

Energy efficiency in low-carbon and energy roadmaps

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Keywords

strategy, scenarios, policy instruments

Abstract

In recent years, several long-term low carbon and energy roadmaps have been developed in Europe. In this study, roadmaps from EU, UK, Germany, Denmark, Sweden and Finland are analysed with a focus on the role that energy efficiency is assumed to play in future climate and energy policy. The intention is to identify similarities and differences among countries. Energy efficiency is in most of these roadmaps seen as a key factor for meeting EU and member states' climate targets. The estimated changes in energy demand vary significantly among the scenarios presented in the plans, ranging from stabilisation at current levels to radical reductions. This is a result of differences in the structure of the energy system being analysed, methodological approaches for energy modelling and assumptions for future energy policies. In all roadmaps, a great variety of policy instruments intended to improve energy efficiency are presented, ranging from general market and fiscal instruments to regulation and voluntary agreements. The paper illustrates that although a common EU framework exists, the approaches to energy efficiency vary among the member states as well as the choice of policy instruments.

Introduction

In January 2011, EU presented its low-carbon road map (European Commission, 2011a). Later that year, it was supplemented by an energy road map (European Commission, 2011b), which was consistent with the low-carbon road map with regard to emission reductions. Several countries within the EU have also

provided long-term low-carbon or energy strategies, in which they present how their societies, in the long term, could develop into low carbon societies (see e.g. Notenboom et al., 2012 for a review).

The solutions for reaching long-term climate and energy targets are quite similar in the various roadmaps. Energy efficiency improvements, electrification (including the diffusion of electric vehicles), renewable energy, carbon capture and storage (CCS) and nuclear power are seen as important pillars of the strategies. The role of the various pillars differs, however, among the roadmaps. For example, nuclear power is in some countries not seen as an option as a result of lack of political acceptance. Some of the technologies included in the low-carbon scenarios – such as electric vehicles, electrowinning in the steel industry¹, and CCS – are not yet readily available for large-scale implementation, which makes their roles rather uncertain. In contrast, much of the potential for energy efficiency improvements is based on broad implementation of already existing technologies.

The focus in this paper is to study how one of the pillars, energy efficiency, is dealt with in a group of European roadmaps. The framing of energy efficiency improvements as GHG mitigation option is studied as well as the methodologies used for estimating future energy demand and efficiency potentials. The various approaches for using energy efficiency targets and various policy instruments as governance methods are compared. The intention is to identify similarities and differences among countries.

1. I.e. using electrolysis to produce iron from the ore.

There are several recent reports in which energy efficiency governance is studied and national policies are compared (Jolands et al., 2011; Wade et al., 2011; Egger et al., 2012). In this paper, however, focus is limited to the role energy efficiency plays in broader climate and energy policy documents. This will not provide a full picture of the countries' energy efficiency policies but rather show how these policies are positioned within the countries' broader climate and energy policy agendas.

Overview of low carbon and energy roadmaps

In this study, the analysis will be based on roadmaps from EU and five EU-member states, namely the United Kingdom, Germany, Denmark, Sweden and Finland (see Table 1). The roadmaps studied here, have all been developed with the intention to show ways to a low carbon society consistent with the 2 °C climate target. Some of the roadmaps include all emission sources within society, whereas a couple of the studied roadmaps focus solely on the energy system (including transport). Although many of these long-term strategies are not named "roadmaps", the term "roadmap" will be used in this paper to describe the type of long-term strategy that details the societal transformation needed to meet future challenges such as climate change and energy security. Target years for these kinds of strategies are typically in the long-term future (i.e. 2050).

It is difficult to make a firm delimitation between roadmaps and climate and energy policy in general. Sometimes the roadmaps are merely summaries of existing policy initiatives, re-packaging them in a comprehensive analytical and political framework. In some cases, the roadmaps are presented together with other initiatives. For example, the EU low-carbon roadmap was presented the same day as a plan for energy efficiency (European Commission, 2011a) and not long after, a white paper for transport was presented (European Commission, 2011d). Both of these documents included initiatives of great importance for the development of energy efficiency in

the union. A sector poorly covered in a specific roadmap text, thus does not necessarily mean that that sector is underdeveloped in the climate and energy policy arena as a whole.

For several of the studied countries it is not evident what document is to be seen as *the* actual roadmap. There is a row of closely related documents that together seem to form the long-term "roadmap". Initial proposals have been slightly adapted as a consequence of sectoral changes (e.g. with regard to nuclear power in Germany) or government changes (e.g. Denmark). These changes have not made the earlier strategies obsolete and most of the information presented in the first strategies still holds. In addition to this, the government roadmaps are often based on important supporting materials presented by various agencies and consultancy firms. It is often necessary to study this supplemental material in order to better understand the roadmaps. The documents studied in this paper are summarized in Table 1.

