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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

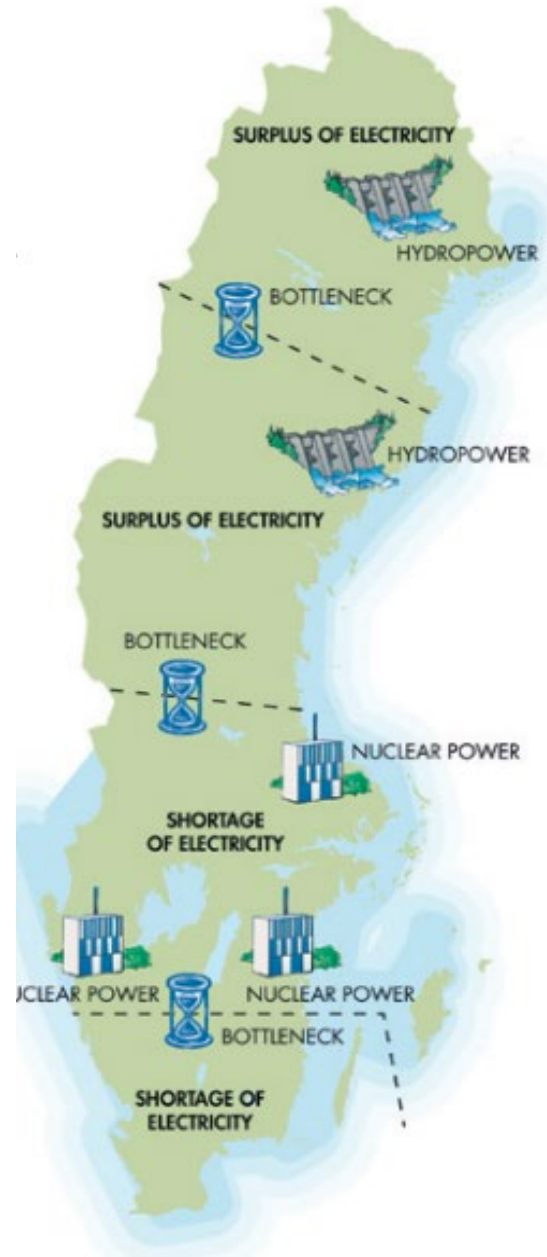
# Background: Sweden

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.

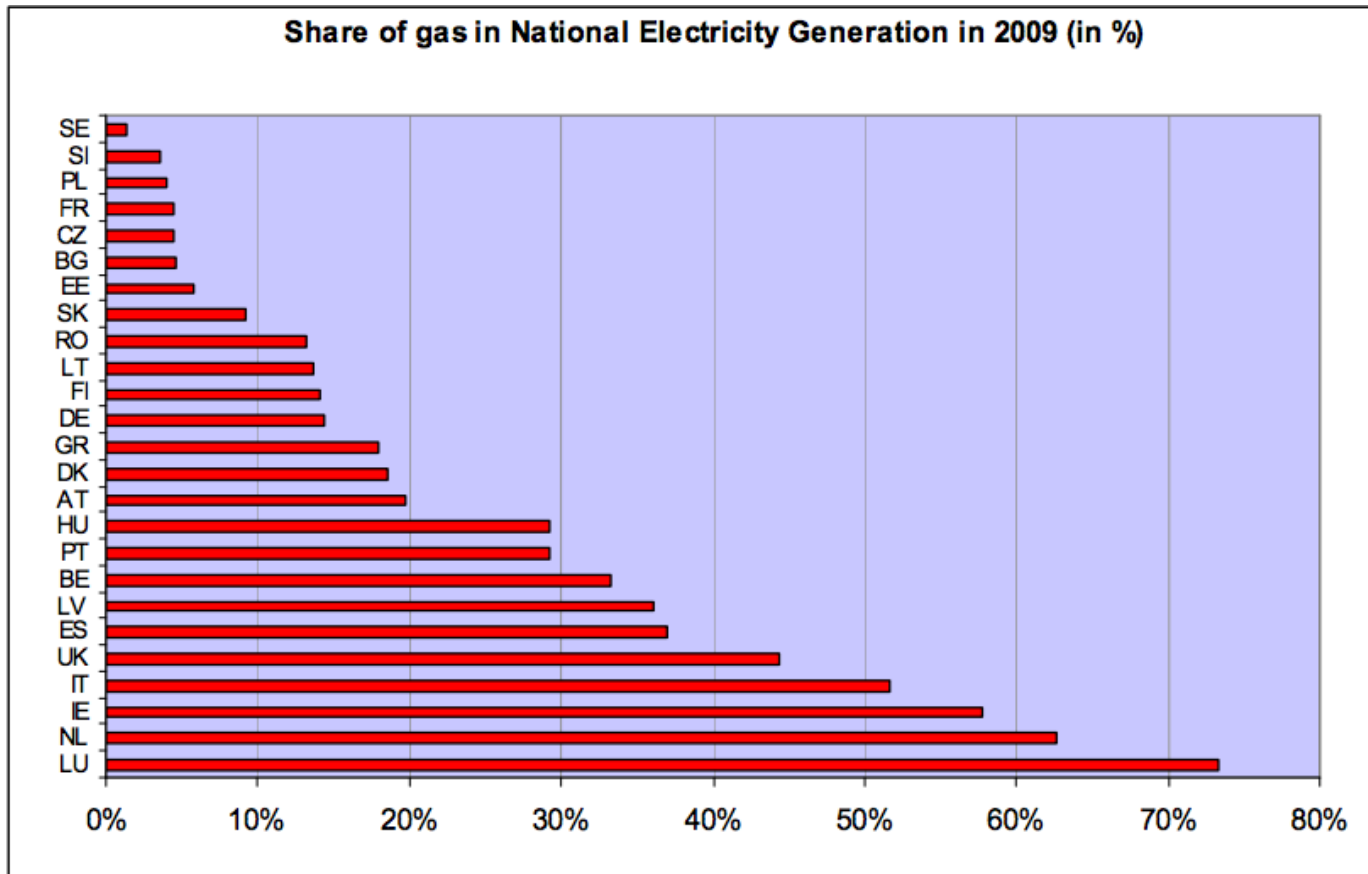


# Motivation:

- 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%)

