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Driving a Green Economy through Carbon Taxation?

- Learning from the Nordic experience

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Abstract

Carbon taxation can be a crucial policy to transform towards a greener economy, which was identified as a key strategy to achieve sustainable development at the United Nations Conference for Sustainable Development (UNCSD) in 2012. As more countries consider the introduction of carbon taxation and other carbon pricing mechanisms, it's relevant to learn from the experiences in Nordic countries, which have had carbon taxation in place since the early 1990's. The purpose of the thesis is to contribute to increase the understanding of how/to what extent carbon taxes has been a driver of greener economies in Nordic countries. In order to understand the progress towards greener economies, a horizontal review has been conducted according to 10 green economy indicators, including energy intensity, carbon intensity and emissions intensity in the period 1990-2012. To estimate the contribution of carbon taxes for the progress, ex-post studies about carbon taxation in Nordic countries have been reviewed according to criteria for environmental policy evaluation, including environmental effectiveness, equity and distributional effects, and effects on industrial competitiveness. Analysis of the indicators shows that Nordic countries perform well on green economy indicators, and the review of ex-post studies indicate that the carbon taxation has contributed to the performance on some of the green economy indicators in combination with other policy instruments. Based on the findings, a number of policy learnings regarding carbon taxation are proposed, methodological challenges are discussed, and further research is suggested.

Keywords:

Green economy, carbon taxation, Nordic environmental policy, carbon risk management, deep emission cuts

Executive Summary

The world is facing urgent challenges with anthropogenic climate change, and countries needs to achieve deep cuts of greenhouse gas (GHG) emissions within upcoming decades. Reducing GHG emissions is also a crucial part of transforming towards a greener economy, which was identified as a key strategy to achieve sustainable development at the UNCSD in 2012. Among the many policy responses, carbon-pricing mechanisms, including carbon taxation, emission trading schemes and corporate shadow carbon pricing has gained increased support and momentum. Carbon pricing mechanisms can contribute to internalize the social cost of carbon emissions and steer towards low-carbon investments. By creating new incentives and changed behavior, such mechanisms can contribute to reduced CO_2 emissions. Carbon taxation also has the benefit that it can create a new tax revenue stream, and has low transaction costs.

As more countries consider the introduction of carbon taxation and other carbon pricing mechanisms, it's relevant to learn from the experiences in Nordic countries. There are many definitions of what constitutes a green economy, and the role of carbon taxes and other carbon pricing mechanisms to steer towards greener economies. In that context, it's also relevant to analyze the experience of carbon taxation in Nordic countries. According to UNEP, a green economy can be defined as an economy that results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP 2011, p. 14). The experience in Nordic countries can be analyzed through the green economy lens.

Nordic countries have had carbon taxation since the early 1990's. However, there are no systematic reviews of if/how carbon taxes have contributed to greener economies in Nordic countries. Further, there is a lack of comparative studies on carbon taxation in Nordic countries. To understand how carbon taxes have contributed to greener economies, there is a need to conduct ex-post evaluations of the taxes. Ex-post studies of carbon taxes are limited, whereas ex-ante studies are more common. Ex-post studies of carbon taxes are resource intensive, and there are methodological challenges with attribution to estimate to what extent carbon taxes have impacted levels of CO_2 emissions. Another research gap regarding the effects of carbon taxation is how carbon taxes and Emission Trading Schemes (ETS) interact, and the effects of these carbon-pricing mechanisms for carbon management on a firm level.

The purpose of the thesis is to contribute to increase the understanding of how/to what extent carbon taxes has been a driver of greener economies in Nordic countries. The research questions include:

(1) How do Denmark, Finland, Norway and Sweden perform on selected green economy indicators?
(2) What is the environmental effectiveness, distributional effects and effects on industrial competitiveness of carbon taxes in Denmark, Finland, Norway and Sweden?
(3) How do carbon taxation and other carbon pricing mechanisms influence carbon risk management on a company level?