The statuses of the various roadmaps differ. The EU roadmaps are products from the commission which have not been affirmed by the council. The UK carbon plan (UK government, 2011) is a product of the government but is to a great extent based on work conducted by the UK Climate Change Committee (see e.g. UKCCC, 2008). The plan is furthermore strongly linked to the legal system of the Climate Change Act. Both the German and Danish roadmaps that are studied here focus solely on the energy sector (see e.g. German Government, 2011a and Danish Government 2011a). In Denmark, the government energy strategy from 2011 (Danish Government, 2011a) was later the same year adopted by a new government (Danish Government, 2011b) with only minor changes. This was followed up by a broad energy agreement in the beginning of 2012 including most of the parties in the Parliament. In Sweden, the Swedish Environmental Protection Agency has, on a commission by the Swedish Government, presented a suggestion for a low-carbon roadmap (Swedish EPA, 2012), but it has to be processed by the government before it can be seen as "the

Table 1. Low carbon roadmaps and energy roadmaps studied in this paper.

EU	European Commission. 2011a. A roadmap for moving to a competitive low carbon economy in 2050, COM (2011) 112 final. Impact assessment: European Commission, 2011e. European Commission 2011b. Energy roadmap 2050. COM (2011) 885/2. Impact assessment: European Commission, 2011f.
United Kingdom	UK Committee of Climate Change. 2008. Building a low-carbon economy – the UK's contribution to tackling climate change. UK Government. 2011. The carbon plan: Delivering a low carbon future, December 2011.
Germany	German Government. 2010. Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply. BMWi, BMU. Schlesinger et al. 2010. Energieszenarien für ein Energiekonzept der Bundesregierung. BMWi. 2012. Die Energiewende in Deutschland. Mit sicherer, bezahlbarer und umweltschonender Energie ins Jahr 2050
Denmark	DCCCP. 2010. Documentation to the report of the commission: Green energy – the road to a Danish Energy System without Fossil Fuels. Danish Government. 2011a. Energy strategy 2050 – from coal, oil and gas to green energy. Danish Government. 2011b. Our future energy. Danish Government et al. 2012. DK Energy Agreement, March 22 2012.
Sweden	Swedish Environmental Protection Agency. 2012. Underlag till färdplan för ett Sverige utan klimatutsläpp 2050 (A basis for a Swedish low-carbon roadmap).
Finland	Finlands regering. 2008. A long-term Climate and Energy Strategy. Prime minister's office publications. 2009. Government Foresight Report on Long-term Climate and Energy Policy: Towards a Low-carbon Finland, Report 30/2009.

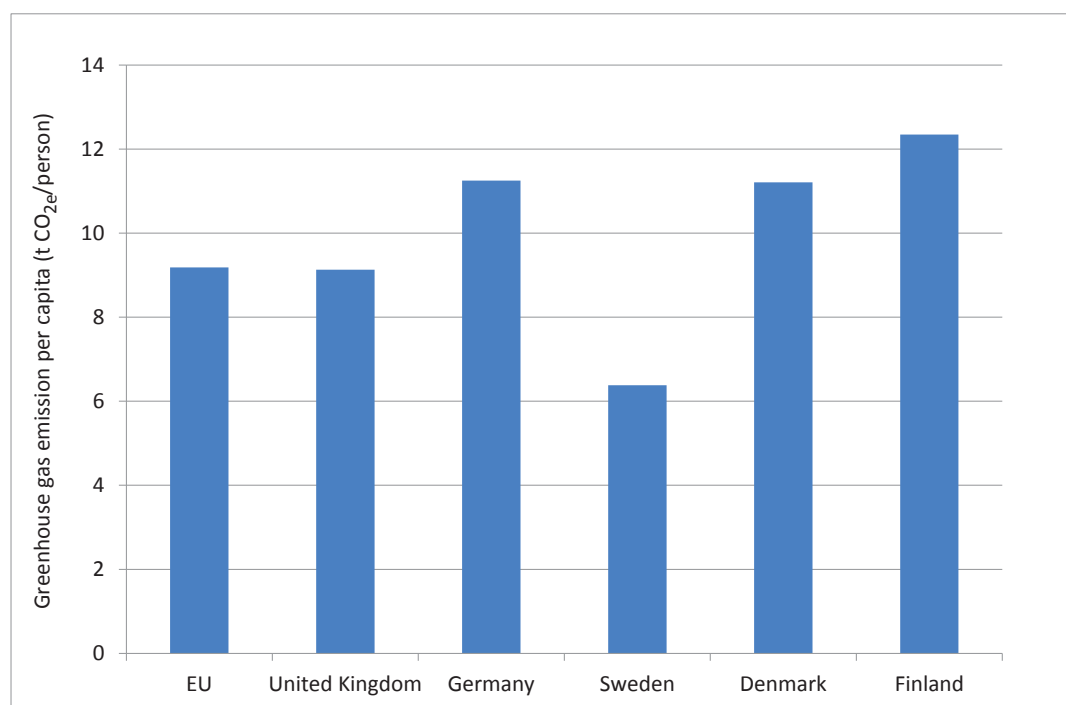


Figure 1. Greenhouse gas emissions per capita in the six geographical areas in 2009. Source: UNFCCC (2011).

