

Towards green growth?

The position of Finland in environmental technology

Raimo Lovio, Tuomo Nikulainen, Christopher Palmberg,
Jenny Rinkinen, Armi Temmes, and Kimmo Viljamaa



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Tekes, the Finnish Funding Agency for Technology and Innovation

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Foreword

Green growth is a way to pursue economic growth and development, while preventing environmental degradation, biodiversity loss, and unsustainable natural resource used. Green growth holds a lot of potential and could define a new era of innovation in the aftermaths of the economic crisis. The concept has gained a lot of interest also in Finland.

This publication is the end result of a Tekes-funded innovation research project "Towards a green post-crisis economy – Finnish opportunities in environmental technologies". The project analyses three main themes. First, it analyzes the global environmental technology investments as well as the green components of global stimulus packages to battle the economic crisis. Especially South Korea and China have invested heavily in these areas recently. Second, part of the project studied environmental technology specialization in different countries. There are several strengths in Finland, but a clear specialization seems to be lacking. Finally, the interesting cases of biofuels and electric vehicles were highlighted as examples of how green growth could be promoted in Finland. These cases have a strong linkage to some new Tekes and SHOK programmes, especially the Biorefinery, Electric Vehicles and Green Growth programmes.

Tekes wishes to express its gratitude to the research team that managed to tackle a topical theme through a versatile approach. Tekes also thanks all those who contributed to the project. The results have a lot of utilization potential in innovation and environmental policy as well as in R&D.

Helsinki, May 2011,

Tekes, the Finnish Funding Agency for Technology and Innovation



Section 1

A synthesis of findings

Christopher Palmberg and Kimmo Viljamaa

1 Introduction

Recent findings on the socio-economic consequences of climate change, are pushing environmental technologies and 'green growth' to the top of the policy agenda in many countries. The various stimulus packages that governments are implementing to tackle the economic crisis also contain significant investments in environmental technologies and add to the momentum. These developments create both opportunities and challenges for many countries, including Finland where new technological and industrial strongholds are sought in an increasingly competitive post-crisis global economy.

With the aim to gain a better understanding of these opportunities and challenges Etlatiето, Advansis and Aalto University, Organization and Management, initiated a project entitled 'Towards a green post-crisis economy – Finnish opportunities in environmental technologies' (FOPET). The project draws on ongoing OECD and other work, including patent data as well as case studies on Finnish developments in the areas of biofuels and electrical vehicles, to assess the position, challenges and policy opportunities of Finland in

emerging environmental technologies. It set out to provide policy relevant insights about the position and opportunities of Finland in the rapidly expanding area of environmental technologies, and renewable energy in particular. It addressed the following questions within its three project modules:

Module I and II (Advansis Ltd. and Etlatiето Ltd.): The economic crisis, green recovery and growth – the position of Finland in environmental technologies

1. How have environmental technology investments developed in recent years, which role do the stimulus packages to tackle the economic crisis play in this context and can they contribute to green growth?
2. How are environmental technologies developing across sub-sectors, regions and countries? Which is the position and technological specialization of Finland in environmental technologies, how does it compare with developments elsewhere?
3. Which are the innovating companies in Finnish environmental technologies, how do these technologies link up to established companies and industries?

Module III (Aalto University, Organization and Management): Can biofuels and electric vehicles contribute to green growth in Finland?

4. Which are the main drivers, actors and policies enhancing the greening of the transport sector?
5. To what extent is it likely that biofuels and electric vehicles businesses can contribute to green growth in Finland?
6. What are other important issues and possible future opportunities in the transport sector?

This is the final report of the FOPET project. This first section of the report synthesizes the main findings of the project as a whole. It also draws on presentations and discussions at a workshop held in December 2010 involving the OECD and hosted by the Ministry of Environment and Tekes. The second section is a revised version of a discussion paper which covers modules I and II of the project (the original discussion paper has been published in ETLA's discussion paper series in 2010, see Palmberg and Nikulainen (2010)), while the third one covers module III of the project.

The project started in November 2009 and ended in March 2011. It has been funded by Tekes, the Finnish Funding Agency for Technology and Innovation.

2 Environmental technologies may drive the next wave of innovation

Increasing concerns about climate change and the environmental sustainability of economic development call for a greener model of growth. Environmental regulations are tightening in line with international treaties (such as the Kyoto protocol to the UN Framework Convention on Climate Change) and regional legislation (e.g., the EU),

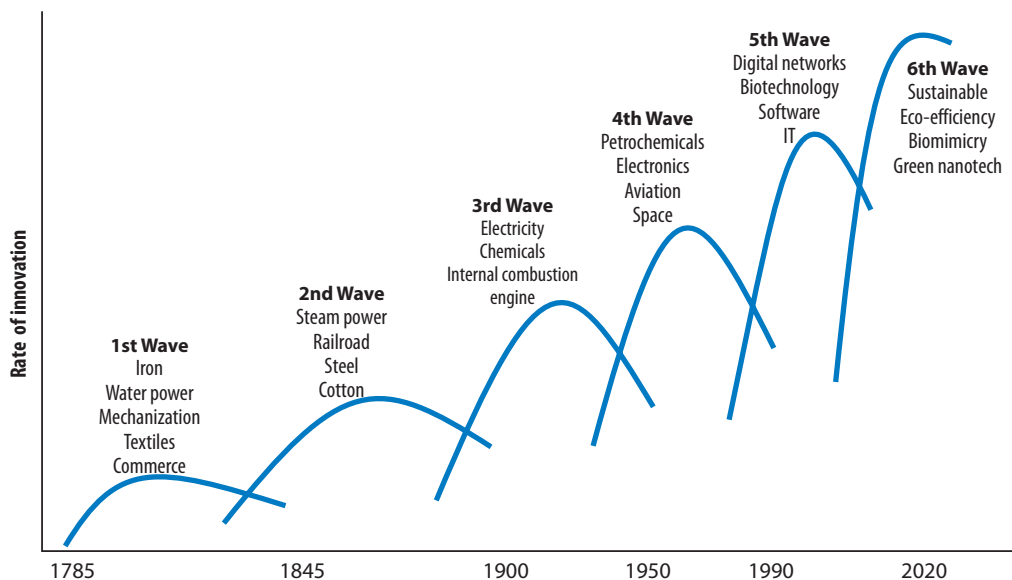
while consumers are becoming increasingly wary of sustainability issues. As a consequence, governments around the world are looking for new opportunities to promote 'greener' environmental technologies while many companies are sensing new businesses in these emerging markets. The Worldwatch Institute has gone as far to suggest, in their State of the World report from 2008, that the next wave of innovation will be driven by environmental technologies (such as renewable energy and green nanotechnology) in a similar way that computers have defined the current wave of IT-driven innovation (see Figure 1).

Environmental technologies comprise a broad set of technologies whose delineation is tricky, and indicators to

monitor developments are hard to develop. This report will largely focus on renewable energy as a sub-area of environmental technologies as defined by the OECD for which relatively reliable indicators exist.¹ Further, renewable energy technologies hold the most promises for achieving the type of innovations that green growth would require (see further below). It should still be noted that many other areas also can contribute to mitigating climate change and supporting environmental sustainability, such as biotechnology, chemistry, material sciences and nanotechnology and engineering (see OECD 2010).

Turning to data on financial investments in renewable energy technologies (both public and private investments in R&D, manufacturing scale-

Figure 1. Drivers for long waves of innovation. Source: Worldwatch Institute (2008)



1 The definition is based on a patent search algorithm that has been developed by the OECD, together with experts, which covers the areas of air-pollution control, renewable energy, water pollution control and solid waste management. It should be noted that this definition is tricky as all technologies with positive environmental consequences may not be included

up and roll-out), available indicators indicate rapid growth in global investments in this area since 2002, despite a slight decline in the growth rate during 2008-2009 due to the economic crisis. Wind power attracted the highest share of new investments in renewable energy. Solar power (primarily photovoltaics, or PVs) reached second place, followed by biofuels, while investments in biomass, marine & small-hydro, geothermal power, and energy efficiency accounted for far smaller shares. Furthermore, analyses of trends show that PVs are the fastest growing field in terms of investments.

Europe accounts for a 37% share of global renewable energy investments, followed by Asia & Oceania (34%), North America (17%), and South America (10%). It is noteworthy that investments in Asia and emerging economies (China, Japan, Australia, and In-

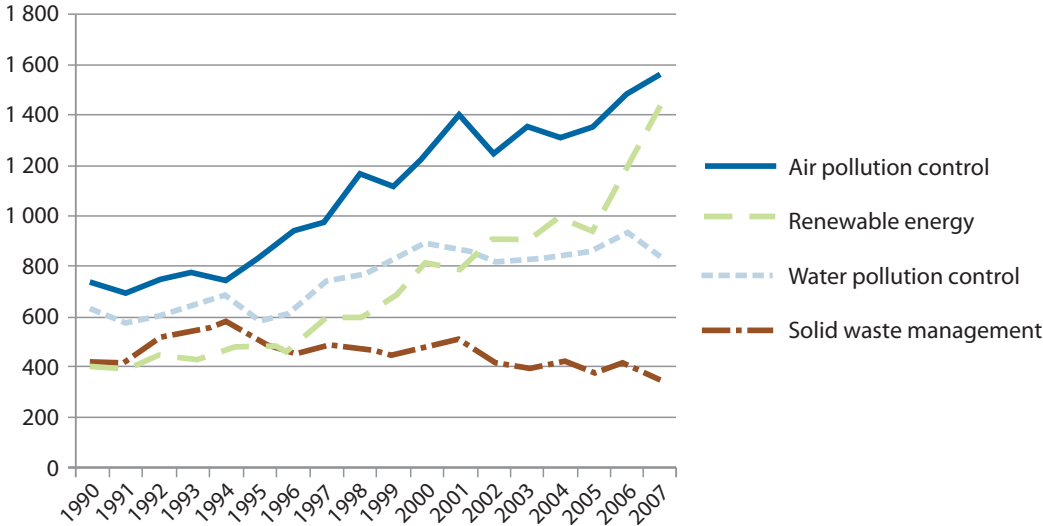
dian in particular) have increased from previous years as renewable energy technologies have become areas with higher priority. Overall, renewable energy investments account for a majority (around 60%) of all energy investments in 2008, meaning that over 40% of all actual power generation capacity additions are related to renewable energy technologies. Therefore, renewable energy technologies are no longer a set of niche technologies; they are part of the mainstream energy sector.

The impressive growth in renewable energy technology investments could provide a good basis for green growth and innovation. These investments also seem to be reflected in the rather impressive growth in renewable energy technology patenting as a sub-area in the OECD definition of environmental technologies (see Figure 2).

The growth of patenting in renewable energy relates to technologies in the areas of biomass, wind, and solar. The growth of patenting activity in biomass technologies has been relatively steady throughout, whereas activity in wind and solar technologies has increased significantly during the last years of the data. The most significant increase in patenting is in solar technologies, corresponding well also with accelerated investments in this field. Regional patterns are similar across the major regions of the world with the exception of the BRICS countries (Brazil, Russia, India, Indonesia, China, and South Africa), where the emphasis even more clearly has shifted to renewable energy in recent years.

Figure 2. Patenting activity in environmental technologies (no. of EPO applications)

Source: OECD PATSTAT; Note: Based on application year



3 Green growth requires radical and system-level transitions

Are increasing investments and patenting, especially related to renewable energy, spurring green growth? The answer to this question significantly depends on the capabilities of companies and governments to appropriate these investments and patents through innovation. The OECD is engaging governments to make this happen. According to the OECD, *“green growth can be seen as a way to pursue economic growth and development, while preventing environmental degradation, biodiversity loss, and unsustainable natural resource use”*. Green growth can benefit from consistent and coherent environmental policies such as carbon pricing, environmental regulations, and tax incentives. However, traditional measures may stimulate incremental innovations but cannot necessarily sufficiently contribute to innovation of the more radical kind that is needed for a transition towards a greener economy. This transition has to involve a combination of incremental, radical, and system-level innovations that not only increase energy efficiencies but also promote environmental technologies and renewable energy in particular.

In the wake of the economic crisis, governments around the world have included significant investments in environmental technologies as part of their stimulus packages. These investments range from 188 to 480 billion USD in total as add-ons to the rapidly increasing overall investments in this area. While Japan and European countries individually were first movers with their stimulus packages, China and Ko-

rea embarked on a similar track soon thereafter. Furthermore, both the Chinese and Japanese stimulus packages have been extended and modified further towards supporting environmental technologies. In the U.S., the presidential election delayed the launch of the U.S. stimulus package (the “American Recovery and Reinvestment Plan”) until February 2009. Modifications and additions of many of these (and other) stimulus packages have been undertaken during 2009–2010.

Unfortunately, assessments of the potential of these stimulus packages to yield green growth in the countries concerned are rather pessimistic. Climate-friendly stimuli in areas like energy efficiency in construction and transport are likely to be outweighed by other spending in construction of, e.g., new roads and other ‘shovel-ready’ projects,

which may bring short-term employment benefits but at the cost of longer-term climate change reduction. Furthermore, most countries focus their green measures on only a few environmental technologies (such as energy efficiency in construction and cars) while ignoring more forward-looking and transformative renewable energy technologies. In the end, the effectiveness of these schemes will depend on how they are implemented, and in particular, which environmental criteria are included in specific project funding selections.

How should policies for greener growth look like to deliver combinations of incremental, radical and system-level innovation that could pave the way for a more fundamental transition towards greener growth? The OECD is addressing these questions in

Box 1

Key policy factors for green growth

- Investments in research to help address global challenges, foster technologies and options that are considered too risky or uncertain for the private sector
- Fostering greater impact from general purpose technologies such as ICT, bio- and nanotechnologies e.g. through smart grids, efficiency improvements, new materials, enabling cradle-to-cradle
- Diffusion of innovation e.g. through the development of knowledge markets and networks
- Entrepreneurship policies aimed at experimentation and commercialization of new innovations
- Policies to support new business models related to eco-innovation
- Demand-side policies to strengthen markets for green innovation e.g. through regulations, standards, public procurements
- Consumer policies to encourage changes in consumption patterns
- Evaluation and policy learning – a long term agenda that is continuously being updated

Source: OECD (2010)

a recent horizontal project to develop a Green Growth strategy. The argument is that a substantial transformation of consumption behaviour, industry structures and technologies are needed. It is argued that the still ongoing economic crisis could create room for policies that could support such more radical system level innovations, without which a transition towards greener growth will not be possible. Traditional market instruments, such as carbon pricing and tradable pollution permits can provide important incentives for green innovation but they will not suffice. Instead a more comprehensive policy approach is being proposed that also considers research needs, international collaboration, eco-innovation and related business models, enabling technologies and infrastructures, smart regulation and public procurement (see Box 1, p. 11).

4 Finland has strengths in environmental technologies but lacks a clear specialization in renewable energy

In Finland environmental technologies have been promoted within the broader context of the so-called National Climate and Energy Strategy in line with guidelines laid down by the UN Framework Convention on Climate Change, including specific initiatives undertaken by the EC (such as the Environmental Technologies Action Plan (ETAP)). The key objectives of the strategy have, already for many years, been to increase energy efficiency throughout the economy as well as to increase the development and use of renewable energy.

The most recent national strategy, from 2008, aims for having a 38% share of renewables of total Finnish final energy consumption by 2020. This ambitious aim is also in line with EU targets.

Altogether some 245 million euro of Tekes investments in 2010 is channelled to environmental technologies and Finland supports environmental technologies on a broad front. Priorities have traditionally reflected the need for cost-efficient energy within process-intensive industries which are in abundance. According to the OECD Environmental Performance Review (OECD, 2009) Finland could do more to promote eco-innovation through e.g. green

procurement, environmental labelling and the active involvement of business and other stakeholders, and consider how environmental policy instruments could be better aligned with innovation policy (and vice versa) to promote innovation. Accordingly, Finland is not yet endowed with a clear and explicit strategy and policy for greener growth despite many like-minded initiatives. A new and interesting development in this context is the Green Growth program launched by Tekes, the Finnish Funding Agency for Technology and Innovation (see Box 2).

Which is the position of Finland in the changing environmental technolo-

Box 2

Tekes Green Growth programme 2011–2015

The aim of the Green Growth programme is to identify potential new growth areas for the sustainable economy business, which are essentially based on lower energy consumption and sustainable use of natural resources. The programme aims at a leap forward in energy and material efficiency of production and service chains over the entire life span of products.

The programme will start with a large-scale anticipatory part aiming to recognise the impacts of climate policy control measures, scarcer natural resources and changes in consumer behaviour on business life over the long term. In the second phase of the programme, this preliminary information will be translated into development projects in companies.

The programme is aimed for companies seeking to grow or renew their business in the face of changes in energy and raw material prices and impacts of laws and regulations. The programme will support the generation of new innovations especially on boundaries between sectors, as future sustainable economy solutions will not be defined by traditional sectoral divisions. Research organisations will play an important role in generating new anticipatory information and skills.

The programme measures will also require close-knit cooperation between Ministries, the Academy of Finland and Centres of Expertise. Strategic Centres for Science, Technology and Innovation may also prove a significant partner in producing and making use of the anticipatory information.

gy landscape in terms of patenting and where could new opportunities arise in this area? By international comparison Finland is relatively well positioned in the environmental technology area by overall levels of patenting activity and belongs to the league of top 25 countries by the absolute number of patents. Nonetheless, the position is more worrying in terms of the distribution of these patents. Finland does not emerge as a country with a specific specialization profile generally speaking neither in relation to renewable energy technologies where most growth in investments and patenting can be detected globally. This contrasts e.g. with the specialization profile of countries such as Austria and Australia (hydropower), Denmark (wind technology), and the UK (ocean technology). Furthermore, a partial Finnish specialization in wind technologies appears to have eroded over time.

There are a total of 125 companies behind these environmental patents. Of the more environmental technology-oriented of these Finnish companies, a majority are in the machinery industry. The company size distribution is rather skewed and dominated by a few large companies. The smaller companies have often been founded around an innovative individual as a spin-off or spin-out from research or other companies. The economic significance of these companies is relatively noteworthy, accounting for approximately 12,094 employees and 3.5 EUR billions in sales.

The economic significance of Finnish environmental technologies should also be assessed by the degree to which they find industrial applications throughout the economy. The 125 companies involved in environ-

mental technology patenting are affiliated with a wide range of different industries beyond the machinery industry as the main one. This diversity suggests that environmental technologies appear to be finding realized or potential application opportunities in many different types of industries throughout the economy. Accordingly, there may also be a range of different commercialization paths where different types of companies (also smaller companies) can play different roles.

5 Biofuels and electric vehicles could contribute to green growth in Finland

Traffic and logistics have gained a lot of attention in discussions on green growth in many countries, especially in the context of the stimulus packages. This is also true in Finland, even though the stimulus package that was introduced as a supplement to the budget bill in 2009 does not include many green components. The reason for an interest in traffic and logistics is that the role of transport in CO₂ emissions is significant (26% in Finland in 2009, of which a majority is from road transport alone). Furthermore, the economic crisis hit the automotive industry hard in the U.S. and in Europe. At the same time, some new promising opportunities have emerged for transforming road transport vehicles in a more sustainable direction by more efficient combustion engines, biofuels and electric motors.

Although Finland is not specialized in the automotive and oil industries, the development of biofuels and

electric vehicles has been quite noticeable even though electric vehicle technologies probably are not captured in the patent-based OECD definition of environmental technologies. The largest Finnish oil company, Neste Oil Oyj, has invested in biofuel refineries in Finland and abroad, based on its technological expertise. A new entrant in the oil business, St1 Oy, has developed a new method to produce ethanol from food industry waste. The Finnish pulp and paper companies have investigated possibilities to build new biodiesel plants based on wood feedstock. As for electric vehicles, the only Finnish passenger car manufacturer – Valmet Automotive – has started to make electric vehicles for its business customers in Norway, Denmark, and the U.S.A. Some other companies have invested in developing batteries, charging equipment, and infrastructure systems. These corporate initiatives have led the Ministry of Employment and the Economy, together with Tekes, to start developing a new electric vehicle cluster in Finland.