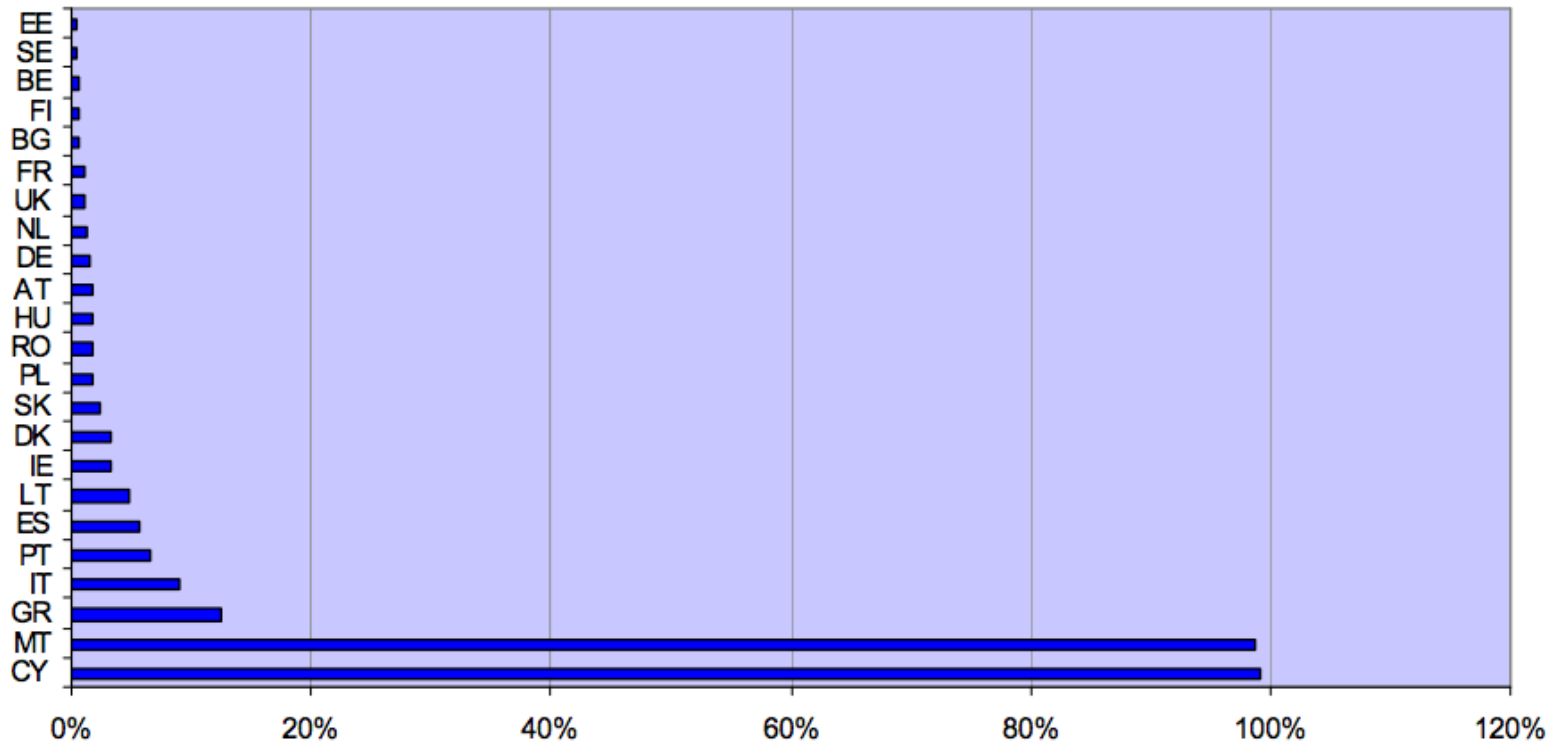


Source: Eurostat May 2011

Market Observatory for Energy

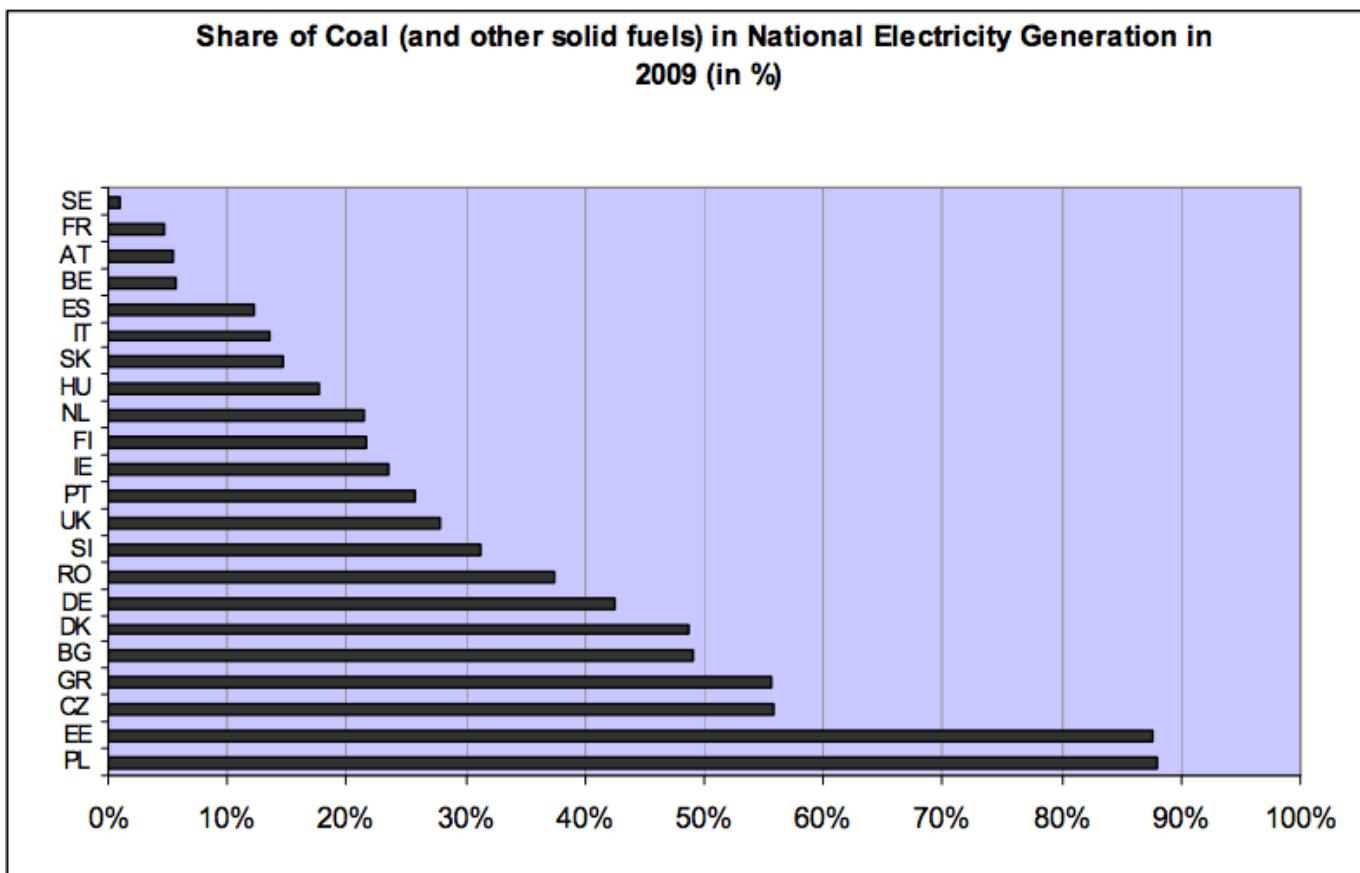
# Share of Oil (1%)