Table 2. Summary of climate targets for the year 2050 in the studied roadmaps.

Geography	Targets
EU low carbon road map	-80 % GHG emission reduction compared to 1990.
EU Energy roadmap	-85 % CO ₂ emission reduction in energy system which is seen as consistent to an 80 % reduction of all GHG emissions in all sectors.
UK	-80 % GHG emissions compared to 1990.
Germany	-80 % reductions of GHG compared to 1990. In energy scenarios -85 % reduction.
Denmark	No national emissions targets. Target: Fossil free energy system.
Sweden	Zero net emissions.
Finland	-80 % GHG emission reduction compared to 1990.

Swedish roadmap". This is a process that will continue during 2013. In Finland, there is a climate and energy strategy from 2008 (Finnish Government, 2012) which has led to continued work that resulted in a foresight report which included several scenarios exploring potential futures (Finnish Government, 2009). An update of the climate and energy strategy was expected to be completed by the end of 2012. Once the update has been completed, preparation of Roadmap 2050 for Finland is expected to begin. Preparation of the roadmap will, according to the Finnish Government (2012), involve extensive consultation with interest groups and citizens.

The ambition levels in the studied roadmaps are quite similar taking their starting point in the two-degree target and EU targets requiring an emission reduction for EU countries of 80–95 % by 2050 compared to 1990. Exactly how this overarching target should be applied for a single country is not evident, especially as the starting points for per capita emissions vary significantly among EU countries, as shown in Figure 1. Whereas the EU, the UK, Germany and Finland suggest rather similar future targets of about 80 % GHG emission reduction between 1990 and 2050, Denmark does not operationalize the

EU target into a specific national target (see Table 2). Sweden, on the other hand, has decided on a target of net zero emissions by 2050. The definition of a net zero emissions target has been discussed but not yet decided (Swedish EPA, 2012).

The availability of various mitigation options, such as renewable energy, could have impact on how the different countries evaluate the needs for energy efficiency improvements. Here the differences between the studied countries are large as shown in Figure 2. Although Denmark and Germany are often highlighted as good examples when it comes to rapid wind and solar energy expansion, they are far behind Sweden and Finland when it comes to total shares of renewable energy where bioenergy and hydro power are important energy sources. Renewable energy is here a very significant source not only for electricity production but also for industrial process energy and building heating. In Sweden, building heating is already almost free from fossil fuels and the rest is expected to disappear in the coming decade as a result of already existing policy instruments. In the UK, however, renewable energy accounts for less than five percent of gross energy consumption, significantly less than the EU average.

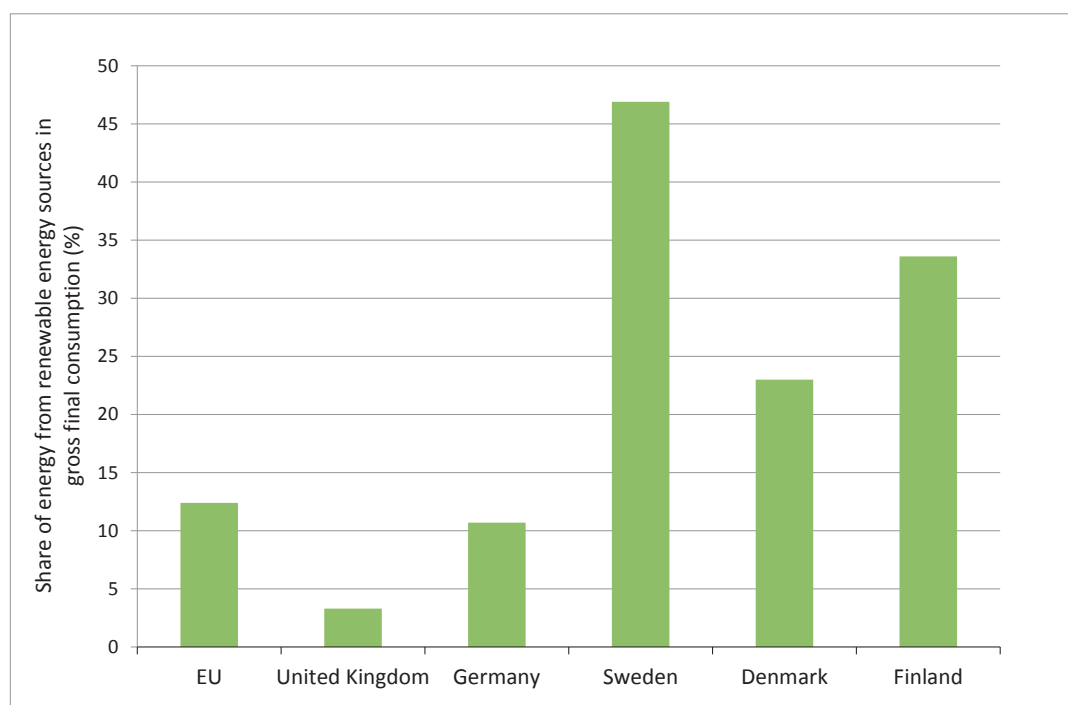


Figure 2. Renewable energy as fraction of gross final consumption in 2010 in the six geographical areas. Source: Euroobserver, 2011.

