



# Analysis of Biofuels Policy in the Nordic Countries

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Contribution to TOP NEST WP3

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## Introduction

This brief study of biofuel policy in the Nordic countries analyses key policy documents, policy instruments for realising the strategies, government funding of related RD&D and considers how European and national policies outline their intentions to develop and use biofuels and describes the policy path taken so far. The study is centred on policies supporting new generations of biofuels which utilize non-food feedstock and are less demanding with regard to the use of land and water resources.

After the introduction this report shows the Nordic developments in a comparative perspective. The next chapters cover the four Nordic countries: Sweden, Denmark, Finland and Norway. The country chapters cover (1) relevant policy documents, strategies and instruments in place over the last ten years, (2) the importance of government RD&D funding for biofuels in the Nordic countries, and (3) the main RD&D funding agencies and programmes in the field of biofuels.

The policy framework conditions provide important background information for the understanding of the development of new technologies. A study of policy documents should reveal national and supranational visions of the future. In the early stages of a new technology we might expect foresight studies; as a technology develops we might expect more documents describing strategies for developing knowledge and demonstrating new technologies, road maps and initiatives directed towards research, industrial development and stimulation of markets. There are some differences in the national pathways, both in defining their goals and deciding on how to achieve them and different policy instruments have been prioritised.

This analysis identifies the main policy instruments used for the development and usage of biofuels. We can distinguish between targeted policy measures and instruments and more indirect measures to stimulate development. Based on the model used by the International Energy Agency (IEA) the following groups of policy instruments are identified (Klitkou et al., 2010b):

- taxes;
- tradable permits;
- incentives and subsidies;
- regulatory instruments (emissions etc.);
- policy processes: White papers, action plans, strategies, agreements, public funds and programmes;
- RD&D: RD&D and technology programmes and RD&D strategies.

For assessing the importance of government RD&D funding for biofuels in the Nordic countries government RD&D funding data provided by the IEA has been used. Missing data for Finland has been obtained by researchers from VTT. For each country the main RD&D funding agencies and

programmes active in the field of biofuels have been identified and their funding activities summarised.

The report is based on analyses conducted in the TOP-NEST project, but it is also informed by a number of research projects funded by Nordic Energy Research: In 2008 the Nordic project Competitive policies in the Nordic Energy Research and Innovation Area (eNERGIA) carried out an analysis of energy research and innovation in the Nordic and Baltic countries (Klitkou, 2008; Klitkou et al., 2008a, b, c). Some of the findings of this analysis are mentioned in this report, under the sections on the different countries. The results of the pilot project Nordic Energy Technology Scoreboard contributed as well to this report (Klitkou et al., 2010a), and finally, the recently published report “Nordic Energy Technology Perspectives” (Nordic Energy Research and International Energy Agency, 2013).

## Europe

Three of the nations covered in this study are EU member states: Denmark, Finland and Sweden, and their national policies for biofuels is therefore highly influenced by European policy in this regard. They have to define their commitment to EU directives on biofuels. Norwegian biofuel policy has also been influenced by EU policy. Therefore this study highlights main events in European policy development for biofuels in the last decade which have had or will have an impact on Nordic biofuel policies (Table 1).

**Table 1: Summary of EU white papers, strategies, road maps, plans, visions and directives relating to biofuels**

8 May 2003	Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport – non- mandatory	European Commission
27 October 2003	Directive 2003/96/EC on the taxation of energy products	European Commission
December 2005	Biomass Action Plan	European Commission (Energy)
8 February 2006	An EU Strategy for Biofuels (Communication)	European Commission
April 2007	Biofuels in the European Union: a vision for 2030 and beyond	Biofuels Research Advisory Council, European Commission
22 November 2007	European strategic energy technology plan (SET Plan) (Communication)	European Commission
23 April 2009	Directive 2009/28/EC on the promotion of the use of energy from renewable sources – Renewable Energy Directive	European Commission
23 April 2009	Directive 2009/30/EC – Fuel Quality Directive	European Commission
10 November 2010	Energy 2020: A strategy for competitive, sustainable and secure energy (Communication)	European Commission (Energy)
8 March 2011	A Roadmap for moving to a competitive low-carbon economy in 2050 (Communication)	European Commission (Climate Action)
24 January 2013	Clean Power for Transport: A European Alternative Fuel Strategy	European Commission

At the beginning of the last decade EU policy documents usually referred to biofuels in the wider context of climate change or renewable energy. However many of the later documents refer more specifically to biofuels. In 2003 the European parliament and the council approved the promotion of the use of biofuels or other renewable fuels for transport in a directive known as the biofuels directive, EC Directive 2003/30/EC (European Commission, 2003). This document was part of the European attempt to meet more general climate change commitments and biofuels was seen as one way of reducing dependence on fossil fuels. The negotiation process was described as "difficult" (Di Lucia and Nilsson, 2007:533) and the main conclusions of the Directive were in the form of an indication of European and national targets for increased biofuel consumption within transport, leaving the different countries to choose the most appropriate policy instruments. The European Commission established the goal of reaching a 5.75% share of renewable energy in the transport sector by 2010.

Di Lucia (2012) showed that for the promotion of transport biofuels in Europe a variety of policy instruments have been applied,

“...command and control instruments (e.g. standards, quotas), economic and fiscal measures, such as tax incentives, and communication and collaborative measures. So far, subsidies through partial or total tax exemptions (complemented by other measures) have proven to be the most successful instrument in creating a market niche for biofuels. However, in recent years, a number of member states have moved towards obligations or mixed systems to lower tax revenue losses” (Di Lucia, 2012:14).

While the different EU member states introduced targets for the deployment of biofuels in transport and policy measures supporting this shifts, the European Commission continued to work on the theme and in 2006 an EU Strategy for Biofuels was produced (European Commission, 2006). In this strategy, the European Commission defines the role of biofuels, and stressed the importance of national targets. The document also discusses the possibility of introducing a regulatory framework for incentives linked to the environmental performance of individual fuels and encourages the use of biofuels in public and private vehicle fleets. This strategy also makes some statements which point towards future development of this technology by stating that it is essential to guarantee that feedstock for biofuels is produced in a sustainable manner. EU member states are encouraged to consider the opportunities offered by biofuels in terms of economic activity and job creation within the context of the cohesion policy and rural development policy. The European Commission state that they will ask the relevant industries to justify their use of practices that act as barriers to the introduction of biofuels and will monitor the behaviour of these industries to ensure that there is no discrimination against biofuels.

The strategy continues to support research and innovation, particularly in order to improve production processes and to lower costs. Research and development into second generation biomass and biofuels (i.e. originating from the processing of lignocellulosic feedstock such as straw and forest residues) is to be promoted via the seventh framework programme. The development of industry-led European technology platforms such as the European Biofuels Technology Platform is proposed to promote a shared European vision and strategy for the production and use of biofuels.

In 2006, "Biofuels in the European Union: A vision for 2030 and beyond" (2006) was developed by the Biofuels Research Advisory Council, which was established by the European Commission. This document includes a strategic research agenda focusing on second generation biofuels using lignocellulosic biomass and refining concepts. The document also includes a roadmap for technological development, suggesting R&D on second generation biofuels and into biorefineries in the period until 2010, then during the next ten years the deployment of second generation biofuel production is expected and large scale production is predicted on the long term, i.e. after 2020. In 2007, this report was an important input for the European strategic energy technology plan (SET-Plan). The SET-plan, was a strategic plan for technology with the aim of stimulating the development of cost-effective low carbon technologies (European Commission, 2010b). This plan was linked to Europe's energy objectives for 2020 and 2050. The plan recognises some of the challenges associated with introducing new environmental technologies and the need for a joint effort by all EU countries. The plan suggests research effort aimed at reducing costs and improving performance of new technologies. Second-level biofuels are specifically mentioned. The SET-plan also introduces a new form of governance based on joint strategic planning across national boundaries.

The 2003 directive was evaluated in 2007 (European Commission, 2007) and it was concluded that most countries had reduced their original targets or not reached their targets for various reasons. This resulted in a new directive 2009/28/EC where targets for renewable energy use by 2020 are increased to 10% for every member state (European Commission, 2009a). At the same time a directive on fuel quality was passed Directive 2009/30/EC – Fuel Quality Directive, taking an important step forward on standardisation, which is an important element in the development of new technologies (European Commission, 2009b). This directive states the aim for 2020 is to "reduce life cycle greenhouse gas emissions by up to 10 % per unit of energy from fuel and energy supplied" compared with 2010. A reduction of ca. 6 % should be achieved by biofuels

In 2010 the European Commission issued the "Energy 2020 – a strategy for competitive, sustainable and secure energy" on energy policy and highlighted the delay in delivery in relation to the Lisbon treaty (European Commission, 2010a). The emphasis is on the urgency of improving energy efficiency

and “making the technological shift” to new clean energy technologies. In 2011 a new roadmap (European Commission, 2011) was issued for the low-carbon economy in 2050 (European Commission, 2011). Regarding biofuels the roadmap stated:

“Sustainable biofuels could be used as an alternative fuel especially in aviation and heavy duty trucks, with strong growth in these sectors after 2030. In case electrification would not be deployed on a large-scale, biofuels and other alternative fuels would need to play a greater role to achieve the same level of emissions reduction in the transport sector. For biofuels this could lead, directly or indirectly, to a decrease of the net greenhouse gas benefits and increased pressure on bio-diversity, water management and the environment in general. This reinforces the need to advance in 2nd and 3rd generation biofuels and to proceed with the ongoing work on indirect land use change and sustainability” (European Commission, 2011:9).

In 2013 the European Commission proposed new legislation (European Commission, 2013) on alternative fuels in a single European Transport Area. The proposal includes a comprehensive strategy for a variety of alternative fuels and includes a plan for implementing new European fuel standards, a European infrastructure, initiatives designed to encourage consumers and the stimulation of further research. It will be up to the nation states to decide with mix of alternative fuels suits best for the own national context.

Each member state will commit themselves to the following:

- assessment of the state and future development of alternative fuels;
- assessment of the trans-border continuity of the infrastructure coverage for alternative fuels;
- the regulatory framework to support the build-up of alternative fuels infrastructure;
- policy measures to support the implementation of the national policy framework;
- deployment and manufacturing support measures;
- research, technological development and demonstration support;
- targets for the deployment of alternative fuels;
- number of alternative fuel vehicles expected by 2020 (ibid: 13).

