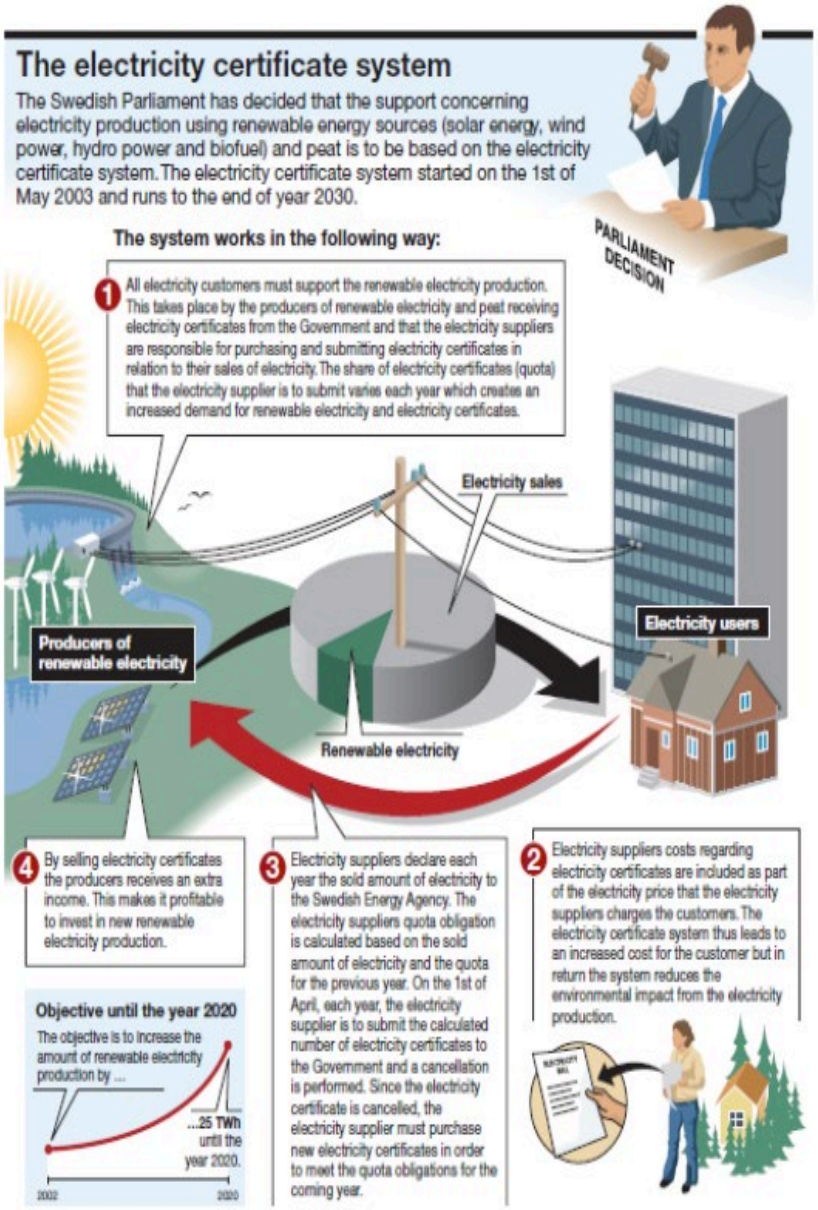
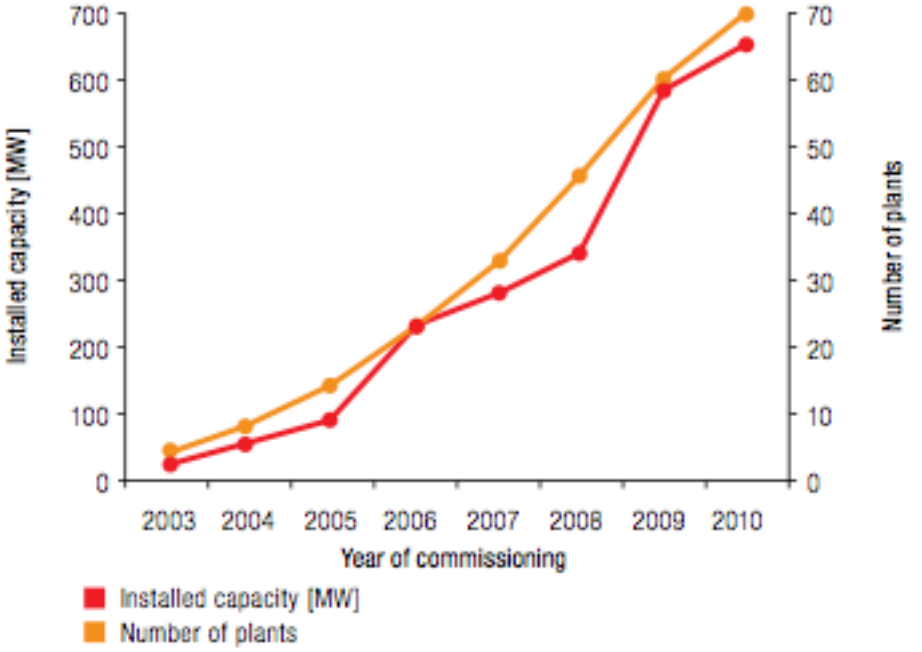