Share of Oil in National Electricity Generation in 2009 (in %)



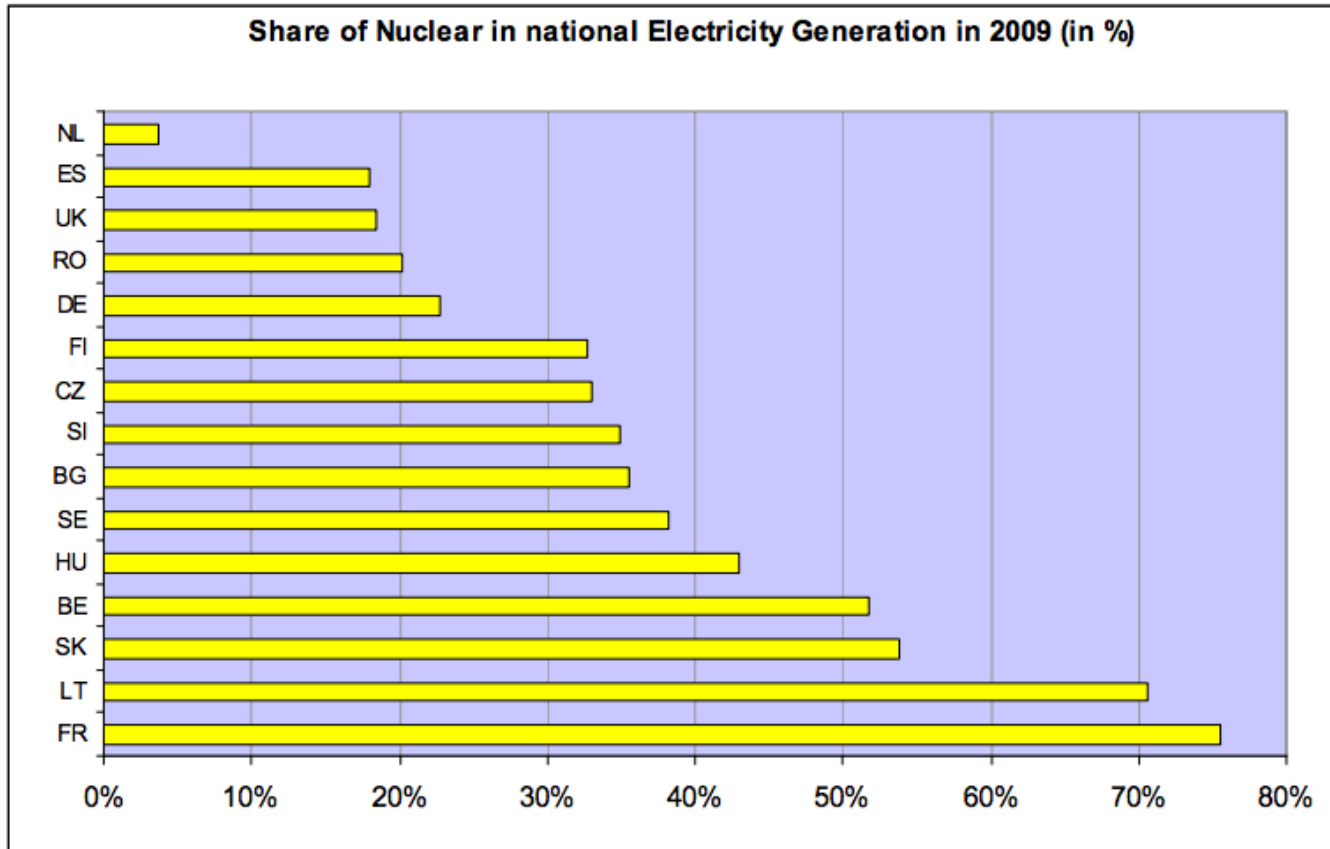
# Share of coal (1%)