The emergence of the Finnish electric vehicle cluster has been mainly based on national and relatively small initiatives by old large companies, new small companies, research and educational institutions, and a user community. It has also been supported by several public innovation policy initiatives. Compared to the biofuel development, there are some clear differences. Biofuel development has been more directly driven by the EU and by climate and energy policies, compared to the developments in the electric vehicle cluster. Companies in the biofuel and electric vehicle fields are totally different. Only ministries, Tekes, and the VTT Technical Research Centre play roles in both



sectors. For example the TransEco programme initiated by VTT Technical Research Centre in 2009 on energy efficiency and renewable energy in road transport covers both advanced biofuels and technology for hybrid and electric vehicles, as well as ICT solutions for road transport.

An interesting question is whether biofuels and electric vehicles can contribute to green growth in Finland.

Based on the empirical evidence and the visions of interviewed persons in different organizations, we can give a positive answer. In the short term, in the 2010s, both biofuels and electric vehicles offer new business possibilities to Finnish firms. However, the prerequisite is that the second-generation biofuel technologies (mainly based on wood and waste) prove to be successful and that in the electric vehicle cluster,

companies succeed in using the home market as a good demonstration case to develop export products and business alliances with foreign companies in the industry.

In the short term, the increasing use of biofuels (and to some extent electric cars) plays a role in achieving Finnish climate policy objectives. Yet a major role is played by more efficient motors, smaller cars, and hopefully also by an increasing use of public transport, cycling, and walking in urban areas. Public transport and related technologies also offer business opportunities to Finnish companies, opportunities which have not been fully recognized. In the long run, it is expected that electric vehicles will play a greater role than biofuels in achieving the very demanding climate policy targets for 2050. Therefore, it is important that policies simultaneously support incremental and radical innovations and that in the future, solutions are not only sought by developing more efficient vehicles but also by focusing on the whole transport system and mobility needs.

Table 1. Major EU and Finnish policy instruments creating markets and activities for green innovations in the transport sector

Policy instrument	Major examples	Main policy target group
General climate change policy instruments	EU: climate and energy package (20-20-20 targets)	The transport sector as a whole
Binding objectives for CO ₂ emissions of cars	EU: Specific emissions of new cars sold on average 130 g/km in 2015 and 95 g/km in 2020 (Regulation 443/2009/EC)	European car manufacturers
Mandatory share of biofuels	EU: share of renewable energy and biofuels 10% by 2020 (Directive 2009/28/EC) Finland: 20% by 2020, 6% 2011–2014 (Biofuel distribution obligation)	Fuel distributors
Research programmes	EU: e.g., Green Cars Initiative Finland: Tekes: BioRefine – New Biomass Products 2007–12, Fuel cell 2007–13, TransEco 2009–2013, Electric Vehicle Environment 2011–15	Research institutions, companies, cities
Demonstration and investment and support	EU: NER300 Initiative Finland: Investment support by Ministry of Employment and the Economy	Companies (e.g., biofuel refineries)
Changes in taxation	Finland: car taxation reform 2008–2011	Users of cars
Other support	Some countries have established grants and tax credits for the purchase of new electric (e.g., France) or flexi-fuel vehicles (e.g., Sweden) Finland: not yet	Users of cars

6 Policies for green growth need to be broad-based and risk-oriented

The case of biofuels and electric vehicles provides some in-depth snapshots of attempts in Finland to promote more radical and system-level innovations in the logistics and transport sector. Specifically, in addition to progressive taxation, new kinds of measures to affect consumer behavior need to be developed. Mere information on the benefits of small cars, diesel cars, hybrid cars,

electric cars, etc., is not sufficient. Consumers seek comfort, safety, luxury, design, and “status” when purchasing a car. Car manufacturers are key players in this: they act when the support for a certain technology is sufficiently stable. Further, fuel distribution infrastructure may not develop because the number of compatible cars is small, and vice versa. One possibility is public procurement. Purchasing new vehicle types for special purposes and visible uses gives rise to an improved infrastructure and sets an example for car users.

There seems to be a risk in Finland that the mitigation of climate change in private passenger transport is seen as a competition between biofuels (combined with improvements in the combustion engine) and electric vehicles. Instead, the greening of road traffic should be based on a roadmap from the combustion engine vehicles to sustainable future mobility solutions that we may not even recognize yet. Reliance on a single dominant solution may run the risk of becoming locked into heavy investment in production facilities or dependence on a given infrastructure limits the possibilities of future development. In addition to this, the improvement in private cars should be accompanied by support for public transport, where there also are Finnish business opportunities.

Engine development is expected to contribute to the estimated reduction of greenhouse gases of traffic by about 60%. Biofuels offer an easy transition contributing to this development without a need for a major change in either distribution infrastructure or car

fleet. However, one major challenge is the availability of raw materials. Palm oil as biodiesel raw material and sugar-cane-based ethanol are not feasible sources of bioenergy for Finland in the long run due to various sustainability concerns. Therefore, the on-going research looking for new raw materials for biodiesel production, like jatropha and microbial biomass, should be continued intensively. Cellulosic and wood-based raw materials could also offer a domestic and sufficient source of biofuel raw materials insofar as this raw material could be domestically produced.

The potential of electric vehicles to reduce greenhouse gas emissions is better than biofuel-based transport, as their energy efficiency is better “from well to wheel” than that of combustion engine cars. There seems to be a general agreement on the importance and export potential of components and infrastructures for electric vehicles. However, it has also been argued that the business advantage of support for electric vehicles leaks out of Finland, as there is no significant car manufacturing in Finland. Therefore the support should not be solely directed to the use of electric cars (e.g., in the form of specific lanes), but also to a large extent to the development of a proper infrastructure for charging and maintaining the cars.

In summary, promoting green growth will also require new policy approaches compared to ‘business as usual’. Incremental innovation along existing technological trajectories will not suffice. More radical and system-level innovations of the more transforma-

tive kind will also be needed. To achieve such innovations synergistic and mutually reinforcing developments in different areas have to be set in motion. The cases of Finnish biofuels and electric vehicle highlight R&D programmes, taxation and performance targets, as well as consumer preferences as some of the key policy areas to be considered. The case studies point to the benefits of such broad-based policy approaches although it is far too early to judge whether one or the other of these technologies really will take off and diffuse more widely in Finland. The Finnish path towards greener growth is not yet fully visible and it is still unclear which environmental technologies could provide a platform for more radical and system-level innovation. Nonetheless, interesting new initiatives and a commitment towards these aims seems to be emerging currently.

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Section 2

Towards green growth?

The position of Finland in environmental technologies

Christopher Palmberg and Tuomo Nikulainen

1 Introduction

Climate change is currently one of the major global challenges that the world faces. The United Nations has played a key role in raising awareness of the causes of climate change and its impact on society mainly through the work of its Intergovernmental Panel on Climate Change (IPCC), which was established in 1998. Meanwhile, leading economists have approximated the effects of climate change on the world economy, projected the investments that have to be made to limit climate change to manageable levels, and highlighted the complex policy challenges involved in a transition towards a greener low-carbon economy. (See the Stern Review on the Economics of Climate Change and Stern (2007).)

While concerns about climate change and sustainable development in general have existed for decades, recent developments have elevated en-

vironmental 'green' technologies to the top of innovation policy agendas around the world. Environmental regulations are tightening in line with international treaties (such as the Kyoto protocol to the UN Framework Convention on Climate Change) and regional legislation (e.g., the EU), while consumers are becoming increasingly wary of sustainability issues. As a consequence, companies are seeing new business opportunities in environmental technologies and engaging in eco-innovation.¹

Only time will tell to what degree (and which) environmental technologies will define the next wave of innovation. What is clearer is that there currently is a significant push towards stimulating innovation related to emerging environmental technologies. R&D investments in these and related fields have already been growing for some time. However, the recent focus on environmental technologies in stimulus packages has raised environmen-

tal technology investments to unprecedented levels. There are expectations that these investments will also contribute to economic growth that is greener than in the past.

Given these developments, innovation policies are now under pressure to capitalize on investments and define priorities in the application of environmental technologies to boost both competitiveness and environmentally sustainable eco-innovation. They are seeking to align framework conditions and business environments with specificities of eco-innovation and key characteristics of environmental technologies.

The overarching aim of this section is to review previous studies with an eye to clarifying the impact of mounting environmental investments as well as how Finland is positioned in the rapidly expanding global environmental technology landscape from the viewpoint of patent data.

1 The EU Environmental Technology Action Plan (ETAP) defines eco-innovation as "the production, assimilation or exploitation of novelty in products, production processes, services or in management and business methods, which aims, throughout its life cycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resource use (including energy)"(see Carrillo-Hermosilla et al. (2009) for alternative definitions).

2 Environmental technology investments globally

Sustainable development and concerns over climate change and the environment generally have been topical issues for decades and environmental technologies have been already promoted for some time. Companies have also been active, as evidenced by, e.g., the proliferation of Cleantech partnerships, clusters, and associations all over the world.

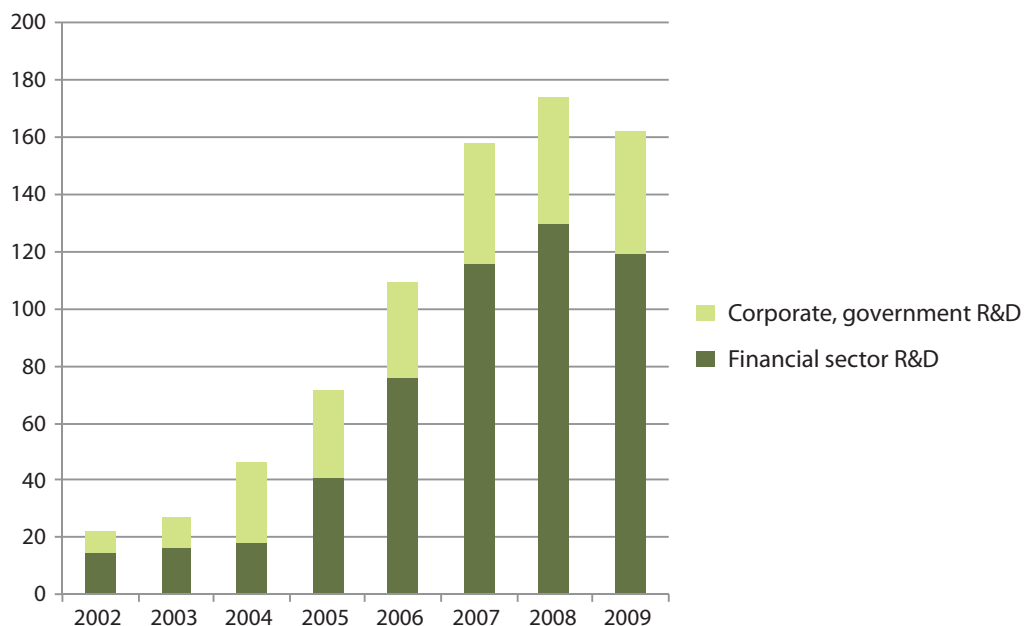
Environmental technologies comprise a broad set of technologies whose delineation is tricky, and indicators to monitor developments are hard to develop and compile. Technology and innovation researchers usually stress the importance of measuring activities all along the innovation chain, from R&D

inputs (mainly R&D investments) and intermediate outputs (publications, patents, new companies, etc.) to innovations and new products as the final outputs (see Godin 2005). This chapter does not assume a linear causality from R&D inputs to innovation outputs. However, it refers to R&D investment data to highlight trends in the dedication given to environmental technologies while turning to patent data for a rough indication of areas where technological and competence developments are particularly rapid. These data together constitute a good setting for analysing the position of Finland in the environmental technology field.

One specific sub-sector within environmental technologies with a fair amount of information available is renewable energy. The annual Global Trends in Sustainable Energy Invest-

ments report, compiled by the UNEP's Sustainable Energy Finance Initiative in collaboration with New Energy Finance Ltd., is one of the most authoritative data source for tracking environmental technology investments globally (see <http://www.newenergyfinance.com/>). These reports draw on the world's largest database of renewable energy investments since the year 2000. It covers investments by venture capitalists, companies, and joint ventures as well as public sector organizations, thereby giving the broadest possible viewpoint of these investments. The database enables the breakdown of investments by type, technology, regions and countries. Nonetheless, disclaimers also apply, especially since these data are drawn from a broad range of miscellaneous public sources, whereby issues related to definition, data coverage and

Figure 1. Global investments in renewable energy technology
(Source: UNEP and NEF, 2010)



completeness have to be taken into account. It should also be stressed that renewable energy is merely a sub-area of environmental technologies as a broader field (the latter also includes air pollution control, waste and water management, and other more traditional areas).

Figure 1 provides an overview of global investments in renewable energy technology since 2002. It distinguishes between investments originating in the financial sector (third-party funding by banks, etc.) and intramural R&D investments by companies and the government, including small residential projects. Overall, there has been growth in renewable energy invest-

ments throughout, and these investments have accelerated significantly since the mid-2000s. The lion's share of these investments originates in the financial sector while the role of intramural company and governmental R&D is still relatively small. The overall growth in investments is therefore mainly driven by increasing asset-based funding, although VC is the single most rapidly expanding source of investments overall (37% growth from 2007 to 2008).

As shown in Figure 2, wind power attracted the highest share of new investments in renewable energy technologies during the last two years, confirming that this field remains the best

established and most mature of the renewable energy technologies. Solar power (primarily photovoltaics, or PVs) reached second place despite a decline in 2009, followed by biofuels, while investments in biomass, marine & small-hydro, geothermal power, and energy efficiency accounted for much smaller shares. Furthermore, analyses of trends show that PVs have seen the fastest overall growth in terms of investments, with a compound annual growth of 70% between 2006 and 2008 (e.g. excluding the crisis year of 2009). On the contrary, biofuels have experienced a decline in investments during recent years, especially related to first-generation biofuels, which have suffered from a combination of higher wheat prices, lower oil prices, and an increasingly heated food-versus-fuel controversy.

A breakdown by geographical region (Figure 3) shows the continued dominance of Europe, with a 37% share of global renewable energy investments in 2009, followed by Asia & Oceania (34%) and North America (17%), and South Africa (10%). According to UNEP & New Energy Finance (2010), the differences (especially between Europe and the U.S.) can be explained by more extensive governmental support for renewable technologies across European countries. The U.S. has seen a slowdown in private sector investments, especially for biofuels, but also for wind and solar power, the latter two fields having suffered the most from the financial crisis. Furthermore, in these regions, tax-based incentives for investments are more widespread while also being mostly inefficient in an economic

Figure 2. Distribution of global investments in renewable energy technology in 2008 and 2009 by technology field (Source: UNEP and NEF (2010))

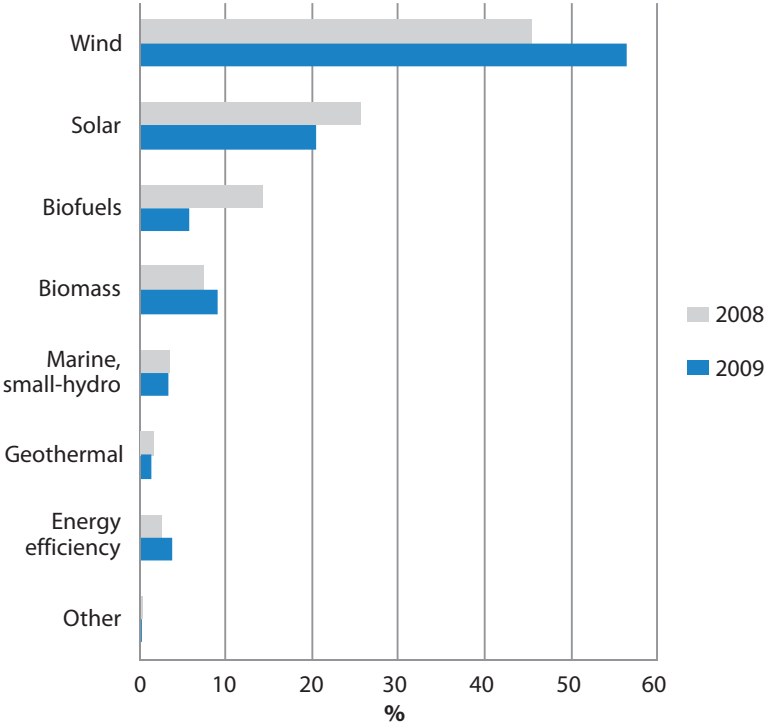
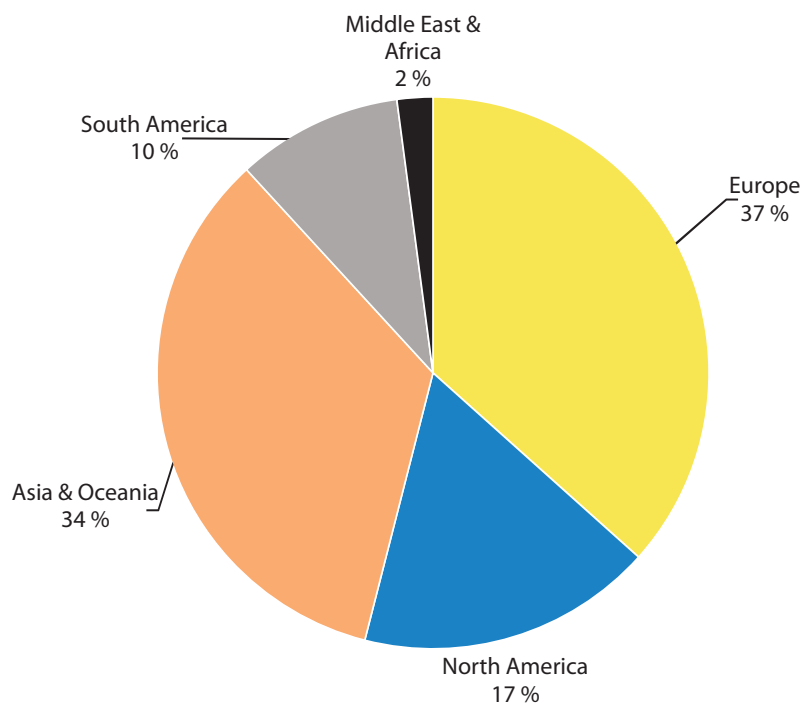


Figure 3. Global investments in renewable energy technology in 2008 by geographical region (Source: UNEP and NEF, 2010)



downturn. Nonetheless, UNEP & New Energy Finance (2010) notes that investments in Asia and emerging economies (China, Japan, Australia, and India in particular) have increased significantly from previous years as renewable energy technologies have become prioritized areas. In South America, Brazil accounts for almost all investments and these investments mainly relate to first-generation biofuels (e.g., biodiesel, vegetable oil, biogas, and bioalcohols).

The report focuses on the renewable energy sector but also places these investments into an overall perspective by examining the contribution of renewables to total new power capacities (e.g., including fossil fuel- or nuclear-based power). From this perspec-

tive, renewable energy investments accounted for a majority (around 60%) of all energy investments in 2008, meaning that over 40% of all actual power generation capacity additions were related to renewable energy technologies. Renewable energy technologies are therefore no longer a set of nice technologies but part of the mainstream energy sector. UNEP and New Energy Finance (2010) also predicts that investments in renewable energy are set to continue in 2011 and beyond as there will be a further scaling up of societal commitments to a greener low-carbon post-crisis economy (according to the report only some 9% of green investments of stimulus packages have been realized to date).

In summary, this chapter gives the following insights:

- Global investments in renewable energy have grown rapidly since 2002 despite a decline during 2008–2009 due to the economic crisis.
- Renewable energy currently accounts for a majority of all actual power generation additions, implying that renewable energy technologies are becoming part of the mainstream energy sector.
- Wind power has attracted the largest share of renewable energy investments followed by solar power and biofuels, while solar power is the fastest growing field.
- Europe has accounted for the largest share of renewable energy investments followed by Asia & Oceania and North America, while investments in Asia and emerging economies have increased very rapidly in recent years.
- Despite large additional environmental technology investments, the ‘greenness’ of these investments and measures have been questioned in recent assessments.