The framing of energy efficiency in the roadmaps

Energy efficiency is presented as a central option for reducing GHG emissions in all of the studied roadmaps. It is stressed as having a significant potential to reduce energy use in all sectors but how this will contribute to a low-carbon future is seen differently in the various countries. Arguments for energy efficiency also change over time. For example, as electricity production in the UK is assumed to be decarbonised by the end of the studied period, energy efficiency is for the long-term argued for from the perspective of cost reduction as opposed to emissions reduction. Similar arguments are given in the Swedish roadmap where it is stated that “the effect of measures that improve energy efficiency turns from direct emission reductions to mainly lowering the cost for implementing the climate strategy”. In addition, energy efficiency is seen in the Swedish roadmap as important for achieving other societal targets including environmental targets such as biodiversity, landscape preservation and air quality. Energy efficiency in systems based on bioenergy is seen as especially important to avoid conflicts with other environmental targets as global low-carbon strategies are expected to create a great demand of biomass potentially leading to a significant stress on biological resources.

In the EU low-carbon road map, energy efficiency is highlighted as one of the major contributors to the decarbonisation of transport where efficient internal combustion engine vehicles (ICEVs), gradual hybridisation and electric vehicles are important technological solutions. It is noted that until 2025 fuel efficiency improvements will be the main option for reducing emissions in the transport sector. On the other hand there is no focus on limiting total passenger transport activity although public transport is expected to provide an increased share of total transport services. When industry is discussed, the focus is on reducing energy intensity and not on energy efficiency. It is not clear how important structural change is for reducing

energy intensity compared to energy efficiency improvements. Energy use in buildings is reduced in low carbon scenarios as a result of better thermal insulation driven by high carbon prices.

In the EU energy roadmap a specific scenario was developed that was called high energy efficiency. This is a clear indication that energy efficiency is seen as a central component in EU energy policy. Significant reductions in primary demand between 2005 and 2050 occur in all five target scenarios, varying from 32 % to 41 %. In the energy roadmap, it is also explicitly stated that the prime focus should be on energy efficiency. It is stressed that near zero emission buildings should be standard and that there is a need for both greater access to capital for consumers as well as innovative business models. A potential conflict between insulating buildings to use less heating and cooling and systematically using the waste heat of electricity generation in combined heat and power (CHP) plants is recognized in the roadmap. In the impact assessment of the energy roadmap, the EU Commission stressed that there is a strong need for targeted support policies and public funding supporting efficient consumer choices. Split incentives, cash problems of some group of customers; imperfect knowledge and foresight leading to lock-in in some outdated technologies, etc. are mentioned as reasons for that.

In the UK roadmap, it is noted that an effective strategy to reach UK's various climate and energy policy aims, will necessarily include using less energy in the various economic sectors (UK Government, 2011). It argues that by managing energy and resource demand, costs to businesses and consumers are reduced, releasing spending power that can increase growth and productivity elsewhere. It is also argued that lower demand for energy reduces risks to the security of energy supplies.

In the German Energy Concept report, energy efficiency is highlighted as a key aspect for reaching the goals. The government, however, urges for common sense and personal re-

sponsibility rather than regulations to reach these targets. The importance of energy efficiency is highlighted by the fact that there are many targets for energy demand both on aggregated and disaggregated levels.

In Denmark, the focus of the roadmap is a fossil free energy system. Energy efficiency and renewable energy are the two measures that could contribute to reach these targets. The demand of energy services is assumed to increase, but energy efficiency is assumed to make energy consumption 50 % more efficient (Danish Government, 2011a). Electrification of many sectors is seen as one way to increase energy efficiency. The Danish government (2011b) also notes that without energy efficiency improvements economic growth will push up energy consumption and make it disproportionally expensive, or ultimately impossible, to cover with renewable energy resources.

In Sweden, it is highlighted that as fossil fuels are phased out energy efficiency turns from contributing to emission reductions to cost reductions for maintaining a low-carbon society. The direct impact of efficiency improvements on GHG emission is already today relatively low in buildings as current policy instruments have led to an almost complete decarbonisation of the sector. Compared to the other roadmaps, the Swedish roadmap takes a rather broad perspective with regard to how to limit energy use for transportation. Here, urban and infrastructure planning is seen as a key aspect in reducing energy demand. Accessibility, in contrast to mobility, is stressed as the important factor to focus on, and it is noted that it can increase even with lower car use. In industry, energy efficiency improvements are, although recognised as important, seen as largely insufficient to reach long-term climate targets. Therefore, new radical fossil-fuel free technologies are essential for reaching ambitious emission reductions.