To connect the green economy and the carbon taxes, Nordic countries can be analyzed based on their progress on green economy indicators. But to measure progress towards a green economy is challenging, and various indicators can be used. In this thesis, a mix of indicators will be used based on the literature about measuring progress towards a green economy and with regards to the overall purpose of the thesis. 10 indicators have been selected based on the literature review of how to measure progress towards a green economy, with focus on

environmental and energy indicators. To analyze the selected indicators, time series data from the International Energy Agency on performance on key energy and economic indicators from 1970-2012 have been used. However, only the performance in the period 1990-2012 has been analyzed. The data has also allowed for international comparison on green economy indicators.

A general challenge for all environmental policy evaluation is the impact or attribution problem, and to estimate to what degree the impact has been influenced by the policy under evaluation (Mickwitz, 2003). This is certainly the case for carbon taxation, and its considered challenging to estimate the effects of the carbon tax on CO_2 emissions. To understand how the carbon taxes have contributed to the performance on the green economy indicators, a systematic and horizontal review of secondary sources have been conducted according to criteria for environmental policy evaluation. The criteria include environmental effectiveness, equity/distributional effects, and effects on economic competitiveness, which are all relevant in the context of a green economy. Due to the limited scope of the thesis, no unique ex-post study has been conducted. Instead the research relies mostly on secondary sources, public statistical data, and interviews. To understand the effects of carbon taxation and carbon pricing mechanisms on a company level, two energy intensive companies are analyzed in a case study.

At the Global Green Economy Index, Nordic countries perform in top, with Sweden ranked as number one among 60 countries. And that is without undermining the economic competitiveness. Nordic countries also rank among top 20 countries on the World Economic Forums' Global Competitiveness Index. In general, this gives an indication that countries can be relatively environmentally sustainable and yet economically competitive. Regarding renewable energy, Nordic countries have a higher share of RES than for all EU countries. Norway, Sweden and Finland have high shares of RES of gross final energy consumption (33-65%), whereas Denmark's share is somewhat lower. In general, this gives an indication that Nordic countries have a relatively high share of renewable energy sources and higher national RES targets for 2020, compared to EU28. On socio-economic green economy indicators, Nordic countries performed well on the Human Development Index, have a lower Gini-coefficient than the OECD average, and have a higher share of employees working in the renewable energy sector than the EU28.

On energy and environmental green economy indicators, data from International Energy Agency (2014) show that Nordic countries have generally performed better than the OECD area in terms of CO_2 emissions/capita, carbon intensity, and emissions intensity (IEA, 2014). The Nordic countries have also improved their energy intensity in the period 1990-2012. All the Nordic countries have the same or lower per capita CO_2 emissions than OECD average, but still higher than the non-OECD average. The relative improvements since 1990 and compared with the OECD average, makes Nordic countries perform relatively well as green economies.

Regarding environmental effectiveness of carbon taxes, the ex-post studies that have been reviewed shows that carbon taxes have been key policy instruments to achieve climate and energy goals, and have been effective in combination with other policy instruments, such as energy taxes, other environmental taxes, investments, and regulations. The exemptions, which are common for carbon taxes, seem to have reduced the environmental effectiveness. Regarding the equity and distributional effects of carbon taxation, it has been shown that Denmark has the highest share of environmental taxation of GDP in EU28, and have also been most effective in revenue recycling of incomes from the carbon taxes. However, households pay a large share of energy taxation in Nordic countries. Incomes from carbon taxes constitute a significant revenue stream, and the transaction costs for administration are low. Regarding the effects of carbon taxation on industry competitiveness, it has been shown that the development of GDP PPP has been lower among Nordic countries (with the exception of Norway), than the OECD area between 1990-2012. But some studies for Denmark and Sweden indicate that industry competitiveness have not been undermined despite the carbon tax. However, all Nordic countries have applied differentiated carbon taxes, and also adjusted the taxes to the EU ETS.