3 Increasing policy support through stimulus packages

The recent surge in environmental technology investments (with renewable energy in the lead), combined with increasing attention given to eco-innovation in industry, is bound to bring environmental policy issues to the closer attention of innovation policy. In addition to increasing focus on environmental innovation in “traditional” innovation policy measures, environment

has received a specific role in the various stimulus packages that were introduced during the recession of 2008–2009. Global commitments (e.g., as declared by the G20 countries) to stimulate economies through additional investments in environmental technologies were preceded by national debates and stimulus packages, some of which were already passed during the latter part of 2008 as the magnitude of the financial crisis became evident.

According to various estimates, the stimulus packages will add another 188 to 480 billion USD (the figures vary across studies) during the next couple of years to environmental technology investments. However, there is large uncertainty in this figure as the ‘greenness’ of the stimulus packages are hard to assess and many packages are only now being rolled-out. And an entirely different matter is the extent countries are able to develop complementary policy mixes to facilitate the industri-

al uptake of these investments and promote eco-innovation that is transformative enough to contribute to addressing the challenge of climate change.

The primary quantitative estimates include Robins et al. (2009), UNEP and NEF (2009, 2010). Robins et al. (2009) is the most prominent and most referred to.

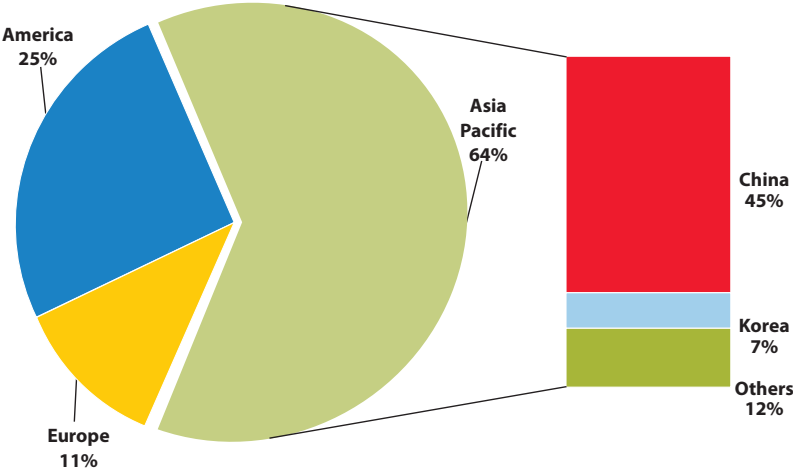
Robins et al. (2009) arrive at a grand total estimate for ‘green’ investments at 478 USD billion, corresponding to 15.5% of all investments of the economic stimulus packages worldwide. This estimate is significantly higher than the 188 USD billion figure suggested by UNEP and NEF (2010), probably because it covers a broader set of environmental technologies. The study by Robins et al. (2009) is not restricted to renewable energy technology investments only. It is based on a systematic collection and analysis of individual country stimulus packages, as well as subjective judgment of the ‘green’

components of these monetary investments for an overall view across regions, countries, and environmental technology areas. The study thereby also covers a broader set of governmental policy schemes (such as tax incentives) compared with the R&D investment report of UNEP and New Energy Finance (2010). It should also be noted that Robins et al. (2009) does not include the most recent additional measures during 2009 and 2010 (additions primarily in France, the UK, and the second German package).

Figure 4 shows how the green components of the economic stimulus packages are distributed globally by regions. China and the U.S. dominate both in terms of the size of their overall stimulus packages (not shown in the figure) as well as the share of green components in these stimulus packages.

The case of China is particularly interesting, and at least these estimates indicate that China appears to be strongly dedicated to a green growth strategy. Almost 40% of the Chinese stimulus package is allocated to ‘green’ measures. The apparent greenness of the Chinese stimulus package also explains the proliferation of the whole Asian region in this context, both in terms of share of green components as well as by absolute monetary size. Nonetheless, the South Korean “Green New Deal” passed in January 2009 is noticeable not only for its name but also for being nominally the greenest stimulus package in the world (see Box 1 for the case of South Korea). European countries appear in Figure 5 with a much smaller share, although it should be noted that EU-wide green measures are excluded from these data.

Figure 4. Global distribution of 478 USD billion of green components of stimulus packages by region (Source: Robbins et al., 2009)



The South Korean economic stimulus packages and its green component

Korea suffered significantly from the financial and economic crisis of 2008 with a noticeable decline in its GDP. South Korea is the 10th largest emitter of greenhouse gases although it is still classified as a developing country under the rules of the UN and therefore does not yet have binding emission caps. Despite this Korea has aggressively pursued emission cut targets, and counts as one of the primary example of a country which has endorsed ideas of a Global Green New Deal and Green Growth. This is clearly demonstrated by its “Green New Deal” stimulus packages, launched in January 2009, of which 80% has been estimated to relate to green measures. The package has nine core projects organized in four main themes:

- Conservation: green cars, clean energy and recycling
- Quality of life: green neighbourhoods and housing
- Environmental protection: revitalizing four major river and securing water resources
- Preparing for the future: IT infrastructure and green transport networks

At project level energy efficiency investments account for the main share of all green investments of the Korean stimulus package, followed by water and waste-related investments (see pie chart below in this box). These investments will cover internet infrastructures; building efficient, low-carbon transit systems and establishing a low-carbon work environment. They will also target the development of specific technologies such as high-efficiency solar batteries, LPG hybrid vehicles, highly efficient light emitting diodes (LED) and an advanced electricity metering system as part of smart grids. In the background are also ambitions to create some 530 000 new jobs by 2013.

Source: Robins et al. (2009)

Breakdown of Korea's Green New Deal by technology area

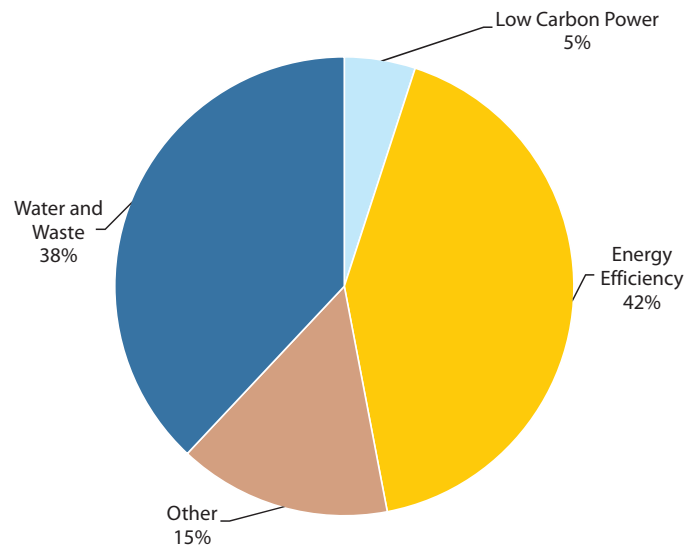


Figure 5. Share of green components of economic stimulus packages

(Source: Robins et al., 2009)

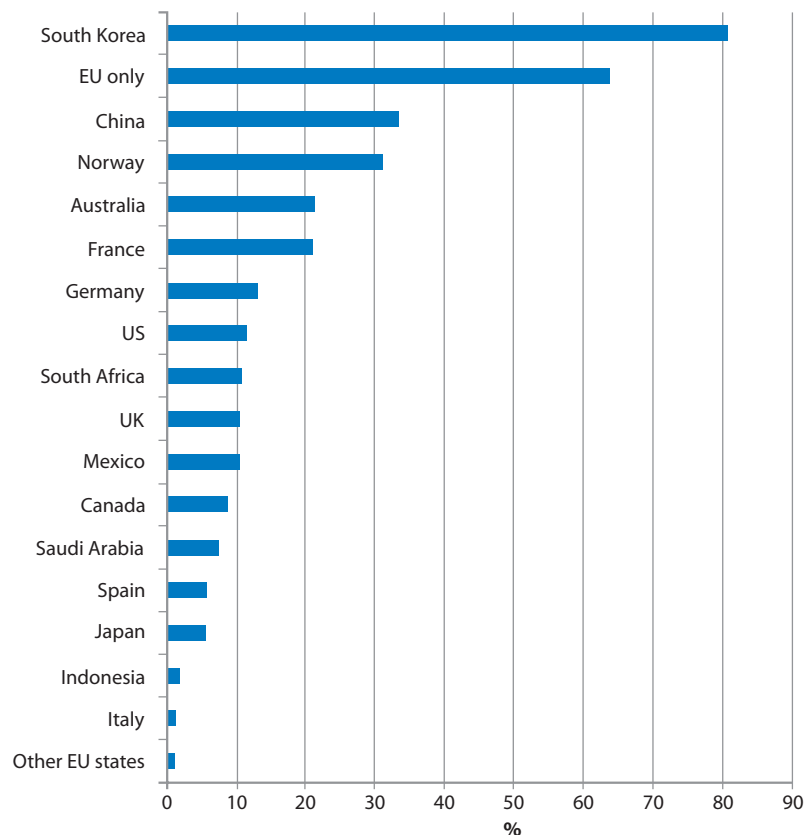


Figure 5 shows the intensity of the green investments and other measures in relation to the overall size of the economic stimulus packages of countries. South Korea tops the list with an estimated 80% share of green measures out of the economic stimulus package passed in 2009. The figure also includes EU-wide stimulus packages with their green measures in second place followed by China. Beyond this, smaller countries also rank high, with Norway, Australia, and France as noteworthy examples. The remaining countries have significantly lower intensities of green measures in their stimulus pack-

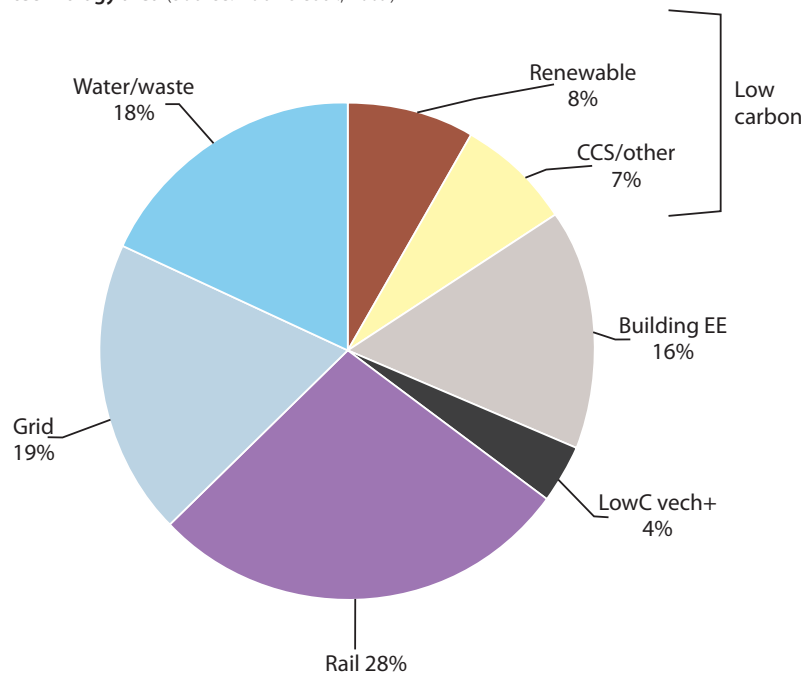
ages with shares around 10% or below. Finland does not appear as an individual country due to the limited green components in the economic stimulus package passed in 2009.

The large share of the U.S. and Asia of green components in stimulus packages is at odds with the dominance of Europe in renewable energy technology investments, which might indicate that the massive governmental economic stimulus packages in the U.S. and Asia partly compensate for the relatively poorer investment track record of these countries in renewable energy technologies in the past. For most other

countries, the share of measures to promote renewable energy play a relatively smaller role, the average share devoted to this field being only 8% (see Figure 6). Instead, altogether 66% of the green components of all economic stimulus packages are targeting energy efficiency, including such traditional areas as construction, low-carbon vehicles, and rail- and grid-infrastructures (e.g., electricity smart grids). Water-related technologies come next, followed by other low-carbon technologies and renewable energy technologies. Many of these more traditional areas can also draw on new and emerging technologies such as nanotechnology, ICT, and biotechnologies.

Although any assessment of these green stimulus measures are subjective and based on limited information about intended (rather than realized) policy objectives, they can provide at least some indication of whether the Green Growth strategies are really taking off. With these caveats in mind, Höhne et al. (2009) arrive at rather discouraging assessments. For quite a few of the countries covered, the positive climate-friendly stimulus in areas like energy efficiency in construction and transport is likely to be outweighed by other spending in construction of new roads and other 'shovel-ready' projects, which may bring short-term employment benefits but at the cost of longer-term climate change reduction. Furthermore, most countries focus their green measures on only a few environmental technologies – such as energy efficiency in construction and cars – while ignoring more forward-looking and transformative technologies. Höhne et al. (2009) also note that the

Figure 6. Distribution of green components of economic stimulus packages by technology area (Source: Robins et al., 2009)



effectiveness of the schemes will depend on how they are implemented and which environmental criteria are included in specific project funding selections.

In summary, this chapter gives the following insights:

- Economic stimulus packages to tackle the current economic crisis are adding an estimated 188–478 USD billion in environmental technology investments, or some 15% of their total stimulus spending.
- Despite large additional environmental technology investments, the ‘greenness’ of these investments and measures have been questioned in recent assessments.

4 Environmental technology patenting globally

4.1 Trends by technology areas

The discussion above highlighted environment technology investment trends. It identified a rapid increase in renewable energy technologies in particular and suggested that investors are seeing the largest opportunities in wind and solar technologies. While no linear causality from R&D inputs to innovation outputs should be assumed reference here will be made to patent data for a rough indication of areas where

technological and competence developments are particularly rapid against the backdrop of environmental technology investments. Towards this end, we rely on a patent based definition of environmental technologies developed by the OECD, which includes the following fields: air pollution control and abatement, water pollution control (including water and wastewater management), solid waste management, and renewable energy (see OECD (2009b) and Johnstone et al. (2010)). Renewable energy is further divided into six sub-areas: wind, solar, geothermal, ocean, hydropower, and biomass.¹

The increasing public and private investments in environmental technologies have, as discussed above, focused on specific areas where the goal is either to promote the diffusion of existing technologies or to provide incentives for both public and private actors to engage in innovative activities in more novel areas, particularly in renewable energy sources. These investments are also reflected in patenting activity where the most significant growth has also occurred in renewable energy technologies (Figure 7). It is thus worthwhile to look at the more detailed development of renewable energy technology patenting in Figure 8 below.

From the figure it is evident that the increasing role of this technology area relates to only a few of the technologies. The growth of patenting in renewable energy relates to technologies in the areas of biomass, wind, and solar. The growth of patenting activity in biomass technologies has been relatively steady throughout the observation pe-

¹ For more on the methodology see Palmberg and Nikulainen (2010) Appendix 2.

Figure 7. Patenting activity in environmental technologies (no. of EPO applications

(Source: OECD PATSTAT) Note: Based on application year

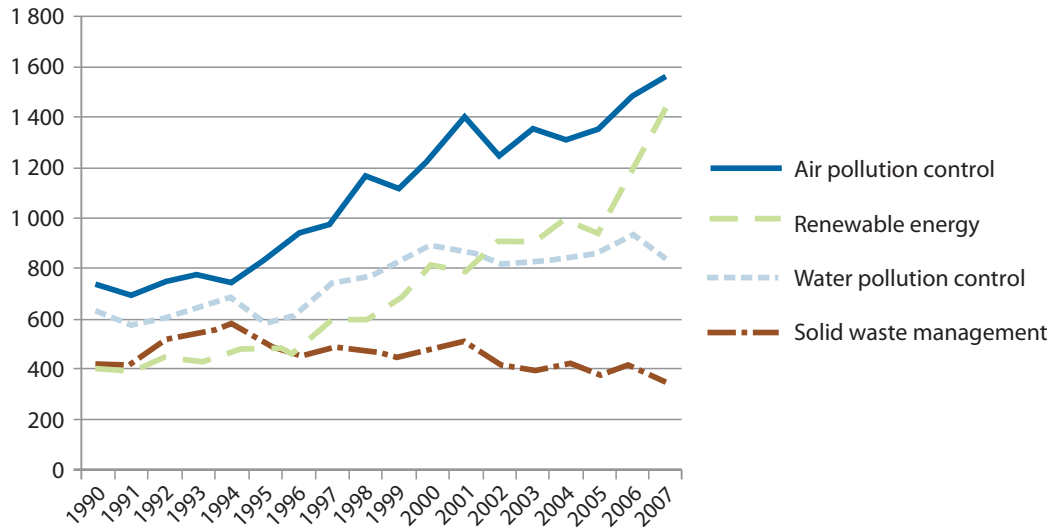
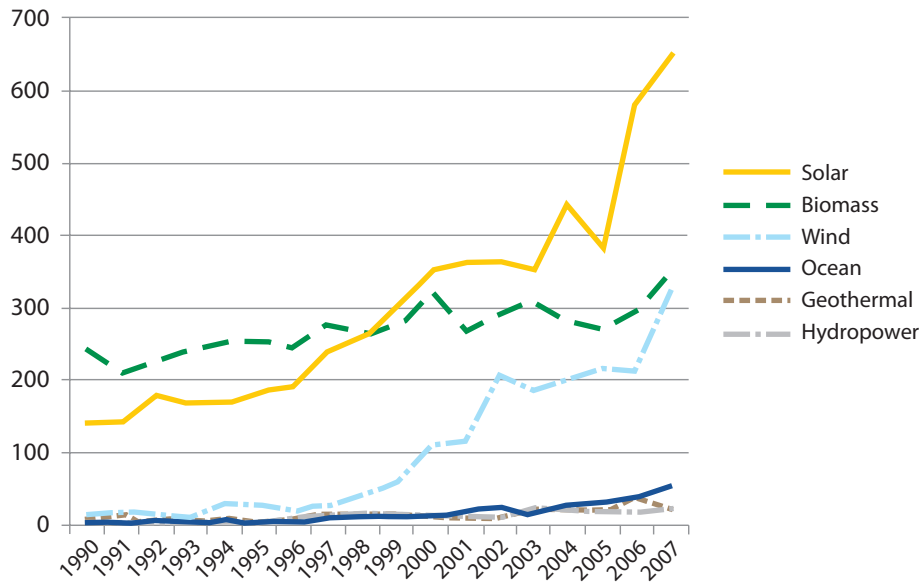


Figure 8. Patenting activity in renewable energy (no. of EPO applications

(Source: OECD PATSTAT) Note: Based on application year



riod, whereas activity in wind and solar technologies has increased significantly during the last years of the data. The most significant increase in patenting is in solar technology. Going back to the discussion of the global investments, this corresponds well to accelerated investments in this field of environmental technology. The remaining technology areas in renewable energy have seen limited or even marginal growth in patenting. In geothermal, ocean, and hydropower-related technologies, fewer than one hundred patents have been applied for annually during the last years of data coverage.

4.2 The position of regions and countries

The aggregate data discussed above provides insights into overall envi-

ronmental technology trends, whereas the activity levels in different geographical regions differ greatly, as shown in Figure 9.

Looking first at the development in EU (EU 27), it is clear that there has been a shift from water pollution control and solid waste management to air pollution control and renewable energy. A similar trend emerges in Japan and the U.S. Overall, the share of environmental technology patents is fairly similar in these regions. Interesting exception are the BRIICS countries (Brazil, Russia, India, Indonesia, China, and South Africa). In these countries, the share of activity in water pollution control and solid waste management was significant in 1996, but the emphasis has shifted to renewable energy since then up until 2006. This suggests that new actors, in addition to the established ones, are

emerging in the field of environmental technologies, particularly renewable energy. Figure 10 provides more insights into patenting activity in individual countries.

From Figure 10, it is evident that EU accounts for a large share of innovative activity in all four environmental technology fields. The other two dominant players are the U.S. and Japan, followed closely by Germany. Interestingly, the BRIICS countries emerge as important players in three of the technology areas: water pollution control, solid waste management, and renewable energy. Finland's position is fairly strong, as it belongs to the top 25 countries in all fields, even in absolute terms. If the shares of Finland were presented in relative terms (for example per capita), the performance of Finland would be even higher in the rankings.