Much of the content of this directive is much more relevant for hydrogen and electricity, however with regard to biofuels the following standard technical specifications are suggested for diesel fuels containing biofuels:

- petrol containing low-blend bioethanol shall meet the standard EN228;
- diesel containing low-blend biodiesel shall meet the standard EN590;
- all fuel pumps serving petrol at refuelling points shall implement the fuel labelling requirements as defined in the standard EN228;
- all fuel pumps serving diesel at refuelling points shall implement the fuel labelling requirements as defined in the standard EN590.

European policy has played an important role setting concrete targets for the proportion of transportation fuel derived from biofuels. Although the national states have adjusted these targets, most national policies are built upon these targets and indeed use the targets as an argument for new policies. The contours of new targets can be seen in the 2013 report (*ibid*), where national states are prompted to set new and more specific targets, such as the number of alternative fuel vehicles. Otherwise the most notable role the European Union has taken, is that of the "setter of standards". The 2013 legislation on alternative fuels clearly provides European standards on realistic increases in use of biofuels as well stimulating the necessary infrastructure, not only at the national level, but also at the European level.



## Nordic developments

This section attempts to discuss biofuel policies in the Nordic countries in a comparative perspective, while the next chapters will analyse each country on its own. A comparative summary of results of the policies in the different Nordic countries will also be presented here, based on data from 2010 and 2011.

Nordic institutions, such as Nordic Energy Research and Nordic Innovation are active in funding and supporting research collaboration between the Nordic countries and disseminating relevant results to the broader public. Nordic Energy Research aims to contribute significantly to energy policy-making. The research programme Sustainable Energy Systems 2050 and the project Nordic Energy Technology Perspectives will strengthen the policy oriented work of Nordic Energy Research.

### *Organisational models for public RD&D in the Nordic countries*

Negotiation has traditionally been easier between the Nordic countries than within the EU and the Nordic research initiatives do not require the same level of commitment as EU directives, however this does not mean that these countries have followed the same pathways. One of the points highlighted here is the different ways in which policy actors are organised in the different Nordic countries. In the case of Denmark and Sweden, strong links have been developed between environmental policy and energy policy. In these two countries they have previously been organised within the same ministry. In Sweden and Denmark specialised energy authorities have also been established under the respective ministries; the Swedish Energy Agency and the Danish Energy Agency are responsible for managing the larger part of energy RD&D funds and supporting commercialisation in addition to other energy policy tasks. In Finland research funding is channelled through the generic funding bodies, TEKES and the Academy of Finland. In addition to being the main national research funding bodies, these organisations have an important policy advisory function. In contrast with the other Nordic countries, energy issues in Norway are handled by the ministry responsible for oil and gas exploitation. All public research funds for renewable energy research are channelled through the more generic Research Council of Norway. Thus the different countries have chosen different ways of organising policy making and research on biofuels.

### *Policy instruments and path dependencies*

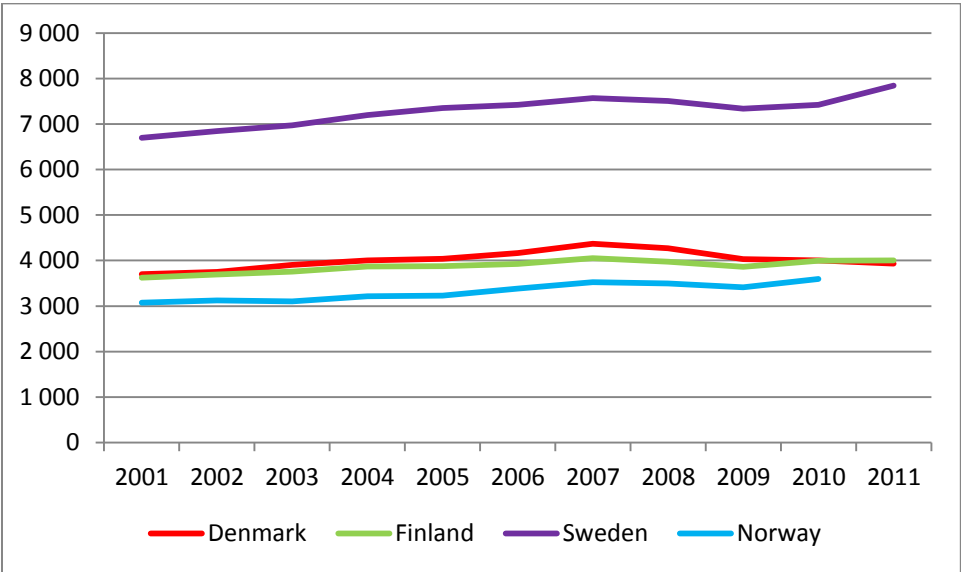
The Nordic countries have also applied different policy instruments for improving the development and deployment of biofuels for transportation means: Sweden has a long tradition for tax exemption for biofuels to increase the use of biofuels in the transportation sector (Econ Pöyry, 2008). In Denmark, the biomass agreement from 1993 supported the introduction of straw and wood chips in electricity generation but not as much for transportation biofuel. Finland has had CO<sub>2</sub> taxes on fossil

fuels since the 1990s, but emphasises investment in industrial development. Norway had CO<sub>2</sub> taxes on fossil fuels since the 1990s and introduced tax exemption for biofuels in 2007, but abandoned this tax exemption for biodiesel in 2009, while bioethanol is still favoured. Grants, R&D programmes and financing pilot and demonstration plants are common instruments across the Nordic countries, especially in the area of second generation bioethanol and biogas.

These different policy instruments are the result of different policy priorities, different traditions regarding the use of bioenergy in general, the different degree of maturity of industrial infrastructure for exploiting bio-resources and different access to national bio-resources. These path dependencies help to explain the differences in national targets of the four countries for biofuels in transport. The Nordic countries adapted the EU target for 5.75% of biofuels by 2010 quite differently: while Sweden maintained the original target, the other Nordic countries reduced this; Norway to 3.5%, Finland to 4% and Denmark did not specify any target for 2010. The Nordic countries differ also regarding types of biofuels available – first or second generation liquid biofuels, biogas from waste, and different blends with fossil fuels.

In the Nordic countries in total the “energy use within the transport sector grew an average 2.6% per year from 1960 to 2010, but only around 1% for the past 20 years. Since the 1980s, road transport has accounted for around 70% of total energy use (up from 55% in 1960)” (International Energy Agency, 2013b, p. 101). The energy use of road transportation grew on average 3.1% since 1960, but only 1.1% since 2001. The highest energy consumption in road transportation had Sweden followed by Denmark, Finland and Norway (Figure 1).

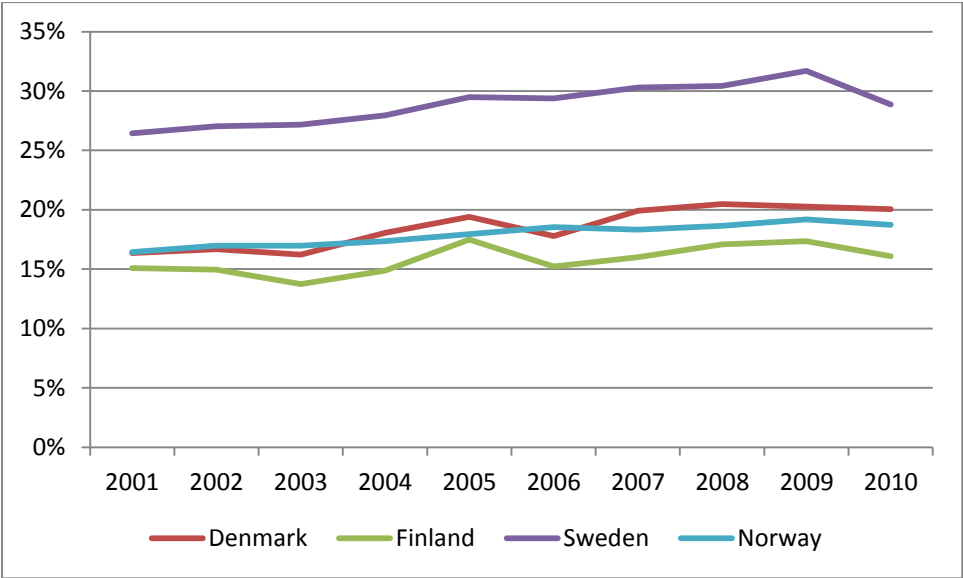
Figure 1: Road transport energy consumption, tons of oil equivalents, 2001–2011



Source: Eurostat

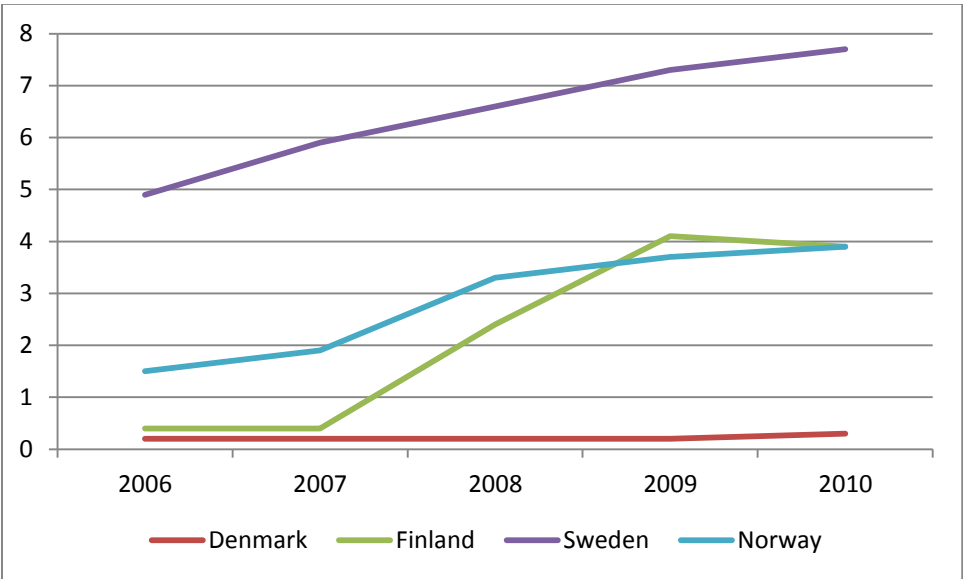
The Nordic countries have traditionally different shares of carbon dioxide emissions from road transportation of the total greenhouse gas emissions. Figure 2 shows the development of this share in the four Nordic countries since 2001. Here it becomes clear that Sweden had a share between 25 and 30% of CO<sub>2</sub> emissions stemming from road transportation while the three other countries have shares between 15 and 20%. Sweden had to address these high shares even more than the three other countries, but also these countries' share of greenhouse gas emissions of the road transportation increased in this period.