Based on the findings, a few policy learnings/implications can be drawn regarding the use of carbon taxation to promote a greener economy. Among the implications are that countries that want to introduce more environmentally effective carbon taxes, uniform rates can be applied for all sectors. However, with regard to the risk for carbon leakage, which could undermine the mitigation potential of the policy from a global perspective. Further, experiences of carbon taxation in Nordic countries show that carbon taxes have been effective in combination with other policy instruments, including energy and environmental taxes, public investements in district heating infrastructure, regulations, and other incentives for households and industry. Therefore its important to consider the whole portfolio of instruments used to improve the performance on green economy indicators.

There is a momentum for carbon pricing mechanisms and the number of countries with carbon taxation has increased in recent years. Carbon pricing mechanisms are crucial for countries that want to adapt green economy policies. For countries that are interested to introduce carbon taxes, expriences from Nordic countries can be interesting for effective design and implementation.

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Abbreviations

CO_2 Carbon dioxide

CHP Combined heat and power

CMS Carbon management system

DG Distributed generation

ETR Environmental tax reform

EU ETS EU Emissions trading scheme

FIT Feed in tariffs

GE Green economy

GDP Gross domestic production

GHG Greenhouse gas

GGKP Green Growth Knowledge Platform

Gt Gigaton

IEA International Energy Agency

IPCC International Panel on Climate Change

KI Kaya identity

MCPE Multi-criteria policy evaluaton

OECD Organisation of Economic Cooperation and Development

PJ Petajoule

PPP Power purchase parity

PPP Polluter pays principle

RES Renewable energy sources

TPES Total primary energy supply

UNCSD United Nations Conference on Sustainable Development

UNDP United Nations Deveopment Programme

UNEP United Nations Environment Programme

UNFCCC United Nations Framework Convention on Climate Change

1 Introduction

Climate change is an urgent problem and deep emission cuts needs to be made within this century. According to IPCC 5th Assessment Report, the world needs zero net emissions by 2100 to stabilize temperatures at 2 degrees Celsius above pre-industrial levels. But with current development, global GHG emissions are expected to raise from 50 Gt CO_2e in 2010 to 59 Gt CO_2e in 2020. According to the PwC Low Carbon Economy Index (2014), "the annual rate of decarbonisation required for the rest of this century for us to stay within the two degree budget now stands at 6.2%" (PwC, 2014, p. 2). Such high rate of decarbonisation is five times higher the current rate, and needs to be achieved every year from now until 2100 to avoid the current trajectory with 3,7-4,8 degrees Celsius within the 21st century (ibid. 2014). Carbon pricing mechanisms is one way to address need for deep emission cuts. According to Ecofys and the World Bank, "The gap between the pledges and a 2°C pathway is estimated to be 10 Gt CO_2e. There is no doubt that increased action is needed. A central question is the role that carbon pricing can play in making this step-change" (Ecofys and World Bank, 2014, p. 89).

Increasingly many countries introduce carbon-pricing mechanisms, including carbon taxation and emissions trading schemes. According to the World Bank, 11 countries and sub-national states have introduced carbon taxation as of 2015, including Denmark, Finland, France, Iceland, Ireland, Japan, Mexico, Norway, Sweden, Switzerland, UK, and on the sub-national level, British Columbia. Also Slovenia has a carbon tax. Further, a carbon tax is scheduled in South Africa, and under consideration in Chile and South Korea. In total, 40 national and 20 sub-national jurisdictions have introduced carbon pricing mechanisms, taxation or Emission Trading Schemes (ETS). The number of countries with carbon pricing mechanisms has increased from 20 to 38 since 2012. Countries with carbon pricing mechanisms are responsible for almost 25% of global greenhouse gas (GHG) emissions. With around 50% of the emissions included in carbon pricing mechanism, it equals to 12% or 6 gigatons of global CO_2e that are priced. The share of emissions included by carbon pricing mechanisms has tripled during the last decade. According to the World Bank, there is a momentum for carbon pricing mechanisms. In 2014, the World Bank launched a number of initiatives to set a price on carbon for the UN Secretary General Climate Leadership Summit. 74 countries, 1000 companies (including 347 institutional investors) 23 sub-national jurisdictions, and 37 non-governmental organizations supported the initiative from the World Bank. According to the statement "Putting a price on carbon", "The momentum is growing. Pricing carbon is inevitable if we are to produce a package of effective and cost-efficient policies to support scaled up mitigation" (World Bank, 2014). 360 investors with USD 24 trillion in assets also signed the 2014 Global Investor Statement on Climate Change, calling for "stable, reliable and economically meaningful carbon pricing that helps redirect investment commensurate with the scale of the climate change challenge". These and other initiatives led to the creation of the Carbon Pricing Leadership Coalition (CPLC), which is a facilitating platform for dialogue between partners from private and public sectors. (World Bank, 2014; World Bank, 2015; Ecofys and World Bank, 2014)

