Efficient strategy to support renewable energy

Integration in overall climate and energy security policies

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Preface

This report reviews how Nordic countries individually, collectively and as part of the larger international community can develop *a strategy for renewable energy that delivers efficiently on the two underlying policy objectives of climate change and energy security challenges*. The study focuses on power generation and district heating, but in the context of the overall energy sector when appropriate. The study has four key elements:

- How would the “ideal” long-term strategy for support of renewable energy look like given the underlying economics of the issues?
- What opportunities and constraints follow from the structure and content of the international co-operation first of all at the EU level?
- How effective are the Nordic countries in pursuing cost effective policies under these international conditions?
- What policy recommendations follow from this analysis?

The overarching elements in the study is to recognise that (1) expanding renewable energy is not an end in itself, but a tool to deliver on the two real policy targets of climate change and energy security, (2) too much policy focus at the Nordic and EU level is dedicated to boosting the renewable energy share of energy production in the near term, and insufficient resources are allocated to develop future low carbon technologies, which are required when CO₂ abatement targets become much more ambitious in the future, and (3) the long-term nature of the challenges and huge investments in low carbon technologies required to deliver on long-term targets puts a very high premium on policies that reduces policy risks as perceived by investors: this will reduce risk premia and ultimately the costs of climate change and energy security policies.

The report emphasises the role of the EU ETS scheme and its potential to drive emissions and promote renewable energy. The role of innovation funding is also analysed. The streamlining of support schemes for renewable energy is an important topic for discussion also in the Nordic countries.

The report can give useful Nordic input to the on-going discussions on the role of renewable energy in climate and energy policy. The report covers especially issues related to climate policy and energy security while broader issues related to competitiveness and green growth are not part of the analysis.

The report was commissioned by the Working Group on Environment and Economy (MEG) under the Nordic Council of Ministers. The report has been written by Copenhagen Economics, who is also responsible for the contents including the conclusions and recommendations in the report.

The authors have been:

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April 2013

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Main findings

Dealing with the two policy objectives: the risk of climate change from greenhouse gas emissions and the risk to energy security require two outcomes: 1) a transformation towards a low carbon economy, and 2) more stable/local energy sources. At the same time we have as a policy objective that the two targets should be reached in a cost-efficient way. Deployment of renewable energy can potentially deliver on both objectives, and is therefore a mean to an end, not a policy objective per se. Some of the same benefits can e.g. also be derived from enhanced energy efficiency as well as other technology solutions such as Carbon Capture and Storage (CCS) in coal and gas based generators, and atomic power as well as efforts to diversify the source countries of energy import.

So this study proposes to look at “Efficient strategies for renewable energy” in this broader perspective: how can Nordic countries individually, collectively and as part of the larger international community cost effectively implement a strategy for renewable energy that meet the climate change and energy security challenges? The study’s mandate is to focus on power generation and district heating, but we will do so in the context of the overall energy sector when appropriate.

Our evaluation has four key elements:

- How would the “ideal” long term strategy for support of renewable energy look like given the underlying economics of the issues?
- What opportunities and constraints follow from the structure and content of the international co-operation first of all at the EU level?
- How effective are the Nordic countries in pursuing cost effective policies under these international conditions?
- Which recommendations follow from this analysis?

The ideal strategy would reflect two basic points about the economics of the challenges. First, we have a well identified *environmental challenge* which should be addressed by pricing greenhouse gases uniformly and at a level that is consistent with long term targets for emissions cuts. That can be done by taxes or cap-and-trade schemes. There is strong evidence that such taxes have substantial long term impact on emissions as well as the incentives to deploy and develop low carbon technologies

such as renewable technologies. We claim that the effects of such taxes tend to be underrated in official long term projections, including in Nordic countries.¹

Second, we also have a well identified *technology challenge*. While carbon pricing can have a strong role in promoting technologies relatively close to market maturity, the promotion of promising yet still immature technologies require government support. This is the well-known spill-over argument: the benefits from research and development often accrue to other actors than those who finance it. This introduces a classical role for governments. Indeed, a substantial part of public support for early stage promotion of promising technologies in the form of pilot and demonstration project should ideally come from international public budgets such as the EU. Knowledge spill-overs across borders are substantial and there is a need to focus on development in innovation clusters with sufficient critical scale and quality. The focus for such schemes is not to produce energy or generate carbon emission reductions in the present time; it is to push down the costs of producing energy in the future! A substantial body of research has suggested that the scale of the transformation of the energy sector in order to achieve a near total decarbonisation will require a substantial increase in government funding: OECD suggests a 2–3 times increase from current levels.

Both the *opportunities and constraints* following from international co-operation are substantial. In the first place, the *opportunities* should be stressed: the Nordic region accounts but for a fraction of global emissions and the pace of technological innovation in low carbon technologies taking place at the international level will be the driver for the technology options available in the Nordic regions. Hence the EU offers an opportunity to ensure (a more) global commitment to carbon pricing and international collaboration on technologies.

But the *constraints* are also being clearly felt, the most important highlighted here:

The ETS system is the key EU market instrument to put a price on the greenhouse gases from power generation and energy consumption. Yet the current price of ETS allowances is at a very low level, arguably even too low to promote a shift from coal to gas based generation let alone deployment of renewable energy. From an economic point of view, this

¹ I.e. too low long term price elasticities: a given increase in taxes on carbon or energy has larger long term effects than typically built into projections.

is problematic for at least two reasons. *First*, on average the pricing of emissions outside the ETS is now easily 5-10 times higher than inside the ETS. For the Nordic countries this difference is even larger as the tax rates on energy are far above the EU average. So EU and the Nordic countries in particular would gain massively from shifting mitigation into the ETS sector by imposing a larger cut in emissions in the ETS. This could be done with or without an overall increase of the reduction target by 2020. *Second*, the very low price is by-itself an indicator that near term abatement targets in the ETS are too low: all long term projections suggest that much higher levels of carbon prices are required to meet long term climate change objectives. The current low prices is therefore likely to reflect that markets have little confidence in EU's willingness to deliver on its ambitions. Otherwise, firms would buy up allowances at the current low prices and use it for future compliance; a process that would push up prices to much higher levels.

EU has set *renewable targets for 2020* binding individual countries to specific results. The reduction target is set such that renewable energy deployment must be a certain share of energy consumption for the total economy, with a separate target for transport. Given the current low ETS allowance price, as well as the reductions in coal and gas prices this implies that very substantial support will have to be provided to deploy the amount of renewable energy needed to meet the EU targets. Seen from an economic point of view, the EU targets in fact force Member States to massively deploy renewable energy sources which are often relatively far from market maturity given the current level of power market prices. Such technologies should arguably still be supported by more narrow demonstration and commercialisation schemes.

How effective are then Nordic countries in putting together renewable energy strategies under these circumstances? Based upon a description of the actual policies, we base our evaluation on the extent to which Nordic energy policies meet the following criteria:

- Least cost implementation of EU's renewable energy targets within a comprehensive overall support system
- Appropriate match between the design of the support instruments and the maturity of the technology from the lab to the market place
- Combining technology neutrality – avoiding picking winners – while also recognising that not all technologies should be (equally) supported

Our conclusions are the following:

- Least cost implementation does not appear to be of equally high priority in the Nordic countries. The Norwegian-Swedish joint implementation of renewable energy targets, by way of a green certificate scheme, is however a promising approach. More generally, support levels to deployment of renewable energy are far too often dependent on arbitrary circumstances such as the tax status of the user (e.g. corporate vs. private) *or* whether a raw material gets a subsidy through a tax exemption from a given energy tax rate (e.g. biomass used in joint production of heat and electricity) or receives an explicit subsidy. Such arbitrary support levels do not support the objective of least cost implementation.
- Most of the public funds for renewable energy go to deployment of still relatively immature technologies, while less is directly targeted at innovation. Meeting 2020 renewable energy targets is likely to increase the need to focus on short term deployment support. As this draws resources away from innovation support, this is likely to make the long term climate goals more costly to achieve.
- The challenge of defining a technology neutral approach to innovation support is an issue in all countries and to a large extent still unresolved.

Our *recommendations* following our analysis are then the following:

First, it is important to recognise that climate change and energy security are the real policy objectives with cost efficiency as an important constraint. Renewable energy and energy efficiency are only means to deliver on these targets. Specific targets for renewable energy and energy efficiency are likely to become unproductive particularly over time. With official estimates of global gas and oil reserves going up - not least in stable regions such as the US - mitigation of climate change should rise in priority relative to energy security. Indeed, the increase amount of fossil fuel supply together with the lower prices implies that tougher measures are needed to reach given climate policy targets (higher carbon taxes and/or higher price of allowances in cap and trade schemes)

Second, focus discussion of the mitigation efforts in Nordic countries in a wider international, first of all EU, context. For power generation it is the future of the ETS that drives incentives to reduce emissions, The emission cap determined at EU level implies that an extra mitigation efforts in Nordic countries has no effect on either national compliance or overall EU emissions.

Third, focus more on policies to improve technology. Our study has clarified that the bulk of public funding to renewable energy in the Nordic countries goes to support deployment and only a fraction of that to innovation. We suggest reversing that priority over time. We suggest that more effort should be put into encouraging more competition for innovation funding, potentially looking at the US experience with “technology prizes”. Funding should be focused on generic technologies often with high technology uncertainty and up-front capital costs that are holding back private investment.

Fourth, streamline support for deployment of renewable energy in a wider sense to ensure a consistent, cost efficient support levels across different sectors, producers etc. The ultimate aim is to ensure that marginal incentives to abatement – the shadow prices of CO₂ – are equal for mature installations/technologies that are meant to be deployed at a large scale.

Fifth, develop a credible long term strategy for climate change policy that could serve as a role model for countries with a less enthusiastic approach to ambitious mitigation targets. The Nordic countries support the most stringent targets, and yet account for but a fraction of global emissions. The role model to be developed should combine a cost efficient approach to reach EU defined short term targets, while boosting innovation strategies that ensures that the Nordic countries can also meet much more stringent targets in the future at lower costs. If this model can be demonstrated to work, then other countries may be less hesitant in following.

1. Description

As an integrated part of their climate and energy policies, all Nordic countries have formulated and implemented policies that will boost the share of renewable energy over the coming decades.² This chapter describes the different policies adopted in order to increase the share of renewable energy in the electricity and the heat sector.

1.1 Describing the power and district heating sectors

This study will focus on renewable energy in the power generation sector and the heat generation sector. These sectors vary across the Nordic countries both with respect to their size and importance and with respect to the input sources used. In this section we will describe these two sectors in the Nordic countries.

1.1.1 *The power sector*

There are large variations between the Nordic countries with respect to the structure of electricity production. Denmark is the only country where the majority of electricity (80%) is produced in combination with heat (CHP), cf. Table 1. Conversely, Iceland, Norway, and Sweden have limited CHP production, and between 86–99% of electricity are produced from pure electricity installations. Finland produces 64% of its electricity from pure electricity installations, and 36% in combination with heat production. Finland has the highest share of own-production by households and industry (autoproducers) of 12% of the country's electricity production. Denmark, Norway and Sweden range from 4–6% from own production while Iceland has 0%.

² Iceland has implemented initiatives only in the transport sector.

Table 1. Electricity production, 2010

%	Denmark	Finland	Iceland	Norway	Sweden
Electricity only	20	63	86	90	86
CHP plant	74**	25	14	0	9
Own electricity production*	0	1	0	1	0
Own CHP production*	6	11	0	5	4
Total gross electricity generation (GWh)	38,785	80,667	9,930	124,505	148,609

Note: * Own production is households' and industry's own production of electricity, so called auto producers. Data is from 2010, except Iceland which is from 2006. Note that in Finland, generation of condensing power in CHP plants is not calculated in CHP production. In Denmark, all generation from CHP plants including "electricity only" is attributed to CHP production.

Source: Eurostat. Table nrg_105a.

There is much variation between the size of the Nordic countries electricity production both in absolute terms and weighted with GDP. Iceland has by far the largest electricity production when it is weighted by GDP, cf. Figure 1. In addition, Finland, Norway and Sweden produce twice as much GDP weighted electricity as Denmark, and Sweden produces more than four times as much electricity as Denmark in absolute terms, cf. Table 1. This reflects among others that Iceland has extensive energy intensive aluminium production, and Finland, Sweden and Norway also has a relatively large share of energy intensive industry, while Denmark has much less. In addition, the relatively low electricity production in Denmark also reflects that heating in Denmark is typically not produced locally from electric heating, but through district heating systems.

Figure 1. Total gross electricity generation weighted with GDP, 2010

Source: Eurostat. Table nrg_105a, and nama_gdp_c.

There is also large variation between the Nordic countries with respect to the input used for electricity production. Denmark and Finland use a significant share of coal and natural gas, cf. Table 2, while Iceland, Norway and Sweden use these inputs to a very limited extent. Denmark's main renewable energy inputs are wind and biomass, while Norway and Iceland mainly uses hydro. Finland and Sweden produce 28 and 38% of electricity respectively from nuclear power, while Sweden's other main source of electricity production is hydro. In Norway hydro completely dominates the electricity production mix.

Table 2. Share of different inputs in electricity production, 2010

%	Denmark	Finland	Iceland	Norway	Sweden
Coal	44	26	0	0	2
Natural gas	20	14	0	4	3
Oil	2	1	0	0	2
Hydro	0	16	74	95	47
Wind	20	0	0	1	2
Biofuels & Waste	13	14	0	0	6
Nuclear	0	28	0	0	38
Geothermal	0	0	26	0	0
Solar	0	0	0	0	0
Tide, wave, ocean	0		0	0	0

Note: Data for 2010 are expected numbers.

Source: IEA (2011), Electricity Information 2011.

1.1.2 The district heating sector

In this section, we describe the heating sector. This is defined as “production” of warm water which is used to district heating. All Nordic countries except Norway produce the majority of their heat in combination with electricity. The share of heat from CHP production ranges from 60% in Sweden to 87% in Iceland, cf. Table 3. In Finland, Norway and Sweden, 8% of heat is own-production, and in Denmark this is 14%. In Iceland, there is no own-production of heat.

Table 3. Heat production, 2010

%	Denmark	Finland	Iceland	Norway	Sweden
Heat only	19	27	13	72	32
CHP plant	66	65	87	20	60
Heat only, autoproducers	3	2	0	8	0
CHP production of heat, autoproducers	11	6	0	0	8
Total gross heat generation (TJ)	150,021	208,999	9,962	19,665	224,047

Note: Heat production of the autoproducers includes only heat production, which is sold. Heat production of the auto producers (households and industry) for own use is not included in the data. Data are from 2010, except Iceland which is from 2006.

Source: Eurostat. Table nrg_106a.