Figure 2: Share of greenhouse gas emissions (CO<sub>2</sub> equivalent) of the road transportation, 2001–2010. Per cent of total greenhouse gas emissions.



Source: Eurostat

Figure 3: Share of renewable energy in fuel consumption of transport, 2006–2010. Per cent of total fuel consumption in transport.



Source: Eurostat

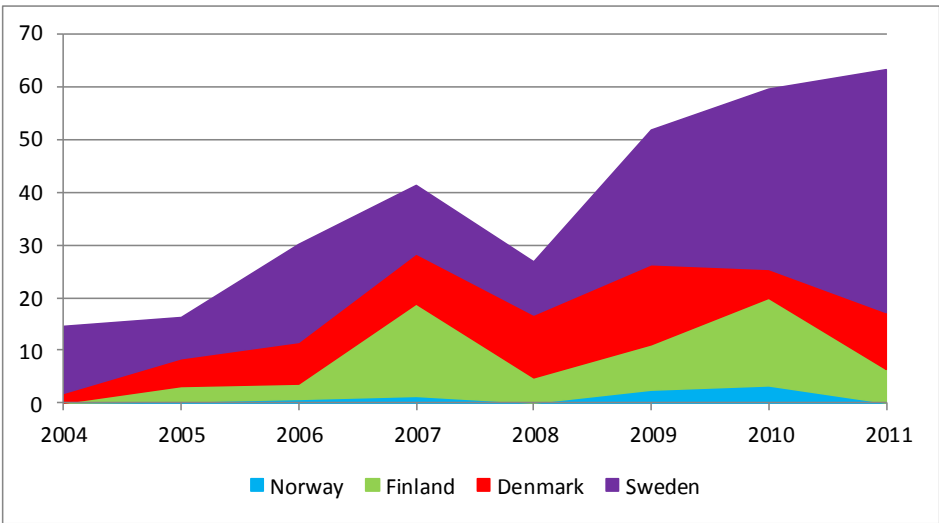
Note: This indicator is calculated on the basis of energy statistics covered by the methodology of the relevant indicator described in the EU Directive 2009/28/EC. However, the contribution of all biofuels is included in this indicator and not only those satisfying the sustainability criteria.

The GHG emissions have been counteracted by the introduction of renewable fuels. This includes both biofuels and electricity. Figure 3 shows the development of the share of renewable energy in fuel consumption of transport from 2006 to 2010. The shares for Sweden, Finland and Norway went up, while the share for Denmark was still rather low in 2010.

*Government funding of RD&D*

The governments in most of the Nordic countries have funded research, development and demonstration of the production of liquid biofuels but not the production of biogas. Figure 4 shows that especially Sweden, Denmark and Finland have provided considerable funding for liquid biofuels RD&D activities while Norway has rather low levels of funding. The total Nordic government funding of RD&D on liquid biofuels increased from 14.56 million € in 2004 to 63.21 million € in 2011.

Figure 4: Government RD&D funding of the production of liquid biofuels, 2004–2011, in million €



Sources: OECD/IEA for Denmark, Norway, and Sweden, and VTT for the values for Finland.

Note: For Norway the values for 2011 were not specified for liquid biofuels.

In addition to the national funding programmes there are also joint Nordic R&D funding instruments. Under the Top-level Research Initiative, there is a programme on sustainable biofuels. Since 2009 this programme had two calls for projects and allocated about 30 MNOK (3.4 million €).

The following sections will give an overview over relevant policy statements and proposed or implemented policy initiatives including RD&D for the four Nordic countries.

## Sweden

### Policy processes and strategies

Sweden's policies on biofuels are part of the more general policies on energy and environment. The key actors in deciding policy are the Ministry of the Environment and the Ministry of Enterprise, Energy and Communication as well as the Ministry of Education and Research. Policy support is provided by The Swedish Energy Agency and by Vinnova. Biofuels became prominent in the political agenda in Sweden after 2000 (Hillman et al., 2011).

The vision of Swedish energy policy is that the country will obtain all future energy from renewable energy sources. Sweden has a long tradition of publically funded research and energy and environmental initiatives are no exception. Large publically funded research programmes on energy have existed since the 1970s.

In 2001 a commission on energy research, development and demonstration was appointed (ERDD) to evaluate initiatives and make proposals for a long-term energy policy for the period after 2003. They recommended an increased focus on commercialisation. This was followed by the publication of the FOCUS II report, in 2005 detailing the long term priorities for Swedish energy research. One of the priorities was the transport sector and one was fuel-based energy systems.

In the meantime a new EU directive had been produced (2003) including a non-binding target of 5.75% biofuels.

In 2005 a commission was appointed to make proposals on how to reduce Sweden's dependence on oil. Their report was published in 2006, "Making Sweden an Oil-free society" with an aim of reducing oil consumption in road transport by 40 to 50% by 2020 (Swedish Commission on Oil Independence, 2006). In 2006 a new Swedish government allocated a "climate billion" to climate initiatives during the period of 2008 to 2010, including support for 2<sup>nd</sup> generation biofuels during the period from 2008–2010.

An integrated climate and energy policy (Swedish Parliament, 2008) was proposed in 2008 in the climate policy bill and in the energy policy bill. Both bills included various action plans designed to reach the target of at least 50% renewable energy by 2020. The Action plan for a fossil-fuel independent vehicle fleet set the following priorities relevant for biofuels: vehicle tax exemption for "green cars" from July 2009, development of an integrated knowledge base on the market for electric cars and plug-in hybrids, extended subsidies for filling stations, biofuels which not generate at least 35% GHG emissions are not accounted for as biofuels, fast implementation of the 2009 EU

directive, analysis of a quota requirement system to speed up the introduction of renewable fuels in the transport sector by the Swedish Energy Agency.

The target is for Sweden to have a vehicle fleet that is independent of fossil fuels in 2030. Currently, the transport system is virtually dependent on fossil fuels and is dominated by road transport. In 2010 greenhouse gas emissions measured in CO<sub>2</sub> equivalents from road transportation made up 29% of the total greenhouse gas emissions in Sweden, which was an improvement compared to 32% in 2009 (compare Figure 2).

The law on sustainability criteria for biofuels (Swedish Parliament, 2010) came into effect on the 26 May 2010, with the Swedish Energy Agency (Energimyndigheten) as the responsible institution. In 2012 a new government inquiry (Statens Offentliga Utredningar) was initiated. The mission is to figure out how to make Swedish vehicles fossil fuel independent by 2030, in accordance with the goal.

## **Policy instruments**

Efforts to reduce the impact of the transport sector on climate are based on pricing instruments for greenhouse gas emissions. The Government's 2008 action plan covers both tax proposals and stimulus for investments in renewable fuels and in the development of alternative technologies.

A tax on fossil oil products was first introduced in the 1970s, to encourage the use of renewable energy (Johansson et al., 2002:7). In 1991, a carbon dioxide tax was introduced, starting at 0,25 SEK/kg and slowly increasing to 0,76 SEK/kg in 2003 and now just over 1 SEK/kg (Nilsson, 2004; Regeringskansliet, 2010:210). After Sweden joined the EU, the tax laws were gradually aligned with EU Energy Taxation Directive (Statens Energimyndigheten, 2010:28). There is currently a parallel system of energy taxes – a general energy tax, levied on most fuels based on energy content and other characteristics; and other 'environmental' taxes (levied for environmental reasons). The carbon dioxide tax mentioned earlier is one such environmental tax. The other environmental taxes are on SO<sub>2</sub> emissions and combustion plants over a certain size pay a fee for nitrogen oxide emissions (budget neutral; plants with large NO<sub>x</sub> emissions per output are net payers and those with low emissions receive money).

Ethanol, biodiesel and biogas are exempt from both energy and carbon dioxide tax. This has been the backbone of the Swedish promotion of biofuels and bioenergy in general. There are also subsidies for filling stations for renewable fuels and since 2006 filling stations over a certain size must offer at least one renewable fuel ("the Pump Law"). The most common and cheapest choice for filling stations is to

provide E85. In 2008 a government grant was provided to help meet the costs of infrastructure and other costs for biofuels other than ethanol.

In 2010, the Parliament adopted sustainability criteria for bio-based motor fuels and liquid biofuels. This means that a sustainability statement is required to get the tax exemption. The sustainability criteria are “that the fuels should lead to a reduction in greenhouse gas emissions by at least 35% compared with the use of fossil fuels, and that certain uses of land for the production of the fuels is not permitted, such as land, which in 2008 consisted of forest, but has been converted to agricultural use” (Swedish Energy Agency, 2011:17).

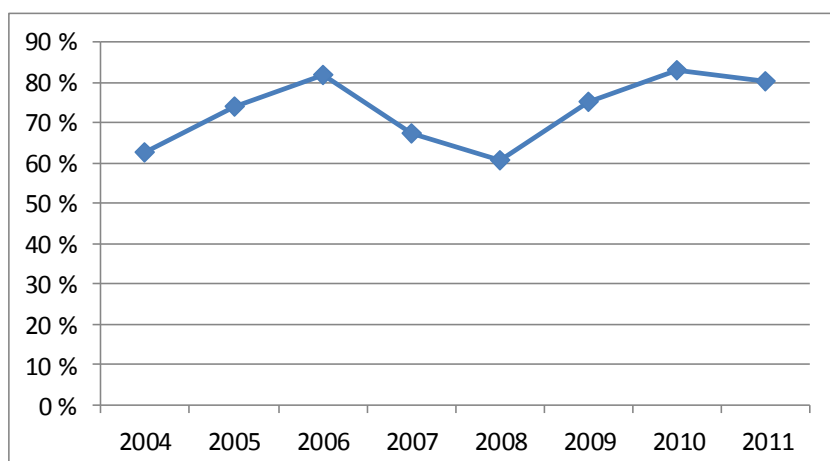
Since 2006, vehicle tax has been calculated according to how much carbon dioxide the car emits, rather than the car’s weight, and charges increased from 2011 (Statens Energimyndigheten, 2010, p. 47). Free or advantageous parking rules for vehicles that meet certain environmental requirements have been implemented. From 2007 to 2009 a subsidy for investing in low energy vehicles (“miljöbilspremie”) of 10,000 SEK was available and on the 1<sup>st</sup> of January 2012 an investment subsidy of SEK 40,000 became available, (“supermiljöbilspremie”) for vehicles with CO<sub>2</sub> emissions less than 50 g/km.