Apart from "getting the prices right" with carbon pricing mechanisms and phasing out fossil fuel subsidies, major investments are required to transform the global economy to a low-carbon green economy. According to Ecofys and World Bank (2014), only the energy sector will require investments of USD 910 billion annually each year 2010-2050 to fulfill the technical mitigation potential, which is three times more than the current entire climate finance of USD 337 billion. These investments needs to come from both public and private actors, and carbon taxation can be one way to help countries finance investments into a greener economy.

Carbon taxes are relevant in the context of a transition to a "green economy", which was chosen as a key strategy to achieve sustainable development in the outcome document "The Future We want" at the United Nations Conference of Sustainable Development (UNCSD) in 2012. According to UNEP, a green economy can be defined as an economy that results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP 2011, p. 14). A green economy includes the economic, environmental and social dimension of sustainability. Green fiscal policy is crucial for the transition to a green economy, including carbon taxation and other carbon pricing mechanisms. Nordic countries, including Denmark, Finland, Norway and Sweden, were among the first to introduce carbon taxation in early 1990s. The carbon taxes can therefore be analyzed as drivers of greener economies in Nordic countries. As more countries strive to green their economies and consider introduction of carbon taxes and other carbon pricing mechanisms, it's interesting to learn from the experiences of carbon taxation in Nordic countries. Based on the experiences in Nordic countries, interested actors can learn about the design of the taxes and their effects.

1.1 Problem definition

Nordic countries have had carbon taxation since the early 1990's. However, based on the literature review in this thesis, no systematic reviews of how carbon taxes have contributed to greener economies in Nordic countries, using the green economy framework as discussed below has been found. According to Ecofys and the World Bank (2014), the energy intensity in Nordic countries has declined between 1990-2006. The strongest decline has been in Denmark and the most limited in Norway. However, its unclear, according to Ecofys and the World Bank to what extent the carbon taxes has effected these changes (Ecofys and World Bank, 2014). Energy intensity is one of many green economy indicators. One way to approach that research gap is to measure progress on green economy indicators for Nordic countries and review studies on how carbon taxation has contributed to the performance on these indicators. But to measure progress towards a green economy is challenging, and various indicators can be used. In this thesis, a mix of indicators will be used based on the literature about measuring progress towards a green economy and the overall purpose of the thesis.

Further, there is a lack of comparative studies on carbon taxation in Nordic countries. Kasa (2005) has done a critical review of three doctoral dissertations on carbon taxes in Denmark, Finland and Norway, and concludes that there is a lack of cross-national and comparative approaches in studies on carbon taxes in Nordic countries. According to Kasa, the studies also have a tendency to use institutionalist and public choice theory to explain why exemptions to the carbon tax have been given to industry in all Nordic countries. Kasa argues that existing studies have not enough looked at the role of external factors, such as international influence and economic context. There is a "comparative deficit" in the research on Nordic carbon taxation (Kasa, 2005). By adopting a comparative approach, Kasa argues that it could be easier to observe the influence of various different factors on the development of carbon taxation in Nordic countries (Kasa, 2005). The research gap can be met by doing a horizontal review of performance on green economy indicators across the countries, and a systematic horizontal review of ex-post studies on the effects of carbon taxes according to certain environmental policy evaluation criteria. Such a horizontal and systematic approach can allow for comparison between countries.