Figure 9. Patents in environmental technologies as a percentage of total PCT patent applications
(Source: OECD – Main Science and Technology Indicators, 2009b)

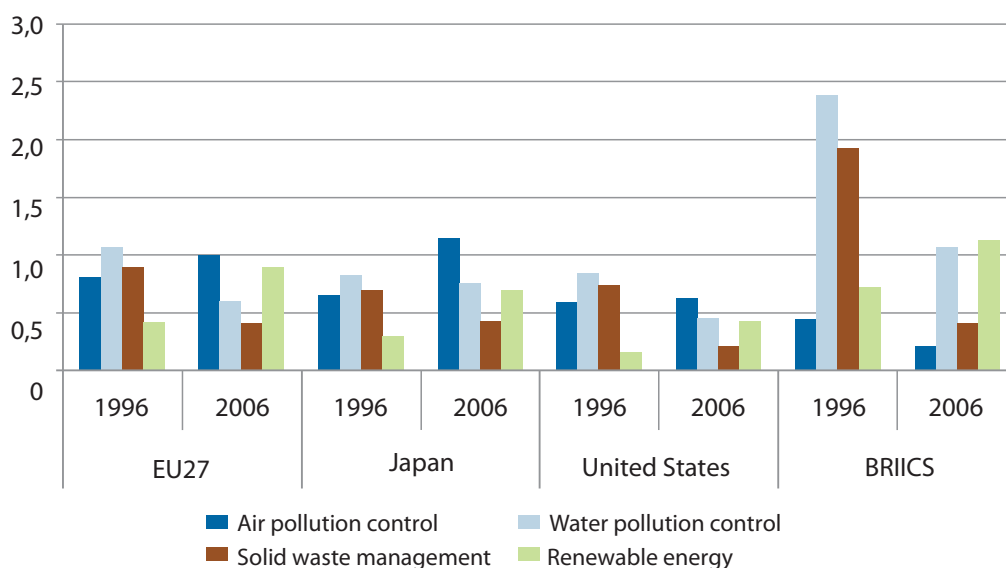
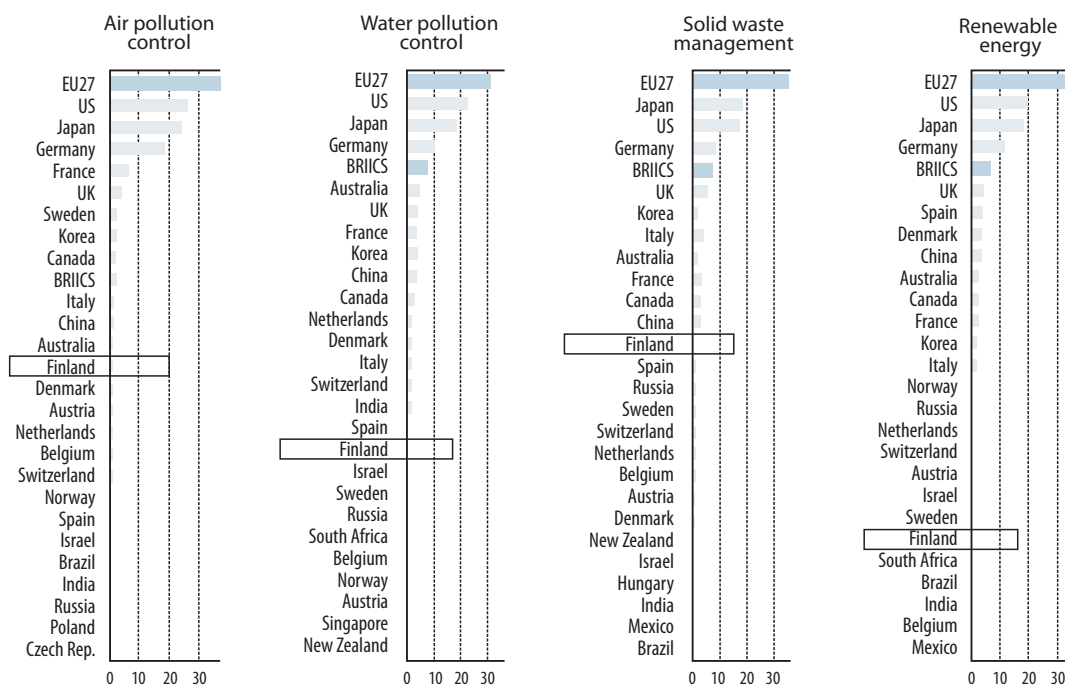


Figure 10. Share of countries in environmental technology patents filed under PCT; Top 25 countries, 2004–06
(Source: OECD – Main Science and Technology Indicators, 2009b)



4.3 The specialization of countries

Whereas the discussion above provided insights into the general development of environmental technologies and positioned countries based on their activity levels, a more detailed analysis is needed to identify national strengths in innovative activity. For this reason, Table 1 identifies the relative technological advantage (RTA) of selected countries and compares the position of Finland to them.² An RTA index value higher than 1 indicates that a country has relatively more patent applications in a technology area and is thus compar-

tively more specialized in that area. To make Table 1 more readable, we have resorted to a simplified coding, where X equals an RTA value higher than 1, XX equals an RTA value higher than 2, and XXX equals an RTA value higher than 4.

Looking first at the technological specialization of Finland over time, it is interesting to observe clear differences between the 1990s and 2000s. In the 1990s, Finland was relatively more specialized in solid waste management, biomass, and wind technologies. In the 2000s, water pollution control (including water and wastewater management) emerged as a specialization field. Interestingly, in renewable energy

technologies, geothermal, hydropower, and ocean technologies emerged as specialization fields during the same period. As these technologies are fairly niche areas (see Figure 8), where patenting activity is only very marginal, the specialisation in these technologies cannot be considered very significant. Maybe the most interesting change relates to wind technologies. In the 1990s, Finland seems to have been very specialized in wind technologies, but in the 2000s, this advantage has been lost. This development may relate to the increasing patenting activity in other countries but also to diminishing activity in Finland in the 2000s.

² The results are presented in greater detail in Palmberg and Nikulainen (2010) particularly in Appendix 3.

Table 1. Summarized RTAs in environmental technologies for selected countries (1990–2007) (Source: OECD PATSTAT)

Technology	Finland - 90s	Finland - 00s	Finland	Austria	Australia	Germany	Denmark	UK	Netherlands	Sweden	U.S.	South-Korea
Air pollution control						X				X	X	
Solid waste management	X	X	X	X	X							
Water pollution control		X	X	X	X	X	X	X	X	X		X
Total - Renewable energy	X				X		X	X	X		X	X
Biomass	X	X	X					X	X		X	X
Geothermal		X		XX		X			X	X		
Hydropower		X		XXX	XXX					X		
Ocean		X	X	XX	XX		XX	XXX		XX		
Solar					X				X			X
Wind	XX		X			X	XXX			X		

Note I: X – RTA higher than 1; XX – RTA higher than 2; XXX – RTA higher than 4.

Note II: An RTA index value higher than 1 indicates that a country has relatively more patent applications in a technology area and is thus viewed to be more specialized in that area.

Looking at Finland’s technological specialization for the entire observation period (1990–2007), it seems that technological specialization prevailed in solid waste management, water pollution control, biomass, ocean, and wind. In comparison to other countries, interesting differences emerge. While similar profiles to Finland exist, many of the countries seem to be very specialized (RTA higher than 2) in specific environmental technologies.

Austria, for example, is specialized in somewhat marginal renewable energy technologies: geothermal, hydropower, and ocean. Australia is very specialized in hydropower and ocean technologies. Denmark has a long history in wind technologies, which is evident from its RTA specialisation profile. In addition, Denmark is highly specialized in

ocean technologies. The UK is very focused on ocean technologies, as is Sweden. These findings invite further exploration into the national activities in the highly specialized technology areas.

Table 2. Industry concentration in highly specialized technologies in selected countries (Source: OECD PATSTAT)

Country	Technology	RTA index	Companies
Austria	Geothermal	2.73	5
Austria	Hydropower	7.71	3
Austria	Ocean	2.68	4
Australia	Hydropower	4.40	4
Australia	Ocean	3.11	5
Denmark	Ocean	2.40	2
Denmark	Wind	8.12	19
UK	Ocean	4.06	29
Sweden	Ocean	2.40	4

To address the national specialisation in greater detail, company concentrations in patenting is addressed to assess whether a high focus in specific environmental technology areas is based on the activities of a single company or a broader set of companies potentially forming a technologically oriented cluster. Table 2 sheds light on this aspect in the context of the countries with a particularly high specialization in a specific technology area.

The results provide more detailed insights into the general results based on the RTA indexes. It seems that very high specialisation in many countries relates to the activities of a small group of companies. Only in two cases can a larger cluster of companies be identified: a wind technology cluster in Denmark with 19 individual companies and an ocean technology cluster in the UK with 29 individual companies. In both of these countries, there is a strong industrial tradition within the respective technology areas, which has been coupled with activity policy efforts.

In summary, this chapter gives the following insights:

- Investment trends are also reflected in patenting, although no linear causality between the two should be assumed. Within environmental technologies, renewable energy has experienced the most rapid patenting growth over time.
- The rapid growth in renewable energy patenting can mainly be traced to wind and solar power; solar power has also been subject to a rapid growth in investments.
- The share of environmental technology patenting of total patenting is similar across regions of the world, even though the BRIICS countries are emerging as comparatively relatively more active in this area.
- Finland is comparatively well-positioned in environmental technology by overall levels of patenting activity, but does not emerge as a country with a specific specialization profile in the area generally speaking nor in the rapidly expanding field of renewable energy.

5 The case of Finland

5.1 Recent policy developments related to environmental technologies

In Finland, as in many other countries, issues related to climate change have been closely intertwined with those of energy. The promotion of Finnish environmental technologies has thus taken place within the broader context of the so-called National Climate and Energy Strategy. This strategy is largely formu-

lated in line with guidelines laid down by the UN Framework Convention on Climate Change as well as the European Union, including specific initiatives undertaken by the EC (such as the Environmental Technologies Action Plan (ETAP)). For many years already, the key objectives of the strategy have been to increase energy efficiency throughout the economy and to increase the development and use of renewable energy. The most recent national strategy, from 2008, draws on policies of the EC and sets a 38% target for the share of renewables of total Finnish final energy consumption by 2020 as one important goal towards complying with the UN Kyoto protocol (VNK, 2008).

The main ministerial policy actors related to environmental technologies are the Ministry of the Environment and the Ministry of Employment and the Economy (MEE). These ministries collaborate in overlapping areas through various committees, panels and other types of forums (see Lemola et al., 2010). However, the Ministry of Environment is mainly involved in regulatory matters and in developing broader guidelines for energy efficiency in alignment with international climate change treaties and policies (such as the Kyoto protocol). The MEE has a more significant role in promoting environmental technologies, including renewable energy. This role is also a consequence of MEE having a key role in the formulation of innovation policy, which has also recognized environmental technologies as key drivers for innovation. However, according to Kivimaa and Mickwitz (2006), further integration of environmental and innovation policies in Finland would be desirable in order both

to streamline policies and to better realize emerging opportunities related to environmental technologies.

Subordinate to MEE, the main organizations and institutions involved in environmental technology promotion and research include the Finnish Funding Agency for Technology and Innovation (Tekes) and the Technical Research Centre of Finland (VTT). Tekes is the main R&D funder in Finland and has also played a key role in funding environmental technology programs and projects. (See Table 3 for a list of recent Tekes programmes.) VTT is the main public R&D organizations and an important partner in environmental technology programs and projects. Tekes focuses on applied research while the Academy of Finland has also funded several research projects in this area. The Ministry of the Environment also commissions research relevant to environmental technologies, the most recent example being the Environmental Cluster Programme, which has been running since 1997. This programme has been co-funded by the ministries of Environment, Employment and the Economy, Tekes, and the Academy of Finland.

In addition, some public funding for environmental technologies is also channelled through the so-called SHOK and Strategic Centre of Excellence Program (OSKE) programs. The SHOK program is based on close cooperation between industry, universities, and research organizations as well as public R&D funders (Tekes plays an important role also in these programs) with the aim to allocate R&D resources in close alignment with needs especially from the viewpoint of significant companies and industrial areas of strength

Table 3. Recent Tekes programmes related to environmental technologies

Program name	Years	Volume (million EUR)	Focus technology areas
BioRefine	2007–2012	200	New, biomass-based products
Climbus	2004–2008	70	Cost-effective, climate-friendly technologies
Climtech	1999–2002	5	Technology and climate change
Code	1999–2002	14	Modelling of Combustion Processes
Cube	2002–2006	40	Building services technology
Densy	2003–2007	56,7	Distributed energy systems technology
Fine	2002–2005	26	Particles technology, environment and health
Fusion	1999–2002, 2003–2006	18	Applications and technology of fusion power
Green Growth	2011–2015	79	Climate change and market change
Jätteen energiankäyttö	1998–2001	17	Solutions for integrated energy (material recovery, municipal/industrial waste)
Kestävä yhdyskunta	2007–2012	100	Sustainable development in real estate and construction clusters
Polttokennot	2007–2013	144	Products and services based on fuel cell technology
Promotor	1999–2003	51	Technology of internal combustion engines
Prosessi-integraatio	2000–2004	23	Planning, management, and use of industrial processes
Puuenergia	1999–2003	42	Wood energy
Puupolttoaineiden pientuotanto ja -käyttö	2002–2006	13,6	Production and use of wood-based fuel
Streams	2001–2004	27,3	Recycling technologies and waste management
Tulisija	1997–1999	1,4	Wood-firing technology (higher efficiency, lower emission)
Uusiutuva energia- Groove	2010–2014	95	Renewable energy

(Nikulainen and Tahvanainen, 2009). The SHOK programs were launched in 2007–2009 and consist of six sectoral programs of which several are relevant to the application and commercialization of environmental technologies (e.g., FIMECC related to machinery and equipment, Metsäklusteri related to forestry-based industries, RYM related to the built environment, SalWe related to health and well-being, and TIVIT related to electric engineering). However, the CLEEN SHOK programme is of primary relevance to the environ-

mental technology field. CLEEN comprises a cluster of 40 major Finnish companies in the area of energy and environmental technologies (Halme, 2010).

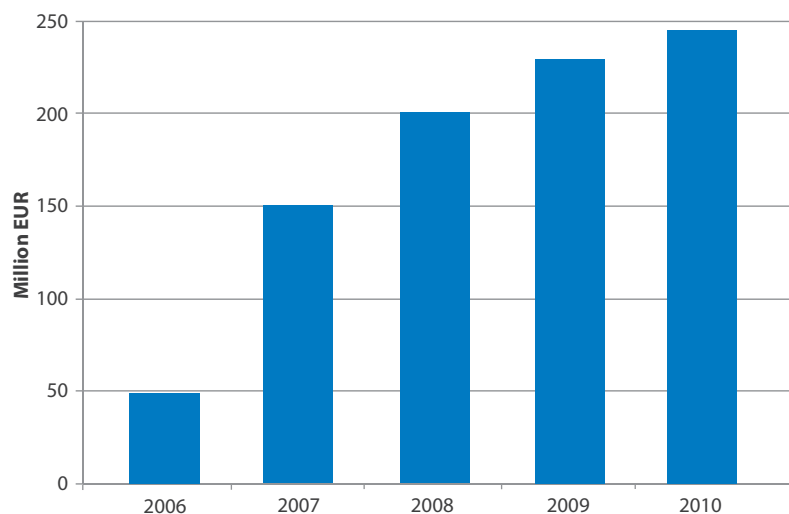
The OSKE programs represent a new policy initiative to increase regional specialization and to strengthen co-operation and coordination between regions. It involves 13 so-called Competence Clusters and 21 regionally associated Centres of Expertise with the idea that these clusters and centres can increase critical mass for innovation in various technology areas and applica-

tion fields as a basis also for international competitiveness. Again, environmental technologies can find application in many of these clusters and centres. Nonetheless, two of these Competence Clusters focus on environmental technologies per se, namely the Energy Technology Cluster and the Cleantech Cluster. The Energy Technology Cluster consists of Centres of Expertise in Western Finland, the Jyväskylä region, North Karelia, Satakunta, and Tampere, with a focus on bioenergy, decentralised energy production, energy solu-

tions for industries, and electrical engineering. The Cleantech Cluster covers around 60% of the Finnish cleantech business and some 260 companies (many of which are SMEs). It consists of Centres of Expertise in the Kuopio, Lahti, Oulu, and Helsinki regions with a focus on ICT-related environmental technologies; environmental monitoring; climate, air quality and health and environmental informatics. Activities in the Lahti Centre of Expertise also focus on capital venturing and the promotion of environmental technology-based entrepreneurship. The Environment Programme 2004–2007 and on-going Energy Programme by Sitra, the Finnish Innovation Fund, has also played an instrumental role in promoting environmental technologies and related Cleantech initiatives in Finland.

Tekes channelled 245 EUR million in 2010 to energy- and environmental technologies through various programs and initiatives, and these investments have also experienced significant growth in Finland since 2006 (Figure 11). This sectoral breakdown suggests that Finnish policies support environmental technologies on a broad front. However, in contrast with international trends in environmental technology investments, renewable energy does not appear to be a particularly prioritized area to date. Indeed, Finnish R&D priorities in recent technology programs have been in the areas of energy efficiency rather than more transformative technologies related to renewable energy (see Vanhanen et al., 2009). Energy efficiency priorities also respond to the need for cost-efficient energy within process-intensive industries, which are in abundance in Finland, and many

Figure 11. Tekes energy- and environmental technology investments in Finland 2006–2010 (Source: Tekes, 2010)



energy efficient technologies are incremental in nature as they mainly focus on process improvements. According to the OECD Environmental Performance Review (OECD, 2009a), Finland could do more to promote eco-innovation through green procurement, environmental labelling, and the active involvement of business and other stakeholders, and consider how environmental policy instruments could be better aligned with innovation policy (and vice versa) to promote innovation.

5.2 Environmental technology patenting and companies

In Finland, the recent policy efforts in environmental technologies are responses to the long-term developments related to climate change and the demands and business opportunities arising from it. In the following, the

focus is on the innovation landscape of environmental technologies in Finland with emphasis on company-level activities in the area. Earlier in the paper, we positioned Finland in various technology areas with respect to other countries and identified that Finland is not very specialized in any of the technology fields, although the level of innovative activity can be considered to be quite high. This is also evident in Table 4, indicating that the activities in environmental technologies are fairly evenly distributed across the four main environmental technology patent classes.

The volume and overall share of Finnish patenting in environmental technologies show that the activity in Finland has concentrated on certain technology areas. For example, water pollution control and solid waste management technologies seem to have slightly larger shares than the other technologies. In renewable energy,

Table 4. Environmental technologies patents and the share of Finland; EPO applications 1990–2007 (Source: OECD PATSTAT)

	All	Finland	%
Air pollution control	20416	176	0.9
Solid waste management	8397	97	1.2
Water pollution control	13974	176	1.3
Renewable energy	13726	124	0.9
Biomass	5047	67	1.3
Geothermal	264	2	0.8
Hydropower	250	2	0.9
Ocean	303	5	1.7
Solar	5843	26	0.4
Wind	2018	21	1.0
Total	56513	573	1.0

Table 5. Environmental technology patent applications of Finnish companies (1990–2007, companies with more than 2 environmental technology patents, with a 20% threshold) Source: OECD PATSTAT and Statistics Finland (authors' calculations)

Firm	Environmental technology patents	Share of all patents	Industry	Firm size
Evac International	32	94%	Machine and process design	SME
Foster Wheeler	30	36%	Machinery	Large
Kemira	29	28%	Chemicals	Large
STX Finland	15	22%	Machinery	Large
Ecocat International	15	94%	Machinery	Large
Andritz	12	24%	Machinery	Large
Oras	10	53%	Metals	Large
Wiser	7	78%	Research and development	SME
Winwind	6	100%	Machinery	Large
Vapo	5	56%	Energy	Large
Steris Europe	5	56%	Machinery	SME
KWH Pipe	4	22%	Plastics	Large
BCDE Group Waste Management	4	80%	Electronics	SME
Larox	4	100%	Machinery	Large
Suomen Rehu	3	23%	Agriculture	Large
Maricap	3	60%	Machinery	SME
Etor	3	100%	Construction	SME
Finn Escone	3	100%	Machine and process design	SME
Proventia Emission Control	3	100%	Machinery	SME

biomass and ocean technologies stand out with somewhat higher shares as is also indicated in the earlier discussion on the technological specialization of countries. As the international trends and country comparisons were presented earlier in this paper, in the following, the focus is on the innovation environment of environmental technologies in Finnish firms.