Public sector requirements for biofuels in public buses have also been instrumental in promoting use of biofuels, especially for the development of biogas as vehicle fuel. In 2011, a new Act on environmental requirements in the procurement of vehicles and certain public transport services came into force. Such environmental requirements include “a vehicle’s energy use and emissions of carbon dioxide and certain air pollutants in operation, during the entire period of use” (Swedish Energy Agency, 2011:19). In the 2013 Budget Bill the Swedish government proposed “to introduce from 2013 onwards an energy tax on biofuels used for low-blend purposes, at such a level that it does not discourage the use of low-blends in the market” (International Energy Agency, 2013a:19).

## **Government funding of RD&D**

Public research funding has stimulated research in bioenergy in general including the development of liquid biofuels. A large share of Sweden’s government RD&D funding is in liquid biofuels: in 2011 46 million € or 26% of the total energy RD&D budget (OECD/IEA, see also Figure 4). This funding includes demonstration projects such as improved production processes of second generation biofuels in pilot-scale plants. Several pilot production plants have been established, such as for lignocellulosic feedstock at Örnsköldsvik, biomass gasification at the Växjö Värnamo Biomass Gasification Centre and black liquor gasification at Piteå. Figure 5 shows the share of the funding of demonstration projects for the production of liquid biofuels: in 2011 about 80% of the public funding of RD&D for liquid biofuels went into demonstration projects.

Figure 5: Share of Swedish government funding of demonstration of the production of liquid biofuels of total government funding of RD&D on liquid biofuels, 2004–2011



Source: OECD/IEA

## RD&D funding agencies and programmes

There is a long tradition for public funding of research, development and demonstration of biofuels in Sweden. Since the first oil crisis in 1973 alternative transport fuels have been on the agenda (Hillman and Sandén, 2008). Hillman and Sandén distinguish between three periods: (a) 1974–1985: due to two oil crises government initiated and funded R&D on methanol to *substitute oil*, (b) 1986–1997: introduction of local bus fleets and local, small-scale biofuels to reduce *local air pollution*, and (3) 1998 to now: private and government funding of RD&D of alternative transport fuels to address *climate change, comply with the EU biofuels directive and handle oil scarcity*. Biogas and bioethanol have received most attention in public funded projects. In 1991, a Fund for energy technology was established to support the development of new technologies, the Agency for Industry and Technology Development established the Ethanol Development Programme and the Communication Research Board started the demonstration programme on use of ethanol in heavy vehicles (Hillman, 2011:9).

### *Swedish Energy Agency*

The Swedish Energy Agency (SEA) supports the achievement of national targets and is responsible for Sweden's National Energy Research Programme. One of their tasks is to manage and monitor the quota requirement system to speed up the introduction of renewable fuels in the transport sector. Energy research in the transport sector is one of the six prioritised thematic areas. The agency gives funding to a range of R&D programmes relevant for biofuels, both for the development of renewable motor fuels and for energy-efficient vehicles such as "The development of renewable motor fuels centres primarily on ethanol, DME/methanol, biogas and synthetic natural gas through gasification



(SNG), i.e. methane" (Swedish Energy Agency, 2011:45). The Swedish Energy Agency also operates as secretariat for the European Biofuels Technology Platform.

From 2007 to 2010 SEA financed a biofuel R&D programme<sup>1</sup> and from 2007 to 2011 an ethanol programme with a budget of 144 million SEK<sup>2</sup>. SEA has a new biofuel R&D programme<sup>3</sup>, running from 2011 to 2015. This programme focuses on feedstock provision (refining waste from forestry and agriculture), processing and sustainability of biofuel. There is also a new programme on ethanol processes, which has a budget of 130 million SEK<sup>4</sup>.

In 2008, the Swedish Government defined strategic research areas in the Bill "A Boost to Research and Innovation". Three of the strategic research areas are in energy research and they are administered by SEA. The budget for research into energy SEK 50 million in 2010 rising to 100 million in 2011, then 160 million in 2012. Three strategic research projects received funding:

- *Bio4Energy* with the aim of "examining the consequences of a shift from fossil oil-based chemicals' production to chemicals' manufacture based on forest-sourced raw materials" and "fine tuning a gasification process used to make biofuels from logging residues". Umea University is leading this project. The point of departure for this project is re-use of all tree products, rather than a direct emphasis on the development of biofuels for transport.
- The *Chalmers Energy Initiative* covers four research areas: Energy combines, Electric propulsion systems and hybrid vehicles, Large-scale renewable electricity generation and grid integration, and Technology Impact Assessment.
- *Standup for Energy* is based on collaboration between the Uppsala University, KTH and the Swedish University of Agricultural Sciences and Engineering. The overall objectives of the project are to reduce the cost of large-scale production of renewable electricity, and to develop cost-effective and energy-efficient hybrid and electric vehicles.

In 2011 the Swedish Knowledge Centre for Renewable Fuels was established with SEK 30 million to cover the first three years of operation. The Centre includes all the universities organised in the three above mentioned strategic research projects, research institutes, such as the Swedish Environmental Research Institute, Inventionia and the Technical Research Institute of Sweden, the Swedish Energy Agency, the Region of Västra Götaland and industrial partners engaged in energy production and vehicle production, such as Eon Sweden, Göteborg Energi, Perstorp, Preem, Scania, Sekab E-technology and Volvo Technology. It is intended to function as a common platform for the development of new technologies. The centre invests in R&D and infrastructure and advises government on policy issues.

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<sup>1</sup> [http://energimyndigheten.se/Global/Forskning/Bränsle/Synteser/Bränsleprogrammet\\_strategisk\\_kunskap.pdf](http://energimyndigheten.se/Global/Forskning/Bränsle/Synteser/Bränsleprogrammet_strategisk_kunskap.pdf)

<sup>2</sup> <http://energimyndigheten.se/Forskning/Transportforskning1/Energieffektiva-fordon/Etanolprogrammet/>

<sup>3</sup> <http://energimyndigheten.se/Forskning/Bränsleforskning/Bränsleprogrammen/>

<sup>4</sup> <http://energimyndigheten.se/Forskning/Transportforskning1/Alternativa-drivmedel/Omrade-Etanol/Programmet-Etanolprocesser-2011-2015/>

The Swedish Energy Agency made considerable contributions to the funding of the Växjö Värnamo Biomass Gasification Centre, in addition to funding from the EUFP6 project CHRISGAS and a number of private enterprises. The Värnamo syngas demonstration project work in 2010-2011 was supported by AGA-Linde, SGCE, EON, Vattenfall, the municipalities of Växjö and Värnamo and financed by the Swedish Energy Agency. However, due to the financial crisis and problems of the participating enterprises, the Agency had to stop the funding of the project in February 2011.

The Swedish Energy Agency and the EU7FP have co-financed a major demonstration project (BioDME) for the production of dimethyl ether from black liquor, a by-product of the pulp and paper industry, through the production of clean synthesis gas and a final fuel synthesis step.<sup>5</sup> Preem Petroleum AM, Volvo Technology Corporation, Delphi Diesel Systems, Chemrec AB, the Energy Technology Centre in Piteå, Total, and Haldor Topsøe in Denmark are industry partners of the project. BioDME has turned out to be as efficient as diesel in heavy duty vehicles and Volvo has developed trucks fuelled with BioDME.

#### *Research Council Initiatives*

From 2001, research funding in Sweden has been organised in four research councils: the Swedish Research Council (VR); the Swedish Agency for Innovation Systems (VINNOVA); the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas); and the Swedish Council for Working life and Social Research (FAS).

The research council is organised in traditional thematic areas such as "Natural and engineering sciences" and is designed to stimulate mainly basic research and national research infrastructures. The research council has 20 strategic research areas within which applicants can apply, one of these areas is the sustainable use of natural resources, where the aim is "mitigating climate change and strengthening Sweden's competitive edge in the global marketplace" (Vetenskapsrådet, 2009). Climate models and nanoscience/nanotechnology are also strategic areas, which may be relevant for research into biofuels.

#### *Vinnova Initiatives*

Vinnova is also a publically funded body who manage funding for research and innovation, where the emphasis is very much upon the commercialisation of science and technology and the involvement of industrial partners. Vinnova's activities are currently divided into 11 strategic areas, Transport and Environment is relevant for biofuels, and although there is a thematic area called Challenge Driven Innovation, this does not currently include any funding directed at biofuels.

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<sup>5</sup> <http://www.biodme.eu/>

The budget for research on renewable energies was SEK 20 million in 2010, SEK 30 million in 2011 and SEK 50 million in 2012. These numbers do not include the funding from SEA. However none of the projects currently registered are related to biofuels. The budget for research into transport was SEK 25 million in 2010, 50 million in 2011, thereafter 80 million. One of the projects in this group is the Chalmers Sustainable Transport Initiative, running from 2009 until 2014 with a total budget of SEK 180 million. This project is quite wide-reaching and covers social and economic factors influencing transport. However it also includes research into hybrid vehicles and into fluid dynamics and fuel catalysis.

Several of the programmes categorised within the theme of Transport and Environment, include research which is relevant to the development of biofuels and to a transition to sustainable transport. These are:

- Innovations for a sustainable future – this a general programme with the aim of introducing new, environmentally-adapted solutions which can contribute to sustainable production and consumption whilst creating economic value and developing the knowledge base in Sweden.
- Passenger Transport in the Future – is a programme that addresses public transport in a broad sense. The overall objective is to facilitate travel by promoting an efficient and sustainable public transport system. The programme is based on collaboration between Trafikverket (the Swedish Transport Administration) and Vinnova on R&D work in the public transport field, and has a total budget of at least SEK 50 million. The programme started in 2007 and will run for five years.
- Innovative Vehicles for Different Transport Modes – this programme attempts to integrate vehicle manufacture with ICT to produce more flexible forms of environmentally friendly transport. The programme also strives to establish positive collaboration between manufacturers, researchers and society at large in order to find solutions to current transport problems.

Vinnova's VINNVÄXT programme at the end of the 1990s initially provided the necessary funding for the BioFuel Region.<sup>6</sup> Sekab in Örnsköldsvik is part of this BioFuel Region and specialised in the production of cellulose-based ethanol. In 2000 the Swedish Energy Agency financed the construction of a pilot plant and it was inaugurated in 2004 (Klitkou et al., 2008b). In 2008 Sekab estimated that a commercial plant could be operational from 2014 to 2015. However, at the end of 2011 Sekab had to announce the closure of its cellulosic ethanol pilot plant in 2012 due to the lack of financial resources<sup>7</sup>.