The development of energy demand in the targets scenarios of the roadmaps differs significantly among countries, as shown in Table 3. For example in the German roadmap primary energy use is reduced by 50 % while it increases in Finnish government (2008). The differences in estimated energy development are discussed in the following section. It is worth noting that even in the scenarios where energy demand is reduced only slightly there are significant energy efficiency improvements.

Approaches for estimating future energy use

Scenarios, describing the development of the energy systems and greenhouse gas emissions until 2050, have been presented in all the studied roadmaps. The scenarios presented consist of

both various types of reference scenarios that show the development without further policy measures, and target scenarios intending to show how various targets could be reached (Table 4). Most of the scenarios are in the form of “what if” scenarios. For the “what-if” scenarios, similar methods are used as in traditional forecasts although, by varying the boundary conditions, outcomes can vary significantly. Often computational models such as Markal and PRIMES have been used. These models are based on an optimization approach searching for the least-cost system under various boundary restrictions. A few studies have used a less formalized approach enabling them to cover a wider range of potential futures.

In the scenarios for EU, energy demand levels are estimated using the PRIMES model framework. The model specifies a least cost energy system under certain boundary conditions. For end-use technologies the assumed consumers in the model always have the possibility of choosing between several vintages of the same technology, which are characterised by different prices and efficiencies. In the target scenarios, GHG emission reductions in line with EU targets act as one of these boundary conditions in the model. Assumptions of specified policy instruments are individually handled within the modeling framework. Several energy efficiency policies are included already in the reference and current policy initiatives scenarios. In addition, in the high efficiency scenario the following policy initiatives and measures are among those included: i) additional strong minimum requirements for appliances, ii) higher renovation rates for building, iii) more rapid implementation of passive house standards, iv) marked penetration of energy service companies (ESCOs) and higher financing availability reflected in the model as lower discount rates for consumers, v) obligations of utilities to achieve energy savings in their customers' energy use at a rate above 1.5 % per year, vi) strong minimum efficiency requirements for energy generation, transmission and distribution, vii) full roll-out of smart grids, smart metering, and finally viii) significant increase in decentralized generation of electricity from renewable energy sources. For each measure, it is described how these assumptions are reflected in the model. The inclusion could be both in the form of direct assumptions for implementation rates and in changes in the economic conditions through lower interest rates for households, business and public energy users. The implementation of energy efficient technologies is based on individual interest rates for various consumer and sector groups. A common social rate of return is not used as starting point.

Table 3. Energy demand levels in 2050 in target scenarios in the various roadmaps (Base year=100).

Geography	Primary energy demand (base year)	End use demand (base year)
EU low-carbon roadmap (European Commissions, 2011e)	65–67 (2005)	70–80 (2005)
EU Energy roadmap (European Commission, 2011f)	59–68 (2005)	63–68 (2005)
UK carbon plan (UK government, 2011)	Per capita energy demand 46–69 (2007)	Not available
Germany (Schlesinger et al. 2010)	50 (2008)	57 (2008)
Denmark (Danish CCC, 2010)	74–91 (2008)	81–87 (2008)
Sweden (Swedish EPA, 2012)	Not available	80–100
Finland (Finnish government, 2008)	118 (2005)	72 (2005)
Finland (Finnish government, 2009)	Not available	50–100

Table 4. Summary of scenarios in the studied roadmaps.

Geography	Scenarios for 2050
EU low carbon road map (European Commission, 2011a and e)	Reference scenarios. Four target scenarios with different assumptions with regard to global policy regimes and technology development (nuclear, CCS, electric vehicles).
EU Energy roadmap (European Commission, 2011b and f)	Reference scenario, current policy initiative scenario and five decarbonisation scenarios: i) High energy efficiency ii) Diversified supply technologies scenario iii) High RES iv) Delayed CCS v) Low Nuclear
UK CCC (2008)	One scenario -80 % CO ₂ and one -90 % CO ₂ in the energy sector
UK Government (2011)	Four target scenarios: i) CoreMarkal – based on traditional low cost modeling ii) Higher renewables, more efficiency iii) Higher nuclear, less efficiency iv) Higher CCS, more bioenergy
Germany: Schlesinger et al. (2010)	One reference scenario and four target scenarios with varying assumptions regarding lifetimes of nuclear power and energy efficiency
Denmark: DCCCP (2010)	Two reference scenarios and two target scenarios which differ depending on the level of global ambitions
Swedish EPA (2011)	Reference scenario and two target scenarios. One scenario reaches 70–80 % emission reductions in Sweden, the other 60–70 %. The rest of the target is handled through sinks within LULUCF or emission trading.
Finnish Government (2008)	Base scenario and 2050 vision.
Finnish Government (2009)	Target scenarios developed from four storylines: i) Efficiency revolution ii) Sustainable daily mile iii) Be self-sufficient iv) Technology is sufficient