There are a total of 125 companies behind these environmental patents in Finland. Since not all of these companies are highly committed to environmental technologies, and since environmental technology patents only account for a small share of the overall patent portfolio of these companies, a threshold of the intensity of environmental technology patenting is applied for further analysis. The threshold is set to 20%, meaning that at least 20% of a company's patents have to be classified as environmental technology patents to be included in the further analysis.³ Another advantage of using the threshold is that it excludes many of the largest companies in Finland that have occasionally patented in the field but cannot be classified as environmental technology companies proper, whereby their inclusion would significantly distort the results. This 20% threshold is used as a basis for the ensuing analysis, unless otherwise stated.

The distribution of patents is skewed, with only a few companies having many patent applications in environmental technologies (Table 5). Interestingly, the list of companies is dominated by large firms representing the machinery industry. The sec-

3 The full list of companies without the threshold can be found in Palmberg and Nikulainen (2010) in Appendix 4.

ond group consists of smaller companies in machine and process design and research and development industries. These findings are in line with earlier studies identifying machinery as a key industry in areas such as pollution abatement (Rodrik 1996; Lanjouw and Mody, 1996; Hanemann 2010). In fact, much of the existing theoretical literature on R&D and pollution abatement assumes that the innovating company is the same as the company that causes pollution and invests in abatement. This assumption is often false. The vast majority of the innovators are not the polluters but rather machinery suppliers and other outside sources, as suggested by our findings.

The intensity by which the companies are involved in environmental technologies also varies greatly. Larger companies are typically more diversified in their technological activities, whereas smaller companies are more focused on a narrower range of areas. While the analysis above has provided us with some insights into the companies who are active in environmental technologies, it is worthwhile to take a broader viewpoint on company characteristics in environmental technologies. These characteristics, presented in Table 6, include total industry sales and

employment, weighted with the share of environmental technology patents of all patents of a company in order to gain an appropriate perspective.

The industry-level indicators highlight the significant role of environmental technologies in the Finnish economy. Looking at the employment indicators, it could be argued that, based on the weighted number of employees, the industry employs around 16,000 persons, and with the tighter threshold, the figure is still around 12,000. When looking at the industry sales, we can again witness the importance of this sector. Even by the most stringent criteria (with the 20% threshold), the sales are 3.5 billion euro. Without the threshold, the sum of the weighted industry sales rises to 7.4 billion euro.

5.3 Environmental technologies in industry

The significant role of environmental technologies in the economy raises the question of how these technologies link up to Finnish industries in terms of realized or potential applications. Some answers to this question can also be provided through patent data by examining the industrial affilia-

tion of the companies that patent in environmental technologies. In the following, the 20% threshold is not applied for included companies, because the interest is also in identifying weaker signals of both realized and potential links between the development and industrial application of environmental technologies throughout the Finnish economy in a broader sense. To highlight these relationships, Table 7 shows the industrial and size distribution of all 125 companies behind the Finnish environmental technology patents as a first approximation.

As mentioned earlier, the main environmental technology related industries (as suggested by the industrial affiliation of the patenting companies) are machinery, research and development, and machine and process design. Beyond these, patenting is spread out across companies in a broad range of industries and represents quite well the overall industrial structure of the Finnish economy. Accordingly, environmental technologies appear to be finding realized or potential application opportunities in many different types of industries throughout the Finnish economy. This finding is encouraging since it may suggest that here are several potential commercialisation paths, and different types of companies in value chains may also be able to play different roles in commercialization. (For more on this, see Nikulainen, 2010.) In most of these industries, Finland hosts large companies that can act as industrialists in the commercialization and diffusion of environmental technologies by providing access to complementary assets such

Table 6. Environmental technology related industry characteristics (weighted)

Source: OECD PATSTAT and Statistics Finland (authors' calculations)

Companies included	Employment	Sales
	# of employees	Millions of €
With threshold	12 094	3 504,4
All	16 127	7 461,4

Note: Weighting is based on the share of environmental technology patents of all company patents.

Table 7. Environmental technology related industries by company size

Source: Statistics Finland (authors' calculations)

Industry	Large	SME	Total	Total (%)
Agriculture	1	1	2	2%
Chemicals	3	5	8	6%
Ceramics	1	0	1	1%
Construction	1	6	7	6%
Electronics	3	4	7	6%
Energy	2	1	3	2%
Fibers	1	0	1	1%
Foodstuff	1	0	1	1%
Machine and process design	1	12	13	10%
Machinery	11	23	34	27%
Metals	4	5	9	7%
Plastics	3	2	5	4%
Pulp and paper	4	0	4	3%
Research and development	1	15	16	13%
Services	0	8	8	6%
Testing	0	2	2	2%
Waste management	2	2	4	3%
Total	39	86	125	100

as marketing and distribution. Other relevant companies include smaller equipment suppliers and new technology-based firms (e.g., related to ICT, bio- or nanotechnology).

A second approximation for identifying realized or potential linkages between environmental technologies and application industries is to consider the activity of these companies in terms of renewable energy technologies (Table 8). Earlier in this paper, we identified solar energy as one of the faster growing areas of environmental technologies. Inter-

estingly, Finland seems to have missed out on this development trend. Looking at the column for solar energy technologies, eleven companies can be identified as having activity in this area, and only one has more than a single patent. A closer look at the company with eight patents reveals that in fact the main application area of their technology is related to x-ray technologies. Moreover, it seems that the company has closed down its operations. These findings suggest that Finland may be left outside of solar technology as one

of the main future technology growth areas within environmental technologies. This aspect would require a more in-depth analysis, particularly focusing on the developments during the recent years, which may have been underrepresented in the patent statistics.

In summary, this chapter gives the following insights:

- Finland has ambitious targets for increasing both energy efficiency and the development and use of new renewable energy technologies, and many R&D programmes and other measures have been undertaken towards these aims.
- Finnish environmental technology patenting is spread across a large number of companies and a broad range of application industries even though their share of all patents in these companies and industries is generally low.
- Of the more environmentally technology-intensive companies, a majority are affiliated with the machinery industry and process engineering, and these companies tend to be larger; companies active in renewable energy specifically tend to be smaller.

6 A summarizing discussion

Increasing climate change concerns, investments, and environmental technology patenting is creating both opportunities and challenges for many countries, including Finland as a small open economy. This section analyses the investments and global patenting trends with an eye to assessing the position of Finland in the changing environmental technology landscape. In the background are also concerns about the sources of future Finnish technological and industrial stronghold in rapidly emerging technologies of which environmental technologies are particularly promising. The section primarily draws on literature research and patent data, linked to company register data. It takes a future-looking perspective that is geared towards providing conceptual and empirical insights of relevance, both to innovation and to environmental policies.

The overall policy framework for environmental and energy technologies in Finland is stipulated by the National Climate and Energy Strategy, which is formulated in line with guidelines laid down by the UN Framework Convention on Climate Change as well as the European Union, including specific initiatives launched by the European Commission. Within the context of these strategies and guidelines, Finland has recently actively promoted environmental technologies primarily through several technology programs by the Academy of Finland, the Finnish Funding Agency for Technology and Innovation (Tekes), and the Ministry of En-

vironment. Company participation has also been facilitated through the so-called SHOK and OSKE programs, the latter of which covers various regional initiatives related to Cleantech and energy technologies. The Finnish Innovation Fund (Sitra) has also played an instrumental role in promoting environmental technologies and related Cleantech initiatives.

Globally speaking, patent data point to the most rapid growth in innovative activity related to renewable energy with biomass, wind, and solar power in the lead. The environmental technology landscape is also changing through the entry of new countries on the scene, with most relative growth in patenting occurring in the BRICS countries. Finland is well-positioned in the environmental technology area by overall levels of patenting activity and it is among the top 25 countries by the absolute number of patents. Nonetheless, the position is more worrying in terms of the distribution of these patents set against global trends. Specifically, Finland does not emerge as a country with a specific specialization profile, generally speaking, neither in relation to renewable energy technologies where most growth in investments and patenting can be detected globally. This finding is in contrast with the specialization profile of countries such as Austria and Australia (hydropower), Denmark (wind technology), and the UK (ocean technology). Furthermore, a partial Finnish specialization in wind technologies appears to have eroded over time. These findings appear at odds with the dual policy priority to promote both energy efficiency and renewable energy. How-

ever, it should be noted that patenting may also have occurred in areas not covered by the patent-based environmental technology definition that this paper uses (e.g., in machinery, equipment, and instruments).

The discussion about energy efficiency versus renewable energy often centres around the idea that energy efficiency mainly supports incremental technological change based on existing energy sources that may often be non-renewable (mainly fossil-based fuels). In contrast, renewable energy technologies can potentially provide the basis for technological change and innovation of the more transformative kind for greener and more sustainable longer-term growth. This comparison may not always hold as energy efficiency can also imply that transformative and radical technologies and innovations are involved, for example, related to nanotechnologies (e.g., smart windows, sensors, new materials, and fuel cells). An important issue for Finland is how to strike a balance between promoting both energy-efficiency and renewable energy technologies.

The data on Finnish environmental technology patent applications identified 125 companies active in this area, of which a sub-sample with over 20% of such patents in their portfolio was analysed in greater detail. Of these more environmental technology-oriented companies, a majority are classified in the machinery industry in confirmation of extant research that also locates environmental technology patenting globally to this more traditional industry. Accordingly, it seems that most of these companies are not major proc-

ess-intensive and polluting companies, but they instead supply such companies with new environmental technologies. Further, the company-size distribution is rather skewed and dominated by a few large companies. The smaller companies have often been founded around an innovative individual as a spin-off or spin-out from research or other companies. The economic significance of these companies is relatively noteworthy, accounting for approximately 12,094 employees and 3.5 billion euro in sales.

The economic significance of Finnish environmental technologies should also be assessed by the degree to which they find industrial applications throughout the economy. This paper also uses patent data for this purpose by considering how environmental technologies link up to industries through the affiliation of the companies patenting in the area. The data shows that the total sample of 125 companies is affiliated with a wide range of different industries, beyond the machinery industry as the main one. This diversity suggests Finnish environmental technologies appear to be finding realized or potential application opportunities in many different types of industries throughout the Finnish economy. Accordingly, there may also be a range of different commercialization paths where different types of companies (small versus large) can play different roles. A more detailed analysis identified a large set of smaller design and R&D-focused companies that might play a critical role in developing more radical technologies alongside more incremental development within larger companies.

In conclusion, the patent analysis of this paper should be deepened and complemented with other data (e.g., case studies) for a richer assessment of the comparative and competitive position of Finland, especially in renewable energy technologies as a rapidly expanding area. From a policy viewpoint, it would be important to consider further possibilities for a more systematic approach towards promoting environmental technologies, both with respect to enhancing the efficiency of existing energy technologies as well as emerging renewable energy technologies. Such an approach may need further integration of innovation (e.g., R&D funding and programmes), environment (e.g., regulations) and also other policy domains (see also Kivimaa and Mickwitz (2006)).

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Section 3

Can biofuels and electric vehicles contribute to green growth in Finland?

Raimo Lovio, Jenny Rinkinen and Armi Temmes

1 Introduction

Traffic and logistics have gained a lot of attention in discussions on green growth and green economy for many reasons. First, the role of transport in CO₂ emissions is significant (26% in Finland in 2009%; 18% from only road transport) (Liikennetilastollinen vuosikirja 2010, 48). Second, the world financial crisis of 2008–2009 hit the automotive industry hard in the U.S. and Europe. And third, at the same time, some promising new opportunities have emerged for transforming road transport vehicles in a more sustainable direction by more efficient combustion engines, biofuels and electric motors. At least in the media, these new developments have received plenty of publicity and space.

Although Finland is not specialized in the automotive and oil industries, the new developments in biofuels and electric vehicles have generated some enthusiasm. The largest Finnish oil company, Neste Oil Oyj, has invested in biofuel refineries in Finland and abroad based on its technological expertise. A new entrant in the

oil business, St1 Oy, has developed a new method to produce ethanol from food industry waste. The Finnish pulp and paper companies have investigated possibilities to build new biodiesel plants based on wood feedstock. As for electric vehicles, the only Finnish passenger car manufacturer, Valmet Automotive, has started to make electric vehicles for its business customers in Norway, Denmark, and the U.S. Some other companies have invested in developing batteries, charging equipment, and infrastructure systems. These corporate initiatives, among other things, have led the Ministry of Employment and the Economy together with Tekes (the Finnish Funding Agency for Technology and Innovation) to start developing a new electric vehicle cluster in Finland.

These developments make biofuels and electric vehicles a topical research subject for a case study on green economy and green growth. The study was done by interviewing company representatives, directors, and researchers in the following organizations: Neste Oil, St1, UPM, Metsäklusteri Oy (Forestcluster Ltd), Ensto, For-

tum, Green Net Finland, Electric car – Now!, VTT Technical Research Centre of Finland, and Tekes (see Appendix 1). In addition, we gathered data at the annual seminar of the TransEco programme in November 2010 (TransEco Programme). Furthermore, national and international policy documents and research reports on developments in the area were essential sources for our study. Jenny Rinkinen's (2010) recent study, "Traffic in the media: Competing visions from electric cars to a car free future", gave us a fresh background picture of the public discussion on the future of traffic.

The research report is structured as follows. We start by defining the focus and the questions of the study (Chapter 2). Then we describe the main drivers of developments in biofuels and electric vehicles (Chapter 3). Chapters 4 and 5 present emerging business opportunities in biofuels and electric vehicles in general and especially in Finland. The impacts of the diffusion of biofuels and electric cars from a climate policy point of view are estimated in Chapter 6. Finally, in Chapter 7, major policy challenges are specified.

2 Framework: Green growth and demand-driven innovation policy in the transport sector

There is a huge technical literature on biofuels and electric cars. The prospects of alternative biofuels and electric vehicles in Finland have also been examined quite thoroughly from a technical and economic point of view (e.g., Nylund et al. 2008, Nylund 2010 and 2011). Moreover, the Ministry of Employment and the Economy and Tekes have published two reports on business opportunities in Finland in the electric vehicle cluster (Biomeri 2009 and Swot Consulting Finland 2010) and Finpro has made a study on global trends and Finnish opportunities in the electric vehicle industry (Finpro 2010).

This study builds on these reports and empirical findings. However, we approach the issue from a somewhat different point of view. Based on international and domestic studies on industrial transitions and related transition policies (e.g., Schot & Geels 2008, Heiskanen et al. 2009, and Lovio et al. 2011), we focus on examining how a socio-technical system change, or systemic innovation (in this case, a transition from the crude oil based transport system towards a more sustainable transport system) is likely to occur and how such a transition can be enhanced by innovation and other policies.

From this point of view, we examine drivers, actors and policies advancing the greening – or green growth – of the transport system, which can include, among other things, an increas-

ing use of biofuels and electric vehicles. As for *drivers* of the change, we ask whether it is technology, economy, or policy that is the most influential factor.

As for *actors*, we examine the roles of new entrants and incumbent firms in the transition. We do so by elaborating and specifying the following five hypotheses, which are based on current research on socio-technical transitions (e.g., Geels 2004) and sustainable entrepreneurship (Wüstenhagen & Wuebker 2011):

1. *The relative significance of new entrants and incumbents*: A shift from oil to biofuels is less radical than a shift from the combustion engine to the electric motor. Therefore, it is likely that incumbents dominate the biofuel field, whereas new entrants dominate the electric car field.
2. *Co-operation and alliances between new entrants and incumbents*: Due to the more radical change and an earlier development stage, there is more co-operation between all companies as well as between new entrants and incumbents in the electric car field than in the biofuel field.
3. *Strategies of incumbents and new entrants*: Oil use can be reduced through improvements in the energy-efficiency of combustion engines, the use of biofuels, or the development of electric cars. It is likely that corporate strategies focus on exploring add-on or hybridization strategies (Raven 2007), i.e., oil companies focus on biofuels, dominant automotive companies on improving combustion engines and hybrid motors, whereas electricity utilities and manufacturers of electric devices support the development of electric cars.

4. *Character of innovative incumbent firms*: Among incumbents, innovative experimentation is likely to occur in companies that are not in dominant positions in the industry (Geels & Turnheim 2010). Relatively small or otherwise destabilized incumbent firms try to use shifts to biofuels and electric cars to improve their positions.

5. *Character of innovative new entrants*: Among new entrants, innovative experimentation is likely to occur in start-up companies that are financed by venture capital firms and managed by Schumpeterian-type entrepreneurs (Hockerts & Wüstenhagen 2010).

Finally, we study *policy* issues and challenges. Basically, green growth is about steering the development of production and consumption in a more sustainable direction. Innovation and economic policies are modified so as to support the emergence and diffusion of new technologies, products and services that help in achieving environmental policy objectives (climate change, local air emissions, noise, etc.) nationally and internationally. Green innovation policy is one example of demand-driven innovation policy.

Based on international and domestic research, it can be argued that green innovation policy in the area of transport needs to be coherent, multifaceted, and dynamic (e.g., van der Laak et al. 2006, Hillman et al. 2008, Ulmanen et al. 2009, Kivimaa 2008).

Policy coherence requires that the incentives and signals of different policies (e.g., climate policy and others) provide target groups with non-con-

flicting signals. Policy co-ordination is one of the means of achieving coherence (Mickwitz et al. 2009, 24; Kivimaa & Mickwitz 2009). In relation to the greening of the Finnish transport sector, a key coordinating measure is "Climate Policy Programme for the Ministry of Transport and Communications' administrative sector for 2009-2020" (Liikenne- ja viestintäministeriö 2009) and its follow-up (e.g., Liikenne- ja viestintäministeriö 2010). The programme presents how the national and European Union targets for reducing greenhouse gas emissions can be achieved. A target set for Finland is to reduce greenhouse gas emissions in the transport sector by 16 per cent from the 2005 level by 2020. The target creates increasing demand and markets for biofuels, electric cars, and public transport services. Finnish innovation and industrial policies try to make sure that domestic firms could benefit from this situation. The domestic market is especially important in this case because traditionally the automotive and fuel industries are not among the strongest areas in Finnish industry. In order to develop products and services for export markets, the domestic market can be used as a demonstration and pilot market.

The need for *multifaceted policy measures* (such as innovation programmes, tax exemptions, infrastructure investments, etc.) is due to strong path dependencies in the automotive and oil industries and in the transport infrastructure. Changes will only take place if different policies create clear incentives for research institutions and companies to develop new solutions and for customers to buy those solutions.

The greening of the motor vehicle fleet in Finland and other countries is a slow process. The Finnish vehicle fleet includes more than 3 million vehicles. Today, passenger cars are scrapped at an average age of about 18 years, and the average age of passenger cars is currently 11 years (Öljy- ja kaasualan vuosikirja 2009). The number of new cars sold every year varies between 100,000 and 150,000. In addition, the development of new fuels and cars and the building of the production capacity for them take several years. Due to these reasons, policies enhancing green growth in the transport sector have to be *long-term oriented and dynamic*. Long-term orientation refers to the consistency of policy: long-term targets motivate companies and consumers to invest in less polluting and more efficient cars. However, policy also needs to be dynamic because some solutions can be adopted immediately (e.g., more efficient internal combustion or diesel engines and smaller cars), some in the short term (e.g., second generation biofuels), whereas some can only be widely taken up in the long run (e.g., electric cars). A major policy challenge is to support incremental and radical changes simultaneously.

In addition to examining the above questions related to drivers, actors, and policies in the greening of the transport sector, we summarize the visions of interviewed persons and recent research reports about the Finnish strengths and challenges in the sector. We ask to what extent it is likely that biofuels and electric vehicle businesses can contribute to green growth in Finland.