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<sup>6</sup>Vinnova, ISA and NUTEK (2005), "Formation for Collective Action - The development of BioFuel Region".

<sup>7</sup>[http://www.sekab.com/media?nd\\_ukey=c558a509958ac3b6122d3c84480e1fae&nd\\_view=view\\_pressrelease&nd\\_nr\\_of\\_items=3&nd\\_id=713995](http://www.sekab.com/media?nd_ukey=c558a509958ac3b6122d3c84480e1fae&nd_view=view_pressrelease&nd_nr_of_items=3&nd_id=713995)

## **Summary**

Sweden has created a clear vision of the move from fossil fuels to clean energy. This vision addresses high energy consumption for road transportation and high share of GHG emissions from the same sector. Sweden continues its tradition of investment in research, development and demonstration and the support of collaboration between industry and research organisations, taxes on fossil fuels and Sweden actively uses public procurement of vehicles and biofuels for public busses to stimulate development of new technologies.

## Denmark

### Policy processes and strategies

Denmark has a long tradition of promoting renewable energy and traditionally energy policy has been viewed, not only as something which contributes to environmental issues, but also as a source of employment and economic growth. To give an idea of the importance of energy in the Danish economy, energy technology export was 9.5% of total industrial exports, in 2010 (Energistyrelsen et al., 2011). Expertise on renewable energies in Denmark has traditionally been concentrated on wind power and the production of domestic heat and power from agricultural waste. Denmark is also committed to increasing the use of biofuels and being an EU member, Denmark has a target for biofuels suggested by the EU, which was 5.75% by 2010. Their own national target is 10% by 2020. By 2050 the Danish government has the vision that all energy supply in the Danish transport sector will be met by renewable energy (Danish Ministry of Climate Energy and Building, 2012:15). In addition to EU goals, Danish policy makes clear their commitment to the Kyoto Protocol and other international climate initiatives.

In the 1990s the Ministry of Energy developed an action plan (Miljø- og Energiministeriet, 1996) outlining their strategy and goals. This was the fourth action plan in a series started in the 1970s. During the eighties, the amount of public R&D spending was rather low, but renewable energy sources began to receive more attention and biomass related R&D increased considerably in the 1990s (Klitkou, 2008).

In 2001, with the government under Fogh Rasmussen, energy research came under pressure. Several instruments were removed and budgets for the remaining instruments were reduced considerably around 2002. In the early stages of the Fogh Rasmussen government, market conditions were used as the basis for research funding and this resulted in little funding for renewable energy research. This had a detrimental effect on some of the research activities and was controversial, but this trend changed considerably when new public funding was allocated again in 2004 and 2005, with the same amount of public spending as in 2001. In 2004 efforts were made to gain broad political agreement on the future energy infrastructure and the Energy Strategy 2025 was formulated by the Ministry for Transport & Energy (Danish Ministry of Transport and Energy, 2005). In the wake of this several measures were introduced, such as research funding and supporting legislation was passed in subsequent years. In 2006 the advisory committee on energy research (REFU) produced a strategy, recommending budget commitment and more field specific R&D including fluid biofuels (REFU, 2006). The first progress report on the National Reform Programme (Danish Government, 2006) suggested a new programme for testing and demonstration of efficient energy technologies, a

programme involving industry and research on 2<sup>nd</sup> generation bioethanol and market based instruments to encourage the move to renewable energies. In an Energy Policy Statement to the Danish Parliament in 2008, the Minister of Climate and Energy emphasised three main challenges (Danish Minister of Climate and Energy, 2008): energy saving and enhanced energy efficiency, increased use of renewable and environmentally friendly energy, and increased investment in research, development and demonstration of cost effective technologies and alternative energy supply forms. In 2008, the Danish government reached an agreement with a broad range of political parties on a national energy policy for 2008 to 2011. In compliance with EU regulation, legislation on sustainable biofuels for the transport sector was passed in 2009 (Lov nr. 468, 12<sup>th</sup> June 2009). This included the development of the necessary infrastructure to make biofuels available for transport users. It includes regulation of producers and importers of petrol and diesel. Targets for the gradual increase in biofuels are included, from 0.75% in 2010 to 5.75% in 2012. Following EU legislation this share can be expected to be increased to 10% from 2020 (Danish Energy Agency, 2012b). There is also a clear emphasis on the move to 2<sup>nd</sup> generation biofuels and the intention to influence EU regulation to enforce the move to 2<sup>nd</sup> generation biofuels, is also stated. In 2011 the government produced an energy strategy for 2050 (Danish Government, 2011a) creating a vision of the move to clean energy, suggesting policy initiatives and public funding priorities.

In the same year the recently elected new government produced the report “Vores energi” (Our Energy) (Danish Government, 2011b), with a distinct emphasis on Denmark’s role in the European and global arenas for energy policy. Danish initiatives are described in terms of their contribution to an international transition to clean energy. The report conveys an understanding that traditional forms of energy cannot simply be replaced one by one, but that a more complex system of changes must be effected. The new goal is 100% renewable energy by 2050. Means of financing a transition to renewable energy are discussed, but the use of biofuels in transport is not central to this report. The report pointed out that, in the short term, Danish policy will focus on relevant sustainability criteria for first generation biofuels, while second generation biofuels will possibly play a more important role in a longer perspective, especially for heavy transport and air transport, but this technology has been assessed as being too expensive to be a part of the present solution. This report resulted in the Energy Agreement being passed by the Danish government in March 2012 (Socialdemokraterne et al., 2012). The strategy points out the need to amend the Law on biofuels to ensure 10% biofuel in transport by 2010 and to analyse alternative initiatives before 2015.

One of the challenges identified by the Danish government was the need to coordinate between different ministries. Their attempt to resolve this was the creation of a new ministry in 2007, the Ministry of Climate and Energy.

## Policy Instruments

Environmental legislation has been important in Denmark and taxes on CO<sub>2</sub> emissions have been in place since the 1990s and since 2005 biofuels have been exempt from fuel taxes. In 2010 it was estimated that the results of these policies in terms of % of biofuels used in transport made up 0.12% of total sales of petrol and diesel for transport. Hydrogen vehicles are exempt from taxation.

Legislation committing oil companies to biofuels sales targets has been in place since 2010. Denmark has also been eager to implement initiatives obliging to comply or contribute in some way to achieving the government aim (Public service obligation, PSO). Pools of partners including local councils and businesses have been established to promote strategic energy planning and better use of local resources (Danish Government, 2011b). Programmes managed by electricity companies have also been established, but so far these have not been directed towards biofuels.

In the field of biogas policy a change in the planning law obliges municipalities to plan the biogas plant installations in the upcoming revision of municipality plan in 2013. Municipal natural gas companies get a possibility to engage in biogas production as an activity connected to their commercial activities.

According to the Energy Agreement (2012), the following changes in the support model for biogas development will be implemented, allowing overall subsidy to biogas (used in CHPs or gas networks) at up to €15/GJ:

- the existing support of €10/GJ biogas used in CHPs continues as basic support;
- biogas delivered to the natural gas network will also receive €10/GJ;
- a new support for process biogas used in industry and transport of €5/GJ;
- launching support is increased from 20% to 39% in 2012;
- implementation of support of €3.4/GJ for all uses of biogas. The support will be gradually decreased in relation to increasing natural gas prices, with €0.13/GJ, when natural gas price increases by €0.13/GJ;
- a support of €1.3/GJ for all uses of biogas will be implemented, gradually decreased with €0.26/GJ from 2016 to €0/GJ in 2020;
- biogas will be one of the energy sources to replace petrol and diesel in the transport sector, beside electricity and natural gas;
- a pool of DKK 70 million in the years 2013-2015 will be established to provide funding for the development of infrastructure, such as more recharging stations for electric cars, hydrogen filling stations and filling stations for gas in heavy transport (ibid.:15).

Currently, Denmark, among other nine EU countries, has set up regulations enabling biogas to be injected into the natural gas grid (Biogas Barometer, 2012).

## **Government funding of RD&D**

From 2008 to 2011 the Danish government provided over 450 million € on energy RD&D. 25% of this funding went into bioenergy and waste (Danish Energy Agency, 2012a).

Public research funding has stimulated research in bioenergy in general including the development of liquid biofuels. A large share of Denmark's RD&D investments goes into liquid biofuels: in 2009 15 million € or 14% of the total energy RD&D budget (OECD/IEA, Figure 4). These investments include public funding of demonstration projects such as improved production processes of 2<sup>nd</sup> generation biofuels in demonstration plants. In 2007 and 2008 between 77 and 78% of the government funding of liquid biofuels went into demonstration projects (OECD/IEA). Several demonstration production plants have been established, such as a demonstration plant for 2<sup>nd</sup> generation bioethanol production at Kalundborg by Inbicon (Larsen et al., 2008; Persson, 2009) and BornBioFuel2 on Bornholm by Biogasol Aps (Langvad et al., 2010).

## **RD&D funding agencies and programmes**

There are several R&D programmes in the field of energy. The Danish Energy Agency is responsible for several R&D programmes, such as the Energy Research Programme (established in 1976 and finalised in 2008), the Energy Technology Development and Demonstration Programme (EDDP, established in 2007) and GreenLabs.DK (2010–2012). The EDDP provides important guidelines for the direction of future developments in energy technologies and second generation biofuels for use in transport and the integration of energy technologies are among the prioritised areas. Important R&D projects included for example the development of improved 2<sup>nd</sup> generation bioethanol technology to prepare for commercialization by Inbicon A/S (2009–2012). A large number of demonstration projects have been funded by EDDP: industrial scale straw-to-bio-methane conversion (C. F. Nielsen A/S, 2012–2015), high yield fermentation process for 2<sup>nd</sup> generation bioethanol production (Terranol A/S, 2012–2015), bio-oil from biomass and waste (Organic Fuel Technology A/S, 2012–2014), advanced methanol synthesis technology (Haldor Topsøe A/S, 2012), REnescience waste refinery (DONG Energy A/S, 2010–2012), BornBioFuel2: A fully integrated 2<sup>nd</sup> generation bioethanol demonstration plant on Bornholm based on the Maxifuel concept (Biogasol Aps, 2009–2012) and the construction of demonstration plant for 2<sup>nd</sup> generation bioethanol production at Kalundborg (Inbicon A/S, 2008–2010).