There is much variation between the input sources for heat production in the Nordic countries. The following data are based on international statistics, which do not include the share of heat production of industry for own use. In Denmark and Finland, 58 and 67% of heat is produced with coal, peat, natural gas and oil.

The remaining heat is produced primarily using biomass and waste. In Norway and Sweden the fossil fuel inputs constitute a much lower share of 14 and 24% respectively. Biomass and waste constitute 57 and 68% of heat production, while heat pumps and electric boilers make up 8% each of heat production in Norway and Sweden. In Iceland, 94% of heat is produced through geothermal installations, cf. Table 4.

Table 4. Input in heat production, 2010

%	Denmark	Finland	Iceland	Norway	Sweden
Coal	25	35	0	2	10
Natural gas	29	25	0	4	6
Oil	4	7	0	8	8
Biomass & waste	40	31	0	57	68
Geothermal	0	0	94	0	0
Heat pumps	0	0	0	8	8
Electric boilers	0	0	0	8	8
Chemical processes	0	1	0	5	0

Note: Data does not include heat production of industry for own use. Data are expected numbers for 2010.

Source: IEA (2011), Electricity Information 2011.

According to the progress reports of EU Member States, the share of renewable heating and cooling was 31% in Denmark in 2010. In Denmark 31%. In Finland and Sweden, the shares were 46 and 65% respectively. These data include the entire heating sector.

1.2 What are the different support mechanisms available?

Most countries provide support to renewable energy through two channels: direct subsidies and indirect subsidies.

Direct subsidies are basically deployment support in the form of direct support per unit of production. This support type is the most common measure to support renewable electricity production. Among European countries, there are mainly two different approaches to offer direct subsidies: 1) feed-in tariffs and 2) market based mechanisms such as tradable green certificates. The Nordic countries have chosen different schemes, as Denmark and Finland use feed-in tariffs, and Sweden and Norway use tradable green certificates. In addition to the support per unit of production, most countries also grant some form of investment support.

Indirect subsidies stem from the tax exemptions that renewable energy sources receive compared to their fossil fuel alternatives, which are subject to energy and/or CO₂ taxes. This support type is typically used to support renewable energy in heat production.

The structure of renewable energy support is illustrated in Figure 2. A production subsidy is granted both to RE-installations that produce electricity alone (such as a wind turbine) and to renewable energy that serves as input in electricity and/or heat production (such as co-firing with biomass in a coal CHP plant). This is illustrated with green arrows in Figure 2.

Fossil fuel inputs used for heat production are taxed with energy and/or CO₂ taxes in all Nordic countries except Iceland. As renewable energy sources used for heat production are exempt from these taxes, this constitutes an indirect subsidy to these sources. This is illustrated with a green arrow in Figure 2.

Figure 2. Structure of support to electricity and heat

Note: The green arrows illustrate subsidy elements.

Source: Copenhagen Economics.

Heat consumed from district heating has typically not been subject to tax at the consumer level. In Denmark, however, a newly adopted energy package introduces such a tax, cf. Box 1.

Fossil fuel inputs used for electricity production are not taxed;³ hence renewable energy inputs in electricity production in e.g. CHP plants do not receive indirect subsidies at national level. But the ETS system provides an indirect support depending on the price of ETS allowances. However, as electricity use is taxed at the consumer level, this constitutes an implicit subsidy to consumers who produce their own electricity from renewable energy sources. We will discuss this further in Chapter 2.

³ Instead, a tax is levied on the electricity consumers.

Box 1. Security of supply tax in Denmark

In March 2012 a new Energy Agreement was reached in Denmark. The Agreement contains a wide range of initiatives. As a response to expected reduction in the consumption of fossil fuels, government revenues from tax on coal, oil and gas will drop correspondingly. Consequently, a new tax (“forsyningsikkerhedsafgift”) has been introduced for heat at the consumer level, which is not the case in Denmark today. The tax applies to heat produced from all fuels—biomass and fossil. In 2020, the tax level is expected to be DKK 27.4 /GJ for biofuels and DKK 19.8/GJ for fossil fuels.

Source: Danish Energy Agency.

1.3 Direct subsidies

In the following we will describe Denmark and Finland’s use of feed-in tariffs, and Norway and Sweden’s use of tradable green certificates.

1.3.1 Feed-in tariffs

Even though Denmark and Finland use feed-in tariffs, there is still some variation with respect to the concrete design. One difference e.g. is that production subsidies in Denmark are financed “off-budget” through a tax on electricity consumers (resulting in a higher electricity bill), while in Finland the subsidies are more directly financed over the state budget. We will discuss this further in Chapter 2.

Denmark uses a combination of fixed feed-in tariffs and premium feed-in tariffs. Fixed feed-in tariffs are granted to offshore wind farms, solar and wave technologies, while premium feed-in tariffs are granted to onshore wind farms, biogas and biomass installations. The support element is relatively low for biomass, solar and wave, while especially biogas and offshore wind installations receive high support.

The fixed feed-in tariff to offshore wind varies from EUR cents 7–14/kWh, cf. Table 5. The tariff level is determined through a tendering procedure, which makes the tariff level more in line with actual market conditions. In addition, Denmark has recently decided that the current fixed premium tariff to onshore wind installations should be replaced with a “sliding premium” where the premium tariff is reduced when the electricity price exceeds a certain threshold.

Finland primarily uses a sliding premium feed-in tariff for wind, bio-gas, and wood used in small CHP plants. This differs from a fixed feed in tariff since the tariff compensates the difference between the target price and the average electricity spot price. Renewable producers receive a market price, which is not necessary the same that average spot price. Finland does not have direct production subsidies to solar and wave technologies. Wood chips are specifically subsidised with a premium feed-in tariff that moves oppositely of the ETS price, so when the ETS price is very low, the premium tariff is high.

Table 5. Feed-in tariffs in Denmark and Finland, 2012

	Technology	Type	Comment	Remuneration EUR cents/kWh	Support ele-ment* Length of EUR cents/ kWhsupport
Denmark	Onshore wind	Sliding premium	Subsidy is fixed at EUR cents 3.37/kWh for "low" power prices. When power price exceeds EUR cents 4.4 /kWh, the subsidy is reduced	3.4 (max) + power price	3.4 (max)
	Offshore wind	Fixed	Tendering procedure. Different tariffs for different offshore installations	7.0–14.2	2.1–9.3Maximum 20 years
	Biogas	Premium		4.9–5.6 + power price	4.9–5.6Unlimited support
	Biomass	Premium		2.0 + power price	2.0Unlimited support
	Solar and wave**	Fixed	Remuneration for power produced above own consumption	8.1 (5.4 after 10 years)	3.120 years
Finland	Wind	Sliding premium		8.4	3.412 years
	Biogas	Sliding premium		8.4 (13.4 if CHP)	3.4 (8.4)12 years
	Wood chip	Premium with ceiling	Subsidy moves oppositely of the ETS price. Subsidy is linearly reduced when ETS price exceeds EUR 10 / MWh.	Max 1.8	1.012 years
	Small CHP using wood	Sliding premium		10.4	5.412 years

Note: * For premium feed-in tariffs the support element is the tariff level. However, for fixed feed-in tariffs, the support element is the remuneration minus the electricity price, as the support element is reduces when the electricity price increases.

To calculate the support element, we have used the average electricity price in Denmark-2 and Finland for 2011 which are EUR cents 4.94/kWh and 4.93 EUR cents/kWh respectively.

Sources: ENS (2011), Energiforlig (2012) and Promoting policy for renewable energy in Finland (2012).

1.3.2 Green Certificates

Sweden and Norway has chosen to cooperate on meeting their renewable energy targets in a common green certificates scheme. In 2003 Sweden introduced the certificate scheme, and Norway joined in 2012. In this scheme, renewable energy producers receive a green certificate for each MWh electricity they produce from renewable energy sources. Oppositely, energy producers will need to buy and surrender green certificates corresponding to their energy consumption. In this way, a price is created, and renewable energy producers will be able to sell their certificates on the market and receive additional remuneration on top of the earnings from the electricity price. As it is a common scheme between Sweden and Norway, any certificates issued in Sweden may be surrendered in Norway and vice versa. This mechanism ensures that the renewable energy installations will be deployed where it is most cost efficient to do so, independent of whether the location is in Norway or Sweden.

In 2011, Sweden issued 19.8 million certificates to renewable energy electricity producers. As the average spot price of green certificates was EUR 20.7 per MWh the ex-ante value of support to renewable energy in 2011 amounts to EUR 410 million, cf. Table 6. The actual value of the support can be measured ex-post taking into account the spot price when the certificates are surrendered.

Table 6. Swedish Green certificate scheme

	Averages spot price 2011 EUR/MWh	Issued certificates (million)	Value of support (million EUR)	Length of support for a given installation
Wind	20.7	6.1	126	15 years
Hydro	20.7	2.7	56	
Bio	20.7	11.0	228	
Total	20.7	19.8	410	

Note: Information is used for Sweden 2011, as data is still limited for Norway.

Source: Svenska Kraftnät/CESAR.

1.3.3 Investment support

All Nordic countries also grant deployment support in the form of investment support programmes, cf. Table 7. This type of support is typically meant to address the gap between direct production subsidies and more long-term energy and climate research. The support is typically granted in the pre-deployment phase to undertake planning initiatives or to finance concrete investment cost.

Table 7. Investment support programmes

Country	Measure	Size
Denmark	EUDP and ForskVE programmes	EUR 85 million per year
Finland	Investment subsidy. Helping to commercialize new RE technologies	EUR 72.5 million per year from 2008–2011
Iceland	Financial support to individuals, industry and municipalities for geological/geothermal research and drilling for geothermal heat/hot water	50% of estimated costs for a project
Norway	- Helping new installations for district heating - Investment subsidy. For production of biogas - Support through Energifondet 2011	- EUR 23.5 million - EUR 18.8 million - EUR 162.9 million
Sweden	- Support for planning initiatives for wind power - Investment support for biogas and other renewables	- 3.34 million

Sources: Kemin (2011), Promoting policy for renewable energy in Finland (2012), Enova, NREAP Sweden, and Nordic authorities' answer to questionnaire.

1.4 Indirect subsidies

Fossil fuel inputs used in heat production are generally subject to energy and/or CO₂ taxes in the Nordic countries. This implies that renewable energy sources such as biomass and biogas, which are generally exempt of such taxes, are indirectly subsidies in heat production. The size of the subsidy depends on the actual tax rate of the alternative fossil fuel which it can be substituted for. For instance, the indirect subsidy to biogas is the tax rate levied on natural gas, while the subsidy to biomass is the tax rate levied on coal.

The tax on natural gas pr. unit of heat production varies according to whether it is produced in combination with electricity or not, and across countries, cf. Figure 3. Denmark, Sweden and, to a lesser extent, Finland levy a relatively high tax on pure heat production. Denmark, and to a lesser extent, Sweden also levies a tax on heat produced in CHP. Iceland does not tax fossil fuel input in heat production. Norway levies a relatively limited tax on natural gas in heat only.

Figure 3. Tax on natural gas for heat production

Note: Tax per output of heat. Iceland does not use natural gas for heat production.

* The Finnish tax rate is applicable in 2015.

** No data has been available.

In Finland CO₂ tax on plants within EU ETS are reduced by 50 pct. Here it is assumed that CHP plants are included in the EU ETS.

The tax rates are given in the appendix table.

Source: Law 527, Energy Taxation in Finland (2012), Prop. 1 LS (2012), and Nordic authorities' answer to questionnaire.

When we look at the tax rate on coal in heat production, a similar picture emerges. While Denmark levies the same taxes on coal and natural gas per unit of heat production, the other countries levy a higher tax on coal than natural gas. In Sweden e.g., the rate for pure heat production increases from 9.1 on natural gas to EUR 14.6/GJ on coal, mainly due to an increase in the CO₂ tax. Note that for Norway we have depicted the tax on oil, as there is no energy tax on coal.

Figure 4. Tax on coal for heat production

Note: Tax per output of heat. Iceland does not use natural gas for heat production.

* The Finnish tax rate is applicable in 2015.

** No data has been available.

*** For Norway the tax on oil has been used, as oil is more commonly used than coal.

In Finland CO₂ tax on plants within EU ETS are reduced by 50 pct. Here it is assumed that CHP plants are included in the EU ETS.

Source: Law 527, Energy Taxation in Finland (2012), Prop. 1 LS (2012), and Nordic authorities' answer to questionnaire.

The Nordic countries do not levy a tax on the inputs for electricity production. Instead inputs are “taxed” through the functioning of the ETS which obliges electricity producers to match their net purchase of ETS allowances with CO₂ emissions, raising their marginal production costs. Instead, electricity is taxed at the consumer level. The Nordic countries, including Iceland and Norway are subject to the EU energy taxation directive, which stipulates that the minimum excise duty on electricity should be EUR 1 and EUR 0.5 per MWh for non-business and business respectively. The Nordic countries have to a large extent adopted electricity taxes significantly larger than the minimum rates, especially for non-business use. Denmark for example levies a tax on non-business consumers and the service sector of EUR 108/MWh, and EUR 0.5/MWh for business use cf. Figure 5. The tax rate in Sweden and Finland is EUR 32 and EUR 17/MWh respectively for non-business use, and EUR 0.5 and EUR 7/MWh for business use. In Sweden energy-intensive industries have (since 2005) been exempt from the EU minimum tax if they have chosen to join the voluntary energy efficiency program PFE.

Figure 5. Tax on electricity consumption

Note: * The low rate for business use in Denmark is not applicable to most service-related sectors. These sectors face the same tax level as the non-business use.

Source: DG TAXUD (2012), Excise duty table, part 2: Energy products and electricity, Law 527.

1.5 Research and development in energy technologies

As all Nordic countries have ambitious climate targets, climate mitigation efforts are likely to increase going forward. This makes it economically very attractive to invest in driving down the future cost of mitigation. Denmark, Finland, Norway and Sweden all have budgets around EUR 142–160 million to research and development in low carbon measures, corresponding to 0.04–0.08% of GDP, cf. Table 8.

Table 8. Research funds to energy technologies, 2010

Million EUR	Denmark	Finland	Norway	Sweden
Solar energy	4	2	18	7
Wind energy	15	4	12	5
Ocean energy	2	0	1	9
Biofuels (incl. liquids, solids & biogases)	26	27	9	51
Geothermal energy	0	0	0	0
Hydroelectricity	0	1	2	1
Other renewable energy sources	0	4	0	1
Total renewable energy sources	48	38	43	73

Table 8a. Research funds to energy technologies, 2010

Million EUR	Denmark	Finland	Norway	Sweden
Total budget for low carbon measures	142	159	153	160
As % of GDP	0.06	0.08	0.04	0.04

Source: www.oecd-ilibrary.org, IEA Energy Technology R&D Statistics.