3 Main drivers of developments in biofuels and electric vehicles

Today's biofuels and electric vehicles are not a totally new phenomenon. They have been under investigation and developments since the first and second oil crises in the 1970s. During the 1980s and 1990s, the main driver for low emission vehicles was the need to improve urban air quality. The recent wave started in the early 2000s, first in biofuels and a few years later in electric vehicles. The new driver is climate policy at the global, EU, and national levels. Other contributors to the current upswing include high oil prices in 2008 and worries about a forthcoming peak oil crisis, the global financial crisis and related problems in the automotive and forest industries, and some new technological developments in biofuel and electric vehicle technologies.

The interviewed company representatives stressed the role of policy, rather than market drivers, in the recent market formation for biofuels and electric vehicles. The EU's climate policy and its applications in the traffic sector has been the strongest driver in the European context (see summary of policy measures in Table 1, Section 1). Finland was first slow in implementing the first EU Directive on biofuels (Directive 2003/30/EC) (Kauppa- ja teollisuusministeriö 2006), but later on the development of biofuels and the electric vehicle cluster has been put high on the agenda of energy and innovation policies.



These policy measures are strong for three reasons. First, some of them are very concrete and directly effective (especially the mandatory share of biofuels and the binding objectives for CO₂ emissions of new cars). Second, economic instruments are used in many forms. Most of them are targeted to companies (such as R&D, demonstration and investment support) but some also to users of cars (e.g., car tax reforms). At least some of the policy measures are also long-term oriented by defining exact targets for the development in the next ten years. All in all, policy measures have been effective enough to create markets for biofuels quite quickly and for electric vehicles in the longer run.

The importance of policy measures is related to cost and price issues. So far, electric cars have been clearly more expensive than internal combustion engine cars. For example, the

price of Norwegian Think City electric car in autumn 2010 was approximately double the price of a combustion engine car of similar size. Similarly, the production of second-generation biofuels is more costly than that of traditional fuels.

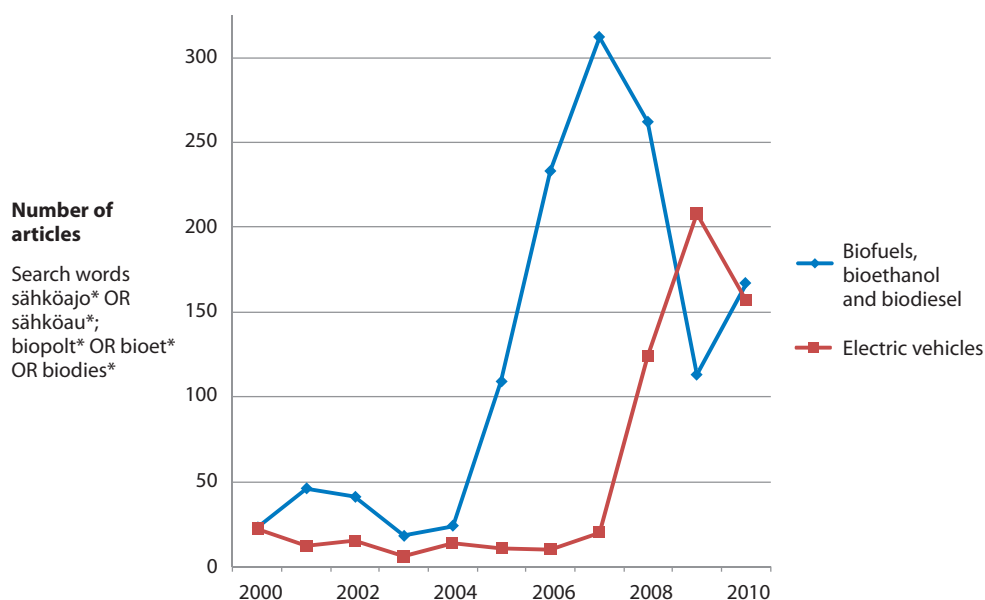
However, second to policy among the drivers of development are oil resources and prices. Transport represents some 60% of the world's oil consumption today, compared to 45% in 1973. Thus, the strong dependence on crude oil represents a high cost risk for the transport sector. The oil price peak in 2008 was a clear signal that the era of cheap oil is ending, which is also indicated by the fact that in Spring 2011 petrol prices in Finland were close to the record level of summer 2008.

A third driver for change in the transport system is technological development. Even though no major break-

through innovation has been made in the area, there is some progress in both biofuels and electric vehicles. From the Finnish point of view, the most obvious examples are related to new second-generation biofuel technologies and batteries in electric vehicles. St1 has developed a new technology to produce ethanol from food industry waste and Neste Oil has developed a novel second-generation biodiesel product. In electric vehicles, old lead-acid batteries have been replaced by lithium-ion batteries. European Batteries, a new Finnish battery company, started to produce lithium-ion batteries in 2010 in Varkaus in Eastern Finland.

However, the technological and commercial progress of new solutions in the transport sector has been far from a linear trajectory. There have been many costly failures, setbacks, hype-disappointment cycles, tensions, and strug-

Figure 1. Electric vehicles and biofuels in Helsingin Sanomat 2000–2010



gles in innovation journeys (Verborg et al. 2008). For example, there was electric-vehicle hype in the 1990s, fuel-cell hype some years later, and biofuel hype after the EU 2003 directive. The current electric vehicle enthusiasm started in 2008, whereas in the area of biofuels, a backlash can be seen, with increasing concerns about the sustainability of producing large amounts of conventional biofuels (i.e., ethanol and biodiesel from edible oil) (Sengers et al. 2010). Figure 1 depicts the recent hypes of biofuels and electric vehicles in the Finnish leading daily newspaper Helsingin Sanomat.

According to the interviewees, the fourth major driver in the development has been the latest crisis in the automotive industries and overproduction problems in the agricultural and forest industry sectors. Traditionally, the dominant players in the international automotive industry have not been active in developing electric vehicles, but the crisis in the industry after the global financial crises has forced old and new players to search for new markets in hybrid and electric technologies. For even a longer period of time, the production of 1st generation biofuels has been supported by the agricultural sector, at least in countries with overproduction problems. In Finland, a similar situation can be seen in the forest sector. The decline in the demand of many paper grades has made the forest companies more interested in wood-based biofuels.

All in all, the above drivers for increasing the use of biofuels and electric vehicles are so strong and manifold that there are good reasons to believe that more will happen in the 2010s than has

happened during the latest decades. Yet it is an open question exactly what will happen.

4 Biofuels: Current use, market formation, Finnish business opportunities

4.1 Current use and market formation

The total consumption of oil products as transport fuels was approximately 1000 million tonnes globally in 2008 (IEA 2011). In the mid-2000s more than 20 Mtoe of biofuels were used (IEA WEO 2006), which was approximately 1% of all transport fuels. The share varies in different regions: some of the important areas are Brazil, where the share is almost 14%, Cuba with 6%, and Europe with 2%. Ethanol, which is mostly produced in Brazil and the U.S., is the dominating biofuel (85%). The remaining 15% of biofuels consists of different grades of biodiesel. Europe is the only region where biodiesel dominates over ethanol. The share of biofuels is estimated to increase 4–7% by 2030 (Nylund et al. 2008).

The early (the so-called 1st generation) transport biofuels are ethanol from corn, vegetable oils, and biogas. The so-called 2nd generation biofuels, such as biomass-based hydrocarbon diesel oils or cellulose-based ethanol, offer improved end-use properties and/or do not compete with food production.

The development and use of transport biofuels is relatively recent in Fin-

land, although bioenergy research in general has a long tradition. The most common biofuels are summarized in Table 1. The present main strategy of Finnish fuel producers is to add 10% of ethanol in the main grade of petrol (95 E10) and varying amounts of biomass-based diesel oil in diesel fuel (if 1st generation, max. 7%). DME is not high on the Finnish agenda, but it is included here because it is actively developed in Sweden.

The advantage of 1st generation biofuels is that they can be processed either on a large or small scale. The costs for processing facilities are relatively low. Production of hydrocarbon diesel oils through hydrotreatment and especially the combination of gasification and Fischer-Tropsch are only feasible for large refinery-type units with high capital costs.

All interviewees agreed that the biofuel business is strongly driven by the biofuel obligation defined by the Finnish and EU targets for climate change mitigation (Figure 2). The obligation is directed to the distributors of traffic fuels, and it creates a steady market for biofuels as components of the present main fuels. Biofuels can reduce the CO₂ emissions of transports because they are based on renewable raw materials and therefore their CO₂ emissions are defined as zero. The Finnish higher target is estimated to be achievable through taking advantage of the possibility to “double-calculate” the energy content of raw materials defined as waste (including wood).¹

The strategy to add a relatively small amount of biofuel component to

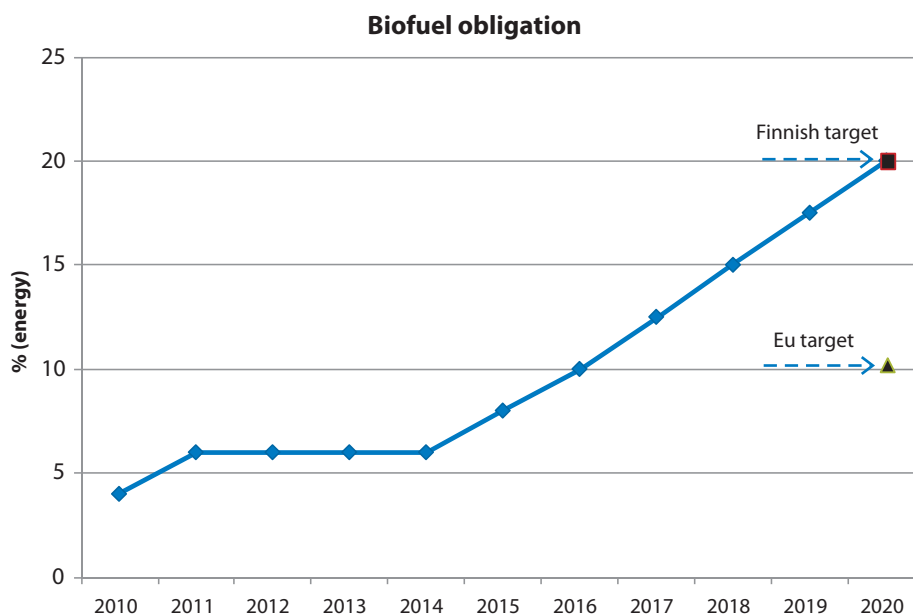
1 “... the contribution made by biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that made by other biofuels” (Directive 2009/28/EC, Article 21)

Table 1. Properties of some of the most common biofuels

	Ethanol		Biodiesel		Gaseous	
	E10	RE85	1st generation	2nd generation	DME	Biogas
Chemistry	Alcohol	Alcohol	Fatty acid methyl ester, FAME	Hydro-carbon	Dimethyl ether	Methane-CO ₂ -mixture
Energy content MJ/kg (for the main component as pure)	43 (petrol)	26,7 (ethanol)	41 (ester)	44	28,4	50,4 ² (varies strongly depending on methane content)
Usability compared to present fuels	Main grade of petrol	New fuel, new infrastructure, may wear the normal fuel system.	Max. 7% can be added to regular grade. Goes bad easily.	As diesel oil, density lower than standard grade.	New fuel, new infrastructure. Low viscosity.	New fuel, new infrastructure.
Suitable for cars	Petrol	Flexifuel	Diesel	Diesel	Diesel, modified	Modified diesel or petrol engines
Raw materials	Carbohydrate-based, e.g., food industry waste, cellulosic waste, grain.	Carbohydrate-based, e.g., food industry waste, cellulosic waste, grain.	Vegetable oil based, e.g. agricultural by-products, oilseed plants.	Vegetable oil based, e.g. palm oil, offal, microbial biomass, oilseed plants. Syngas, e.g., of wood.	Syngas, e.g., of wood.	Various carbohydrate-based waste materials.

¹ Paasi et al. 2008; ² Lampinen 2009.

Figure 2. Development of the mandatory share of biofuels in transport fuels in Finland and the EU
(Ministry of Employment and the Economy 2010)



the main fuel grades does not require any changes in the socio-technical system because the new fuels fit into the majority of the existing cars and to the fuel distribution system. It is therefore an easy transition, based on technical development of the fuels, their production, and the supply of raw material.

Broadening the strategy to high-concentration ethanol mixes (RE85), however, causes changes in the system, because it needs special cars (FFV, flexifuel vehicles, in which the materials of the fuel system are modified to tolerate the higher ethanol content) and a new distribution network (new product item for petrol stations). In addition, the lower price of RE85 is to a large extent lost because of fuel consumption increases in cars (approx-

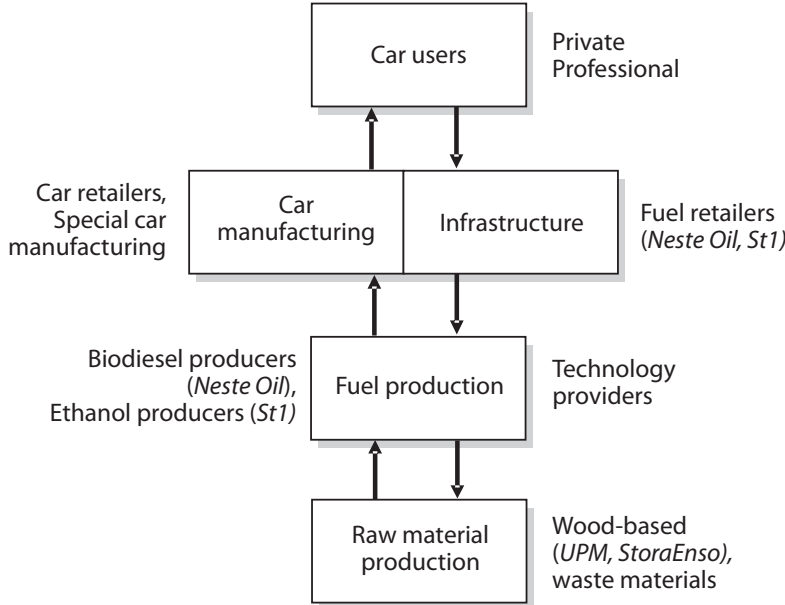
imately 25%). Therefore, the growth in the use of RE85 fuel is slow and uncertain, but it is needed if a larger reduction in petrol use through biofuels is sought than what is achieved with E10 (7% reduction).

Biogas is suitable for vehicles using natural gas (e.g., buses). The methane content of biogas varies from 40–50% in landfill gas up to 85% in gas from anaerobic treatment of effluent treatment sludge (Lampinen 2009). In addition, biogas contains sulphur. Therefore, the gas is purified in order to achieve sulphur-free gas, which contains more than 95% methane. Waste is an abundant raw material, and the energy content of methane is very high, which makes purified biogas a very favourable transport fuel.

4.2 Finnish business opportunities

The real challenge of the biofuel business and use in Finland (described in more details in Figure 3 and Box 1) is availability and acceptability of raw materials. The ethanol business is mainly based on imported sugarcane-based ethanol (where the use of food materials and/or agricultural land for energy production is a problem), as the domestic potential of the food waste raw material is already more or less exhausted (at a level of 6000 t ethanol/annum). Sufficient raw materials for ethanol production are available in municipal waste and different cellulosic waste materials. There is a long-standing research tradition of these processes in

Figure 3. Actors of the biofuel cluster (cases discussed in more detail are emphasized)



Finland, but the main challenge is the cost of production. The present biodiesel production is mainly based on palm oil, which is heavily criticized by the environmental organizations and some-

times claimed not to fulfil the sustainability criteria of biofuels defined by the EU directive (Directive 2009/28/EC). A small amount of food industry waste is used, but there is little growth potential.

There are many new potential raw materials under development, but commercialization may still take time. The most promising source for diesel at the moment is wood. The consump-

Box 1

Business cases on biofuels

St1: The story of St1 is one of building networks and expanding the fuel distribution network rapidly. Originally a fuel trader, today the owner of St1, Mr Mika Anttonen, built a small distribution operation with a very lean structure and an oil trading operation in cooperation with ABC, another Finnish-owned fuel distributor. When the biofuel obligation was introduced, they started the trading of Brazilian ethanol for a petrol additive.

VTT Technical Research Centre of Finland had studied food industry waste management technologies, in the course of which Dr Antti Pasanen developed a process efficiently combining fermentation and evaporation of ethanol. The investment cost and energy consumption of the process were low. Mr Anttonen saw the potential of this process in the production of fuel ethanol and started a joint venture with VTT to commercialize it. Later, St1 acquired full ownership of the joint venture.

St1 now produces appr. 100,000 tonnes per annum of dehydrated ethanol at their dehydration plant. Five per cent of it is produced from food waste using the technology developed at VTT, and a small share from municipal waste (in a joint venture with a local waste management company) using a new technology. Future plans include both technology sales for ethanol production and the development of new processes for mainly cellulosic raw materials.

Ethanol is used both in the regular petrol (10% in 2011) and in RE85 fuel (containing 85% ethanol), which is in a pilot marketing phase.

Neste Oil: The story of Neste Oil is that of innovative strategies for a relatively small oil company in international competition. "Green" fuels have been the choice of Neste Oil and its predecessors since the early 1990s. Another long-standing development is the focus on diesel fuels based on the popularity of diesel vehicles in Europe. Biofuels were devel-

oped for heating purposes already in the 1990s, but there was no market. When the biofuel directive was being discussed in the early 2000s, the work was restarted with the objective to develop diesel fuels. A decision to build a second-generation biodiesel plant in Porvoo was made in 2005.

The strategy of moving directly to second-generation biodiesel, as opposed to the choice of the large oil companies to procure first generation biofuels from the world market, was possible because the technology was developed on time and the Finnish authorities agreed to delay the implementation of the biofuel directive for a few years. The product is technically excellent and production has been expanded to both Central Europe and Asia, and also aircraft fuels have been introduced. Neste Oil is now a major player in the second-generation biofuel business. The challenge is raw material availability and the heavy criticism towards the present main raw material, palm oil.

UPM: UPM started developing its business for biodiesel raw materials (and other wood-based biofuels) as part of its own energy business area, which mainly consists of its shares in various electricity production companies. StoraEnso chose to develop similar biodiesel processes in cooperation with Neste Oil.

The preparations include development of biomass gasification and syngas purification technologies in cooperation with technology providers (in the case of UPM, Andritz/Carbona and GTI in the U.S.) and environmental impact assessments for the eventual production facilities. The production of biodiesel raw material from syngas is based on existing technology. The decision-making struggle for UPM includes the challenges of profitability (investment support is sought for both from the EU and the Finnish state), the further processing and distribution of the product, and the overall profitability of the business.

tion of wood by the pulp and paper industry has already decreased and is projected to decrease further until 2020. Even if the estimates vary, this would increase the potential of energy wood by up to 10 million m³/annum by 2020 from the level of 2007 (Kärhä et al. 2009, Hetemäki & Hänninen 2009).

All three Finnish big forest industry companies are developing biodiesel raw material production from wood using gasification and the production of crude biodiesel from the syngas using the Fischer-Tropsch-process. The main challenge of these processes is profitability, as the required investments are large. In addition, there are still technological uncertainties in the gasification and syngas purification processes. The companies actively seek public investment support for these facilities, both through national and EU sources. According to the latest public information, UPM plans to build a biodiesel plant (annual capacity 100,000 tonnes), either in Finland (Rauma) or in France (Strasbourg). Neste Oil and Stora Enso have published a plan to build a biodiesel plant (annual capacity 200,000 tonnes) in Finland (either in Imatra or Porvoo). However, production in these plants is not expected to start before 2015, and according to The Ministry of Employment and Economy, support is not expected to be available for more than one unit.

The choice between the competing uses of wood is one of the challenges of forest-based industries. Traditionally the pulp and paper industry has argued forcefully for the use of wood for fibre production rather than energy production because of the better value added (Cepi 2007). This approach has been criticized by Hetemäki (2008) because the situation has quickly changed

in the 2000s due to sinking paper prices and increasing energy prices.

The feasibility of the wood-based energy business options can be illustrated with the following rough example comparing the business potential of generating either fuel or electricity from wood raw material. One cubic metre of wood can be transformed into approximately 1 MWh of electricity or 0.7 MWh of electricity + 1.4 MWh of heat in a power plant (based on general data of transformation efficiencies in condensing power plants and combined heat and power production), or 1.1 MWh of biodiesel raw material through gasification and Fischer-Tropsch reaction (based on data of environmental impact assessments of UPM). With the present (early 2011) price levels this would give rise to potential sales of 70 € as pure electricity, 130 € as heat and power or 75 € as biodiesel. Assuming that the investment for a biodiesel production plant is much larger than that of a combined heat and power plant, the business potential of biodiesel production from wood is much poorer than that of production of combined heat and power.