GreenLabs.DK gave funding to test centres for new energy technology and received public funding of 129 million DKK in the first round and 82 million DKK in the second round. At least 50% of the total



budget had to be co-financed by private enterprises. One minor project in the first funding round was the Green Gas Test Centre in Hørsholm, receiving 2 million DKK.

Since 2004 the Danish Council for Strategic Research has had a Programme Committee for Sustainable Energy and Environment; their funding is administrated by the Danish Agency for Science, Technology and Innovation. The Danish Council for Strategic Research also assists other government research agencies in the assessment of high quality project proposals, such as the programmes under the Energy Agency or relevant energy projects funded by the Danish National Advanced Technology Foundation. The Danish Environmental Protection Agency is also an active player in shaping energy policy.

In addition to these government programmes Energinet.dk's has the ForskEL programme which focuses on technologies for environmentally-friendly power generation and the Danish Energy Association have ELFORSK focusing on efficient use of electricity. Both have contributed considerable R&D funding of energy projects, but not so much for liquid biofuels.

There is also the Danish National Advanced Technology Foundation that supports Danish high-tech companies also in energy area. For the year 2013 there is 530 million DKK available for distribution in two main rounds.

Denmark is active in EU research programmes specialised in energy. Denmark is also active in several ERA networks, COST for cooperation on scientific and technological research in Europe and OPET for the promotion of energy technologies. 43% of all EU-funding for Danish firms under the 7<sup>th</sup> EU Framework Programme went to firms specialised in energy and 9% to firms specialised in transport (Styrelsen for Forskning og Innovation, 2012:15). For the years 2008 to 2010 Danish participants under the 7<sup>th</sup> EU Framework Programme received 68.2 million €, a share of 7.38% of the total funding. Of this 25.8 million € were spent on biofuel R&D: here the Danish share – 14% – was even higher (Danish Energy Agency, 2011:38).

## **Summary**

Denmark has been proactive in developing a clean energy policy, but until recently there has been little emphasis on stimulating the increased use of biofuels in transport. More recent policy demonstrates a greater understanding of and commitment to biofuels and the expressed interest in participating and promoting second generation biofuels in Europe suggests a more long-term commitment to developing this technology.

## Finland

### Policy processes and strategies

Energy production in Finland has traditionally been highly diversified in order to increase the security of energy supplies and to ensure a reliable operating environment of the Finnish energy intensive industries. Finnish pulp and paper industries have long traditions and these have influenced long term RD&D on the whole biomass value chain. Today Finland is one of the global leaders in fluidized bed technology (combustion, gasification, pyrolysis) and wood harvesting technologies. An interesting business strategy is to integrate new technologies, like second generation biofuel production, to forestry and related industries. Finland is also an EU member and is committed to meeting EU targets and to the Kyoto Protocol. These issues form the backdrop of recent Finnish policy on biofuels.

Since 2008 responsibility for energy policy and innovation policy in Finland have been within the ministry of Employment and the Economy. This ministry is based on the merging of the previously separate ministries of Trade and Industry and Labour. Tekes, the Finnish Funding Agency for Technology and Innovation is the organisation which distributes and manages R&D funding, they also provide expert services and create networks between companies and researchers. The Ministry of Employment and Economy manages investment and other support to promote the use of clean energy technologies.

Finland produced a National Energy Strategy in 2005 (Finnish Government, 2005) which included recommendations on Renewable Energy Sources (RES). It proposed a strategy directed towards development of new technologies, tax subsidies for end-users of renewable energy were proposed and new investment subsidies of up to 30% of development costs for renewable energy technologies were proposed (EU statistics). On the basis of the recommendations of an expert group in 2006, the government proposed legislative changes to be implemented in 2008. These changes were aimed at creating a demand for biofuels by placing an obligation in respect of the marketing of biofuels on the distributors of transport fuels. In 2008, the Government approved a new ambitious climate and energy strategy (Finnish Government, 2008), with detailed insights into climate and energy policy measures up to 2020 and suggestions up to 2050. The strategy reveals an understanding that EU climate targets will not be reached unless there is a greater commitment to "new, prominent climate and energy policy measures (ibid). In 2009, the Finnish Government published a Foresight report, which included targets to reduce Finland's greenhouse gas emissions by 80% by 2050 (compared to the 1990 level). Currently, Finland is updating its energy and climate strategies which include measures up to 2030, and additionally, the ministry's new Clean Tech programme, which was

launched summer 2012. In 2013, the Ministry of Employment and the Economy will prepare Finland's low carbon strategies up to 2050.

A presentation of the Tekes strategy includes "the sustainable use of energy and natural resources and versatile and responsible exploitation of renewable resources are competitive factors in sustainable economy" (TEKES, 2011). The areas prioritised are:

- energy and raw material efficiency;
- renewable energy solutions;
- new forest and biomass solutions;
- sustainable solutions for mineral resource use and water consumption.

With regard to bioenergy, Finland has been considered a "superpower for bio-energy" (Klitkou et al., 2008a:51) with up to 25% of total primary energy being renewable sources. Until recently the emphasis has been on energy production rather than biofuels; however Finland has a long tradition of finding new ways to exploit wood products and this has recently become particularly interesting with regard to 2<sup>nd</sup> generation biofuels. Funding of technology development and commercialisation of renewable energy technology has been managed by Tekes; this includes funding of biofuels and in particular the refining of new biomass products.

In 2010 the proportion of transport fuels which were biofuels reported to EU in 2008 was 3.6% and consisted of bioethanol, ethers and biodiesel.<sup>8</sup> Finland's obligation to EU targets on biofuels is that 10% of transport will run on biofuels by 2020, however Finland's own target is in fact 20% for the same period of time (Finnish Ministry of Employment and the Economy, 2012). This ambitious target is based on the government's assessment of the availability of raw materials and the technological competence to produce enough 2<sup>nd</sup> generation biofuels that are eligible in "double-counting", i.e. made from lignocellulosic, waste or other similarly classified raw material. Recent developments in technology can take advantage of Finland's forest by-products and not only will it be possible for Finland to reduce dependence on other fuel sources, but the production of biofuels is viewed as being a source of major business opportunities. In the same announcement the goal of constituting several large-scale biorefineries with investment of €100 million from the Finnish government and EU's NER funding was stated. Three applications for biorefineries were submitted to the ministry which forwarded the applications to the European Investment Bank (EU's NER funding). One of these applications has good opportunities to receive the NER funding. Additionally, the Finnish forest company UPM is building a biofuel plant (using tall oil as raw material), which should be operational in 2015.

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<sup>8</sup> 2009 Report on promotion and use of biofuels and other renewable fuels for transport in Finland required pursuant to directive 2003/30/EC

## Policy instruments

Finland was one of the first Nordic countries to impose a carbon-based environment tax by introducing a CO<sub>2</sub> tax on fossil fuels in 1990.

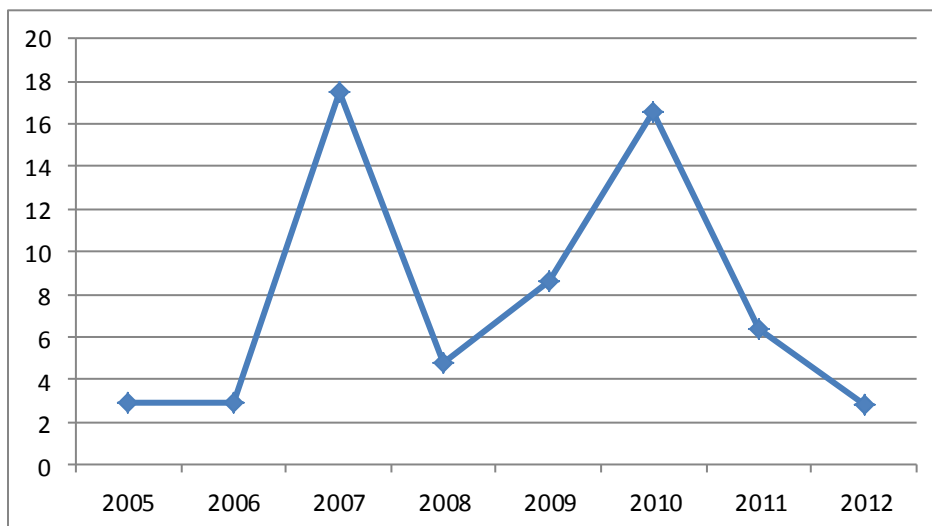
Public funding for investment in renewable energies has been available since 2002 providing up to 40% of the costs of innovative technology projects (Finnish Ministry of Trade and Industry, 2002).

In 2010, an energy tax reform was prepared, which came into force at the beginning of 2011. The most important element of the reform is that the taxation of all fuels, including transport fuels, is now based on their energy content and carbon dioxide emissions.

## Government funding of RD&D

The RD&D work in Finland on biofuels for transport has been focused on the development of production technologies for next generation biofuels and demonstration for their use. For the period 2007-2012 governmental biofuel RD&D funding mainly consists of the BioRefine programme of Tekes, 'Second Generation Transport Biofuels' piloting and demonstration funding by the Ministry of Employment and the Economy and SusEn programme of the Academy of Finland.

Figure 6: Government funding of RD&D in Finland, 2005-2012, in million €



Note: The information in this figure was calculated by summing up relevant funding of BioRefine, SusEn, "Second generation transport biofuels and Climbus programmes.

The BioRefine programme and TEM programme have worked in close cooperation. Under these two programmes the governmental funding to transport biofuels have been about 52 million € in 2007-2012. The funding in the SusEn programme to basic research in this field have been about 3 million €.

In 2004-2007 Tekes ClimBus programme was the main source of relevant governmental RD&D funding (the programme had a broader scope, but some of the projects focused on biofuels). The funding to transport biofuels was 7.2 million €.

## **RD&D funding agencies and programmes**

The main funding agency for basic research in Finland is the Academy of Finland. Tekes is the funding agency focused on technology and innovation and SITRA is the Finnish Innovation Fund.

*Tekes, the Finnish Funding Agency for Technology and Innovation*

Tekes was founded in 1983 and is part of the Finnish innovation system under the domain of the Finnish Ministry of Employment and the Economy. Tekes has coordinated Finland's technological research and innovation and has launched several programmes relevant for renewable energy in general.