1.6 Overall picture of expenditure on renewable energy support

Due to the lack of comparable official sources, it is difficult to construct a full-fledged overall picture that compares between the Nordic countries. Based on our analysis we find that there is a tendency to spend more money on subsidising deployment of renewable energy technologies which will reduce current GHG emissions than spending money on research, innovation and development that will lower the cost of bringing reducing GHG emissions in the future, cf. Table 9. This picture becomes clearer when the subsidies through tax exemptions are also accounted for. It has not been possible to construct an overall estimate of the value of tax exemptions in the Nordic countries.

Table 9. Overall picture

Million EUR	Subsidies	Research and development	Value of tax exemptions	Total support	Support (EUR) per MWh	MWh per support (EUR)
Denmark	351	142	Minimum 30*	EUR 493 million	18.86	0.05
Finland	120	159	-	EUR 279 million	6.57	0.15
Iceland	-	0	-			
Norway	-	153	-	EUR 153 million	1.20	0.84
Sweden	410	160	-	EUR 570 million	4.87	0.21

Note: * Tax exemption only for household use of solar panels. The total value of tax exemptions is much higher as it also covers e.g. exemption from CO₂ and energy tax in heating production.

Source: ENS (2012), NREAP Finland, the Nordic authorities' answer to questionnaire, Kraka (2012) and IEA Energy Technology R&D Statistics IEA.

2. Success criteria for a renewable energy policy

Before discussing specific instruments and targets for renewable policies and instruments, we will recap the central *objectives* behind EU and member states energy policies that can motivate specific action to promote renewable energy. This is required to develop clear success criteria for such policies.

The first objective is to deal with *climate change* that requires a massive reduction in GHG emissions over time, particularly energy related CO₂ emissions.

The second objective is directly linked to *energy security*. It is typically subdivided into at least two sub issues. *Strategic energy security* is about reducing the dependency of imports of fossil fuels from what is commonly projected to be an ever decreasing group of producers, located in potentially unstable regions of the world.⁴ *System energy security* is about ensuring the constant availability of access to energy in real time, preventing power outages etc. This is particularly relevant for power generation.

The third objective is *cost efficiency*. We should put in place a policy mix that meets these two objectives in a cost effective manner. This criterion has a number of implications. First, it implies cost effective over time: net benefits of reducing emissions today should equal net benefits of reducing emissions tomorrow. This has implications across a wide range of issues such as:

⁴ The high oil and gas prices in recent years have encouraged successful development of oil and gas resources in relatively “friendly” regions earlier considered to be too difficult to extract for technological and economic reasons. The upshot is that the energy security perspective should probably be downplayed and the climate part takes a more prominent place as upward pressure on the prices of fossil fuels will be reduced as more supply surfaces in coming decades.

- The profile of abatement over time for a given climate change objective.
- The scope to use technology policies to push down future abatement costs which does also have implications for abatement profiles for a given.
- The use of flexible instruments that can potentially exploit lower cost abatement projects in other jurisdictions.
- Proper evaluation of leakage:–high(er) domestic carbon prices may move emissions to countries with less stringent emission policies which may impact on the net costs associated with worldwide abatement.⁵

All these three objectives have *implications*. Reducing energy related CO₂ emissions requires *low carbon solutions* to energy production in the form of *energy savings*, deployment of (close to) zero carbon technologies such as Carbon Capture and Storage (CCS), *atomic power* and *renewable energy* such as wind power, biomass etc.

The objective concerning energy security may also be attained by low carbon solutions (which lead to less import of fossil fuels). From a broader perspective, it requires a more general shift towards the use of primary energy sources, produced “at home”, or at the very least, in stable and friendly regions. When energy technologies are ranked in this way, most renewable energy technologies come out top while coal is better than gas and gas is better than oil. The relation between objectives, implications, and technologies is illustrated in Figure 6.

⁵ Copenhagen Economics(2012b).

Figure 6. Objectives and implications in EUs climate and energy policies

Source: Copenhagen Economics.

The challenge is to convert these central objectives into specific and meaningful policy targets. In climate change, policy targets are, at least on paper, relatively straightforward: the central driving force in climate change is the level of accumulated greenhouse gas emissions. We therefore need a path for emissions reductions that is both consistent with long-term requirements and is economically efficient (more about that below). The objective concerning energy security is substantially more difficult to operationalize: what is actually meant by being independent and what is the willingness to pay for less dependency? Due to these inherent difficulties, we would propose a pragmatic strategy where *climate change* is the primary driver of policies while *energy security* is the secondary. One possibility would be to rank solutions that achieve the same emission reduction according to their achievements in terms of energy security. IEA has in earlier work made a heroic attempt to establish such indicators.⁶

⁶ IEA (2007).

It is much more difficult to set rational and firm targets for *energy savings* and *deployment of low carbon technologies*. Essentially these are competing solutions to the same problem and the proper mix should be based on cost-efficiency. Moreover, it is highly unlikely that policy makers, in advance, can design a mutually consistent mix of targets that are also cost efficient 10 to 20 years down the road. We may be able to guess the generation costs of renewable energy in 10 years' time by orders of magnitude and compare it to our estimates of marginal costs of energy savings, but any ex ante estimates are unlikely to match reality by 2050.

In the subsequent parts of this chapter, our analytical approach to define an efficient support strategy for renewable energy will be built around the following logic. In the section 2.1 we try to answer the question of how a long-term cost efficient strategy to deal with climate and energy security challenges should be designed and what this imply for renewable energy policies. In section 2.2 we move on to the question of the optimal mix between carbon/energy taxes and technology policies to develop new low carbon technologies such as renewable energy. In section 2.3, we dig deeper into the issue of technology policy by discussing how efficient support schemes for technology policies should look like. To what extent should focus of support for innovation be linked to natural endowments and comparative advantage in research and industrial fields? Section 2.4 focuses on the interaction between renewable energy, energy security and climate policies. We ask the question how specific renewable energy policies can help achieve strategic energy security. In the last section, 2.5, we discuss policy options on different levels. What could and should Nordic country do at the regional/national level to deliver on objectives as opposed to EU level and wider agreed policy instruments?

2.1 A long-term cost effective strategy

Given that both energy savings and deployment of renewable energy can deliver on the objectives of climate policy and energy security, what is then the cost effective mix of the ingredients?

The short answer is that it depends both on two key issues:

1. The shape of the abatement curves for low carbon technology solutions now and over time.
2. Stringency of policy targets over time.

All available evidence suggest that over the coming decade, energy savings plus highly mature renewable energy technologies are by far the lowest cost option to realise policy objectives. This idea is encapsulated in the (in)famous abatement curve from McKinsey that shows that a wide range of energy savings technologies have low or even negative costs of deployment, cf. Figure 7. Especially energy efficiency renovations in buildings seem to have the highest benefits (negative costs) related to reducing CO₂ emissions. If this potential in fact exists, it suggests that there are serious barriers preventing the private sector from reaping these benefits. Several studies suggest that removing especially regulatory barriers such as energy consumption subsidies and restrictive rent regulation can play a role in realising the potential.⁷

Figure 7. Carbon mitigation cost curve

Source: McKinsey (2010).

Looking more narrowly at power generation linked to the EUs emission trading system, it is also clear that with the current levels of ambition for the ETS very little if any of even the most mature renewable energy

⁷ See Copenhagen Economics (2012a) for an overview.

sources are economically viable. The basic fact is the ETS allowance price is extremely low and well below expectations when the Energy and Climate package was adopted in 2009. Even substantially higher targets for 2020 such as 30 or 35%, would at best only re-establish grid parity for some well-placed onshore wind power installations.

Figure 8 Stylised supply curve for renewable energy

Note: The EU RES target in 2020 is app. 1070 TWh.

Source: OpenEI (open energy information), Pöyry (2008) and Copenhagen Economics calculations.

It thus seems safe to say that market based carbon and energy tax policies would be fully sufficient to deliver on energy policies in a near term perspective leaving little need for supporting renewable energy per se. Indeed, the potential of carbon pricing to drive energy saving and long-term innovation may tend to be overlooked. A recent study from Copenhagen Economics, pointed out that long-term effects on energy demand from energy taxes are 3–4 terms larger than short term effects while often applied international/national models typically have much lower effects.⁸

One caveat we will note in relation to the power generation is that carbon pricing as an instrument to drive deployment and innovation of re-

⁸ Copenhagen Economics (2011), "Green innovation and energy taxes," a study for EU Commission (DG TAXUD).

newable energy suffers from an unequal balance between mitigation targets inside and outside the ETS sector. The non-ETS sector in the EU and particularly in the Nordic area, face much higher carbon taxes, per ton of carbon than the ETS sector, cf. Figure 9. In fact EU and its member countries could reap substantial economic benefits from shifting mitigation into the ETS sector. The consequence in terms of higher allowance prices would substantially reduce the need to subsidise renewable energy by national subsidy schemes, to reach renewable energy targets and provide a more stable long-term investment framework.

Figure 9. Carbon prices inside and outside the ETS sector

Note: The prices are calculated based on the six largest countries Germany, France, UK, Italy, Spain and Poland, and Sweden, Norway and Finland. The carbon prices are weighted by GDP shares for the 9 countries.

Source: Copenhagen Economics, EIC, www.ecx.eu.

The real argument for focusing on renewable energy per se is the increasing stringency of climate abatement targets over time. Indeed, all large projections of carbon policies shows that over time the role of low carbon technologies (CCS, wind, biomass etc.) will take a still larger role in reducing the use of fossil based technologies. This also makes economic sense: relying on energy savings alone to achieve such a massive reduction would lead to steadily welfare losses: the larger the required reduction, the larger the welfare loss. We discuss this below in our discussion on the benefits of direct technology policies that go beyond market based instruments such carbon taxes, EUs emission trading system etc.

2.2 Mixing carbon pricing and direct technology policies

In this section we address the so called different roles economic theory attaches to environmental taxation and R&D support with a focus on two issues:

- The dual externality problem.
- The long-term credibility issue.

Dual externalities: environmental damage and knowledge creation

Environmental taxes can help address a negative environmental externality. If the social costs of an activity exceed the private costs, governments should impose a tax on the activity so that private actors actually pay the true costs of the activity. This is the first externality, which is negative.

However, imposing a tax on emissions will not address the traditional issue of technology spill-overs. A new innovation may create positive spill-overs to other firms and the rest of the economy since innovations can be improved, standardized and create the basis for new technology classes. But these positive effects, which may exceed the direct profit creating effects to the company by several factors, are not fully appropriated by the company financing the research. Thus, the investments in company R&D are not sufficient when compared to the societal gains they create. In other words, we again see a missing

price (payment in this case) for the effects created by an economic activity, R&D.⁹ This is the second externality, which is positive.

More importantly, the ambitious long-term goals requiring a drastic reduction of emissions provides a case for much higher levels of support for innovation in low carbon technologies.¹⁰ The higher the required reduction in emissions, the higher is the value to society of innovations that can replace high carbon emission energy technology. Indeed, in the absence of such innovations, the increase in carbon taxes—or other instruments—to deliver on targets would have to be higher. This would require a higher level of reductions in the activity that cause the energy use, for example transport. The larger the reduction in that activity, the larger the welfare loss will be. Indeed, the size of the welfare loss is not proportional to the change in activity, it is much higher. Using conventional estimates, the second unit of required reduction in activity, would lead to a significantly higher welfare loss than the first unit of reduction, see example in box Box 2. This implies that the value to society of low carbon technologies is rapidly increasing in value to society as policy stringency, and hence carbon prices, goes up.

Furthermore, while the value to society of innovation rises exponentially with the level of target reductions, the markets' ability to deliver such innovation unaided falls with the level of ambition. Firms' incentives to innovate will go up by higher carbon prices/energy taxes and as suggested above, that should be a key driver. But price driven innovation primarily works for incremental research and innovation that improves and expand existing technologies: they are of relatively less help to provide bridges to fundamentally new types of technologies that are far from market maturity. We explore this issue in more detail in our review of efficient support instruments for renewable energy (2.4).

⁹ "All private sector innovation suffers from market failures. These are even more acute in the case of climate change, as environmental market failures compound the problem. Thus, policy plays a key role in shaping both the direction and magnitude of climate-friendly technological change," Popp (2010). The standard measure to address these market imperfections is by granting patents for innovation, but this may often work rather inefficiently in many industrial sectors and the energy sector. It is typically hard to identify engineering patents in ways that cannot be circumvented over time. Industrial processes consist of a large set of components and require the expertise of several companies to improve them. For this reason public R&D may play a particularly important role in climate policy.

¹⁰ Hart (2008).

Box 2 Stringency of policy targets, welfare losses and derived value of innovations: an example

To understand the potential welfare losses from climate policies that require us to save on energy or find new energy source, it is important to understand that energy use is a derived demand from a “front” activity. It is the fall in that front activity which causes welfare losses; not lower energy use per se. Road transport is as a good example. I do not get more satisfaction because my car burns more petrol nor from it using less: consumption is the pleasure of driving the car and the ability to use it for travelling from one place to the next along with friends and family.

The basic idea is then that a higher carbon/energy tax makes driving cars more costly which leads to a reduction in travel use and purchase of cars. This is indeed what is intended, but it also infers a loss on consumers and society. From an overall policy perspective the key is that the costs to society from forcing consumers to change their behaviour are offset by gains from avoiding climate change etc.

The direct loss to consumers from an increase in the energy tax rate is then related to the change in the economic activity that causes the use of energy; here road transportation. This is illustrated in panel A below. An increase in the carbon tax from 5 to 6 results in a reduction in transport activity corresponding to distance between 11 and 10. This implies a loss to consumers that can be approximated by the area A in the diagram (namely the price increase multiplied by the reduction in the economic activity divided by 2).^{*} A further increase in the price from 6 to 7 leads to a further reduction in the transport activities from 10 to 9. The total consumer loss is now equal to the sum of the two areas A and B. Note that the area B is significantly larger than A, implying that the subsequent price increase infers a larger welfare loss than the first. The same applies to each subsequent equal sized price increase: the *additional* welfare loss increases for each step.

Panel A

This is illustrated in the panel B where the curve showing the total consumer loss slopes upwards with the size of carbon price. This is by definition equal to the welfare gains that can be achieved by gaining technological changes that can help avoid leading to the behavioural changes that cause the welfare losses.

Panel B

The basic conclusions are that the larger the required change of behaviour, the larger the welfare loss will be. Hence the value for society of new technologies that can avoid particularly drastic changes in behaviour increases exponentially with the stringency of policy targets.

To the extent that new technologies are financed by tax payers, the net welfare calculation should compare increased welfare resulting from avoided reductions in energy intensive consumers services and products with higher welfare costs from the distorting results of higher taxation (marginal costs of public funds).

Source: Copenhagen Economics.