In the UK, different approaches for analysing future energy systems have been used. Several of the relevant studies have used Markal models for analyzing the potential developments. For the UK carbon plan, the UK emission calculator (DECC, 2012) has been used in addition to the UK Markal model. When using the calculator, there is a possibility to vary a number of specified parameters. Among those connected to energy demand are assumptions regarding transport demand and modal split, vehicle technologies, energy intensity in industry, building temperature and efficiency improvements in buildings etc. Of these, the UK carbon plan highlights two assumptions as key for differing between scenarios: i) how many of houses have been subject to solid and cavity wall insulations and ii) how large fraction of the total vehicle stock is ultra-low emission cars.

In the German target scenarios that form the basis for their “Energy Concept”, energy efficiency is treated in different ways. In two of the scenarios, energy efficiency is estimated endogenously within the model. In two other scenarios, exogenous assumptions of specific annual energy efficiency improvements determine the energy use levels. In the first two scenarios, estimates of energy demand are based on historical experiences, specific assumptions on social and technological parameters, and the structure of the capital stock in the system. The response to energy price changes is based on an elasticity approach. In industry, structural change is assumed to continue following current trends and, as a consequence, the share of production coming from energy intensive sectors is reduced. In

the transport sector, small changes in modal split are assumed for passenger transport, whereas more significant changes in modal split is assumed for goods transport.

In the scenarios for the Danish energy strategy, which were presented by the Danish Commission on Climate Change Policy (DCCC, 2010), a bottom-up method was used to estimate future energy use. The estimation took its starting point in a large technology data-base. In the building sector, heating efficiency improvements up to 0.6 DKK/kWh (0.8 cEUR/kWh) are included compared to 0.35 DKK/kWh (0.5 cEUR/kWh) in the reference scenario. In other sectors, it is assumed that current BAT (Best Available Technology) levels will dominate the market in 2050. Only technical measures are included. This means for example that no changes in the modal split are expected in order to reach the targets, neither is spatial planning for reducing the need for transport included in the scenarios as an option for reducing energy demand.

In the scenarios presented in the Swedish EPA's roadmap (Swedish EPA, 2012), energy demand levels have been estimated with various bottom-up methods for the different sectors. These energy demand levels have then been fed into the optimization model MarkalNordic from which total energy balances were calculated. Two main target scenarios were developed. In one of the scenarios, measures that intend to reduce transport demand were included in addition to technical measures. In the other scenario, only technical measures were included. In the first target scenario, energy demand levels for the building sector were taken to be a consequence of reaching the previous

energy targets for 2050 for the Swedish Environmental Quality Objective “A good built environment” which was a 50 % reduction of specific energy.² In the other scenario energy use levels in the building sector were estimated to be the same as in the reference scenario (in which it also is assumed that a significant reduction in energy use will occur). For industry, energy use in the target scenarios is assumed to be 10 % lower 2030–2050 than in the reference scenario as a response to higher willingness to invest in energy efficiency. No significant change in industrial structure is assumed which leads to a significant increase in the industrial production values in the energy intensive industry. In contrast to the transportation sector, energy service levels in the industrial and building sector are assumed to be unaffected by climate policy. The different approach is probably at least partly an effect by the choice to delegate the development of sectoral scenarios to various sectoral government agencies. The different approaches could lead to inconsistent assumptions regarding the potentials for the various sectors to contribute to GHG emission reductions.

Fundamentally different methods for making 2050 scenarios were used in the two different Finnish governmental reports studied here. In the visions for 2050 presented in the climate and energy strategy (Finnish governments, 2008), end-use energy demand seems to be taken from the target presented in the report and used for the one single target scenario (the vision) presented in the study. No detailed analysis for this target was presented in the study nor were there any clear criteria of on what ground technologies are assumed to be implemented. In the foresight report from 2009 (Finnish government, 2009), a much broader array of scenarios was presented. The various energy demand levels presented in the scenarios were not dependent on assumed variations on technology. Instead they were the result on widely diverging assumptions regarding future industrial, urban and transport structure. Although the qualitative assumptions of the scenarios are described clearly, it is not transparent how these assumptions transform into energy use levels.

Targets and policy instruments for energy efficiency

The EU and the studied member countries have different approaches for increasing energy efficiency. Many countries have targets for the period to 2020 in line with existing EU targets. The EU, however, does not present any long-term target for energy efficiency in its roadmaps. The same is valid for the UK, Sweden and Denmark. In Sweden, on the contrary, the previous long-term energy efficiency target for buildings has been removed by the current government. In Denmark, the possibility to use much less energy 2050 is highlighted in the plan, but no target is presented.