Similarly, Professor Nils-Olof Nylund and his co-workers have argued for the better economy of electricity production in their recent reports: "Generally, biomass is more efficiently used in power and heat production than in transport"; "the solid biomass is more efficiently used for power and heat than for liquid transportation fuels" (Nylund et al. 2008, 37, 40).

In summary, environmental policy has been successful in creating a strong domestic market for biofuels. The Finnish fuel companies have been able to grasp the opportunity with innovative technologies because of stable R&D support in the bioenergy area, and because the products fit the existing socio-technical system as such. The success of the home market has also created export possibilities both for technology (ethanol production and biodiesel production) and for products (2nd generation biodiesel and renewable aircraft fuel). The main challenge is the availability of raw materials and the existence of an "anti-biofuel-lobby", which may change the general attitude towards biofuels. The main success factors and challenges are summarized in Table 2.

Table 2. Success factors and challenges of biofuel business in Finland

Success factors	Challenges
<ul style="list-style-type: none"> • Long-standing R&D support to bioenergy -> technology (ethanol production, NexBTL). • R&D support for new waste management solutions. • Availability of wood raw material (and other "double-calculated" materials). • Availability of diesel cars (also private) • Innovative relatively small oil companies with distribution. • Forest industry crisis and R&D support. • Government support. 	<ul style="list-style-type: none"> • Dependence on imported (and controversial) raw materials at the moment. • Poor profitability of biofuel business. • Uncertainty about the stability of the policy-driven business. • Low number of FFV vehicles in use and no manufacturing of FFV vehicles.

5 Electric vehicles

Unlike biofuels, the market penetration of electric cars is still at a very early stage. Yet in the long run, they are expected to achieve larger market shares for many reasons.

- Electric cars are more energy efficient than traditional petrol and diesel cars. For example, according to an estimation made by Mitsubishi, the so-called well-to-wheel efficiency for electric car is 28–36%, for hybrid cars – 25%, diesel motor cars – 16%, and for petrol-using cars with internal combustion engines – only 13% (Biomeri 2009, 16).
- Electricity for electric vehicles can be produced from a number of energy sources. The EU mandatory target for 2020 for renewable energy includes biofuels and electricity from renewable sources.
- Local emissions of electric cars (air emissions and noise) are negligible.
- An electric car will create new opportunities for automotive design.

Yet today's battery technology is still a limiting and cost-raising factor and a reason why the supply and sales of electric cars have been limited. In fact, the coming years are likely to form the first real market test for the diffusion of electric cars because for the first time there will be reasonable and affordable electric models available.

5.1 Types of electric cars

Electric cars or vehicles can be divided into three main categories: hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and battery electric vehicles (BEV).

A *hybrid electric vehicle (HEV)* is a vehicle that combines a conventional internal combustion engine propulsion system with an electric propulsion system. These vehicles cannot be charged from the grid or other external electricity sources. *Mild hybrid vehicles* rely on the internal combustion engine to provide constant power for moving the vehicle. In this arrangement, the electric drive motor acts to assist the engine when extra power is needed, but is incapable of propelling the vehicle alone. A *full hybrid vehicle* is a vehicle in which the arrangement of the electric drive motor, the internal combustion engine, and the battery system allow the hybrid vehicle to be powered solely by the electric motor under certain operating conditions – generally low-speed manoeuvring and light cruising. The most popular hybrid electric vehicle has been the Toyota Prius. The Prius went on sale in Japan in 1997, making it the first mass-produced hybrid vehicle. In May 2008, cumulative worldwide Prius sales reached the 1-million vehicle mark, and in September 2010, total sales reached 2 million units. Toyota forecasts it will sell one million Prius annually in the early 2010s. In Finland, about 5,000 hybrid electric cars have been sold by the end of 2010. CO₂ emissions of the full hybrid Toyota Prius model are less than 100 g/km. In January 2011, the price (including taxes) in Finland was 30,000 Euros.

A plug-in hybrid electric vehicle (PHEV) is a hybrid vehicle with rechargeable batteries that can be restored to full charge by connecting a plug to an external electric power source (usually a normal electric wall socket). A PHEV shares the characteristics of both a conventional hybrid elec-

tric vehicle (with an electric motor and internal combustion engine) and an all-electric vehicle, by having a plug that connects to the electrical grid. In *plug-in hybrid electric vehicles*, increased energy storage capacity provides additional range using only electricity. The Chinese BYD F3DM, the world's first mass-produced plug-in hybrid car went on sale to government agencies and corporations in 2008 in China and to the general public in 2010. The F3DM is slated to go on sale in Europe and the U.S. in 2011. In addition to Chinese BYD, the Opel Ampera and Chevrolet Volt will be among the first models to be produced for the mass market in the U.S. and Europe starting in 2011.

Battery electric vehicle (BEV) is a plug-in battery powered automobile that is propelled by electric motor(s) alone. Today's BEVs mainly use lithium-ion batteries. Examples of this type of car are Tesla Roadster, Think City, and Nissan Leaf. In 2004, Californian electric car maker Tesla Motors began development of the Tesla Roadster, which was first delivered to customers in 2008. Think Global is a Norwegian electric car manufacturer. The first Think City electric car was manufactured in 1991. Ford owned the company from 1999 until 2003, but today it is owned by various investors, and cars have been manufactured by Finnish Valmet Automotive since 2009. Nissan introduced its Nissan Leaf in Japan and the U.S. in 2010. Nissan Leaf is the first all-electric, five-door family hatchback produced for the mass market by a major manufacturer. In November 2010, Nissan Leaf was elected European Car of the Year in 2011 by European car journalists as the first electric car in the history of the competition.

5.2 Market formation in general and in Finland

In the early 1990s, the California Air Resources Board began a push for more fuel-efficient, lower-emissions vehicles, with the ultimate goal being a move to zero-emission vehicles such as electric vehicles. Toyota, Honda, Ford, and General Motors all developed electric vehicles in the 1990s in order to comply with the Zero Emission Vehicle Mandate. Later, the mandate was relaxed and the supply of battery-electric vehicles almost disappeared in the early 2000s.

After 2008, a new start began, and after that, several forecasts have been made of the diffusion of electric cars in the 2010s. The most often referenced forecasts in Finland are by Frost & Sullivan (2010) (referenced by Nylund et al. 2010 and Biomeri 2009). According to Frost & Sullivan, sales of electric vehicles in 2020 are expected to account for 7% of all new car sales. Biomeri's basic scenario for 2020 estimates that the share could be 13% (10% hybrid plug-in electric vehicles and 3% battery electric vehicles) (Biomeri 2009, 7).

Nylund et al. (2010, 26-27) present a scenario for maximum sales of electric cars in Finland. According to this scenario, 30% of new cars sold in 2020 could be electric cars and the cumulative fleet could be about 170,000 electric cars. The maximum share of this fleet in total vehicle kilometres in Finland in 2020 could be 4–5%. According to Nylund, a more realistic scenario would be 1–2% (November 2010 interview).

The key factors affecting the diffusion of electric cars (in addition to the price of oil) are: the price and supply of

various types of electric cars, a reliable and easy-to-use charging infrastructure, and an extension of today's short range of electric vehicles. It is often assumed that the market penetration of hybrid plug-in electric vehicles will occur faster than that of battery electric vehicles and that China will be the real forerunner in the electric car industry in the late 2010s.

5.3 Emerging electric vehicle cluster in Finland

As in many other countries, the Finnish industry first developed an interest in electric cars after the first and second oil crises. According to Haakana (2010), companies such as IVO (today Fortum), Neste (today Neste Oil), Kymi-Strömberg (today ABB), Saab-Valmet (today Valmet Automotive), and Leo Laine Oy were involved in small-scale experiments in the area in the 1980s. In the 1990s, IVO's Elcat project manufactured some 200 electric vehicles, and about 60 of them were in daily use in Suomen Posti. Fortum closed the Elcat project in 2001, and Elcat Oy was acquired by its personnel.

Some years later, based on international development, today's Finnish electric vehicle cluster started to re-emerge from various sources. In 2003, Finnish Electric Vehicle Technologies was established for developing battery technology. The company was later integrated into European Batteries, which was established in 2008. In 2007, the Sähköautot – Nyt! (The eCars – Now!) user community was organized with the idea to transform ordinary Toyota Corolla combustion engine cars to electric cars. In 2008, Valmet Automotive and an American premium car com-

pany, Fisker Automotive Inc., signed a contract to manufacture Fisker Karma plug-in hybrid sports sedans in Finland. Moreover, Fortum re-established R&D activities in the area, followed later by Helsingin Energia. Also, Ensto, Efore, and some other manufacturers of electric devices started to develop products for electric vehicles. Moreover, in Helsinki Metropolia University of Applied Sciences, a group of teachers and students organized a project called Electric Raceabout for building an electric racing car for a competition in the U.S. in 2010. The first Electric Motor Shows were organized in Helsinki in 2009 and 2010.

Based on these kinds of initiatives, the Ministry of Employment and the Economy appointed the Electric Vehicles in Finland Working Group to examine the prospects of electric vehicles in Finland and elsewhere in February 2009. In the background report, it was estimated that there are about 40 Finnish companies in the area, with net sales totalling 200 million Euros (Biomeri 2009). As a conclusion, the working group set an ambitious target for Finland in 2020: "Net sales of the Finnish electric vehicle cluster in 2020 are 1-2 billion Euros and the number of employees several thousands. Society enhances the diffusion of electric and other energy efficient vehicles in Finland. The share of electric vehicles of all new cars sold in 2020 is 25% (of which 40% are battery electric vehicles)." (Ministry of Employment and the Economy 2009, 7).

The following year, in 2010, the Ministry of Employment and the Economy and Tekes commissioned a new background report (Swot 2010) and started preparations for a new technology programme. The Electric Vehicle Systems Programme (EVE) was

launched in January 2011. According to Tekes, "the programme is planned to help electric vehicles and mobile machinery business development for Finnish companies from the current approx-

imately 200 million Euros to around 2 billion Euros by 2020" (Tekes 2010). The Electric Vehicle Systems Programme is a five-year programme from 2011 to 2015 with a budget of 80 million Eu-

ros. In 2010, also Finpro made a study on global trends and Finnish opportunities in the electric vehicle industry (Finpro 2010).

Box 2

Company examples in the emerging Finnish electric vehicle cluster

European Batteries (established in 2008). The company's roots are in Finnish Electric Vehicle Technologies (established in 2003), which developed advanced battery management systems and is today a part of the group. European Batteries develops and manufactures large, rechargeable lithium-ion based prismatic cells and battery systems. Its production facility in Varkaus, Finland, began operations in summer 2010. It is the first independent large lithium-ion battery manufacturing unit in Europe. The plant aims to reach an annual production capacity of 300 MWh by the year 2013 (= batteries for about 10,000 cars). The company's technology partner is K2 Energy Solutions Inc. (USA). The focus is on large lithium-ion batteries as well as in developing comprehensive, customer-specific solutions. The company is owned by private investors and venture capital firms. In January 2011, Finnish Industry Investment (a government-owned investment company), Fennia Group (private insurance company), EM Group (family-owned group which also owns Ensto), and private investors subscribed for European Batteries Ltd shares worth 13.7 million Euros in connection with a directed share issue organized by the company. In 2010, European Batteries had a turnover of 1 million euros and 70 employees. The expected turnover for 2011 is approximately 15 million euros.

Valmet Automotive (established 1969) has produced over 1 million combustion engine cars (Saab, Porsche, et al.). Today, Valmet Automotive is an engineering and manufacturing partner for the THINK City (Norway) and Golf Car Garia (Denmark) electric cars as well as for the premium plug-in hybrid electric vehicle Fisker Karma (serial production started in 2011). The Norwegian THINK City car was introduced in the Finnish market in 2010. With many Finnish partners, Valmet Automotive has also developed an electric concept ve-

hicle "Eva" (2010) to improve its capabilities and know-how in designing and manufacturing electric cars. Today, Valmet Automotive is owned by Metso Group, government-owned Finnish Industry Investment, and private investment company Pontos Group. Valmet Automotive's net sales in 2009 totalled 56 million euros, and it employs some 800 people in Finland. In addition to the current electric car businesses in Finland, in 2010 Valmet Automotive acquired the European convertible roof system business of the Karmann company, with production sites in Germany and Poland (net sales 180 million Euros and 700 employees).

Ensto (established in 1958) develops and manufactures electric vehicle charging systems. First-generation products for slow charging have been on the market since the beginning of 2010. They have already been installed in several cities around northern Europe in addition to Finland. The biggest delivery so far is exported to Norway. Ensto is a family-owned company established by Ensio Miettinen (1929-2010), who was famous for his interest in innovations.

Fortum (formerly IVO, established in 1932), the biggest Finnish energy company, has been involved in electric car development projects since the 1980s. A new start took place in 2007-2008. Fortum is interested in promoting electric cars in general (as a utility company) but also in developing a charging infrastructure. In Finland and Sweden, the company has some 100 charging points. One charging point, in Espoo, is based on solar energy. Together with other companies, Fortum has also started to develop smart grid demonstration cases with charging services for electric vehicles. In addition, Fortum is developing payment systems to be used in public charging points.

5.4 Finnish strengths and challenges in electric vehicles

It is essential to notice that the Finnish electric vehicle cluster includes, in addition to electric cars, a charging infrastructure and related services, electric mobile machinery, components (batteries, electronics, and software), and even new mining possibilities of materials used in batteries. More details of some major companies in the cluster are presented in Box 2.

The analysis of Finnish strengths and challenges in electric vehicles can be reasonably divided into two parts. First, we can assess how quickly electric vehicles may penetrate the Finnish market, and second, we can explore Finnish opportunities in creating new export products in the area. The Finnish domestic market is so limited that all companies need to aim at export; but on the other hand, a swift development in the home market would create necessary testing, demonstration, and piloting possibilities. Dynamic development in the home market also serves transport and climate policy objectives. The new Tekes programme for electric vehicles focuses mainly on building common test environments and is thus serving both export and home-market purposes.

As for Finnish strengths in the home market, the most often mentioned factors are widespread use of electrical heating plugs, which can easily be used for charging, and sources of

electricity in Finland. Due to the high share of renewable and nuclear energy, CO₂ emissions of electric cars in Finland are 27–45 g/km. On the other hand, the cold weather is a challenge for electric batteries.

Valmet Automotive is the only passenger car manufacturer in Finland. In international terms, it is a small contract manufacturer of premium specialty cars. Its move from combustion engine cars to electric cars in 2008 took place because the manufacturing of Saabs had already ended in 2003 and the annual numbers of the Porsche Cayman model manufactured since 2005 are not increasing. Thus, Valmet Automotive tries to use the shift from internal combustion engines to electric motors as a way to find new markets and improve its position in the industry.

Because of the lack of domestic car manufacturers, Finnish component producers have to make alliances with foreign companies. This may be difficult because car manufacturers may want to produce batteries in their own production units. To overcome the problem, a Finnish component company (Efore Oyj) announced in January 2011 that it would establish its first component unit for electric cars in China.

Another possibility is that Finnish manufacturers will specialize in making components not for electric cars but for other electric vehicles that are manufactured by Finnish companies, such as electric machinery, mobile electric trucks, snow mobiles, etc.

6 The role of biofuels and electric vehicles in achieving the Finnish climate policy objectives

In this report, biofuels and electric vehicles are considered as potential cases for green growth. The rate of greenness of these technologies and businesses depends on the role these technologies are estimated to play in achieving the climate policy objectives in Finland and elsewhere.

In Finland, the previously mentioned "Climate Policy Programme for the Ministry of Transport and Communications' administrative sector for 2009–2020" estimates the measures needed to achieve a 16 per cent reduction of greenhouse gas emissions in the transport sector from the 2005 level by 2020. In this programme, biofuels and electric vehicles play the following roles. Some 20–25% of the reduction goal is achieved by biofuels if their share in consumption is about 10% in 2020. The role of electric vehicles is not specified because of the assumption that the use of electric vehicles in 2020 is so minor (about 1–2% of vehicle kilometres). The main role is given to the reduction in specific emissions of new cars sold (60% of the goal). It is estimated that the specific emissions of the Finnish vehicle fleet would be reduced by one-third from 2005 (180 CO₂ g/km) to 2020 (138 g/km), and this is mainly achieved by



more efficient petrol and diesel cars. In addition, some roles are given to transport operators and to an increased use of public transport, cycling and walking in urban areas. Traffic is expected to grow annually by some 0.5–1.5 per cent (Liikenne- ja viestintäministeriö 2009).

The reduction in specific emissions of new cars sold in Finland has been significant in 2006–2010 due to changes in taxation and the financial crises (Figure 4). Already in 2010, some 25% of new cars sold meet the EU goal for 2015 (130 g/km) (TraFi 2011), but the problem is the slow renewal of the car fleet as a whole.

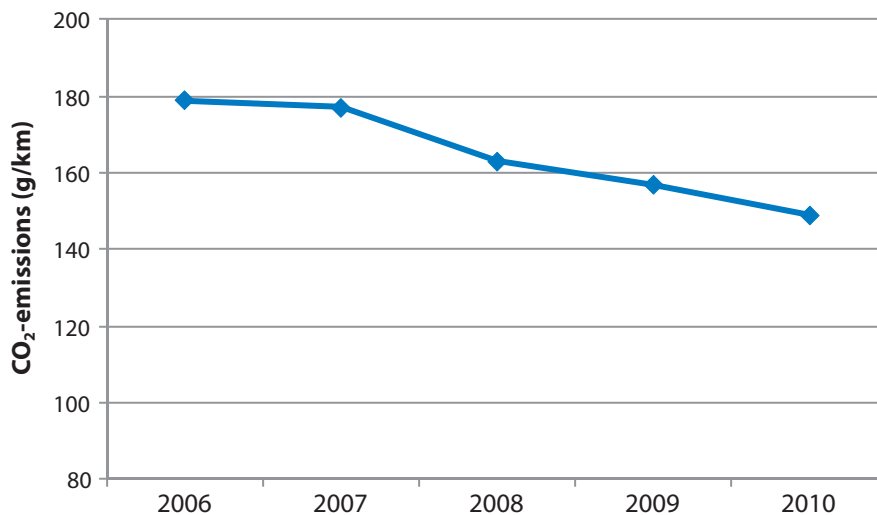
In addition, even a slight increase in road traffic can be enough to wipe

out the benefits of the increased use of biofuels and electric vehicles. Therefore, it has been underlined that the expected penetration of biofuels and electric vehicles does not alone lead to the greening of the transport sector. In fact, energy conservation by all other means is at least as important as the use of biofuels and electric vehicles. Energy conservation through smaller cars and engines "is ultimately the most cost-effective way to reduce CO₂ emissions in passenger car traffic" (Nylund et al. 2010, 111).

From this point of view, it is interesting to note that the policy measures for biofuels and electric vehicles have mainly been taken in the areas of innovation, transport and economic pol-

icies, whereas the Ministry of the Environment has focused more on measures to decrease the growth of transport and to enhance public transport. In the media as well, electric vehicles and biofuels are far more prominent than improvements in public transport (Rinkinen 2010), in spite of the fact that public transport did not increase at all from 1990 to 2009, whereas passenger kilometres in passenger cars increased by 25% (Liikennetilastollinen vuosikirja 2010). There are Finnish companies like Transtech Oy (city trams and railway coaches) and Kabus Oy (hybrid busses) that could merit more attention in policies supporting the electrification of traffic and public transport.

Figure 4. The average CO₂ emissions of new passenger cars registered in Finland in 2006–2010 (TraFi 2011)



7 Policy challenges

In international comparisons, Finland is not a forerunner in the production or use of biofuels and electric vehicles. For example, biofuels are more widely used in Sweden and electric vehicles in Norway (Ulmanen et al. 2009, Swot 2010). However, the above analysis of Finnish business actors and policies in these fields indicates that companies and policy makers have tried to catch up to the international forefront in recent years.