*According to according to Variance rule of half.

2.2.1 The long-term credibility problem

R&D is a risky investment that, when yielding new profit opportunities for private companies, will pay off in a distant future. Cost-benefit analyses of various research projects must therefore include the risk that pollution prices are not predictable far in the future.¹¹ Since many research projects in green technologies can move from profitable to not-profitable for small variations in carbon prices, it is extremely important that long-term tax policies are well-defined, credible, and can demonstrate a high degree of continuity over time.

This is particularly relevant for power generation. Lead time from R&D to introduction of products is long, while the life time of assets is measured in decades rather than years. So decisions now to invest in R&D as well as deploying new installations are based on revenue calculations, which include policy effects decades ahead.

The literature has recognised that it is the expectations of future policies that motivate R&D, and that emission caps put in place before innovations resulting from R&D can be deployed have no effect as incentives.¹² Indeed, the literature emphasises the “announcement effect” of future carbon limits.¹³

In the case of emission prices, studies point to the large uncertainty attached to future commitments and allocation of allowances.¹⁴ The literature suggests that high volatility in prices of CO₂ considerably reduce willingness to make early investments in low carbon power generation and carbon and capture storage (CCS) technologies.¹⁵ Such volatility significantly increases investment risk and cost of capital which makes it profitable to postpone investments. So, CO₂ price volatility may hamper the investments that climate policy is attempting to encourage. Uncertainty in climate policy contributes to volatile CO₂ prices and therefore long-term policy certainty is vital to minimise investment risks in low carbon technologies.

The example of carbon prices, therefore, fits quite well with the notion of dynamic inconsistency.¹⁶ Carbon prices will need to be high to create additional R&D investment possibilities, but even if the policy makers announce

¹¹ Baker and Adu-Bonnah (2008).

¹² Yang *et al.* (2008).

¹³ Montgomery (1972), Montgomery and Smith (2007).

¹⁴ DEFRA (2008).

¹⁵ Blyth *et al.* (2007), Celebi and Graves (2009), Weber and Swider (2004).

¹⁶ Montgomery and Smith (2007).

future emission levels that create such an incentive, the government will prefer reneging on this level once the technology is developed.

To sum up, according to the above discussion, the two main ingredients in defining the efficient policy mix are the respective externalities from knowledge and from pollution which need to be defined in a long-term perspective. The literature seems to suggest that pollution externalities are larger than knowledge externalities.¹⁷ Indeed, while all such calculations are very sensitive to parameter assumptions as well as the policy goals, a number of recent empirical studies confirm the primacy of taxation and equivalent instruments in reaching long-term climate and energy policy goals, while also underlining the very useful role that direct R&D support policies can deliver.¹⁸ See Box 3 for a discussion of this.

Moreover, due to the long-term nature of investments in the area of power generation, it is highly desirable that policy instruments have a high level of credibility.

Complementarity of carbon price and technology policies. Well targeted R&D policies focused on solving research externalities still need to be backed up by continued strong carbon pricing by way of taxes and/or cap-and-trade systems. There are three basic arguments:

First, public R&D support to increase the energy efficiency of fossil fuel technologies will lead to more energy efficient cars on the roads, but also to lower costs of driving. Recent research from Germany suggests that up to 60% of the energy savings from more energy efficient cars are transformed into consumers driving longer distances and/or buying cars with more performance, a pattern often referred to as *the rebound effect*.¹⁹

Secondly, for end-of-pipe technologies such as Carbon Capture and Storage power plants based on fossil fuels, the benefits are exclusively CO₂-savings, while the output–electricity–is exactly the same as for traditional fossil based power plants. So these plants will never be deployed unless they receive a premium when selling electricity: despite up-front subsidies total costs per unit sold will exceed traditional power plants. It is the role of carbon pricing to deliver this premium.

¹⁷ Popp (2006), Fisher (2008).

¹⁸ Popp (2010).

¹⁹ Copenhagen Economics (2010).

Thirdly, R&D policies supporting renewable energy may well lead to a reduction in demand for fossil fuel, but that will at the same time lead to a reduction of crude oil, coal and gas prices on a global scale, triggering higher second round demand for such fossil fuels. The only real response possible is higher carbon taxes at a global level including in the EU.

Box 3 Relative importance of carbon pricing and technology policies in climate policies

An OECD study suggests that carbon pricing consistent with ambitious 2050 global goals could induce a “four-fold” increase in energy R&D expenditure while public R&D policies could most productively be focused on “major” technological breakthroughs rather than marginal innovations.*

An EU study suggests that, in addition to much higher carbon prices, substantially frontloaded R&D support is needed to adjust to ambitious long-term climate goals.** Other subsidy mechanisms are also investigated, but the combination of tightening emissions-caps (rising carbon prices) and up-front R&D support for green technologies yields the most favourable economic outcome. The study also concludes, similar to our previous findings, that R&D support must not favour green technologies in the long run and therefore suggests a phasing out of R&D support for green technologies by spreading it to all sectors of the economy. The results are based on a forward-looking, general equilibrium model of the European economy where R&D and innovation is specifically modelled.

A study focusing on US compliance with climate policy objectives finds that carbon taxes alone achieves 95% of the welfare gains compared to the first-best case of both an optimally-designed carbon tax (one equating the marginal benefits of carbon reductions with the marginal costs of such reductions) and optimally designed R&D subsidies. By contrast, working with an optimal R&D subsidy alone attains just 11% of the welfare gains.

A study on climate policies directed at the US electricity sector finds that the ranking of potential policy instruments is roughly as follows: (1) emissions price/tax, (2) emissions performance standard, (3) fossil power tax, (4) renewables share requirement, (5) renewables subsidy, and (6) R&D subsidy. Nonetheless, an optimal portfolio of policies—including emissions pricing and R&D—achieves emission reductions at significantly lower costs than any single policy.

* Bosetti *et al.* (2009).

** DG ECFIN (2010).

2.3 Fitting policy intervention to maturity of technology

The preceding two sections, have demonstrated the following points:

- For the coming decade, with only a few mature renewable energy installations being viable, *energy savings* is the low cost option to deliver on both targets, emission savings and energy security.
- In a long-term perspective, the benefits to society of *new low carbon technologies* will increasingly rise as “an energy savings only” strategy will impose far too high welfare costs on society.
- There is a clear case for *support for new technologies* to deliver on climate and energy security objectives: carbon pricing cannot do it alone: substantial market failures from technology spill-overs, particular for immature but promising technology, will hold back private funding.
- Given the long-term nature of investments in power generation and a substantial gap between the economic viability of fossil based and non-fossil power and heat generation over the coming years, the *credibility of public support mechanism*—carbon pricing as well as specific support for low carbon technologies—are of extreme importance.

So how should these learning points be translated into more specific recommendations for more direct technology policies that go beyond credible carbon pricing policies?

A good way of shaping the discussion is to look at the standard innovation cycle from the initiation of R&D to final products that are sufficiently viable to penetrate the market with an appropriate level of carbon pricing, cf. Figure 10. The figure shows a standard innovation cycle from the initiation of R&D to final products that are sufficiently economically viable to penetrate the relevant market.

Figure 10. Policy instruments during the innovation cycle

Source: Copenhagen Economics based on IEA (2008).

In the idea stage, leading up to the patenting point, where researchers develop conceptual descriptions of new green technologies. At this stage uncertainty about the prospects of the technology as well as its usefulness across a number of application fields is at the maximum level. Estimates of future generation cost are typically provided with huge uncertainty.

Ingredients in an optimal policy approach are

- A high level of public to private funding.
- Open access to results i.e. close to free dissemination of results.
- Collaboration between industry partners and government.
- Cross-border/international funding to ensure critical mass in early research as well as inclusion of best research institutions.
- Results from public funding in terms of patents etc. to be owned proportionally by financial backers (the government).

The next phase concerns *prototype development*. After this stage, the technologies are largely classified by their cost-effectiveness compared to current market technologies. Some innovations may climb up the ladder rather quickly while others require longer development times, e.g. due to complementarities with other technologies.

Ingredients in an optimal policy approach are

- Support to prototype and demonstration projects. Access to results from such projects to third parties: dissemination of results speeds up innovation.

Then we come to the *deployment phase* in somewhat larger scale. For technologies where learning effects can be substantial while costs are still far too high to be priced in by carbon pricing, production well beyond prototype/demonstration size can be useful. The purpose of such production is then not so much the displacement of CO₂ per se as it is pushing down generation costs by accelerating technology progress i.e. the standard concept here is “learning costs” or rather “learning gains.” Solar PV and off shore wind are typically classed in this category.

Ingredients in an optimal policy approach are

- Fixed support levels (for example fixed feed in tariffs) but capped in overall level.
- Progressive reduction of support levels to reflect required improvements in inefficiency.

Finally, the most mature renewable energy technologies with generation costs (very) close to gas and coal based sources can be supported by so-called renewable energy mandates. Such mandates set specific targets for the level of renewable production—typically as a share of production—for the mature technologies covered by the scheme. At present that includes first generation bio mass technologies and on-shore wind in good locations. All technologies receive the same compensation level. The support level per unit of production is essentially determined by three parameters, 1) the ambition of the mandate i.e. the targeted share of production, 2) the marginal price of coal/gas based power, and 3) the marginal costs of renewable energy sources needed to reach the target for the technologies included in the scheme.

Several policy purposes might support the use of such schemes. It provides investors in mature renewable energy with some certainty that overall remuneration over the periods covered by scheme will be sufficient to cover investments and generation costs for the volume of investments covered by the scheme. Reductions in generation costs of fossil fuel based alternatives and price of ETS allowances will lead to corresponding rises in the price of allowances and vice versa. This feature is particularly relevant if a certain amount of renewable energy in the energy system is seen as being good per se and/or mandated by international obligations and can help drive innovation for such mature technologies.

2.4 Overall mix of instruments and potential trade offs

The description above provides a roadmap that fit the instruments to level of market maturity which is commonly accepted.

However, when framing the overall design of instruments, policy makers will face a number of challenges and potential trade-offs between equally desirable objectives. In this section we will focus on four main policy challenges often referred to in studies:

- How to spur competition between technology solutions while at the same time addressing the “picking the winners” problem?
- How to avoid that generators of energy are “overcompensated” relative to the costs they face?
- What are the net benefits from pushing massively deployment of renewable energy to reduce future costs of generation (the learning cost argument)?
- What should be the appropriate mix of the policy instruments?

Rather than answering these questions one-by-one, it is useful to go back into the “fit to maturity” diagram and see how that can be applied in practice in a manner that addresses the implicit concerns in the questions above.

At a very early stage, various basic research ideas will often compete with each other. Essentially, the choice between *competing* research projects should be based on standard selection criteria for basic research projects. The counterpart for research funding is open access to results as described above. This implies that issues of *overcompensation* do not arise, as society is compensated by the spill-overs from the technological improvements.

At the next stage, support is typically provided for demonstration projects that help inventors—public and private—to move ideas from laboratories to the test field. At this stage, commercial interests start to appear. An appropriate strategy is to have a fixed pool of funding that investors can apply for. Given the more advanced stage of the technology, it may at this stage be appropriate to set specific and conditional performance standard as a counterpart to funding, see box on technology prizes below. This will deal with the inherent information asymmetry between investors and funders in terms of the given level of funding that is required to deliver a given level of progress in a given technology. Given the relative high level of funding, a natural counterpart might be open access to results and shared right to intellectual property rights between public and private partners.

Box 4 Fostering competition in innovation by technology prizes

The use of “inducement prizes” to reward successful innovation particularly in applied science has a long history and has experienced resurgence in recent years. Prizes have a number of features that make them a potentially useful R&D policy tools:

- Unlike subsidies and grants, they address governments’ lack of information about the likely returns to R&D by shifting the risk of failure to researchers.
- They entail low administrative barriers to entry and only limited risks lobbying by private interests.
- Prizes could increase R&D spending at a lower cost to the government than subsidies and grants, and would even be temporarily costless as they are only paid in case of success. Compared with patents, prizes are potentially less distortive, provided the social value of the invention is certain and the distortions associated with prize financing are smaller than the welfare loss from monopoly power under patents.
- They could help alleviate the political uncertainty surrounding future carbon prices and the potential lack of credibility of IPRs, both of which undermine R&D incentives.
- Unlike domestic R&D policy instruments, international prizes would pool risks and rewards across countries.

Crucial issues of design of prizes:

- Policymakers can enhance the credibility of their commitment by setting the funds aside, or by purchasing an insurance policy that secures prize payment in case of success.
- In order to minimise judicial uncertainty, the winning conditions need to be defined precisely. This may imply that insufficient attention is being attached to difficult to measure but still important trade-offs. An example being that enhanced fuel efficiency might be reached at the cost of impaired functionality and value to the end customer: getting a BMW 300 series do run more per litre is no art if you simple downsize the motor: the trick is to keep horsepower performance unchanged while consuming less gasoline! But often the trade-offs are much less easy to define and hence include in winning criteria.

Source: Based on OECD (2012), page 173.

Then comes the potential third stage. This part is particularly relevant for highly capital intensive investments where there are strong priory arguments that actual deployment in larger volumes will be instrumental in driving down generation costs. The litmus test is whether potentially high deployment costs are justified by progress in technol-

ogy. Overall costs can be high because of substantial subsidy rates while the level of deployment required to get the needed learning in industrial process can be considerable

International reviews suggest that private sector financing is particularly difficult if moving towards demonstration and commercialisation projects is capital intensive and with high technology risks cf. Figure 11 (see sources below figure). Thus such projects are likely to fall into the so-called “hard to fund” “valley of death” in the absence of government support.

Figure 11. The “Valley of Death”: Technologies with high capital intensity and technology risks

Source: Gosh and Nanda (2010), Venture Capital Investment in the Clean Energy Sector as summarised in OECD(2012), “Fostering Innovation for Green Growth.”

Finally we would highlight that innovation support should first of all foster a more broad enabling technology in line with more general innovation policy lessons. Targeted support to narrow fields of innovation or technologies runs the risks of attempting to “pick the winners.”²⁰

To ensure a balance between gains from increased efficiency in industrial processes and overall costs, we recommend that an overall cap on deployment for the technology is imposed. The basic arguments are the following: Marginal gains from additional deployment of a given vintage of technology are rapidly falling. Furthermore, most studies suggest that it is the combination of continuous (private and public) research and development spending that in conjunction drives down costs.²¹

While the progress in the deployment of solar cellar in Germany has occasionally been hailed as a good example of how technology progress led by feed-in tariffs can led to successful innovation and job creation, we suggest that it provides a good case for being cautious with open support programmes with no cap on overall spending: the costs of the programme has been in excess of EUR 50 billion while displacement of fossil fuels have been limited and at very high implicit shadow prices of carbon cf. Box 5.