In 2004, Tekes launched a technology programme called ClimBus<sup>9</sup> – Business Opportunities in Mitigating Climate Change. The programme invested in the development of technology and business concepts related to reduction of greenhouse gas emissions. It ran from 2004–2008, with the total budget exceeding €90 million. ClimBus focused on:

- clean energy production and fuels;
- business services;
- technologies for energy efficiency and non-CO<sub>2</sub> greenhouse gases;
- the programme also generated an overview of the business opportunities that climate policy creates and the most lucrative technologies on the market after 2010.

In 2006 an R&D project consisting of public and private actors was launched to demonstrate use of biofuels in public bus transportation in the Helsinki area (International Energy Agency, 2012). The project "OPTIBIO" was part of the Tekes Biorefine programme and was originally a large-scale field test of paraffinic (HVO) synthetic diesel fuel (NExBTL; produced by Neste Oil), and the primary target was R&D and not to convert busses to run on biofuels. However, the policy of Helsinki Region Transport that controls all the public bus transport in the Metropolitan area is in favour of biofuels, and extra credits have been available for those operators who comply. About 100 busses are running on CNG, and recently the natural gas supplier (Gasum) has started actively seeking for suppliers of bio-methane, to be fed into the gas pipeline. They have managed to get capacity to equal the demand of busses, so in practice those busses now run on biogas.

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<sup>9</sup> Before the ClimBus programme Tekes had a ClimTech programme and there have also been several other programmes to support R&D on renewables. In 2011, Tekes launched the Electric Vehicle Systems Programme, which will run until 2015 (<http://www.tekes.fi/programmes/EVE>).

The BioRefine – New Biomass Products Programme of Tekes<sup>10</sup> for 2007–2012 has aimed to generate new and unique expertise in the processing of biomass and to apply it to the creation of processes, products and services related to biorefineries. A further objective has been to promote the development and use of second-generation production technologies in biofuels for transport. The main technologies being developed are:

- synthetic biodiesel from wood/forest residues, gasification;
- synthetic biodiesel from new raw materials, algae, microorganisms etc.;
- biofuel oil from wood/forest residues, integrated pyrolysis; and
- lignocellulosic ethanol, straw, refuse and waste.

The programme harnesses an extensive network of Finnish research institutes, universities and enterprises. The total volume of the projects in the programme is expected to reach about €250 million by 2012. The projects funded by the programme cover a spectrum of products – biofuels, chemicals, materials – utilising biomass in a variety of forms. Some examples of the projects carried out within the BioRefine programme (Mäkinen and Savola, 2011):

- three industrial-driven development and demonstration projects on commercializing the so-called syngas route for producing biofuels for transport: Neste Oil and Stora Enso, UPM and Vapo;
- research projects coordinated by VTT Technical Research Centre of Finland in which new fundamental data on the methods of producing biofuels for transport via the synthesis-gas route were generated with emphasis on the synthesis-gas production and gas cleaning steps;
- production of sugars and alcohols has been studied in several research projects;
- Metso, UPM, Fortum and VTT Technical Research Centre of Finland have developed a new concept for the production of biomass-based bio-oil by fast pyrolysis to replace fossil fuels in heating and power generation;
- pilot-scale development of new second generation BTL technologies based on gasification and pyrolysis coordinated by VTT;
- the sustainability of biofuels and the sustainability criteria, in particular those set by the EC, have been assessed by Finnish research institutes in two projects.

In 2010 Tekes launched the Groove programme to support commercialisation of renewable technologies.<sup>11</sup> It will run until 2014. Here funding goes to projects on wind technology, commercialisation of renewable technology in China, India and Africa, biogas, and projects on algae in the production of biofuels in India (ALGIND-project).

The Ministry of Employment and Economy is implementing a special development programme with the emphasis on pilot and development projects for second generation transport biofuels technologies. This programme was launched in 2007 and yearly funding has been 5-7 million €. It focused on

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<sup>10</sup> <http://www.tekes.fi/biorefine>

<sup>11</sup> <http://www.tekes.fi/programmes/Groove>

piloting and demonstrating second generation biofuel production technologies and chains. The programme has been carried out in close cooperation with the BioRefine programme of Tekes.

In their Framework and Action Plan for demand and user-driven innovation, the Ministry propose the implementation of models for financing the development of technological pilots and demonstration projects (Innovation 48/2010). This latter initiative is not aimed specifically at biofuels, but since the Tekes programme includes several projects with business partners, these businesses may be candidates for technology demonstration projects.

A research programme called “TransEco” has been initiated by VTT Technical Research Centre of Finland, and co-funded with Tekes and several ministries and some private-sector actors, such as Neste Oil and St1. The main aim is to increase energy efficiency and use of renewable energy in road transport. The programme has had a budget of some €8 million between 2009 and 2011, and it will run until end of 2013. Relevant research on the use of biofuels has been in the area of high-concentration ethanol fuels for cars (E85), and use of new bio-based hydrocarbons as components of petrol.

In 2012 the first research projects in the Tekes Green Growth Programme kicked off. This programme has three main thematic areas:

- sustainable networking in industry and society – fresh operational models;
- strengthening companies’ expertise in consumer behaviour and market knowledge during shift to sustainable economy;
- sustainable and green economy – the significance of policies and regulation as enablers of systemic change.

Some of the relevant projects are mentioned here:

- future innovation and technology policy for sustainable system-level transitions: the case of transport;
- green transitions, global policies;
- Low Carbon Finland 2050–platform;
- shaping markets for sustainability (SHAPE);
- accelerating transition towards sustainable energy system within system-level innovation network (SUSER).

An interesting aspect of this programme is the emphasis on changing systems and transitions, stressed in their aim: "To generate a new model for more intensive cooperation between different national programmes and policy measures within the theme of sustainable economy" (TEKES, 2012) and like all Tekes projects there are business partners in the steering group.

One of the projects Low Carbon Finland 2050 – platform received 0.6 million € from the Green Growth Programme (total budget 1 million €). The project aims to develop robust roadmaps for a

competitive low carbon society and create sustainable green growth strategies for Finland. The project is based on collaboration between VTT, VATT, GTK and METLA. The main objectives are 1) to analyse strategic natural resources focused on mineral and forest biomass resources 2) to create alternative low carbon scenarios up to 2050 3) to build an interactive platform which could create and analyse successful green growth strategies for Finland. The quantitative analyses are based on different model assessments, and the use of VTT's, VATT's, METLA's, and GTK's comprehensive databases. The main focus of the studies is on Finland's low carbon pathway(s), but the project also includes global and EU level analysis and global socioeconomic scenarios created in the international collaboration (EMF, IPCC, WEC, IIASA). The main idea is to use the analysis produced by the project as background information for creating alternative low carbon pathways. Model analysis will be used to assess the impacts of policies and other choices on Finland's welfare and the sustainable use of natural resources. The role of the Low Carbon Platform is thereby to create and process information on Finland's green growth success factors (TEKES, 2012).

#### *Academy of Finland*

The Sustainable Energy (SusEn) research programme of the Academy of Finland directs research towards developing sustainable solutions and know-how for future energy system alternatives.<sup>12</sup> The programme started in 2008, is multidisciplinary and the core themes include new technologies for energy production, effective energy systems, and energy use efficiency. Among the projects funded by the programme are Algae for biodiesel production (ALGISEL), Forest-based fuel and material demand and the overall climatic impacts (FOBIT), New innovative sustainable transportation fuels for mobile applications: from bio-components to flexible liquid fuels (SUSFUFLEX), Upgrading Biogas for Vehicle Use, Production of green diesel from algae), and Efficient production of fuels from biomass.<sup>13</sup> The projects are co-funded by Nessling Foundation, Fortum Oyj, UPM-Kymmene Oyj and Neste Oil Oyj, and a number of international funding partners.

As a part the SusEn programme, the Academy of Finland and the Brazilian National Council for Scientific and Technological Development (CNPq) have launched calls for joint projects in the field of energy research.<sup>14</sup> The aim is to promote and strengthen collaboration between Finnish and Brazilian researchers in the field.

#### *Centre of Expertise Programme*

Public funding has also been made available to promote collaboration between partners and develop networks and industrial clusters. The Energy Technology Competence Cluster is aimed at improving

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<sup>12</sup> <http://www.aka.fi/en-GB/A/Programmes-and-Cooperation/Research-programmes/Ongoing/Susen/>

<sup>13</sup> <http://www.aka.fi/en-GB/A/Programmes-and-Cooperation/Research-programmes/Ongoing/Susen/Projects/>

<sup>14</sup> Academy of Finland, Call for applications June 28/September 3-26 2012



the success of Finnish energy technology in global markets and activities are focused on industrial enterprises developing energy technologies. The Energy Technology Competence Cluster is part of the Centre of Expertise Programme, a government programme focussing on regional resources and activities on development areas of key national importance. The programme is coordinated by the Ministry of Employment and the Economy, in compliance with the Act on Regional Development. The Energy Technology Competence Cluster is aimed at promoting innovation and education, strengthening competitive ability and creating new jobs, by providing the appropriate collaborative environments. Some of the technological themes are bio-energy technologies and decentralised energy production.<sup>15</sup>

## **Summary**

Finnish policy on biofuels has developed gradually and it appears that recent development in knowledge on the role of forest waste in the production of biofuels has increased, as has interest in this kind of technology. Otherwise the Finnish policy documents make frequent mention of the business opportunities of energy technologies and the potential to create employment opportunities and the development of new forest-related technologies, where Finland has an advantage and the related business opportunities appear to be strong motivating factors influencing the direction of development.

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<sup>15</sup> [http://www.oske.net/en/competence\\_clusters/energy\\_technology/](http://www.oske.net/en/competence_clusters/energy_technology/)

## Norway

### Policy processes and strategies

For many years, energy policy in Norway has been part of the Ministry of Petroleum and Energy and the emphasis has been on fossil fuels and hydropower. Many of the earlier references to biofuels in Norwegian policy documents are grouped together as potential alternatives for fossil fuels, as in the government report on energy perspectives of 1998 (Strøm-Erichsen, 1998).