Figure 1: Electricity certificate system (Picture taken from electricity certificate system 2009)

Biomass: 2003- 2010

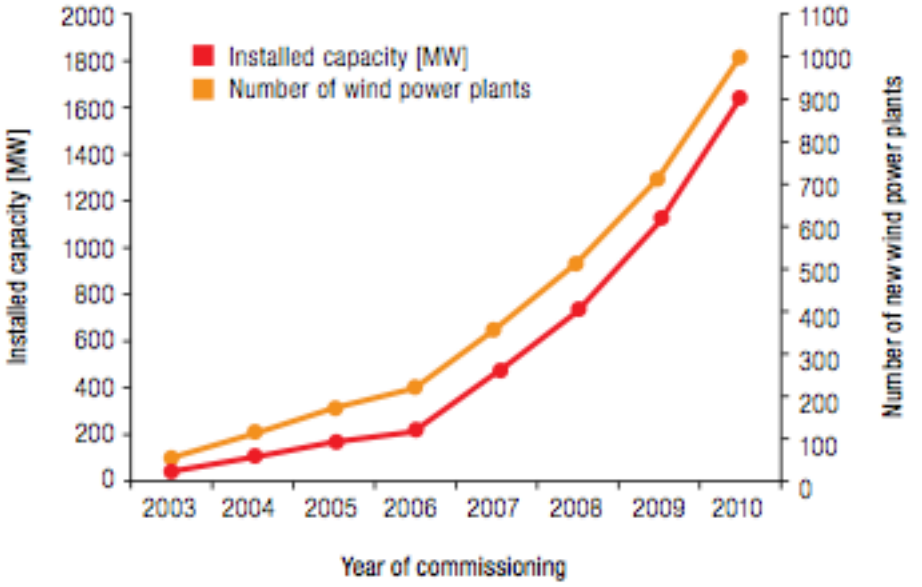
Figure 10. Total number of new biofuel-fired power plants registered in the electricity certificate system and their installed capacity, 2003–2010



Source Svenska Kraftnät's Cesar accounting system and the Swedish Energy Agency

Wind Power: 2003- 2010

Figure 8. Total number of new wind power plants registered in the electricity certificate system and their installed capacity, 2003-2010