²⁰ OECD (2012), “Fostering Innovation for Green Growth,” for example page 12 executive summary and page 47.

²¹ See for example OECD (2012), “The economics of climate change mitigation.”

Box 5 The German solar cell experiment

Solar panels provide a good example of how rapidly market positions can change globally and how risky it can be to build long-lasting competitive advantages through subsidies for technology deployment in a local market. Germany has created a solar industry through very high subsidies over a period of ten years. As a result, Germany today provides nearly half of the total installed global solar power capacity. However, their global market share of solar power production has dropped below 10% and falling with Taiwan and China providing more than half of global production as they are able to sell at lower prices in important new markets such as the United States and China itself. The total production value of solar panels in Germany is actually in decline in spite of a growing global market cf. Figure 12.

In effect, German electricity consumers have, through higher electricity prices, paid for the development of a relatively efficient Chinese solar industry which delivers products at a lower price than the German one. The massive increase in Chinese production has basically been created through exports to e.g. Germany, Spain and the United States with a very limited amount of production to the domestic market until now.

The environmental benefits have so far been limited compared to the costs. In total, German electricity consumers are expected to pay an estimated EUR 100 billion for the relatively limited amount of abated CO₂ resulting from installations between 2000 and 2011. German electricity consumers pay about EUR 716 for every ton of abated CO₂ approximately 30–40 times the ETS quota price.*

* RWI (2009) and RWI (2012).

Figure 12 Indicators for German solar cell industry

Source: Eurostat, Comext, Prodcom and EWEA.

Electricity mandate schemes—equivalent to the use of Green Certificate schemes in Norway and Sweden—are generally recognised to be the most efficient instruments, at least on paper, to deliver the most cost-effective delivery for a given target production. That is of particular interest in the context of EUs targets of renewable energy which requires a massive increase in production of renewable energy. In other words, electricity mandates are useful when the policy target is to promote the deployment of renewable energy per se at the lowest costs.

Such mandate schemes are however also faced with criticisms. The main arguments are the following:

- They fail to drive innovation of more immature technologies.
- They may lead to overcompensation of technologies with generation costs below the marginal installation setting the price in the mandate scheme.
- They may increase uncertainty about future support levels and thus increase investments risk thus making generation costs higher relative to support instruments with fixed support like fixed feed-in systems.
- They may be difficult to operate by just one smaller country, co-operation of groups of countries are required to provide the sufficient stability, credibility and liquidity required.

That innovation in far-from-mature technologies cannot be driven by electricity mandates is clear. Indeed the whole idea of such schemes is to boost mature technologies only. The appropriate answer to that criticism is to underline that a broad palette of instruments is needed to underpin innovation with instruments fitted to maturity of technologies as described above.

The issue of *overcompensation* has attracted substantial attention and, in our view, unduly so for a number of reasons:

First, the range of technology included in a green certificate scheme should be mature and their costs of generation at a relatively comparable level. The whole point of the competition within the scheme is to let the market drive the choice of technologies with support levels which provides a relatively modest mark up on the power market price. So provided that overall renewable targets are set at meaningful levels—i.e. not forcing deployment of highly expensive and not yet mature technologies—the problem of overcompensation to the most cost effective instruments could be kept to a low level.

Second, there may well be types of renewable energy with very low generation costs on average which would receive very high and overcompensating support when included in the scheme. But that is not a very relevant point. Any policy that punishes production of fossil based energy by increasing their production tends to push up power market prices, benefiting all zero/low carbon production sources. Yet, that does not call for differentiated carbon taxes targeted separately for each technology. In the Nordic area the prime winner from higher carbon taxes—as well as inclusion in green certificate schemes—is hydro power. Essentially, the owners of hydro power will see increased resource rents as the power price goes up. The proper way to deal with this “problem” is to make a distinction between the marginal incentive to produce/invest *and* the average remuneration to a particular source of technology or even a particular existing installation like a hydro power plant. This can be done by taxing away any well identified resource rents while making sure that marginal investment incentives are set at the same levels as other renewable producers in the mature end of the technology scale.

The uncertainty argument needs to be seen in a somewhat broader picture. A fixed feed-in support system can provide a very high level of certainty that a given project in a given year, will receive sufficient income over its life time to make it viable for the investor. But it does not provide safety about the future viability of that technology. Over the next decades, subsidies for each technology are subject to specific negotia-

tions; the outcome of which may be difficult to predict. Finally, more certainty for some players in the energy market such as RES producers may have to be paid for by more uncertainty for others such as producers of traditional energy sources. Increased uncertainty could be reflected in higher power prices and less investments for example in clean coal technologies. A prime example is fixed feed-in tariffs and priority access for wind energy that leads to more volatility in power markets as described above. This has in turn led to demand for capacity payments to keep such stable power producers in place: payments likely to be paid by electricity consumers by way of surcharges on electricity bills.²² Providing safety for certain investors is very seldom a “free lunch” for society as a whole.

Indeed we would argue that both an electricity mandate scheme and feed in systems can be constructed so as to provide a high level of investor confidence. Based upon a recent study, we have summarised the key requirements in Box 6.

²² Both France and Great Britain have already introduced such capacity payment systems which in turn also challenge the internal market as they affect the location of electricity production and exports/imports of power.

Box 6 Investor confidence in electricity mandate and feed in systems

Support mechanisms basically have three main characteristics: 1) Is the supported period long enough? 2) Is the support level high enough? 3) Is the support period and level going to be changed? Each of these characteristics affects investors' perception of risk and thereby the investment premium they require. A good policy mechanism must address all three characteristics, and can be summarised as fulfilling the "three L's": long, loud, and legal*.

When investors evaluate support mechanisms, two overall considerations are taken into account: 1) conditions making a deployed installation profitable and 2) conditions that ensure investors that a future installation will be profitable at the time of deployment. Different support mechanisms may affect these two considerations differently. Basically, it is a question of whether the mechanism is transparent and credible. A transparent mechanism makes it easier to predict the revenue flows of a concrete installation. A credible mechanism makes it easier to trust that an installation in the pipeline will receive the expected remuneration.

All three types of support mechanisms can be tweaked in order to boost the "long" and "legal" criteria. In the following we evaluate the support mechanisms according to the elements relevant for both deployed installations and future deployment of installations.

Table 10. Important features to minimise risk perception

Risk element	Fixed feed in tariff	Premium feed in tariff	Tradable green certificates
Deployed installation			
High up-front capital cost	Support period should cover a substantial period of the project's lifetime		Policy period should be sufficiently long. Certificates should be bankable
Transparency of remuneration (exposure to volatile power market prices)	No exposure to price volatility	Full exposure in case of no price floors and ceilings. Price floors will reduce investors' risk by transferring it to the public	Exposure to short term volatility in power market price. However, the TGC price will move in opposite direction of structural power market fluctuations, thus offering a hedge Obligation to surrender certificates should be predictable, and adjustments should be based on transparent criteria in order to secure a stable TGC price
Future deployment of installations			
Long-term certainty about demand for renewable energy (credibility)	Certainty to be embedded in policy. Absence of "legality" due to the need for flexibility, instead, policy credibility to be earned over time. EU binding targets may support national targets		Credible medium- to long-term targets. Price shall reflect these targets. Regular review clauses with adjustments based on transparent objective criteria in line with overall climate ambitions

Source: Copenhagen Economics(2012), Support Mechanisms for Wind Energy, a study for Vestas.

The argument about “one country” being a too small zone to run an efficient certificate trading scheme may have more merit for very small countries if there too few potential suppliers. Yet there is no empirical evidence that we know of that has suggested a lower bound which would limit the ability of any Nordic country to run a tradable certificate scheme. But in any case, as discussed below, the emerging joint Norwegian–Swedish scheme now provides a case for expanding the scheme across borders. This will be discussed in the evaluation part.

2.5 Interaction between renewable energy, energy security and climate policies

The motivation for the promotion of renewable energy has officially been promoted as much by energy security as by climate policies. We would here restrict our concept to strategic energy security understood as having energy resources that are not too dependent on fewer and potentially unstable regions. The overall focus has mainly been on import of gas from Russia and oil from the Middle East. In the context of power generation, oil is largely irrelevant in the Nordic region so the issue is more about the availability and geopolitical stability of coal and gas supplies.

This raises the question whether success criteria for renewable energy policy from an energy security perspective differs from a climate policy perspective.

In a number of respects, the policy conclusions to be drawn are the same. We argued above that over the next decade the least cost approach to replace fossil fuels in power generation is energy efficiency not renewable energy with the possible exception of the most mature technologies in good locations. Furthermore, from an energy security perspective a combination of coal, gas, on shore wind power, biomass, hydro and atomic power should provide a relatively broad palette of energy sources that does not leave Nordic countries exposed to larger risks of non-supply and disruptions. This is essentially the outcome that would follow also from our preferred option to deal with carbon policies: (enforced) carbon pricing in the ETS combined with support to only the most mature technologies such as on shore wind and biomass *plus* technology policies now to push down generation costs of the technologies of the future.

But here are also potential differences. Energy security has a more direct national or regional perspective while reductions of greenhouse gases by definition have a global perspective. Geographical proximity to hydro, wind and biomass resources has value from a security perspective while it is difficult to measure in practice. But it could call for a quicker deployment of renewable power and heating based on local resources than pure climate policies objectives would suggest. A derived question is whether access to power from a wind power installation in e.g. the north of Sweden has higher/lower value for a customer based in Copenhagen than a Danish off-shore installation in the North Sea. The answer to that question will be a co-factor in discussing the benefits of joint implementation of renewable energy targets as discussed below.

Until recently, there was also a case for suggesting that the ranking of coal and gas from a climate and energy security perspective were different. While gas emits less CO₂ per unit of energy produced, estimates of available resources globally were lower than for coal and its production more concentrated in countries such as Russia. However, the rapid progress in the technology of extracting shale gas in addition to the effects of higher energy prices, has led to substantial upwards revisions to estimates of available gas resources, thus also increasing its availability from more friendly minded regions. Now gas increasingly appear as appealing from a climate perspective while less problematic from an energy security perspective.

2.6 Division of labour: global, regional and nation level

Both individual Nordic countries as well as the Nordic region as a whole must inherently frame their renewable energy policies in the context of international constraints as well as opportunities. The international perspective is predominant in at least four different perspectives.

First, the very nature of the policy challenges is international in nature. What counts in relation to climate change are the accumulated emissions at a global level. Emissions from Nordic countries account for only a fraction of that. So even massive reductions of emissions will only have a miniscule impact on the underlying problem. For energy security, the policy challenge is more regional in character as discussed above.

Second, the access of Nordic countries to low carbon technologies at low costs are highly dependent on the energy policies being pursued beyond its borders. As the Nordic markets account for only a fraction of global investments in power generation, the economic incentives to do

R&D in low carbon technologies are primarily driven by the policy actions taken in China, India, US as well as in EU countries. That applies in fact even to the incentives facing such well known Nordic renewable wind power producers such as Vestas: Vestas' main markets are not in the Nordic countries.

Third, three out of five Nordic countries are members of the EU (Sweden, Finland and Denmark) while Norway and Iceland both have joined the EU Renewable Energy Directive and have concluded legally binding agreements on climate and energy policies with the EU. As the EU's ETS system effectively determines the overall emissions of greenhouse gases for the power generation as a whole, it implies that any increase or decrease in emissions in any of the Nordic countries will simply be offset with increases or decreases elsewhere. So on the margin, expansion of renewable energy in Nordic power generation has no impact on either national emission reduction targets as agreed in EU context or on global emissions.

Fourth, as the EU has set legally binding targets for renewable energy for each Member State, it implies that whatever the merits of expanding renewable energy upwards, there is legal requirement to meet those targets. The EU policy does not require a specific target for the power generation per se, but the power sector is generally considered as the least cost option for so doing.

We draw two main conclusions from this in terms of the policy actions to be taken by actors in the Nordic region.

First, Nordic countries—individually and collectively—should use to the maximum the leverage they might have to influence EU policies. It is the EU ETS that determines the carbon prices prevailing in power generation and there are strong arguments for suggesting that the present price is too low both in relation to carbon prices outside the ETS sector and in relation to long-term abatement objectives as argued above. The basic fact is that the ETS system relies on banking: allowance unused now can be used to comply with future compliance. So a low price now is also an indication of a low price in the future: the price today plus the value of the discount rate is the price tomorrow.²³ So a more stringent ETS with a reduced amount of allowances in a more credible long-

²³ In a study for the Swedish Think-tank Fores, Fores (2012), Copenhagen Economics review the evidence around the importance of discount rates etc. in the pricing of allowances in cap-and-trade schemes with banking including the EU ETS.

term framework is needed for a more market driven push for deployment and development of renewable energy in the power generation.

Furthermore, the setting of EUs renewable policies is of course equally important. It is by now evident that even substantially higher carbon prices will be insufficient to raise power prices to a level where 2020 targets for renewable energy will be possible without substantial subsidies to renewable energy: possibly reaching EUR 100 billion annually in EU and also at high levels in Nordic countries as clarified in chapter 1. So clarification of EU policies with respect to targets and instruments for renewable energy beyond 2020 is also highly important. We would in particular propose a rigorous review of the relative weights attached to deployment of renewable energy now as opposed to the development of new technologies to meet the future challenges.

Second, at the national and Nordic levels, priorities should be provided to boost innovation in areas where the region has a priori the “largest bang for buck” potential. A region that accounts for less than 25 million inhabitants cannot aim to be best in all technology areas relevant for the transformation to low carbon technologies. Such policy could have two focus points for prioritising of funds:

- Technology areas where Nordic industries have an established comparative advantage: this ensures that there is absorption capacity and such comparative advantage can be maintained.
- Technological advances which due to the geographical and other natural characteristics of the region, the Nordic countries would inherently benefit more from than other countries.

3. Evaluation

Our evaluation is based on the learning points from chapter 2 applied to the different countries area by area. In the evaluation, we will focus especially on the importance of the learning points as a guide for future policy making. We have used the learning points selectively to highlight points where a national evaluation makes most sense.

So our evaluation has focused on 4 areas namely: Dealing with constraints of EU policies (3.1) has the countries found an appropriate overall balance between supporting deployment versus nursing future generations of technology (3.2); have policy interventions been fitted to the maturity of technologies (3.3) how have the countries been dealing with potential trade-offs in practice (3.4).

3.1 Dealing with constraints and options resulting from EU policies

As we discussed in chapter 2, the Nordic countries have to frame their renewable energy policies in the context of international policies, especially the EU regulations. In this section we evaluate how the Nordic countries deals with the constraints that EU regulation puts on national action and how well opportunities are being seized.