In a report to the Norwegian parliament (Norwegian Ministry of Petroleum and Energy, 2003) biomass was seen as an important source of heating in urban areas and the green paper on research included energy research related to environmental issues and sustainable development as one of the main areas (Ministry of Education and Research, 2004). It was first in 2005 that we observe a more direct interest and commitment to the development of renewable energies. This was part of the declaration of the coalition government, which laid a clear emphasis on renewable energies (Norwegian Government, 2005). This was followed by a white paper on climate, which set ambitious targets of reducing CO<sub>2</sub> emissions from transport by between 2.5 and 4 million tons by 2020 (Ministry of the Environment, 2006). This white paper also highlighted the need for second generation biofuels in Norway. In 2006 the Norwegian government introduced a tax exemption for bioethanol blended gasoline. In 2007, the national budget included the creation of a fund dedicated to investment in environmentally friendly energy production and stated that research into new energy technologies should be prioritised and managed by the Research Council of Norway (RCN) and Enova, a government agency devoted to the promotion of energy saving. In 2008 all the political parties agreed on targets for CO<sub>2</sub> reduction and to increase climate research. This was followed up by the RD&D strategy on energy, Energi21, commissioned by the Ministry of Petroleum and Energy and developed by the main energy stakeholders in Norway (Energi21, 2008) and the Bioenergy strategy (Norwegian Ministry of Petroleum and Energy, 2008). This strategy explicitly included increased R&D on second generation biofuels including subsidies for selected demonstration projects. In 2011, the Energi21 strategy was revised (Energi21, 2011). The revised strategy has a focus on demonstration and commercialisation of new energy technologies, but biofuel technologies are no target areas in this strategy.

The Ministry of Transport has also been active in developing policies for biofuels specifically related to transport. In 2007, the ministry prioritised in the proposition to the Parliament research into biofuels and supported the RCN R&D programme Renergi (Ministry of Transport, 2007). In 2010, the ministry again prioritised the development of biofuels, hydrogen and electricity for powering vehicle transport and Transnova, a government agency which is supporting reduction of greenhouse gas

emissions of the transport sector, participated actively in this development (Ministry of Transport, 2010). In 2011, the Ministry of Transport included targets for use of biofuels in transport (3.5%).

Other government ministries influencing policy development in this area are the Ministry of Agriculture and the Ministry of the Environment. They financed work on a report of future biofuel solutions in Norway published in 2007 (*Fra biomasse til biodrivstoff*, 2007). The report was based on collaborative work between researchers in bioenergy, forest products and transport economics. It included industrial partners in forestry, the oil industry and agriculture, and environmental NGOs. This project received funding from the Research Council of Norway and the government agency Innovation Norway as well as the Ministry of the Environment and the Ministry of Agriculture.

In 2008 the Norwegian Pollution Control Agency (now Climate and Pollution Agency) commissioned a report on policy instruments for second generation biofuels (Econ Pöyry, 2008). This report gave a comprehensive list of recommendations for the further development and deployment of second generation biofuels in Norway. As a conclusion the agency declared that it will not further favour first generation biofuels.

## **Policy Instruments**

The policy instruments preferred in Norway to stimulate increased use of biofuels are mainly CO<sub>2</sub> taxes, in place since the early 1990s, and tax reductions for biofuels. Since 1999 biodiesel was exempt from fuel tax (NOK 3.02 per litre) and CO<sub>2</sub> charges (NOK 0.54 per litre). It was not until after 2000 that use of biodiesel began to increase. E85 became exempt from fuel tax (NOK 4.17 per litre) and CO<sub>2</sub> tax (NOK 0.80 per litre) in 2006 and was sold by Statoil. At the end of 2009 the removal of the tax exemption for biodiesel led to a high debate on framework conditions for the development of biofuels in Norway. However, some financial incentives are still in place, such as the tax exception for high blends of bioethanol with gasoline and a reduced one-off motor vehicle registration tax for flexi-fuel cars, both favouring bio-ethanol. Other tax incentives are directed at those purchasing vehicles with CO<sub>2</sub> emissions below 110 g/km.

A regional programme was introduced in 2004 making grants available local authorities, who increased the use of public transport use and reduced the use of private vehicles. The programme encourages the introduction of local congestion charges, parking restrictions, better cycle paths and improved public transport. The programme targets Norway's twelve largest cities. To be eligible for the rewards, the cities must enter into agreement with the State. The allocation of funds is being doubled for the period 2010-2013, to NOK 330 million a year (38 million €), after a previous doubling in 2009 (International Energy Agency, 2011:42).

## **Government funding of RD&D**

Public research funding has stimulated research in bioenergy in general, but not that much in the development of liquid biofuels. Only a minor share of Norway's RD&D investments is in liquid biofuels: in 2010 2.9 million € or 2% of the total energy RD&D budget, none of this was reported as funding of demonstration activities (OECD/IEA, Figure 4). However, not all of the funding has been reported. Borregaard has received funding for bioethanol projects: in 2009 about 2 million € for the Biomass2Products RCN project and in 2010 for the BALI Biorefinery Pilot by the programme for environmental technology of Innovation Norway and by RCN with 7 million €. RCN funded a pilot plant for Weyland AS on second generation bioethanol which was opened in 2010. Since 1995 Cambi AS received funding for several RCN projects for developing biogas technology.

## **RD&D funding agencies and programmes**

In 2001 Enova was established to promote clean energy and Transnova to promote clean transport. These are both government agencies. Transnova is managed by the Norwegian Public Roads Administration. From 2009 to 2011 Transnova had an annual budget of NOK 50 million (5.7 million €) to encourage the use of alternative fuels projects, a much smaller budget than Enova had. Transnova is a trial RD&D funding programme for limiting CO<sub>2</sub> emissions in the transport sector. Transnova's area of focus is on testing, standardising, pilot projects and demonstration projects. So far Hydrogen projects have been the largest recipients of Transnova funding (International Energy Agency, 2011). In spring 2010 Enova and Transnova commissioned a feasibility study on biofuels which addressed potential barriers (Econ Pöyry, 2010).

The R&D programme Renergi was established by RCN in 2004 and will run until 2013. The aim is to finance both basic and applied research into renewable energies. Some projects are to take a long-term perspective of up to 30 years, while others are to be short term from 5 to 10 years. The annual budget is around 20 million € and in 2010 around 15% of this was used to finance biofuel development projects. However, the funding of second generation biofuels was not a key target for Renergi.

One of the biofuel projects receiving funding from the research council is a project piloting a new production technique for bioethanol from residuals in Weyland AS a university spin-off firm. As well as RCN, Innovation Norway has also been active in supporting business development and in 2003 they started a bioenergy programme providing better access to public funding for SMEs. In 2008 the R&D strategy on energy resulted in the programme Energi21 to stimulate research collaboration between industry, research and NGOs. In 2009 RCN introduced a programme for the creation of Centres for Environmentally friendly technology. The main focus of these centres is not second

generation biofuels; however CenBio working on bioenergy includes some relevant research. In October 2010 the Climate and Pollution Agency published a report on R&D priorities and concluded that public support should be concentrated exclusively on second generation biodiesel, but not bio-ethanol. This provoked a coalition of all important actors in the field of second generation biofuels – companies, research organisations and NGOs – to protest against such a prioritisation of one technology.

In 2010 Innovation Norway launched a programme for environmental technologies with a total budget of 140 million NOK, and out of this 100 million NOK was targeted on pilot and demonstration facilities for second generation biofuels. Under this instrument Borregaard received substantial funding. In 2012, Innovation Norway launched a new programme for environmental technologies. This programme supports pilot and demonstration facilities, including planning, investment support for constructing the facilities, and costs for starting and testing the facilities, but not running costs of these facilities. Projects for the production of second generation biofuels are eligible for investment support.

Norway participates in Nordic research via the Top-level Research Initiative with a specific programme on sustainable biofuels. Three projects have so far received funding and Norway has partners in all three. Norway also participates in European research, in the 6th Framework Programme Norway participated in projects in the categories Alternative Motor/Engine fuels and in Renewable Energy Sources. Norwegian actors also participate in the European Technology Platform working groups, notably the European Biofuels Technology Platform and the Forest-Based Sector Technology Platform.

## **Summary**

Energy policy in Norway includes the production of fossil fuels and biofuels, thus the future development of biofuels is dependent on balanced policies designed to protect the development of the tiny biofuels sector. RD&D into biofuels competes with the oil industry for resources but also with electrical mobility and hydrogen and fuel cells. Recently, there has been some emphasis on demonstration projects in Norway. Such support has been given more by innovation policy instruments for supporting environment technology in industry, than by energy specific policy instruments. The introduction of tax exemptions on biofuels, then the subsequent removal for biodiesel may have made business investors more cautious. Otherwise Norway's position outside the EU does not appear to have reduced the priority of biofuels and we find similar policy instruments such as taxes on fossil fuels and vehicles as well as R&D funding earmarked for biofuels.

## Conclusions

All the Nordic countries have set goals for increased usage of biofuels in transport and all have produced strategies which include the usage of biofuels alongside fossil fuels, thus all the countries envisage a future where an increasing proportion of transport energy is derived from biofuels. All the Nordic countries also envisage themselves as producers of biofuels, with different inputs to the production process such as agriculture and food waste in Denmark and municipal waste and forestry residuals in Finland and Norway or municipal waste, forestry and agriculture residuals in Sweden. Policy makers face different challenges in the different countries based partly on their traditional industries. Sweden has a high number of personal vehicles and both their owners and their producers need to be considered in future policies. In Norway energy policy is traditionally highly influenced by the production of fossil fuels and hydropower and unlike the other Nordic countries, the desire to replace gasoline and diesel with biofuels is less prominent. Here electric mobility is an avenue which is more supported due to the availability of cheap renewable electricity.

Policies aimed at stimulating industrial development allow for the creation of new SMEs and for existing industries to branch out into biofuels. Similar policies are producing different kinds of collaborations such as vehicle producers in Sweden collaborating with biofuel producers while in Finland and Norway the forest industry is heavily involved in deployment of biofuel technology.

There is a potential for the Nordic countries to learn from each other, an example of this is the public funding of demonstration projects which is more explicit in some countries than others. All countries have implemented local or regional projects such as busses in cities or the usage of local waste for biogas and biofuel production, but it is uncertain how these strategic niches initiatives are aligned with regional development goals.

Judging by the references to the EU targets in the central policy documents reviewed here, it appears that these targets are among the stimuli for much of the strategic work carried out. The measurement and reporting of biofuel use in transport is followed up at the European level for Sweden, Denmark and Finland. The most recent reports from EU indicate a move towards the development of a European infrastructure supporting sustainable fuels. It is not clear what role the Nordic countries will play in this new infrastructure. Although most of the policy initiatives are at the national level, research into biofuels is being carried out at a Nordic and European level and all the Nordic countries are active in the international area.

In conclusion it can be said that the Nordic countries appear to have very similar aims in terms of increasing the use of biofuels in transport and they are utilising similar policy instruments. However, when examined more closely, it can be seen that their motivation and focus has been different and the paths they have chosen to reach their goals are different.

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