In its energy concept paper, Germany has presented a target for reducing primary energy by 50 % by 2050 compared to 2008 (German Government, 2010). In addition, transport energy use should be 40 % lower than in 2008. Electricity consumption is to be reduced by 25 % between 2008 and 2050, and the

annual renovation rate for buildings is to increase from current less than 1 % to 2 %.

In Finland, energy end-use should follow the target scenario which implies that it in 2050 should be about two-thirds of the 2005 level (Finnish Government, 2008). In the foresight report (Finnish Government, 2009), a target is set to cut energy intensity by 50 % by 2050 compared to current level presented. Building energy use should be reduced by 60 % by 2050. Targets for reduction of GHG emissions from passenger cars are also presented. Such targets have historically been closely related to energy efficiency but this relation may be less direct in a future with more alternative energy carriers available for the transportation sector.

In all roadmaps, policy suggestions are given with the intention to reduce emissions and energy use (indirectly or directly). These are summarized in Tables 5 and 6. In all countries, there is an underlying assumption that a price on carbon will be a significant instrument for reducing carbon emissions. This will of course have an indirect effect on energy use as a carbon price leads to higher energy prices. The carbon price is set both through a pricing mechanism (the EU emission trading system) and through fiscal measures in the form of carbon and fuel taxes. The EU in its roadmap also proposes smart taxation systems for the transport system including infrastructure fees, and fees handling congestion and air pollution are proposed.

Strengthened energy standards for buildings, appliances and private cars are important measures in all of the roadmaps, in line with EU policy. One strong example comes from Germany where a climate neutral building standard is proposed for 2020. In most roadmaps, a continuing strengthening of EU vehicle fuel efficiency regulation is expected. In the UK, minimum efficiency standards for rented buildings are another suggestion as well as mandating the installation of smart meters. The latter is expected to be a strong incentive for energy conserving behavior. Direct regulation is rarely suggested for industrial sectors. Instead various forms of voluntary agreements are frequently suggested. Both Germany and the UK propose tax credits granted in exchange for energy efficiency improvements.

New financing models are highlighted in the EU roadmap without exactly specifying what they would look like. Some models are however found in some of the national plans. For example, the UK plan highlights the Green Deal, an investment scheme removing upfront costs from the consumers and recouping those costs from savings on the energy bill (cf. the so called on-bill financing in the US). In both the UK and Denmark, requirements are set on energy companies for supporting energy efficiency improvements. For example, in the UK energy companies are to be obliged to undertake solid wall insulation, to install central heating and to subsidise cavity and loft insulation.

Direct economic support with impact on energy efficiency is also suggested in several of the roadmaps. Examples are support for building infrastructure for ultra-low emission vehicles (ULEVs) and electric vehicles in the UK, the German energy efficiency fund, and support for public transport in Finland. In the UK, the Local Sustainable Transport Fund is intended to support people who make low carbon transport choices.

The need for improved urban planning systems has been stressed in the EU, Swedish and Finnish road maps. The Swedish EPA suggests a revision of the current planning legislation.

2. This target was recently removed by the parliament as a part of a broader reform of the Swedish system of environmental quality objectives. However, according to the government, the removal of the target should not be seen as a way to lower the ambitions in the area (Swedish Government, 2012).

In addition, government instructions to the National Transport Administration should, according to the Swedish EPA, be clearer to advocate for a more transport-lean system. Their planning systems are suggested to be clearer in giving priority to measures that reduce the need for individual motor transport and have a clear focus on accessibility.

The role of public actors is highlighted by the UK, Germany and Denmark. In Germany, it is suggested that there should be an obligation to make energy efficiency a factor in awarding public contracts. In Denmark, it is proposed that the government's budget agreements with municipalities and regions include voluntary agreements on energy consumption in buildings.

Discussion

Energy efficiency is a central building block in all the studied road maps enabling a future with low GHG emissions that is affordable and does not threaten other environmental factors.

The exact role differs, however, between the various road maps and between sectors within roadmaps. In sectors where fossil fuels are expected to be dominant also in the future, energy efficiency leads to direct emission reductions. However, in a country like Sweden where the electricity and residential sectors are essentially already fossil fuel free, energy efficiency improvements are rather motivated as a way to reduce potential conflicts with various environmental targets and to reduce costs.

Although energy efficiency is presented as a key factor, only two roadmaps presents 2050 targets for energy efficiency or energy use. Germany presents a target to reduce primary energy use by 50 %; whereas Finland presents a target that energy end use should be reduced by around a third compared with today. Although the EU has presented energy use targets for 2020, no targets have been suggested for the longer term. Sweden, Denmark, and the UK have neither defined long-term targets for energy efficiency. This can probably be explained by reluctance to specify targets for something that is not really seen as

Table 5. Policy instruments that, in addition to carbon pricing instruments, are suggested for achieving energy efficiency improvements presented in the roadmaps of the EU, UK and Germany.