3.1.1 Renewable energy targets and possible use of joint implementation within the Nordic and other countries

In line with the EU directive 2009/28/EC, each Member State as well as Norway and Iceland has negotiated a minimum national renewable energy target to be realised up to 2020. In addition all countries have submitted so called National renewable energy action plans (NREAP) to the EU on how they are planning to reach the targets. Compared to the overall EU target of 20% renewable energy in final energy consumptions in the EU in 2020, the targets for the Nordic countries are quite ambitious. Norway has the most ambitious target of 67.5% followed by Sweden with 49%. The ambitious

renewable energy shares should however be seen in context of the current quite high shares in the Nordic countries, cf. Table 11.

Table 10. Share of renewable energy in gross final energy consumption (%)

Denmark	22	30	30.4
Finland	32	38	38
Iceland	67	n.a.	n.a.
Norway	61	67.5	67.5
Sweden	48	49	50

Source: Data on renewable energy shares comes from Eurostat for all countries except Iceland, which comes from EU Commission (2011), "Screening report Iceland." EU targets and national projections comes from NREAPs for each country.

Based on the statements in the four Nordic countries national action plans, there seems to be limited use of joint implementation to meet the targets in 2020. Denmark and Finland both aims to reach their targets exclusively through national measures and although Sweden and Norway have recently established a joint electricity certificate system, current projections suggest no net trade for compliance reasons between the two countries. Nevertheless, both Sweden and Denmark (who both expect a very small surplus of renewable energy compared to their national targets cf. table above) are willing to make their surplus available to other countries through the use of statistical transfer (one of four possible cooperation mechanisms, cf. Box 7).

Box 7 Co-operation mechanisms

The EU directive has set out four co-operation mechanisms:

1. Statistical transfer.
2. Joint projects among EU Member States.
3. Joint support systems.
4. Joint projects among EU Member States and third countries.

Statistical transfers

Member states that exceed their target can transfer (sell) target accounting units to countries that miss their target. Selling accounting units is only allowed if it does not affect the target of the selling country. The transfer must be reported to the commission no later than 3 months after the end of the year for which they are valid.

Joint projects among EU Member States

Two or more member states (and private operators) can share the financing of a project and share the realised target units. They have to specify the proportion or amount of electricity, heating or cooling from the project that will count towards the target of each member state and report this to the commission no later than 3 months after the end of the year for which the energy units are valid.

Joint support systems

Joint support systems require a high degree of cooperation between countries. Examples are feed-in tariffs or trade in green certificates. A certain amount of energy produced in one country may count towards the target for another country (statistical transfer or a distribution rule). A distribution rule must be reported to the commission no later than 3 months after the end of the first year it is in effect.

Joint projects among EU Member States and third countries

Basically the same as "Joint projects among EU Member States" but including non-EU Member States.

Source: EU Directive 2009/28/EC, Article 6 (1).

In the future however, all the four Nordic countries have indicated an interest in exploring the use of cooperation mechanisms. The possibilities to utilise opportunities are currently being investigated through the two-year research programme "Nordic Testing Ground," which is a joint initiative by all four countries. Furthermore, the Swedish Energy Agency

conducted a study in 2011 studying the effects of cooperation's mechanisms, where it strongly induced the Swedish government to take an active role in promoting the realisation of cooperation mechanisms among the EU Member States.²⁴

In general, the major benefit from using joint implementation is that the EU targets deployment targets can be achieved at a much lower cost, because production could take place where it is most cost efficient. The EU commission has estimated that up to EUR 10 billion annually could be saved if the Member States treated renewable energy as a tradable good on the EU single market.²⁵ Due to the lack of envisaged joint implementation between the Nordic countries towards 2020, the Nordic share of these benefits will not be reaped. Instead, by establishing a tradable certificate scheme currently will be able to bring other benefits, such as 1) price predictability, 2) credibility to the entire support scheme.

1) In a tradable certificate scheme (and with a premium feed in tariff) power producers are unavoidably exposed to power market volatility which is also an intended consequence. Predictable prices of tradable certificates going forward are therefore an important aspect of a well-functioning market. By establishing the market this provides benefits going forward as market actors gain the possibility of experiencing the market in function and building models of the different demand and supply drivers.

As the price of tradable certificates are highly dependent on the policy objectives, the scheme also gives market actors the possibility to test the scheme in action, and how policy makers react to changing circumstances. Are the quota requirements defined in a clear and transparent manner at scheduled reviews? If so, this may greatly improve investors' confidence in the support scheme and may attract capital to renewable energy investments at much lower costs of capital.

2) A well designed tradable green certificate system has inherently less scope for political interference with the actual remuneration through the certificate prices. This is so as the forward setting of prices is partly embodied in the market, as prices are the direct consequences of the quota obligations covering years in advance. If regular reviews are envisaged with transparent and objective price-readjustments according to the actual RE-deployment, this will create confidence in the long-term

²⁴ Swedish Energy Agency (2011), "Samarbetsmekanismerna enligt förnybartdirektivet – en fördjupad analys."

²⁵ Meddelande från Kommissionen till Europaparlamentet och Rådet. Förnybar energi: Framsteg mot 2020-målet. Bryssel den 31.1.2011 KOM(2011) 31 slutlig.

price. One key aspect of the increased scope for credibility is that setting up a market based mechanism such as a green certificate system creates a strong lock-in effect for policy makers. It is most likely perceived as much more difficult to tamper with the rules of an existing market, than it is to change the level of next year's support in a fixed feed in tariff. This locking-in effect becomes even stronger once more countries engage in the same market, as it becomes much more difficult to backtrack on commitments, which the economic crisis has shown to be the case in several countries, especially in Southern Europe.

3.2 Supporting deployment versus nurturing future technologies

As discussed in Chapter 2, a well-designed support policy should seek to 1) deploy mature technologies in a cost efficient manner in order to meet climate targets, and 2) nurture non-mature technologies in order to make them economically viable in the years going forward.

3.2.1 *How is the split on costs along the maturity of technology?*

In most countries there is a tendency to focus a very large share of support to deployment on close-to-mature technologies. In Sweden and Denmark, it seems that the direct support to deployment of renewable energy technologies is significantly higher than the money spent on innovation in energy technologies, cf. Table 12. This is even without including the vast support granted through exemptions from energy and CO₂ taxes. In Finland it seems that there is a more equal distribution of funding between deployment of renewable energy technologies and support to innovation in new technologies. It should be noted that the numbers in Table 12 have been put together from several different sources, and may therefore not be directly comparable, as there are most likely other, typically smaller scale, support instruments in use in the different countries.

Table 12. Support to RE deployment vs. innovation

Yearly cost (EUR million)	Denmark	Finland	Norway	Sweden
Mature technologies	351	120	?	410
Non-mature technologies	30			
Innovation in energy technologies	142	159	153	160

Note: The table does not include the value of tax exemptions to some renewable energy use, for example in heating production. The only exception to this is the value of tax exemptions to individual owners of solar panels in Denmark.

Innovation in energy technologies covers not just renewable energy but other low-carbon technologies such as energy efficiency, nuclear power, power and storage technologies etc.

Denmark: All subsidies to wind are grouped together under mature. The non-mature category includes tax exemptions to individual owners of solar panels.

Finland: It has not been possible to divide the total production support on different technologies, including mature and non-mature.

Norway: It has not been possible to divide the total production support on different technologies, including mature and non-mature.

Sweden: It has not been possible to divide the total production support on different technologies, including mature and non-mature.

Sources: Copenhagen Economics based on ENS (2011), Svenska Kraftnät/CESAR, Kemin (2011), Promoting policy for renewable energy in Finland (2012), Enova, NREAP Sweden, Nordic authorities' answer to questionnaire and Kraka (2012).

It has not been possible to obtain information on the value of the different tax exemption programmes that the Nordic governments have in place. This is potentially a very large source of support, which should be considered in addition to the numbers in Table 12. This is typically an issue for renewable energy sources used in heat production but also for private household electricity production through e.g. solar panels or individually owned small-scale wind turbines.

Our evaluation here is that arguably too large a share of funding is provided to the deployment of not yet mature technologies as opposed to boosting innovation. Given the legally binding nature of EUs renewable energy targets, the Nordic countries may however have little choice in the medium term perspective until 2020.

3.3 Fitting policy interventions to maturity of technology

In this section we will review whether the characteristics of different support schemes follow the logic of the maturity line. This implies that:

- The highest subsidy rates should be reserved for promising long-term products and processes with counterpart in public ownerships of results including e.g. access to results.
- Non-mature technologies should be supported through demonstration projects with capped support and with a focus on technology progress in order to bring down the future cost of the technology. The focus should not be on deployment of the technology at a scale beyond what can be justified by learning effect.
- Mature technologies can on the other hand be supported without a cap on a specific technology, since the mature technologies should be used to cost efficiently reach climate and energy security targets. These targets then set the overall cap for renewable energy deployment, but without restricting a relatively cheap technology from being deployed. Common carbon pricing schemes such as the ETS should do as much of the job as possible.

With respect to the level of support for individual technologies, the Swedish and Norwegian green certificate scheme by definition provides the same amount of support irrespective of the technology type. In Finland, the support to electricity produced from wind and biogas is the same, while wood chip receives a lower support element, cf. Figure 13. Support to CHP production is however, significantly higher both for biogas and wood.

Figure 13. Support element to different technologies in Finland

Note: The figure depicts the support element of the feed in tariff. For example, if it is a fixed feed in tariff, the support element is the target price minus the electricity price.

Source: Copenhagen Economics based on Promoting policy for renewable energy in Finland (2012).

In Denmark, there is some difference between the support elements to different technologies. While the cheapest offshore wind farm receives a support element of app. EUR cent 2/MWh which is comparable to the onshore wind turbines, the most expensive offshore wind farm receives more than EUR cent 11/MWh, cf. Figure 14. Biomass in electricity production also receives a subsidy comparable to onshore wind, while biogas in electricity production receives a significantly higher support element.

Figure 14. Support element to different technologies in Denmark

Note: The figure depicts the support element of the feed in tariff. For example, if it is a fixed feed in tariff, the support element is the target price minus the electricity price.

Source: Copenhagen Economics based on ENS (2011) and Energiforlig (2012).

As discussed in Chapter 2 and above, an important element in a well-designed support policy is the use of capped demand for renewable energy deployment. In Sweden and Norway, the green certificate scheme does not specify a cap on the technologies included in the scheme. This is helpful, as the market will ensure that the least costly technology is deployed as much as possible. As most other support in Sweden and Norway is through research, innovation, and investment programmes, this support is capped by the national budgets.

In Finland and Denmark, the feed-in tariffs are not capped. That is, there is currently no limit on the amount of e.g., wind or biomass that can be deployed and receive support. As biomass and onshore wind are relatively low-cost technologies, it is helpful that the support to these technologies is not capped. In Denmark, deployment of offshore wind is de facto capped, as the government puts bulks of demand out to tender, and therefore can control the amount of deployment.

One example of a how an uncapped subsidy can backfire is the current example in Denmark of households' purchase of solar panels for own production of electricity. The subsidy element to these solar panels consists both of the implicit exemption for electricity tax by producing one's own electricity, and a subsidy for producing electricity beyond one's own consumption. The subsidy for "overproduction" is much

smaller than the value of the implicit tax exemption, and most households have therefore chosen solar panels with a production capacity matching their electricity consumption.²⁶ Due to the very high Danish electricity taxes, solar panels became profitable for a large range of households, which led to a massive increase in solar panel deployment, way beyond what any cost efficient CO₂ reduction path would recommend. In addition this strained public finances to an unexpected degree. Estimates have shown that the yearly subsidy will be almost EUR 30 million by 2012, and is expected to increase to more than EUR 130 million in 2020 if the subsidy arrangement is continued.²⁷

This development could have been avoided if the demand for the relatively non-mature technology, which solar PV is, had been capped. This situation has now spurred the government to change the solar panel subsidy scheme, which may increase the uncertainty about the stability of the Danish support system for renewable energy.

3.4 Dealing with policy trades-off in practice

In this section, we will touch upon three important criteria in a well-designed support policy, namely 1) Technology neutrality, 2) Consistent set of support instruments, and 3) Avoiding overcompensation.

3.4.1 *Technology neutrality*

As described in Chapter 2, an important success criterion for support instruments is that it provides different technologies with the same marginal incentive to reduce CO₂ emissions. This ensures so called technology neutrality and is a key element in achieving deployment of low carbon technologies in a cost efficient manner. Technology neutrality cannot help to bring innovation in non-mature technologies, but is a good guide to achieve least costly deployment of close-to-mature technologies.

In practice in the Nordic countries, the green certificate system in Sweden and Norway ensures full technology neutrality between different renewable energy technologies. When a certified renewable energy producer delivers 1 KWh of electricity, the producer is rewarded in

²⁶ See e.g. Kraka (2012).

²⁷ See Kraka (2012).

the same way independent of what technology type is used to produce the electricity. This guarantees technology neutrality and ensures that the cheapest production sources deliver energy, while the more expensive sources are driven out of the market.

With the feed-in tariff systems in Denmark and Finland, technology neutrality aims have been down played. This is because feed-in tariffs are typically designed for each type of technology such that e.g. onshore wind receives a different subsidy level than biomass or biogas. The aim has been to set support levels so as to compensate for differences in production costs to avoid either over or under compensation. In Denmark, while electricity generated from biomass receives a total subsidy (from direct support and indirectly through the ETS) of almost DKK 0.3/KWh, electricity produced from onshore wind receives almost DKK 0.4/KWh, and electricity from biogas almost DKK 0.6/KWh, cf. Figure 15. As 1 KWh of reduced fossil fuel based electricity generation essentially has the same value in terms of climate change and energy security issues, the level of support should preferably also be the same regardless of the technology of choice.

Our evaluation is here that the countries have taken somewhat different strategies. Given ample capacity for the installation of onshore wind in Norway and Finland, investments in offshore wind have not been considered necessary to comply with targets. Conversely in Denmark, lack of suitable onshore sites has without doubt been a factor in the focus on offshore installations to reach the EU targets. In this respect, the joint green certificate scheme in Norway and Sweden offers an opportunity to comply with future EU targets at lower costs as well as to increase the share of renewable energy in the overall Nordic power markets.

Figure 15. Support to mature technologies, Denmark

Note: For onshore wind and biogas, the highest available subsidy is depicted. The comparison assumes an ETS price of EUR 30 per ton.

Source: Based on Copenhagen Economics (2011).

3.4.2 Consistent set of support instruments

Support to low carbon technologies can be delivered through many different channels, and is typically also done so. As described in Chapter 1, electricity generation from renewable energy is typically supported through direct production subsidies (e.g. feed-in tariffs or green certificates) while district heating from renewable energy is typically supported indirectly through exemptions from energy and CO₂ taxation.