## Sweden has a low-carbon economy



Source: Eurostat May 2011

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



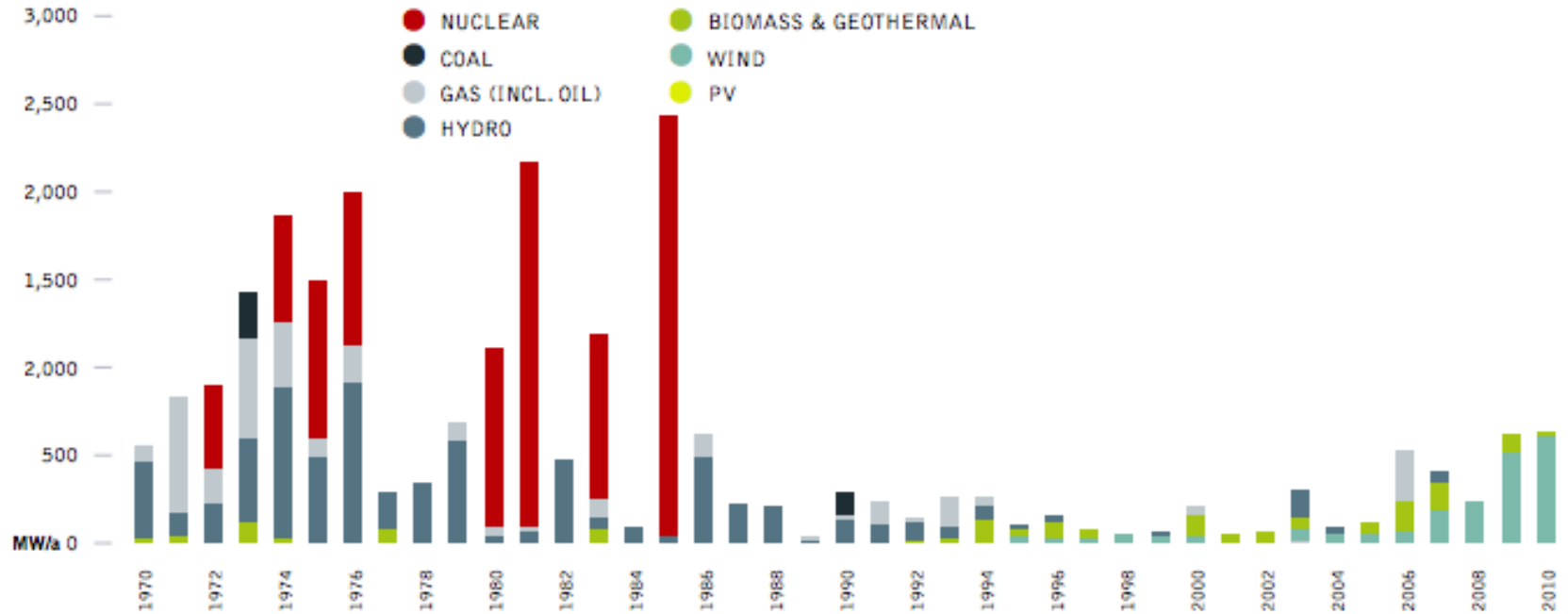
Source: Eurostat May 2011

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# Annual power plant market

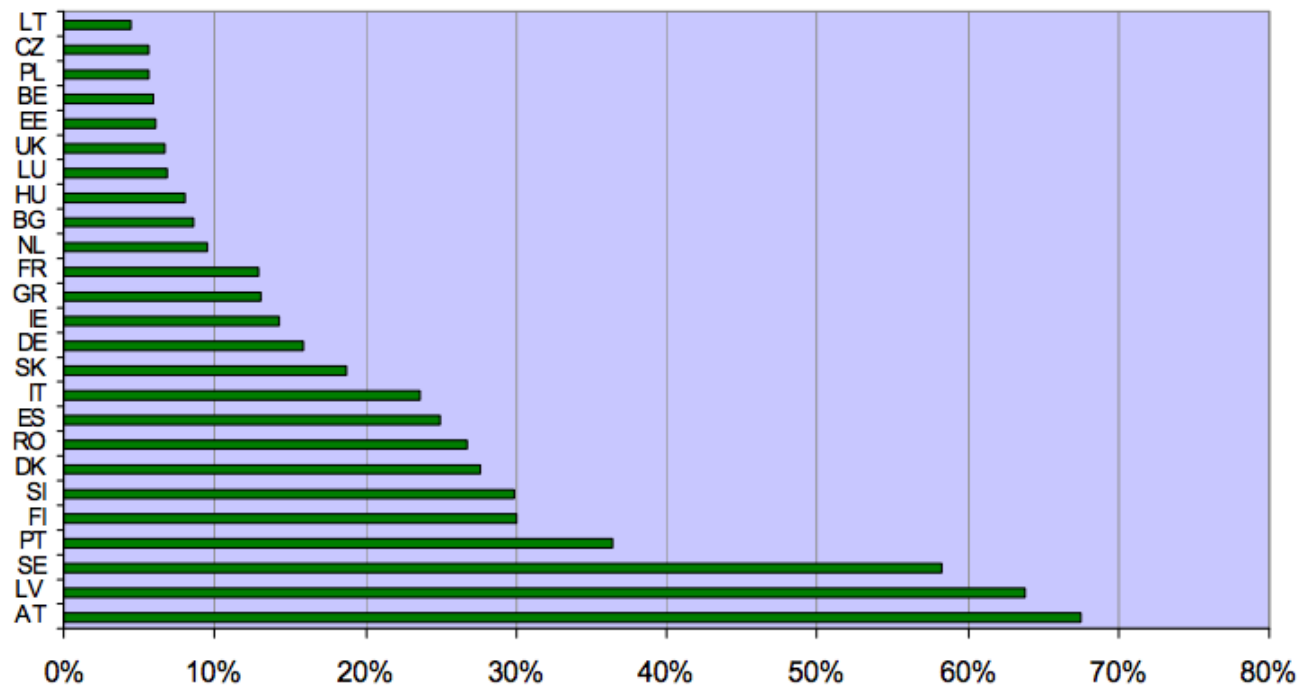
figure 7.7: sweden: annual power plant market 1970-2010



source PLATTS, IEA, BREYER, TESKE.

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

Share of Renewables in national Electricity Generation in 2009 (in %)



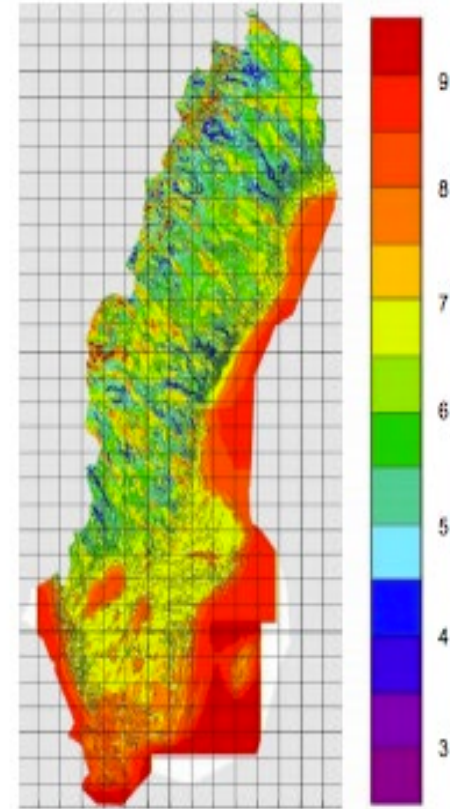
Source: Eurostat May 2011

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# Proposed Path: Wind power and Biomass

- For a transition to 100% renewable energy, fossil fuels are not the 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.