EU ^a	UK	Germany
<ul style="list-style-type: none"> – Carbon standards – Smart taxation systems in the transport sector – City planning – Infrastructure fees – Fees handling congestion, air pollution etc. – Regulation of energy performance in built environment – New financing models 	<ul style="list-style-type: none"> – UK initiatives within government as good examples – Green Deal – Energy Company Obligation – Minimi-standard for rented housing – New-build standards – Further development of minimum standards for appliances in EU – Mandating smart meters – Energy Performance Certificates – Press for stricter EU vehicle regulation – Local Sustainable Transport Fund – Economic support for ULEV and EVs and its infrastructure – CCL combined with CCA (Voluntary agreements combined with tax deductions). – CRC Energy Efficiency Scheme 	<ul style="list-style-type: none"> – Obligation to make energy efficiency a factor in awarding public contracts – Advice through “Energy Efficiency Initiative” – Push for transparent energy consumption labeling – “White certificates” pilot project – Eco tax relief vs. energy efficiency measures in industry – Energy efficiency fund (for information, networking, market introduction etc.) – Climate neutral building standard 2020 – Building rehabilitation programme – Review of rent law

Table 6. Policy instruments that, in addition to carbon pricing instruments, are suggested for achieving energy efficiency improvements presented in the roadmaps of Denmark, Sweden and Finland.

Denmark	Sweden	Finland
<ul style="list-style-type: none"> – Increasing the saving obligations of utilities and targeting them towards existing buildings and businesses – Support strengthened regulations on appliances and improved labeling systems – Work for a more ambitious EU building directive – Enhance public sector savings – Voluntary agreements between state and municipalities – Green subsidy regime for building renovation – Future proof the minimum standard for building components 	<ul style="list-style-type: none"> – Support more strict vehicle regulation in EU – Reform of the vehicle sales tax to support energy efficiency – Support rapid implementation of the eco-design directive with successive revision in all product fields – Revision of building regulation – Regulate infrastructure planning procedures to support a low transport society – Reform land-use planning for a low transport society 	<ul style="list-style-type: none"> – Public financing for development and market introduction of EE technologies – Implementation of energy efficiency certificates in line with EU regulations – Stricter energy regulation for new buildings – Financial support for energy renovations – Preparation for road tolls – Energy savings advice – Economic support to public transport – Land use planning should be used for reducing transport demand

the main objective. Introduction of specific EE targets could according to this line of reasoning be seen as inefficient and reducing flexibility as a tool for achieving high overarching level targets such as emission reductions, energy security or economic development.

The advantages of long term energy efficiency targets could depend on how one chooses to regard the governance approach of “steering by objectives”. One perspective could be to see the target mainly as criteria for policy evaluation. In this case it is seen as a value in itself to reach the targets and much effort is directed to steering to exactly reach a specific target, for example a certain level of GHG emission reductions. In this case, a broad range of detailed targets and sub-targets could make the governance system rather rigid. If the perspective instead is that the targets act more as guiding principles to support the various actors in understanding in which direction they should go, the need to exactly reach any single target is reduced. In this case, many sub-targets feasible for the various conditions within which the stakeholders’ work could be advantageous.

Many of the studied roadmaps concentrate solely on technical measures for reducing emissions and energy use. In the UK the climate change committee notes that it is a way to avoid underestimating the cost of its strategy. The UK CCC (2008) thus states: “To the extent that behavioural changes are likely, the cost of achieving radical emission cuts would be lower than those we present in this chapter”. In Sweden, however, one of the target scenarios includes several planning measures in the transport sector that intend to create a “low transport society”. This is also reflected in the policy instruments suggested in the road map.

In the roadmaps, it is argued that there is a need for stable policies and adequate policy instruments. Although carbon pricing is understood as a major tool for reaching long-term emission targets, many other instruments are suggested as complements. These instruments are also motivated by the existence various market imperfections, other targets such as energy security, and the perceived need to protect certain industries and individuals from energy prices that are too high (which prevents the introduction of a carbon price at an adequate level).

Although the main timeframe of the roadmaps is 2050, many of the policy suggestions are intended for the next ten years. This seems quite reasonable as governments have small possibilities to lock in decisions for longer periods without severely hampering future generations’ manoeuvre space. The roadmaps lack in clarity, however, in how exactly the suggested short-term policy instruments fit in a longer term strategy. Are they far-reaching enough and are they targeting the right areas?

It is worth noting that there are less policy suggestions regarding energy efficiency in the EU roadmap than in the national roadmaps. This probably reflects a pragmatic approach from the commission that it is often easier to steer by objectives than through various policy instruments, as the feasibility of policy instruments depends on policy styles, institutions and culture (Nilsson, 2011). However, several of the national plans policy suggestions are closely correlated to such instruments that have already been implemented or are on the way within the EU.

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Acknowledgements

I hereby acknowledge the financial support of Swedish Energy Agency and the Swedish Environmental Protection Agency.