The challenge of applying several different support channels is that it becomes very difficult to ensure that the subsidy to marginal CO₂ reductions is equal across different technologies. In fact, when support is granted through tax exemptions, the specific level may more or less arbitrarily be determined by e.g. the rate of energy taxes. As Denmark and Sweden typically tax heat production and electricity consumption higher than Finland, Norway and Iceland, cf. Chapter 1, the value of a tax exemption to the same type of technology will differ arbitrarily between the countries. This can be illustrated hypothetically by a household deploying a solar panel. A large part of the subsidy to this technology will come from the fact that the household no longer needs to purchase electricity from the grid, and therefore is exempt from the tax on electricity consumption. As stated in Figure 5, this tax rate is significant-

ly higher in Denmark than in Sweden and in Finland, which awards the household a much higher support level in Denmark.

Another illustration can be the difference between the subsidy element to biomass and biogas in Denmark, when used for electricity and heating production respectively. Biogas is e.g. subsidised significantly higher when used to produce electricity than when used to produce heat, cf. Figure 15. The same goes for biomass, but this result is conditional on the assumed price of ETS allowances.

Figure 16. Different support to same technologies DK

Note: For Denmark. The comparison assumes an ETS allowance price of EUR 30 per ton.

Source: Based on Copenhagen Economics (2011).

3.4.3 Avoiding overcompensation

When subsidies are designed in order to induce certain behaviour—for example deployment of renewable energy—there is a risk that the subsidies are set too high and the society thus pays “too much” for a given wanted behaviour. We have identified three elements that renewable energy support mechanisms can include to reduce the possibility for overcompensation: 1) Structurally pushing down support rates over time, 2) Addressing resource rents from natural resources, and 3) Using tendering processes to determine the needed level of support.

Structurally pushing down support rates over time

In the Swedish and Norwegian green certificate scheme, there is in general no need to take special action to push down support rates over time in order to match technological cost reductions. This is because the price of the green certificate will reflect the cost of renewable power generation. As the cost of deploying e.g. onshore windmills is reduced through technological progress (or learning by doing), more onshore wind will be deployed and the certificate price will decrease. This will render more costly technologies e.g. old vintages of onshore wind mills unprofitable.

In Denmark and Finland, where feed-in tariffs are heavily used measures of support, one way to avoid overcompensation is to reduce support rates over time for new vintages of technology. This is e.g. done in Germany where the feed-in tariff to wind installations is set to decline with a fixed amount every year for new installations, exactly to address technologically driven cost reductions. However, we have not identified such automatic mechanisms in neither Denmark nor Finland. It may be possible to achieve the same effect by “manually” deciding to reduce the tariff over time. This, however, will come at the cost of reduced transparency and increased uncertainty for actors involved. In addition, it will be very difficult to achieve the beneficial quality of ensuring that the marginal incentive to reduce CO₂ is the same across different instruments.

Addressing resource rents from natural resources

As different renewable energy technologies have different production costs, the subsidy needed to induce production is different. For example, there are a vast amount of hydroelectricity installations in especially Norway and Sweden, which can produce electricity at a relatively low cost.²⁸ In order to induce production from these cheap hydro installations, a much lower (or zero) subsidy is needed than for example for less mature technologies such as solar PV or wave and tidal technologies.

In Denmark and Finland, this issue is addressed by having a vast range of different subsidies for different technologies, and by seeking to scale the size of the subsidy to the generation cost of the specific technology. In Sweden and Norway, the cheap technologies such as hydro installations receive the same support as more expensive technologies such as wind. In order to avoid overcompensation of the cheap technologies, a natural

²⁸ When including both the capital cost of the installation and the variable cost of the production.

resource rent tax is levied in both Norway and Sweden. Such a tax—if well-designed—is able to ensure that the producers of electricity reaps enough of the rent to cover the total cost of production, while ensuring that any excessive resource rents accrue to the public finances.

Box 8 Resource rent taxation in SE and NO

Sweden: In Sweden the natural resource tax is designed as a property tax. The property tax on a hydro power plant was 2.8% of the property value in 2011. Hence, tax levels are not influenced by profits. Except for the ordinary income tax of 26.3% of profits, hydropower is not subject to any additional rent taxation.

Norway: The design of the Norwegian resource tax on hydropower is more in line with the text book example than the Swedish design. Hydropower production is (in addition to the ordinary income tax of 28%) subject to a resource rent tax on extraordinary profits (30%). The tax level therefore varies with profits and hence the power market price. Hence, producers are able to cover production costs, while extraordinary profits go back to the state. In addition to the resource rent tax hydropower plans are subject to a property tax of 0.7%.

Source: SvenskEnergi, Finansdepartementet:

http://www.regjeringen.no/nb/dep/fin/tema/skatter_og_avgifter/bedriftsbeskatning/kraftverksbeskatning.html?id=449525.

Furthermore, addressing the issue of resource rents becomes even more acute when and if ETS allowances reach levels consistent with EUs long-term climate policy targets. The basic point is that any policy that puts a premium on low carbon technologies by raising the price of power produced by coal and gas based electricity producers will provide substantial rent income to low cost electricity producers. In fact, the rents are much higher with carbon pricing as it applies to all installations, new or existing, while traditional renewable energy support schemes only cover a certain period/amount of production for each installation (creating problems of their own in terms of defining when (re)investments are considered repair work and when the installation should be considered as new relative to access to support schemes).

So the message here is: the rent/windfall profit issue needs to be dealt with any case.

Using tendering processes

When the government is specifying the level of support through e.g. a feed-in tariff, it faces a problem of asymmetric information. It is only the renewable energy producers that know the true cost of production, and they have an incentive to lobby the government for high subsidies. This makes it difficult for governments to design such subsidies without overcompensating the producers.

In Denmark, subsidies to electricity produced from offshore wind farms are currently being decided through a tendering process. This process helps to ensure that overcompensation is limited by making the different potential producers bid against each other for the right to build and operate the wind farm. If there are enough potential producers, and the tendering process is well-designed this should be able to drive the subsidy amount down to the cost of production plus a risk premium, and thus avoid overcompensation.

In Finland tendering has not yet been applied to increase the production of renewable energy. However, the potential of using tendering has been investigated and it has been discussed that it could be a suitable measure for implementing a pilot project concerning offshore wind energy production.²⁹

²⁹ Ministry of Employment and the Economy (2010).

4. Recommendations

Based upon our review of actual policies and the analytical approach proposed, we would like to provide five recommendations:

The first is a policy focus that should be (more) explicitly based on a clear distinction between ultimate *policy objectives* such as climate change and energy security with energy efficiency and renewable energy as the *means* to achieve these objectives. Promotion of energy efficiency and particularly renewable energy has no intrinsic value. Bearing in mind the recent “discovery” of large oil and gas reserves that can be exploited at current levels of oil and gas prices, we suggest that climate change may ultimately be the really challenging policy constraint while access to coal, gas and oil from relatively “stable” countries will be a less important, while still a real, concern. So the need to reduce greenhouse gases is the most important goal.

The second is to focus discussion of the mitigation efforts in Nordic countries in a wider international, first of all EU, context. For power generation, it is the future of the ETS that drives incentives to reduce emissions and the cap determined at EU level implies that mitigation efforts “on top” in Nordic countries has zero effect on either national compliance or overall emissions. If Nordic countries are serious about the long-term need to deal with climate change, then reform of the EU should take central place. We have argued in this report for much larger reduction targets. The present low prices suggest that (1) emissions can be cut at lower prices than in the coming decades if targets are to meet (so low prices is a signal that markets do not believe that long-term targets will be met) and (2) mitigation should be shifted from the non-ETS sector where carbon prices are much higher. What is needed is a combination of hard binding commitments going decades ahead in the ETS to provide clear guidance and certainty to investors about the firmness of future climate policies as they apply to the power generation sector.

The third is to focus more on the quality of the technology policies in places. The study has clarified that the bulk of public in Nordic funding to renewable energy goes to deployment costs and only a fraction of that to innovation. We have suggested reversing that priority over time. The room for manoeuvre is relatively limited in the coming years as the legally binding renewable energy targets requires substantial funding giv-

en the level of power market prices (even much more stringent ETS targets will still require substantial deployment support). Yet, more can be done to promote the market share of the most mature, low cost producers in the Nordic region inter alia by more countries joining the emerging Norwegian–Swedish green certificate scheme. That will free resources to promote genuine innovation, focusing on overcoming barriers in particular knowledge spill-overs and technology uncertainty that will hold back RDI investment from the private sector.³⁰

While there is strong evidence of the benefits for more support for innovation, there is more uncertainty about how to accomplish this cost efficiently in practice. OECD surveys focus on promoting (1) promising generic technologies and (2) technologies with high capital intensity and technology uncertainty, both factors holding back private investment. Within this framework, more competition for public funds should be encouraged, the US concept of technology prizes could be explored and the Nordic countries is encouraged to explore this concept in more depth and possibly start joint funding programmes on that basis.

The *fourth* is to streamline support for deployment of renewable energy in a wider sense. Current support in Nordic countries is provided through a mixture of budget measures financed by general tax revenue, off budget public service obligations financed by electricity consumers, tax expenditures in the form of exemptions to energy taxes and high taxes on electricity in particular that provides de facto high subsidies to installations in households and industries paying standard rates of electricity taxes. The result is risks of uneven deployment support to the same technology depending on the tax status of the buyer, whether heat or electricity is produced as well as unintentional very high support for example solar cells in private households. The ultimate aim is to ensure that marginal incentives to abatement–shadow prices of CO₂–are equal across technologies that are meant to be deployed at a larger scale. Higher rates should only be accepted for immature technologies in demonstration and commercialisation phases where the real aim is not abatement but getting down future costs of abatement through learning and RD-efforts.

³⁰ The relevance of this extension to other countries and indeed continuation of the certificate scheme should be seen in light of at least two other factors 1) will ETS allowance prices rise substantially so as to make support schemes to mature renewable energy unnecessary 2) will EU decide to provide renewable energy targets beyond 2020 that requires support well in excess of implicit support from the ETS system?

None of the Nordic countries have yet achieved a comprehensive system. We would in particular favour a system where either all support to renewable energy is put in PSO kind of system or none. The mixture has a risk of focusing at the parts that is financed out of general government revenues. Given the long-term nature of investments to be undertaken we would underline in both case an approach that provided clear policy commitments at least 5–10 years ahead, preferable with substantial and wide political support.

Getting incentives for mitigation and deployment of renewable energy more aligned inside and outside the power generation (ETS) sector is a policy objective of high priority in this perspective. A key problem presently is very different levels of carbon prices outside (for example on gasoline) and inside (the price of allowances). A reform of the ETS could help deliver on this. While it is not a decision at the discretion of the Nordic countries, they have a high joint interest in achieving it given very high levels of non-ETS energy taxes in the Nordic countries.

The *fifth* is to develop a credible long-term strategy for climate change policy that could serve as a role model for countries with a less enthusiastic approach to ambitious mitigation targets. The basic facts is that the Nordic countries at the international level are supporters of the most stringent targets, yet accounts for only fraction of global emissions. The power generation sector is characterised by having both a highly efficient use of fossil resources and high – and increasing – level of renewable energy.³¹ Hence this, in combination with the overall cap of emissions in the ETS, implies that more mitigation in the resource efficient Nordic countries will be followed by more emissions in other EU countries. Our bottom line on this is that the role model to be developed combines a rigorous cost effectiveness to reach nearer term targets as determined in the EU context, while developing innovation strategies that ensures that the Nordic countries can also meet much more stringent targets at lowest costs when they are being adopted at the international level.

³¹ Copenhagen Economics (2012b).

5. References

- Acemoglu *et al.* (2009), "The Environment and Directed Technological Change."
- Baker and Adu-Bonnah (2008), "Investments in risky R&D programs in the face of climate uncertainty."
- Blyth *et al.* (2007), "Investment risks under uncertain climate change policy."
- Bosetti *et al.* (2009), "Climate Policy after 2010."
- Celebi and Graves (2009), "Volatile CO₂ prices discourage CCS investment."
- Copenhagen Economics (2010), "Innovation of Energy Technologies: the Role of Taxes."
- Copenhagen Economics (2011a), "Green innovation and energy taxes."
- Copenhagen Economics (2011b), "Sammenligning af støttesatser til vedvarende energi."
- Copenhagen Economics (2012a), "Multiple benefits of investing in energy efficient renovation of buildings."
- Copenhagen Economics (2012b), "Carbon leakage from a Nordic perspective."
- DEFRA (2008), "An analysis of the technical feasibility and potential cost of a personal carbon trading scheme."
- DG ECFIN (2010), "What is the growth potential of green innovation? An assessment of EU climate policy options."
- DG TAXUD (2012), "Exercise duty–Part II–Energy products and Electricity."
- ENS (2011), "Oversigt over afregningsregler mv. for VE-baseret elproduktion."
- ENS (2012), "Offentlige Serviceforpligtelser (PSO). 7 maj 2012."
- Energiforlig (2012), "Aftale mellem regeringen (Socialdemokraterne, Det Radikale Venstre, Socialistisk Folkeparti) og Venstre, Dansk Folkeparti, Enhedslisten og Det Konservative Folkeparti om den danske energipolitik 2012–2020." 22 March 2012.
- Energy Taxation in Finland (2012), Annex 2, 01.03.2012.
- Fankhauser (1993), "Evaluating the social costs of greenhouse gas emissions."
- Fischer (2008), "Emissions Pricing, spillovers, and public investment in environmentally friendly technologies."
- Hart (2008), "The timing of taxes on CO₂ emissions when technological change is endogenous."
- IEA (2007), "Energy, Security and Climate Policy."
- IEA (2011), "Electricity Information 2011."
- Kemin (2011), "Kortlægning af offentlig grøn energiforskning, –Udvikling og –demonstration i Danmark."
- Klima- og energiministeriet (2010), "National Action Plan for renewable energy in Denmark."
- Kraka (2012), "Subsidieringen af privatejede solcelleanlæg."
- Law 527 (of 12 juni 2009), "Lov om ændring af lov om afgift af elektricitet og forskellige andre love."
- McKinsey & Co (2010), "Impact of the financial crisis on carbon economics."

Montgomery (1972), "Markets in Licenses and Efficient Pollution Control Programs."

Montgomery and Smith (2007), "Price, quantity and technology strategies for climate change policy."

Popp (2006), "Innovation in Climate Policy Models: Implementing Lessons from the Economics of R&D."

Popp *et al.* (2009), "Energy, the environment, and technological change."

Popp (2010), "Innovation and Climate Policy."

Promoting policy for renewable energy in Finland (2012), May 2012, Annex 1.

Prop. 1 LS (2012), "Skatter, avgifter og toll 2012. Proposisjon til Stortinget (forslag til lovvedtak og stortingsvedtak). For budsjettåret 2012."