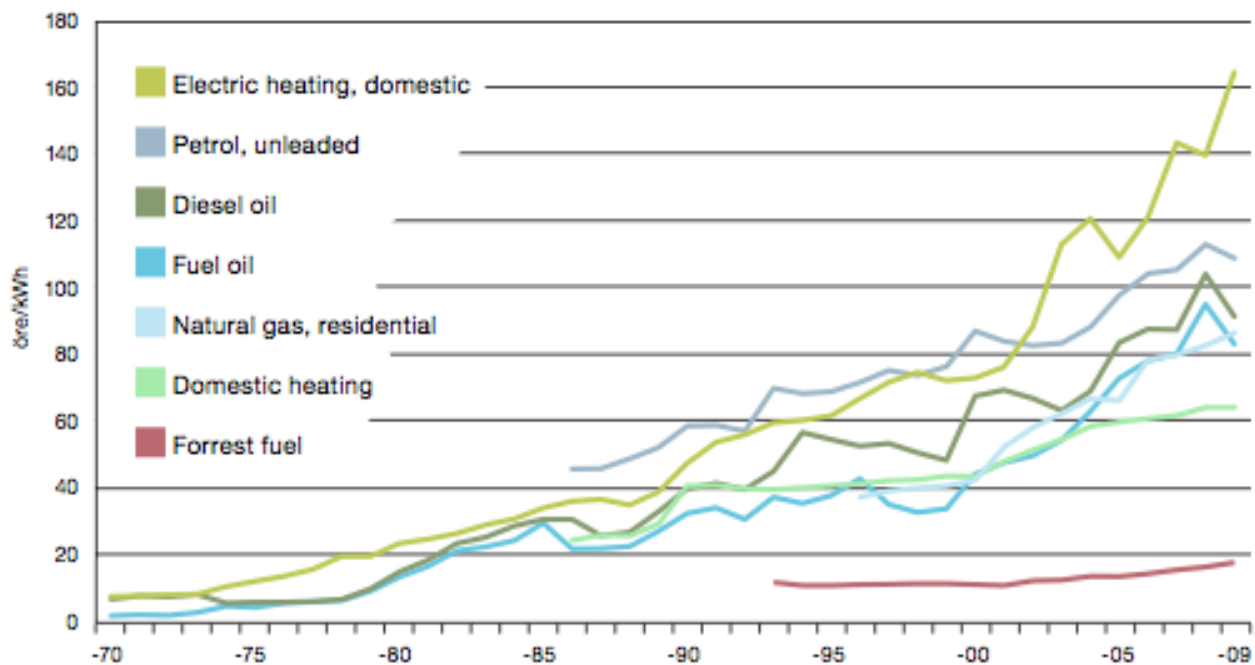
Wind potential in Sweden



Strong wind locations

# 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 otherwise 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

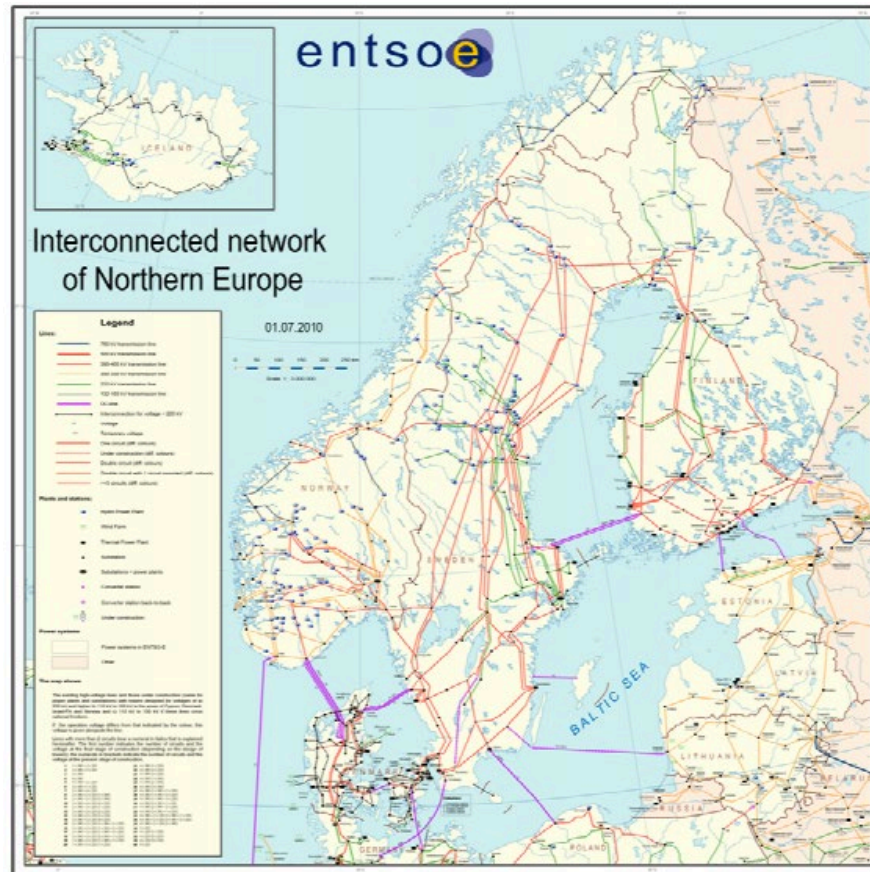
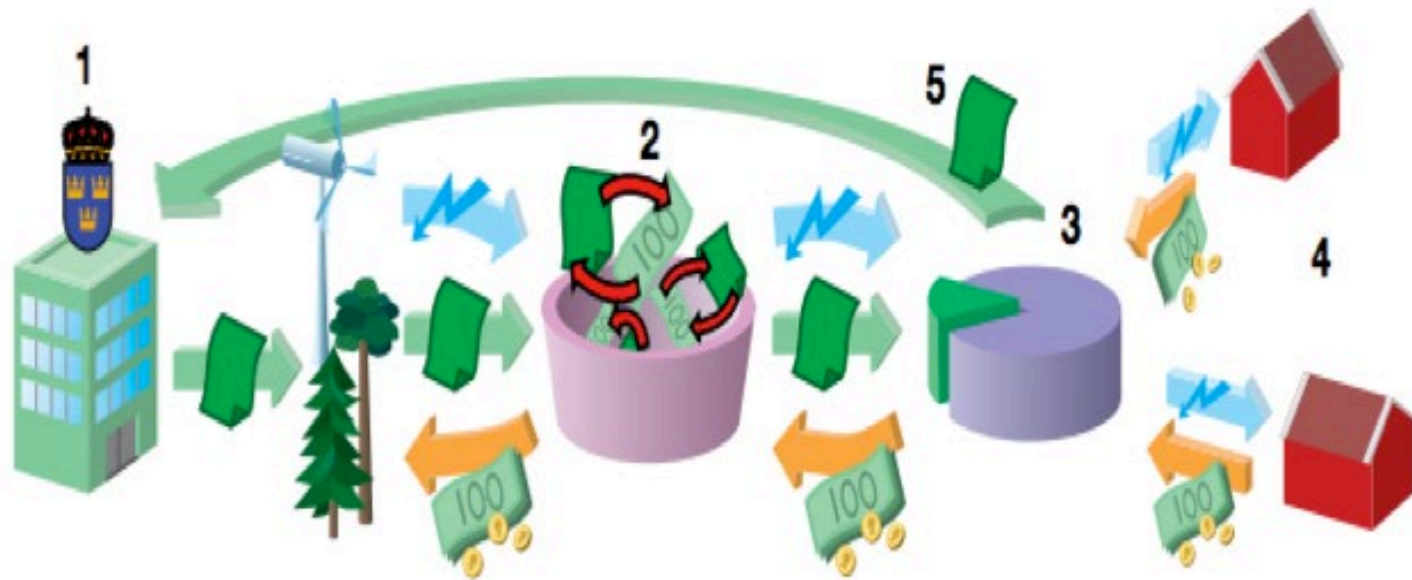