Source: Svenska Kraftnät's Cesar accounting system and the Swedish Energy Agency

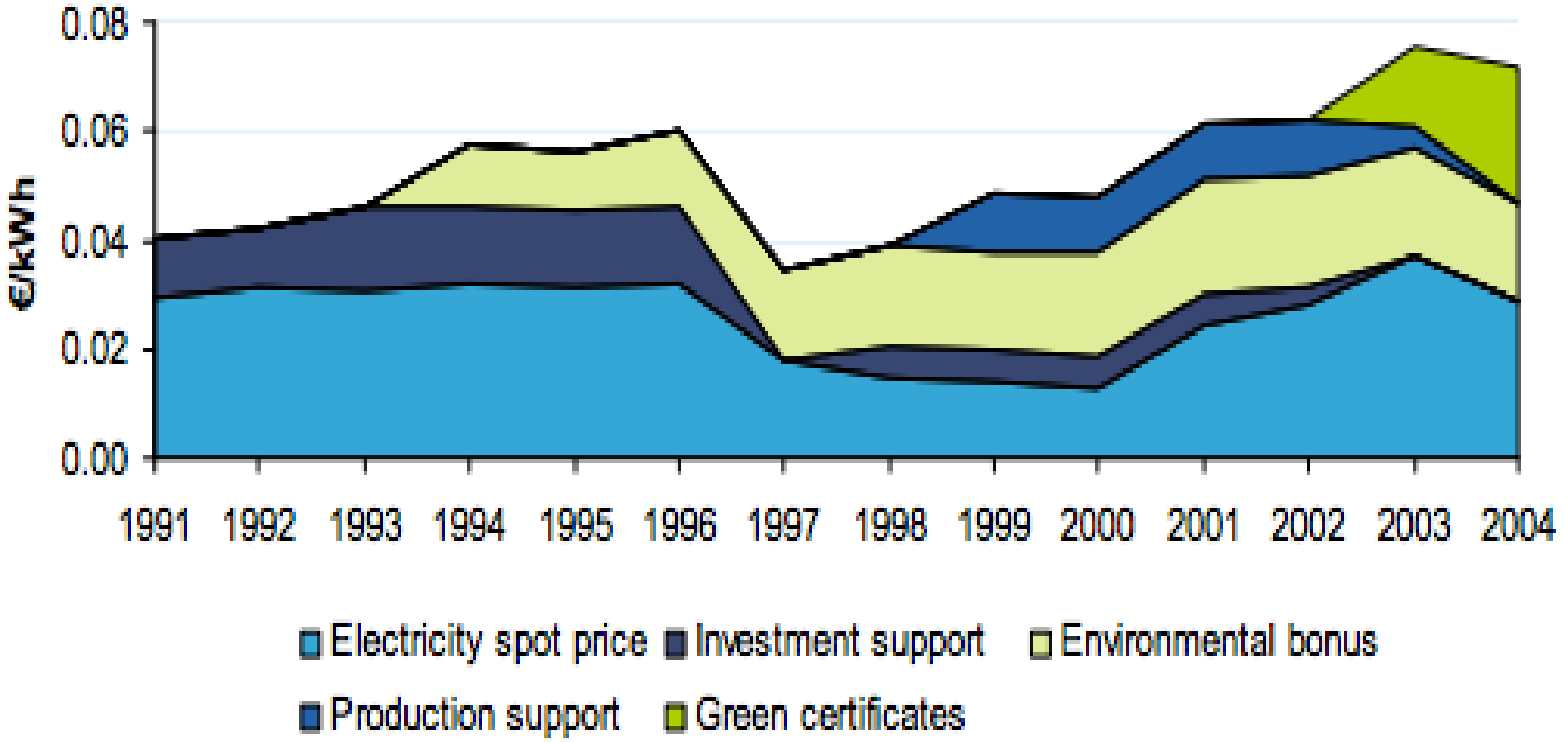


Figure 14: Support schemes for wind power in Sweden

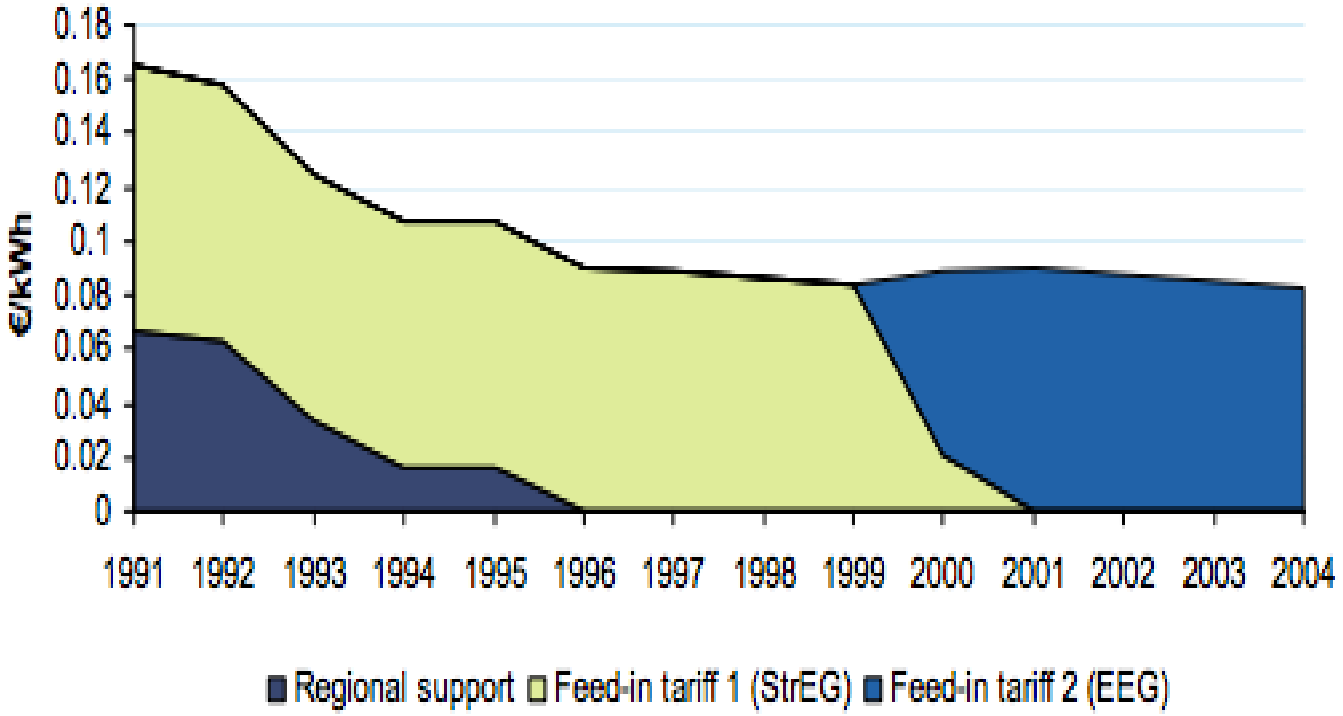


Figure 15: Support schemes for wind power in Germany

Wind power: Germany's Feed-in-Tariff vs. Sweden's Green Certificate System

Figure 16: Installed wind power capacity in Sweden and Germany

“The main challenge for wind turbines in Sweden is icing, not low temperatures.”

There is no current support mechanism for offshore wind power in Sweden

Solutions

- The Swedish government should gradually turn its certificate system into a FIT system.
- The government should increase the quota for wind power