Pöyry (2008), "Enhancing economic efficiency–Benefits of trade."

RWI (2009), "Die ökonomischen Wirkungen der Förderung der Erneuerbaren Energien: Erfahrungen aus Deutschland."

RWI (2012), "Germany's Solar Cell Promotion: An Unfolding Disaster," Ruhr Economic Papers #353.

Schneider and Goulder (1997), "Achieving low-cost emissions targets."

Weber and Swider (2004), "Scenarios on the conventional European electricity market."

Yang *et al.* (2008), "Evaluating the power investment options with uncertainty in climate policy."

6. Sammenfatning

I klima og energi politikken har de fleste lande to målsætninger: håndtering af drivhusgasemissioner og forbedring af forsyningssikkerheden. Opnåelse af begge målsætninger kræver to resultater: 1) En transformation mod en low-carbon økonomi, og 2) mere stabile/lokale energikilder. Implementering af vedvarende energi kan potentielt levere på begge disse målsætninger, uden dog at være et mål i sig selv. Vedvarende energi er nemlig i sin natur er fattig på CO₂, og kan typisk opnås lokalt. Nogle af de samme fordele kan også opnås via øget energieffektivitet, andre teknologiske løsninger såsom *Carbon Capture and Storage* (CCS) i kul og gas-baserede generatorer, atomkraft eller via bestræbelser på at diversificere de lande, der importeres energi fra.

På baggrund af ovenstående foreslås det her at se på "effektive strategier for vedvarende energi" i et bredere perspektiv: Hvordan kan de nordiske lande enkeltvis, samlet og som en del af det større internationale samfund gennemføre en omkostningseffektiv strategi for vedvarende energi, der opfylder klima- og forsyningssikkerhedsudfordringerne? Undersøgelsens mandat er at fokusere på elproduktion og fjernvarme, men vi vil også perspektivere til den samlede energisektor, når det er relevant.

Vores analyse har fire hovedelementer:

- Hvordan ville den "ideelle" langsigtede strategi for støtte til vedvarende energi se ud – givet de underliggende økonomiske sammenhænge?
- Hvilke muligheder og begrænsninger følger af strukturen og indholdet af det internationale samarbejde – først og fremmest på EU-plan?
- Hvor effektive er de nordiske lande i forfølgelsen af omkostningseffektive politikker under de internationale forhold?
- Hvilke anbefalinger følger af denne analyse?

Den ideelle strategi vil afspejle to grundlæggende punkter om de økonomiske sammenhænge i udfordringerne. For det første har vi en velafgrænset miljømæssig udfordring, som bør løses ved at beskatte drivhusgasser herunder CO₂ ensartet og på et niveau, der er i overensstemmelse med de langsigtede mål for reduktion af emissionerne. Det kan gøres

ved skatter eller cap-and-trade-ordninger. Der er stærke indikationer for, at sådanne afgifter har en betydelig langsigtet indvirkning på emissioner samt incitamenter til at implementere og udvikle CO₂-fattige teknologier såsom vedvarende energi. Vi påpeger, at virkningerne af sådanne skatter har tendens til at være undervurderet i de officielle langsigtede fremskrivninger, herunder i de nordiske lande.³²

For det andet har vi også en velafgrænset teknologiudfordring. Mens CO₂ beskatning kan have en vigtig rolle i at fremme relativt markedsmodne teknologier behøver lovende, men umodne teknologier, offentlig støtte. Dette er det velkendte spill-over argument: fordelene ved forskning og udvikling tilfalder ofte andre aktører end dem, der finansierer dem. Hermed introduceres en rolle for det offentlige.

En væsentlig del af den offentlige støtte til fremme af lovende teknologier bør gives i den tidlige fase ved igangsættelse af pilot-og demonstrationsprojekter. Ideelt bør støtten komme fra internationale offentlige budgetter såsom fra EU. Viden spill-over på tværs af grænser er betydelige, og der er et behov for at fokusere på udviklingen i innovationsklynger med tilstrækkelig skala og kvalitet. Fokus for sådanne ordninger er ikke at producere energi eller generere CO₂ emissionsreduktioner nu – det er at sænke omkostningerne ved at producere energi i fremtiden! Meget forskning har antydnet, at en fuldstændig transformation af energisektoren fra fossile brændsler vil kræve en betydelig stigning i de allokerede offentlige midler til low-carbon teknologi: OECD's estimater peger på en 2–3 gange stigning i forhold til det nuværende niveau.

Både mulighederne og begrænsningerne, der følger af internationalt samarbejde er betragtelige. For det første bør mulighederne fremhæves: De nordiske lande står kun for en brøkdel af de globale udledninger og den internationale innovation indenfor low-carbon teknologier vil være drivkraft for de teknologiske muligheder i Norden. På denne baggrund tilbyder EU en mulighed for at sikre en (mere) global forpligtelse til carbon beskatning og internationalt samarbejde om teknologiudvikling. Men begrænsningerne fornemmes også tydeligt. De vigtigste fremhæves nedenfor:

- *ETS systemet* er nøgleinstrumentet på EU-markedet, som benyttes til at sætte en pris på drivhusgasserne – hovedsageligt udledt ved elproduktion og ved anden energiforbrug. Alligevel er den nuværende

³² Dvs. for lave langsigtede priselasticiteter: En given stigning i afgifterne på CO₂ eller energi har større langsigtede virkninger end typisk indbygget i fremskrivningerne.

pris på ETS-kvoter på et meget lavt niveau. I denne sammenhæng kan der argumenteres for, at den endnu er for lav til at fremme et skift fra kul- til gasbaseret produktion ej heller et skift til vedvarende energi. Fra et økonomisk synspunkt er dette problematisk på to punkter. For det første er beskatningen af af emissioner udenfor ETS-sektoren i EU landene 5-10 gange højere end inden for ETS-sektoren. Denne forskel bliver endnu større i de nordiske lande, hvor skattesatserne for energi ligger langt over EU-gennemsnittet. Det følger heraf, at EU og de nordiske lande vil kunne høste store fordele ved at flytte CO₂-reduktioner fra ikke-kvotesektoren til kvotesektoren ved f.eks. at stramme på reduktionskravet indenfor kvotesektoren. Dette kunne gøres med eller uden en overordnet forhøjelse af reduktionsmålet i 2020. For det andet er den meget lave pris i sig selv en indikator for, at reduktionsforanstaltningerne i ETS ikke er tilstrækkelige: alle fremskrivninger tyder på, at CO₂-priserne skal være meget højere for at opnå de langsigtede klimamål. Dette afspejler sandsynligvis, at markederne har en begrænset forventning om EU's vilje til at gennemføre sine ambitioner. Ellers ville virksomheder i langt højere grad opkøbe kvoter til de nuværende lave priser og gemme disse til fremtidigt brug. En sådan dynamik ville skubbe priserne op til meget højere niveauer.

- EU har fastsat 2020 *mål for vedvarende energi*, som binder landene til specifikke mål. Målene fastsættes som en andel af energiforbruget i den samlede økonomi med et separat mål for transport. Den lave ETS kvotepris samt reduktionen af kul- og gaspriserne indebærer, at meget stor støtte skal leveres til vedvarende energi for at opfylde EU-målene for vedvarende energi. Set fra et økonomisk synspunkt tvinger EU-målene i virkeligheden medlemsstaterne til massivt at implementere vedvarende energikilder, der ofte er relativt langt fra at være markedsmodne ved de nuværende priser.

Hvor effektive er de nordiske lande så i at sammensætte strategier for vedvarende energi under disse omstændigheder? Med udgangspunkt i en beskrivelse af de faktiske politikker baserer vi vores vurdering på i hvilket omfang, de nordiske energipolitikker opfylder følgende kriterier:

- Omkostningseffektiv implementering af EU-mål for vedvarende energi inden for el-produktionssektoren
- Passende match mellem udformningen af støtteinstrumenter og teknologisk modenhed i overgangen fra forskningsstadiet til markedsmodenhed

- Sikre teknologineutralitet – ingen picking the winners – men samtidig anerkende, at ikke alle teknologier bør støttes (ens).

Vi drager tre konklusioner:

1. Omkostningseffektiv implementering synes ikke at være af lige høj prioritet blandt de nordiske lande. Den fælles norsk-svenske gennemførelse af målene for vedvarende energi i form af grønne certifikater er imidlertid en lovende tilgang. Mere generelt er støtteniveauerne i de nordiske lande ofte afhængige af arbitrære omstændigheder, såsom brugerens skattemæssige status (f.eks. virksomheder vs. private), eller om et råmateriale får tilskud ved en fritagelse fra en given energiskat (biomasse, der anvendes i fælles produktion af el og varme), eller modtager et eksplicit tilskud.
2. De fleste offentlige midler til vedvarende energi går til støtte af forholdsvis umodne teknologier, mens langt færre midler er direkte rettet mod innovation. Opfyldelse af 2020 målene for vedvarende energi vil tendere til at øge fokus på støtte til implementering i dag i stedet for teknologiudvikling. Det er sandsynligt, at dette vil gøre det dyrere at opnå de langsigtede klimamål.
3. Udfordringerne med at definere en teknologineutral tilgang til innovationsstøtte er i vid udstrækning stadig er uløste.

Vores anbefalinger som følge af analysen er som følger:

- *For det første* er det vigtigt at gøre sig klart, at klimaændringer og forsyningssikkerhed er de reelle politiske mål, hvor omkostnings-effektivitet er væsentlig betingelse. Vedvarende energi og energi-effektivitet er blot midlerne til at levere på disse mål. At sætte bindende mål for etablering af vedvarende energi eller energieffektivitet i sig selv tjener ikke et nyttigt formål. Idet de officielle prognoser for størrelsen af de globale olie-og gasreserver stiger – ikke mindst i stabile regioner som USA – bør bestræbelser på at modgå klimaforandringer stige i prioritet i forhold til forsyningssikkerhed. Stigende forsyninger af fossile brændstoffer kombineret med lavere priser indebærer, at der skal skrappere tiltag til, for at nå givne klimapolitiske mål f.eks. i form af højere CO2 skatter og/eller højere kvote priser.
- *For det andet*, bør reduktionsindsatsen i de nordiske lande være mere fokuseret om den internationale kontekst, først og fremmest i EU. For elproduktion er det ETS, der fremadrettet skal drive incitamenterne til at reducere emissionerne. Loftet for udledninger inden for ETS ligger fast, hvilket indebærer, at en ekstra reduktionsindsats i de

nordiske lande ingen effekt vil have på hverken den nationale overholdelse af EU mål eller de globale CO2 emissioner.

- *For det tredje*, bør fokus i højere grad være på understøttelse af teknologiudvikling. Vores studie har præciseret, at størstedelen af den offentlige støtte i de nordiske lande går til at etablere vedvarende energi, og kun en brøkdel gør til innovation og teknologiudvikling. Vi foreslår, at en omprioritering bør finde sted over tid. Vi foreslår, at denne større indsats f.eks. bør give tilskyndelse til at konkurrere om den ekstra finansiering. En mulighed er at se til USA, hvor en del af innovationsstøtten bliver tildelt som "præmier" i en konkurrence. Innovationsfinansieringen bør være fokuseret på generiske teknologier der har høj teknologiusikkerhed og store up-front kapitalomkostninger, hvilket hæmmer private investeringer.
- *For det fjerde*, bør støtten til anvendelse af vedvarende energi i en bredere forstand strømlines for at sikre et ensartet, omkostningseffektivt støtteniveau på tværs af forskellige sektorer, producenter etc. Det endelige mål er at sikre, at marginale incitamenter til at reducere (skyggepriserne på CO2) er lige store for teknologier, der er egnet til at blive implementeret i en stor skala. Dvs. for de teknologier hvor det primære mål er opsætning, i modsætning til udvikling af mere f umodne teknologier.
- *For det femte*, bør der udvikles en troværdig langsigtet strategi for klimapolitikken, der kan tjene som et forbillede for lande med en mindre entusiastisk tilgang til klimamål. De nordiske lande har i dag de strengeste reduktionsmål samtidig med, at de kun står for en brøkdel af de globale emissioner. Forbilledet bør kombinere en omkostningseffektiv metode til at nå de kortsigtede målsætninger for opsætning af vedvarende energi, samtidig med, at den booster innovation for at sikre, at de nordiske lande har omkostningseffektive teknologier til at opfylde de langt strengere klimamål, som ligger på længere sigt. Påvises denne model at virke, kan også mere tilbageholdende lande tilskyndes til at følge med.

7. Appendix A:

Tax rates on CHP production

Table 12. Tax rates on production of heat in CHP and pure heat respectively

EUR/GJ		Energy tax	CO ₂ tax	Total tax
Denmark	Natural gas-CHP	8.0	1.2	9.2
	Coal-CHP	8.0	2.1	10.1
	Natural gas-Pure heating	6.4	1.6	8.0
	Coal-Pure heating	6.4	1.6	8.0
Finland	Natural gas-CHP (2015)*	2.1		
	Coal-CHP	2.1		
	Natural gas-Pure heating (2012)	0.8		
	Natural gas-pure heating (2015)	2.1		
	Coal-Pure heating	2.1		
Iceland	Natural gas-CHP	0	0	0
	Coal-CHP	0	0	0
	Natural-Pure heating	0	0	0
	Coal-Pure heating	0	0	0
Norway	Natural gas-CHP			
	Oil-CHP			
	Natural gas-Pure heating	0.0	1.5	1.5
	Oil-Pure heating	3.6	2.2	5.8
Sweden	Natural gas-CHP	0.8	2.0	2.7
	Coal-CHP	0.8	3.5	4.4
	Natural gas-Pure heating	2.5	6.5	9.1
	Coal-Pure heating	2.7	11.9	14.6

Note: * The energy tax is expected to increase substantially from 2012 to the numbers given here in 2015.

Source: Law 527, Energy Taxation in Finland 2 (2012), Prop. 1 LS (2012), and Nordic authorities' answer to questionnaire.

Efficient strategy to support renewable energy

This report reviews how the Nordic countries can develop a strategy for renewable energy that delivers efficiently on the two underlying policy objectives of climate change and energy security challenges.

The overarching elements in the evaluation of existing policies and the policy recommendations that follows from the analysis falls into three main parts:

- Expanding renewable energy is not an end in itself, but a tool to deliver on the two real policy targets: climate change and energy security.
- Too much policy focus at the Nordic and EU level is dedicated to boost renewable energy share of energy production in the near term, and insufficient resources are allocated to develop future low carbon technologies, which are required when CO₂ abatement targets become more ambitious.
- The long term nature of the challenges and huge investments in low carbon technologies required to deliver on long term targets puts a very high premium on policies that reduces policy risks as perceived by investors.

The report was commissioned by the Nordic Council of Ministers and written by Copenhagen Economics.