Figure 13 Transmission network in north-western Europe

Source: Svenska Kraftnät

# Electricity Certificates, “similar” to feed-in tariffs, but not quite!



HOW THE ELECTRICITY CERTIFICATE SYSTEM WORKS



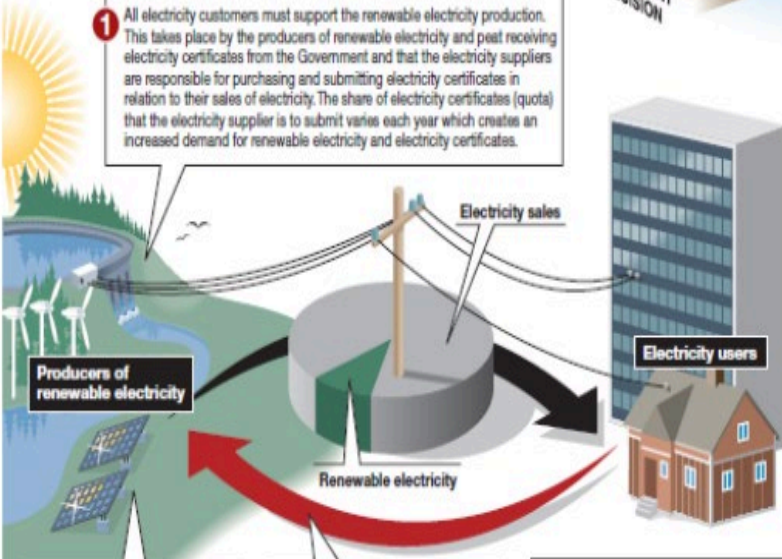
## The electricity certificate system

The Swedish Parliament has decided that the support concerning electricity production using renewable energy sources (solar energy, wind power, hydro power and biofuel) and peat is to be based on the electricity certificate system. The electricity certificate system started on the 1st of May 2003 and runs to the end of year 2030.



PARLIAMENT DECISION

The system works in the following way:



**1** All electricity customers must support the renewable electricity production. This takes place by the producers of renewable electricity and peat receiving electricity certificates from the Government and that the electricity suppliers are responsible for purchasing and submitting electricity certificates in relation to their sales of electricity. The share of electricity certificates (quota) that the electricity supplier is to submit varies each year which creates an increased demand for renewable electricity and electricity certificates.

**4** By selling electricity certificates the producers receives an extra income. This makes it profitable to invest in new renewable electricity production.

**3** Electricity suppliers declare each year the sold amount of electricity to the Swedish Energy Agency. The electricity suppliers quota obligation is calculated based on the sold amount of electricity and the quota for the previous year. On the 1st of April, each year, the electricity supplier is to submit the calculated number of electricity certificates to the Government and a cancellation is performed. Since the electricity certificate is cancelled, the electricity supplier must purchase new electricity certificates in order to meet the quota obligations for the coming year.

**2** Electricity suppliers costs regarding electricity certificates are included as part of the electricity price that the electricity suppliers charges the customers. The electricity certificate system thus leads to an increased cost for the customer but in return the system reduces the environmental impact from the electricity production.

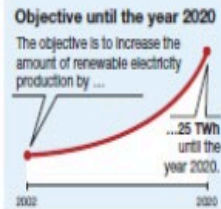
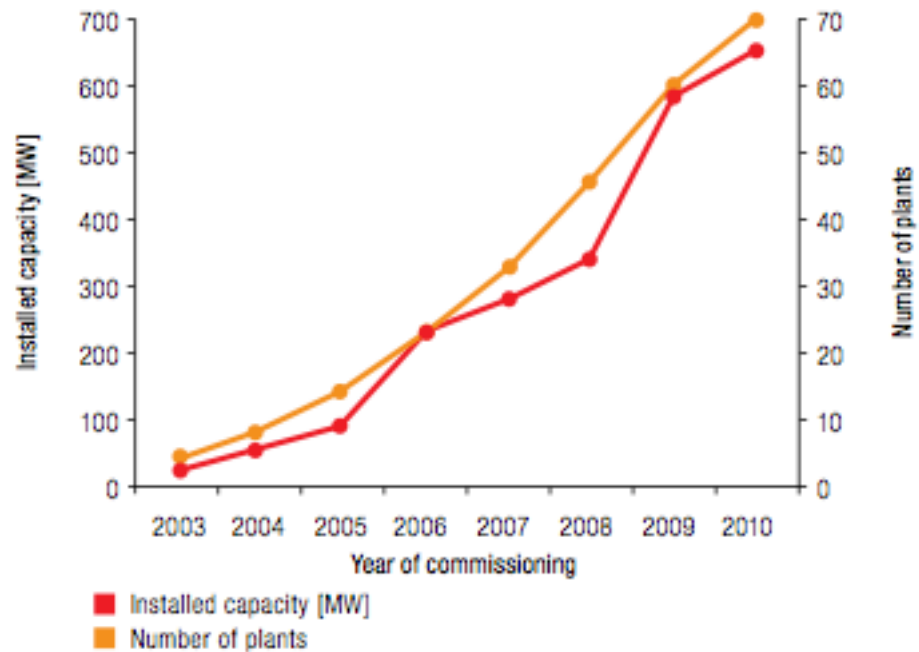