The emergence of the Finnish biofuel and electric vehicle fields has been strongly policy-driven. In addition to EU policy, there have been many national initiatives. The emergence of the Finnish electric vehicle cluster resembles the strategic niche management approach developed in the Netherlands. In this tradition, the basic idea is that new radical technologies need protec-

tion in the early phase of their development because old dominant technologies have many advantages in terms of prices, reliability, performance, and infrastructure. Recently, Smith & Raven (2010) have specified different forms and goals of protection. Their model is presented in Table 3. We have inserted in the table major Finnish policy measures supporting the development in the biofuel and electric vehicle fields. It shows that Finnish policy is oriented toward nurturing new technologies and changing permanent rules (such as car taxation) instead of temporarily shielding new technologies (such as temporary tax exemptions or subsidies and special permits for driving and parking), which have been popular in many other countries. In the short term, particularly strong temporary shielding quickly creates a market for new solutions, but in the long run, there is a risk that

this kind of policy creates uncertainty among producers and users about the stability of the policy. Permanent changes in institutional rules in relation to all types of technologies and cars and their use may therefore work better in the long term.

In nurturing the new fields, it seems that various Tekes programmes and the TransEco network programme have a significant role in supporting R&D activities in private companies and building networks and sharing learning between researchers, company representatives and policy makers. The VTT-driven TransEco network programme seems to have a special role also in voicing and shaping expectations. TransEco programme aims to provide "tools for adapting the Finnish road transport system in a cost-effective way to national and EU-level climate and energy targets. The data generated within the

Table 3. Major Finnish policy measures in relation to biofuels and electric vehicles by form and goal of protection

(Based on Smith & Raven 2010 typology).

Form of protection	Temporary shielding	Nurturing	Permanent empowering
Economic	Temporary tax exemptions	Investment support	Car tax based on energy consumption and CO ₂ emissions
Institutional	NOT so far in Finland (in Sweden, e.g., special permits for driving and parking)	Participation in creating standards for biofuels and charging systems	Mandatory share of biofuel Binding objectives for CO ₂ emissions of cars
Socio-cognitive	Electric car working group in 2009	Tekes programmes for biofuels and electric vehicles	TransEco network programme
Cultural	Electric car – now! - social movement	Media activity on biofuels and electric cars	Electric cars in car shows and car races
Geographic	-	Infrastructure pilots in the metropolitan area	-
Political	Transport Climate Programme 2009 – 2020	Demand and User-Driven Innovation Policy 2010	National Renewable Energy Action Plan 2010



programme will be used as input in the process of drafting and implementing EU directives, for the selection and implementation of the energy pathways most suitable for Finland and for supporting technology exportation. ... The programme is extensively supported by the public sector (ministries and agencies), as well as by industry" (www.transeco.fi). It is clear that the new Finnish car and fuel taxation and the policy of mandatory shares of biofuels have been heavily influenced by VTT researchers within the TransEco programme. Moreover, in February 2011, the Ministry of Transport and Communications published a special report written by Research professor Nils-Olof Nylund at VTT on the future role of electric vehicles in the Finnish transport system (Nylund 2011).

Earlier in this Section, we argued that green innovation policy in the area of transport needs to be multifaceted, dynamic, and coherent. In the following, we comment on the policies from these perspectives. There still is need for improvements in the activities and policies of different actors because in both biofuels and electric vehicles, there still is a risk that necessary innovations, investments, and penetration rates do not transcend critical boundaries.

7.1 More user-orientation in policies

Biofuels have been an easy solution for the car user so far – you do not even need to be aware of the change. Therefore, no strong incentives for users have been considered necessary. The poor success of the E10 fuel, however, shows that even a minor possibil-

ity of risk in the absence of any positive incentives affects the buying practices of consumers.

Even if the CO₂-based car taxation has brought an incentive for the user to choose less emitting cars, we argue that more efficient incentives are needed to make the new car technologies and smaller cars more attractive to the user. Both safety considerations and a general “status factor” have led to the increasing size of new passenger cars, which partly counteracts the technology improvements for greenhouse gas emission reduction. Commuting distances have also increased over the years.

In addition to sufficient and more progressive CO₂-based taxation, new kinds of measures to affect consumer behaviour need to be developed. Mere information on the benefits of small cars, diesel cars, hybrid cars, electric cars, etc., is not sufficient. Consumers seek comfort, safety, luxury, design, and “status” when purchasing a car. Car manufacturers are key players in this: they act when the support for a certain technology is sufficiently stable. A success story in this respect is the development of diesel cars over the years due to stable support in Europe. Diesel cars have been transformed from robust “working machines” to comfortable cars during the past decades.

One specific target for public support is a system change like RE85 fuels and electric vehicles, where the “chicken-egg-problem” hampers development. Fuel distribution does not develop because the number of compatible cars is small, and vice versa. Electric cars are difficult to use because the charging systems have not been developed. One possibility for giving a positive sign to all

parties of the system is public procurement. Purchasing new vehicle types for special purposes and visible uses gives rise to an improved infrastructure and sets an example for car users. As a step in this direction, in January 2011, a group of influential representatives of the Finnish private and public sectors gathered together with the aim of building a world-class innovation cluster for business related to electric vehicles, intelligent traffic systems, and smart grids in Finland. The first concrete step is to form a test fleet of 500 electric vehicles for the Helsinki Metropolitan area during 2011–2012 (Tekes/Eera Oy 2011).

7.2 Roadmap of greener passenger transport

There seems to be a risk that the mitigation of climate change in private passenger transport is seen as a competition between biofuels (combined with improvements of the combustion engine) and electric vehicles. We argue that the greening of road traffic should instead be seen as a roadmap (from the combustion engine vehicles to sustainable future mobility solutions that we do not even recognize yet). Reliance on a single dominant solution may include a risk of developing a lock-in-situation, where either heavy investment in production facilities or dependence on a given infrastructure limits the possibilities for future development.

In addition, the improvement of private cars should be accompanied by support for public transport; both bus transport and rail traffic, and bicycling in cities. The Ministry of Transport and Communications is relatively pessimistic about the role of the planned meas-

ures for reducing passenger car traffic through public transport, walking, and cycling to reduce greenhouse gas emissions (Liikenne- ja viestintäministeriö 2009). However, environmentalists consider public transport, especially rail traffic, the most important means to improve the sustainability of passenger transport, because no cars are totally emission-free and do not solve the land-use and congestion problems of road traffic (Vihreä Lanka 2010). As mentioned earlier, there are also Finnish business opportunities in public transport vehicles.

The first steps in the road map of private road transport (already ongoing) include engine development and reduction of car size (Regulation 443/2009 EC) and enhancement of biofuels (Directive 2009/28 EC; the Finnish legislation for the implementation of the directive was approved by the Finnish Parliament in December, 2010). Engine development is expected to contribute by approximately 60% to the estimated reduction of greenhouse gases of traffic. Biofuels offer an easy transition contributing to this development without a need for a major change in either distribution infrastructure or car fleet.

One of the major challenges in the biofuel programme is the availability of raw materials. Palm oil as biodiesel raw material and sugar-cane-based ethanol are not feasible sources of bioenergy for Finland in the long run. Especially first-generation biofuels are considered to threaten food production, causing global increases in food prices and offering little improvement in greenhouse gas emissions (Doornbosch and Steenblik 2007). Also, palm

oil is mainly used for food industry purposes and the increased use for energy production causes pressures for availability and land use in the main production areas, Indonesia and Malaysia (Nylund et al. 2008) – already manifested in strong public criticism against the use of palm oil. Therefore, the ongoing research with the aim of finding new raw materials for biodiesel production, like *jatropha* and microbial biomass, should be intensively continued.

Instead, cellulosic and wood-based raw materials would offer a domestic and sufficient source of biofuel raw materials, even for the present programmes. However, when public support is considered, wood as a new raw material source should be seen as a replacement for imported raw materials for biofuels for the domestic market rather than as an additional material stream allowing major export business in biofuels.

These measures, even if necessary, are not sufficient in the long run. We are convinced that more radical changes in the transport system are needed. One of the promising solutions for car transport is the development of electric vehicles. The potential of electric vehicles to reduce greenhouse gas emissions is good, as their energy efficiency is better “from well to wheel” than that of combustion engine cars. For example, depending on the variables used, one cubic metre of wood as biodiesel allows a car to drive approximately 1700 km (1500–2000), and electricity produced from the same amount of wood gives power for approximately 4700 km (3800–5600) (Figure 5).

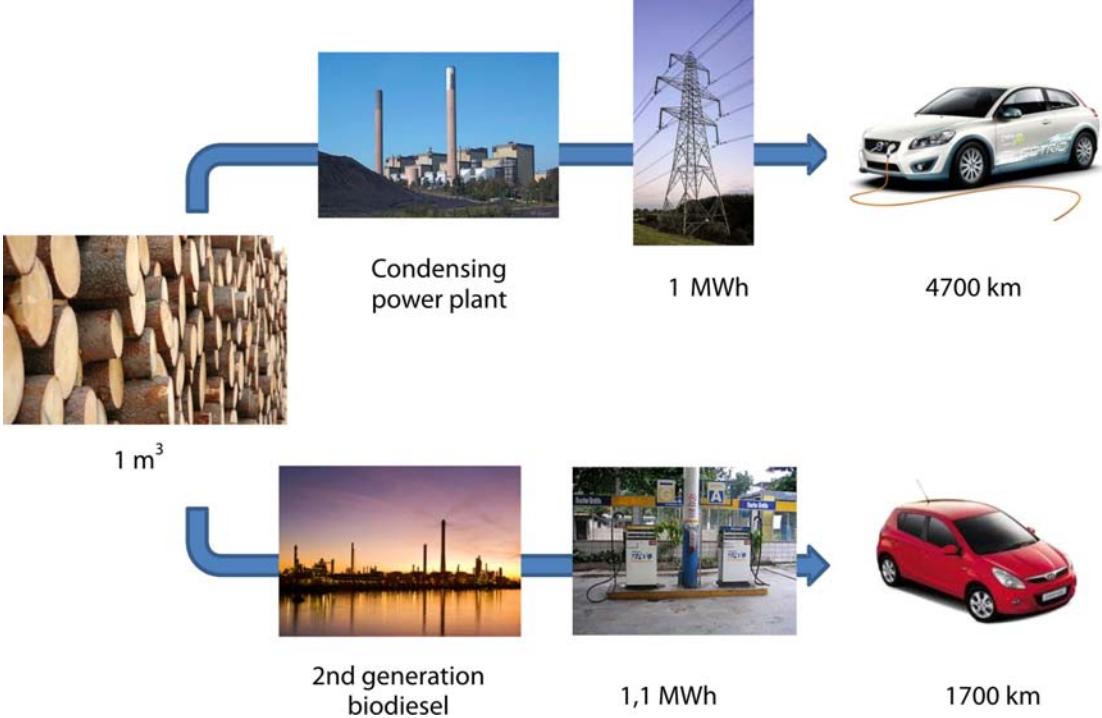
As the electric vehicle system differs in a profound way from the present system, the change takes more time and requires more support to allow the transition of the socio-technical system (Geels & Schot 2007). Today it seems that electric vehicles are not competitive in Finland where distances are long, but technical development may change the situation – as it has done with many so-called disruptive innovations (Christensen 1997).

There seems to be a general agreement about the importance and export potential of the business in components and infrastructures for electric vehicles compared to the significance of car manufacturing in Finland (Swot 2010, Nylund et al. 2010, 109, 110). However, it has also been argued that the business advantage of support for electric vehicles is low Finland, which has no significant car manufacturing. Therefore, the support should not be solely directed to the use of electric cars (e.g., in the form of specific lanes), but to a large extent to the development of proper infrastructure for charging and maintenance of the cars. However, domestic use of electric vehicles is needed for the support of the infrastructure and component business. The cluster initiatives of the Ministry of Employment and the Economy and Tekes are steps in the right direction.

The electric vehicle is not an ultimate sustainable solution for mobility either. The long-term objectives require a more thorough consideration of the future of mobility, which could include different kinds of flexible combinations of public and private transport means. Support for research and development in this area is needed.



Figure 5. Comparison of the energy efficiency of diesel cars and electric cars. Kilometres driven using 1 m³ (solid) of wood as the fuel



7.3 From efficient vehicles to efficient transportation

The above roadmap is based on the idea of green growth, which has recently been studied extensively by the OECD (OECD 2009), and the possibility of companies to develop shared value, which is simultaneous advancement of economic and social conditions. It requires from the companies a strategic and long-term approach to societal activities. From the government, it

requires regulation with clear and predictable goals without prescriptions for the means for achieving those (Porter & Kramer 2011).

The green growth approach has, however, been criticized by the so-called degrowth-movement. This movement advocates for a diminished focus on economic growth, because growth in consumption and the use of natural resources is bound to nullify the impact of technological improvements (e.g., Jackson 2009). The criticism

of the degrowth movement is targeted towards GNP as the major indicator of well-being in macroeconomics and the pressures towards ever-increasing consumption.

Traffic is indeed an area where the growing volumes tend to offset all improvements in the eco-efficiency achieved by improved cars and better fuels (e.g., Tapio 2005). Therefore, these so-called rebound effects (Hofstetter et al. 2006, Hertwich 2005) are very relevant in this sector.² In the case of trans-

2 "A Rebound Effect (also called a Takeback Effect or Offsetting Behavior) refers to increased consumption that results from actions that increase efficiency and reduce consumer costs. For example, a home insulation program that reduces heat losses by 50% does not usually result in a full 50% reduction in energy consumption, because residents of insulated homes find that they can afford to keep their homes warmer. As a result, they reinvest a portion of potential energy savings on comfort. The difference between the 50% potential energy savings and the actual savings is the Rebound Effect" (TDM Encyclopaedia 2002).

port, the main rebound issues are the generation of more traffic as a result of road construction aimed at reducing congestion, increased driving enhanced by reduced fuel consumption of cars, and the increase of “risky” driving because of the improved safety of cars and roads (TDM Encyclopaedia 2002). One of the findings of this study indicates that electric cars may be considered as “third cars of the family” that are used for additional driving.

Therefore, the policies for greening passenger transport need to be designed to reduce the rebound effects. Policies that require manufacturers to sell more fuel-efficient vehicles (like Regulation 443/2009 EC) were found to increase driving miles, thus increasing congestion and cost for roads and parking and decreasing traffic safety. Alternative fuels, like biofuels, have the same impacts, but somewhat milder ones, because the cost of biofuels is relatively high. To the contrary, fuel taxes and mileage-dependent insurance policies tend to reduce driving (Litman 2005).

The future goals for the greening of traffic include the demand to reduce traffic based on private cars, which requires a good infrastructure (short distances, bicycle routes, etc.) and public transport to avoid adverse effects on overall mobility. The ultimate question about the need to reduce overall mobility would be a significant change to the present attitude of most people and would probably also include adverse social impacts.

8 Conclusion

Most of our hypotheses presented in the beginning of this Section in relation to business actors and their activities are supported by empirical evidence. The relative significance of new entrants is higher in the electric vehicle field than in the biofuel field. However, the difference is not large. In biofuels, St1 can be considered as a new entrant and in electric vehicles, old incumbents such as Valmet Automotive and Fortum play important roles in addition to new entrants such as European Batteries. Co-operation between companies seems to be tighter and more open in the Finnish electric vehicle cluster than in the biofuel field. At least there is clear competition between the biodiesel projects of different forest companies and their collaborators. Valmet Automotive and Neste Oil are examples of internationally relatively small incumbent companies that try use shifts to electric cars and biofuels to improve their positions in the industry. Venture capital companies have invested mainly in the electric vehicle field (e.g., Valmet Automotive and European Batteries). There are Schumpeterian-type entrepreneurs in both fields, such as Mika Anttonen in St1 and Ensio Miettinen and his family in Ensto and European Batteries.

The emergence of the Finnish electric vehicle cluster has been mainly based on national and relatively

small initiatives by old large and new small companies, research and educational institutions, and a user community. It has also been supported by several public innovation policy initiatives. Compared to the biofuel development there are some clear differences. Biofuel development has been more directly driven by the EU and by climate and energy policies, compared to the developments in electric vehicle cluster. Companies in the biofuel and electric vehicle fields are totally different, as assumed in our framework. Only ministries, Tekes, and VTT Technical Research Centre play roles in both sectors. Especially the TransEco programme initiated by VTT Technical Research Centre in 2009 on energy efficiency and renewable energy in road transport is a programme that covers both advanced biofuels and technology for hybrid and electric vehicles, as well as ICT solutions for road transport (www.transeco.fi).

The emergence of a national electric vehicle cluster resembles the strategic niche management approach developed in the Netherlands (Schot & Geels 2008), even though the concept is not used in Finland in this context. Attempts are made to create a new path for electric vehicles through a collaborative approach without any strong managerial core. “So far, this has been a small partisan group, and not a hierarchical army unit”, said a company representative in an interview. The new Tekes programme “seeks to create a commu-



nity of electric vehicle companies and researchers in Finland. That community would have close links to international research and business networks", says Teija Lahti-Nuuttila, Tekes's director for the energy area (Tekes 2010).

The emergence of the electric vehicle cluster can be characterized as a bottom-up process, whereas Finnish investments in biofuels follow a more top-down logic. In innovation literature, bottom-up development is often also labelled as "bricolage" (= to make creative and resourceful use of whatever materials are at hand regardless of their original purpose), whereas top-down development is termed a breakthrough strategy (Garud & Karnøe 2003).

The title and a key question of this section was whether biofuels and electric vehicles can contribute to green growth in Finland. Based on the empirical evidence and the visions of interviewed persons in different organizations presented here, we can give a positive answer. In the short term, in the 2010s, both biofuels and electric vehicles offer new business possibilities to Finnish firms. However, the prerequisite is that the second-generation biofuel technologies (mainly based on wood and waste) prove to be successful and that in the electric vehicle cluster, companies succeed in using the home market as a good demonstration case to develop export products and business alliances with foreign companies in the industry.

In the short term, the increasing uses of biofuels, and to some extent electric cars, plays a role in achieving the climate policy objectives. Yet a major role is played by more efficient motors, smaller cars, and hopefully also by an increasing use of public transport, cycling, and walking in urban areas. Public transport and related technologies also offer business opportunities to Finnish companies, which have not been fully recognized. In the long run, it is expected that electric vehicles play a greater role than biofuels in achieving the very demanding climate policy targets for 2050. Therefore, it is important that policies simultaneously support incremental and radical innovations, and that in the future, solutions are not only sought by developing more efficient vehicles but also by focusing on the whole transport system and mobility needs.

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A Multi-level Perspective on Technological, Business and Policy Innovations).

Interviewed persons in different organizations

- Electric car – Now! Community activist *Jiri Räsänen* 28.9.2010.
- Ensto: Director (new technologies) *Matti Rae* 17.9.2010
- Fortum: Research Director (new technologies) *Eero Vartiainen* 19.9.2010
- Green Net Finland: Development Manager (urban energy efficiency) *Arto Haakana* 29.9.2010.
- Metsäklusteri Oy (Forestcluster Ltd): CEO *Christine Hagström-Näsi* 8.9.2010.
- Neste Oil: Vice President (Business Development) *Timo Sarikkola* 1.10.2010.
- St1 Biofuels Oy: Managing Director *Mika Aho* 19.10.2010.
- Tekes: Chief Technology Adviser *Martti Korkiakoski* 13.9.2010
- UPM: Senior Vice President (Technology) *Markku Karlsson* 1.10.2010.
- VTT Technical Research Centre of Finland: Research Professor *Nils-Olof Nylund* 17.11.2010.

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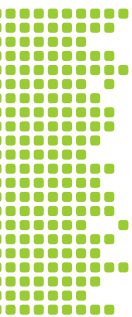
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Further information

Christopher Palmberg

Tekes

christopher.palmberg@tekes.fi

Pekka Pesonen

Tekes

pekka.pesonen@tekes.fi

**Tekes – Finnish Funding Agency for
Technology and Innovation**

Tel. +358 10 191 480

Fax +358 9 694 9196

Kyllikinportti 2, P.O. Box 69

FI-00101 Helsinki, Finland

E-mail: tekes@tekes.fi

www.tekes.fi

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