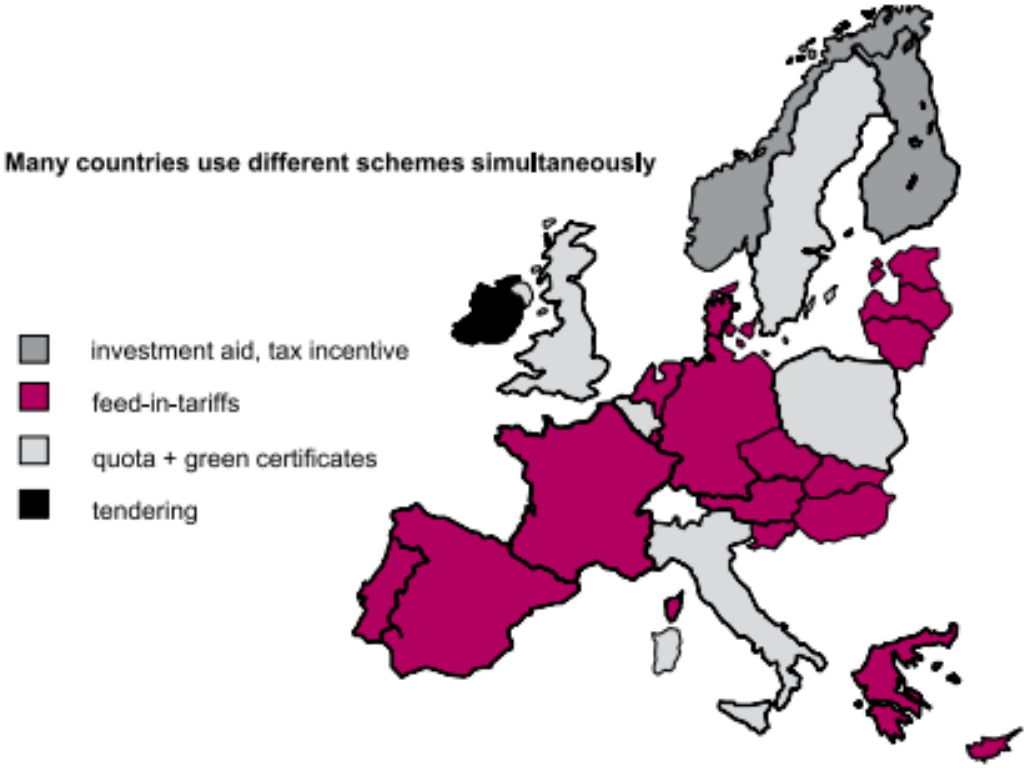


Figure 9.3: Main RES support schemes in EU countries and in Norway

The renewable energy industry estimates are much more ambitious and this projection can be achieved

TABLE 1 : Projections for Renewable Electricity in 2020

RES-E 2020 Projections	National RES industry Roadmap			NREAP		
	RES Electricity Generation (GWh)	% in Electricity Consumption-SERO Demand Assumptions	% in Electricity Consumption-NREAP Demand Assumptions	MW Installed	RES Electricity Generation (GWh)	% in Electricity Consumption
Large Hydro	68,000	50.9	44[1]	15,412	64,444[1][2]	41.7
Hydro (below or equal to 10 MW)	5,300	4	3.4	905[2]	3,485[2]	2.3
Photovoltaic	4,000	3	2.6	8	4	0
Tidal, Wave, Ocean	100	0.1	0.1	0	0	0
Wind Onshore	15,000	11.2	9.7	4,365	12,000	7.8
Wind Offshore	5,000[3]	3.7	3.2	182	500	0.3
Biomass (solid, biowaste, bioliquid)	20,000	15	12.9	2,872	16,700	10.8
Biogas	100	0.1	0.1	42	53	0
Total RES-E	117,500	88	76	23,786	97,186	62.9

Another sign of hope: Small-scale hydropower

Hydropower in Sweden began on a small scale as the technology to build large turbines did not exist. Within the EU, power stations below 10 MW (10,000 kW) are regarded as small-scale. According to the Swedish Hydropower Association, there are 1,894 small-scale hydropower stations in operation, generating 4.3 TWh of electricity per year. In the mid-1950s, this number was 4,000, before cheap fossil fuel sources and uranium put them out of business. The time of cheap energy is over as energy consumption increases, because fossil energy and uranium are finite raw materials that cannot be renewed.

If these small, currently dormant hydropower stations could be started up once more, and some new ones built, we could extract around 7 TWh of electricity from small-scale, natural, renewable hydropower in Sweden.

Source: http://www.triventus.com/hydropower/en/projekt/

Acknowledgements

- I would like to thank GENI for giving me the opportunity to intern there. I had a great experience and gained valuable knowledge on renewable energy thanks to this opportunity.
- I want to thank Peter Meisen for his guidance on my project and the GENI staff.
- I would also like to thank my faculty mentor, Dr. Jungie Zhang from the IRPS Graduate School at UCSD, who offered me great advice.