Figure 1: Electricity certificate system (Picture taken from electricity certificate system 2009)

# 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

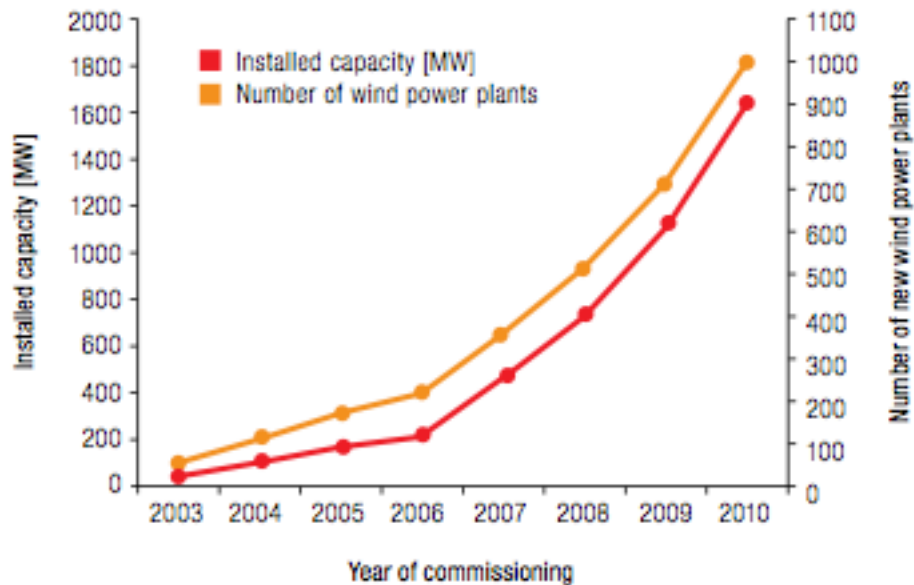


Source Svenska Kraftnät's Cesar accounting system and the Swedish Energy Agency

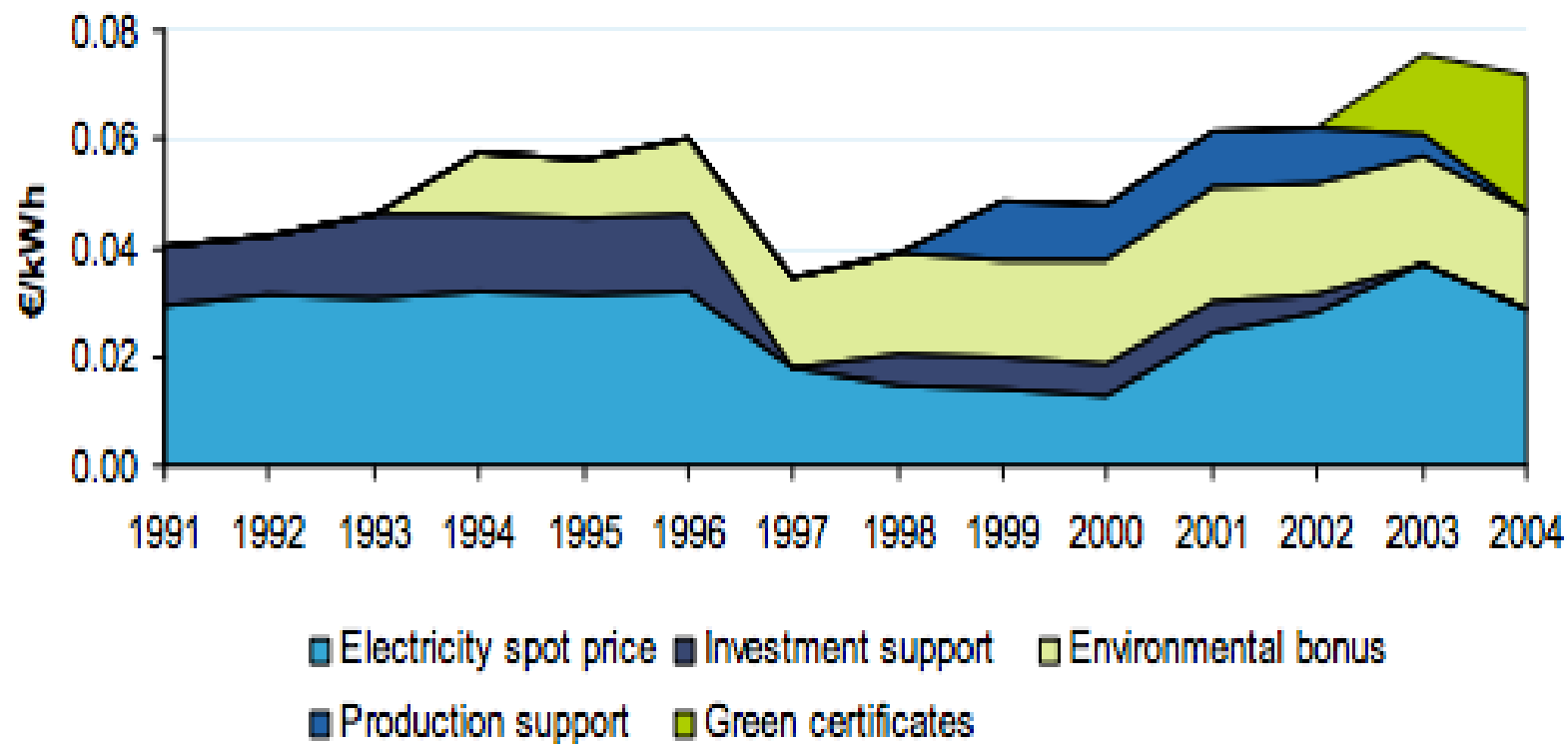


# Wind Power: 2003- 2010

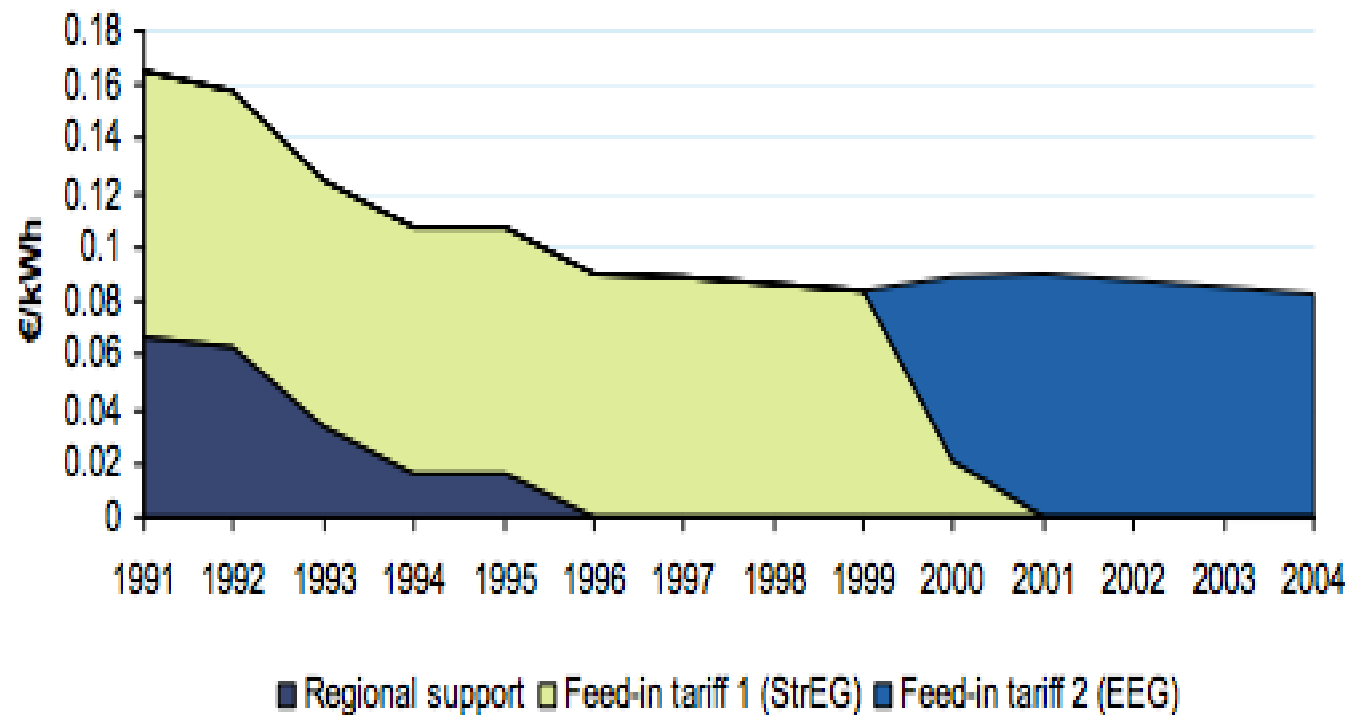
**Figure 8.** Total number of new wind power plants registered in the electricity certificate system and their installed capacity, 2003-2010



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

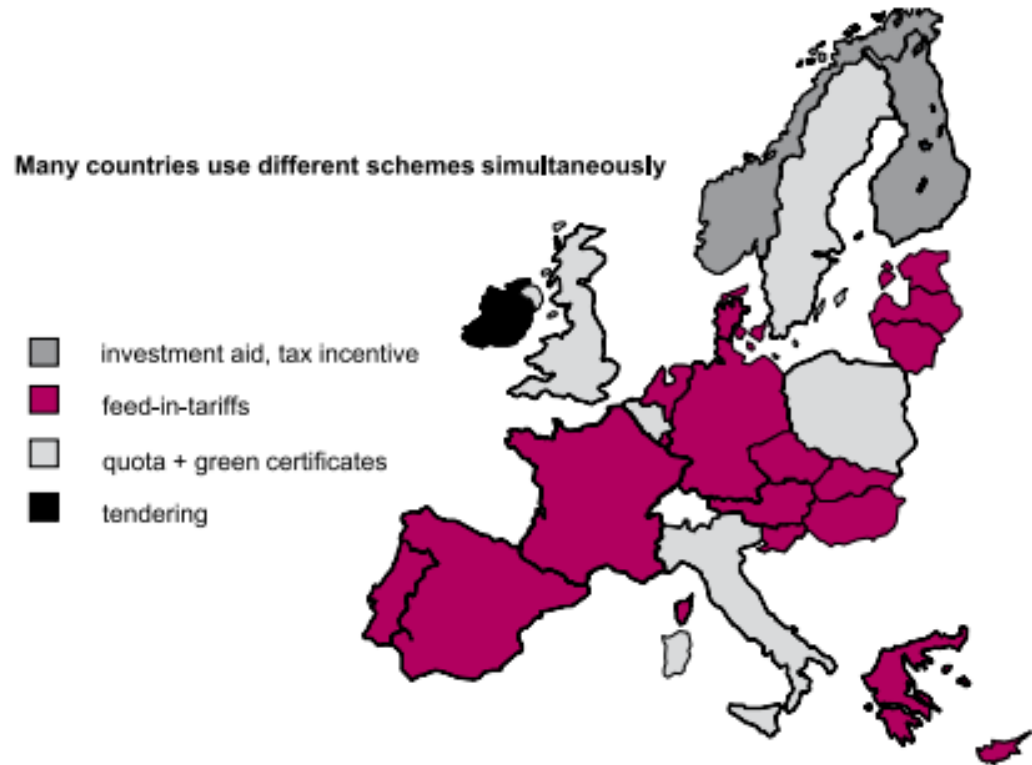


Figure 9.3: Main RES support schemes in EU countries and in Norway

# 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 <sup>(1)</sup>	15,412	64,444 <sup>(1)(2)</sup>	41.7
Hydro (below or equal to 10 MW)	5,300	4	3.4	905 <sup>(2)</sup>	3,485 <sup>(2)</sup>	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 <sup>(3)</sup>	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
<b>Total RES-E</b>	<b>117,500</b>	<b>88</b>	<b>76</b>	<b>23,786</b>	<b>97,186</b>	<b>62.9</b>



# 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.
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