To understand how carbon taxes have contributed to greener economies, there is a need to conduct ex-post evaluations of the taxes. The numbers of ex-post studies of carbon taxes are limited, whereas ex-ante studies are more common. According to Bruvoll and Larsen (2004), the effects of price mechanisms in climate policy "remains unanswered empirically" (2004, p. 493). According to Andersen (2004), there are only around 20 empirical ex-post studies that investigate the effects of the CO_2 tax on emissions in the Nordic countries, and more ex-ante studies about carbon taxation in Nordic countries than ex-post studies. According to Kasa (2005) and Vehmas (2004), few scholars have analyzed the effects of the carbon tax in Finland. According to Lin and Li (2011) who have studied the effects of carbon taxes on CO_2 emissions/capita in Denmark, Finland, Norway, Netherlands and Sweden, most studies about carbon taxes are ex-ante simulations, and only few studies have an empirical analysis of the effects of carbon taxes. The COMETR study (2007) is among the most comprehensive ex-post study of carbon-energy taxes in seven European countries (Andersen et al, 2007). Ex-post studies of carbon taxes are resource intensive, and there are methodological challenges with attribution to determine to what extent carbon taxes have impacted levels of CO_2 emissions. According to Vehmas (2004), it's challenging to empirically estimate the economic and environmental effects of the CO_2 tax. Methods that can be used to study the effects empirically include case studies on a firm level, economic modeling, surveys, comparative studies, interviews, energy system modeling, and a combination of methods (Andersen, 2004; Kasa, 2005; Vehmas, 2004). Due to the limited scope of this thesis, it will not provide a unique ex-post analysis of the effects of carbon taxes, but instead a systematic review of ex-post studies of effects of carbon taxes according to certain evaluation criteria.

1.2 Purpose and research questions

The purpose of the thesis is to contribute to increase the understanding of how/to what extent carbon taxes has been a driver of greener economies in Nordic countries.

Research questions

(1) How do Denmark, Finland, Norway and Sweden perform on selected green economy indicators?
(2) What is the environmental effectiveness, equity and distributional effects and effects on industrial competitiveness of carbon taxes in Denmark, Finland, Norway and Sweden?
(3) How do carbon taxation and other carbon pricing mechanisms influence carbon risk management on a company level?

The research questions are relevant for the purpose of the thesis to understand the development on an aggregated level, contribution of carbon taxes according to specific critieria that are relevant for the green economy, and to understand the effects on a firm level.

1.3 Limitations

Iceland is also a Nordic country, but introduced a carbon tax in 2010, and is therefore not included in the study. Due to the limited scope, no unique ex-post study of the effects of carbon taxation has been conducted for this thesis, which is a major limitation. Many exemptions exist in Nordic carbon taxation, but due to the limited scope of the thesis, these exemptions will not be analyzed in detail. Another limitation of the thesis is that the effects of the carbon taxes on households will not be analyzed in depth. Further, the reviewed studies often refer to effects of both carbon-and energy taxes, and it's difficult to single out the effect of the carbon tax. A related limitation is the difference of explicit and implicit carbon prices, which have not been analyzed in depth and compared to other countries. Last, a limitation of the paper is the limited scope of the case studies, which does not provide sufficient data to make any final conclusions.

1.4 Outline

In section 2, the methods will be explained and justified. Section 3 introduces the theory around carbon taxation and green economy. Concepts and theory green economy, carbon taxation and externalities, and carbon risk management are included. The analysis is based on the green economy indicators and criteria for environmental policy evaluation, which are drawn from the literature review in section 3. In section 4, research question 1-3 will be analyzed based on empirical data. The paper is concluded in section 5. Bibliography, list of interviewees and appendix is located in section 6.

2 Methodology

2.1 Methods for data analysis

To address the purpose of the thesis of how/to what extent carbon taxes in Nordic countries has been a driver of greener economies, the research is carried out in three major analytical steps and follows a top-down approach based on indicators, evaluation criteria and carbon management at the firm level. These steps are elaborated below.

First, an indicator-based analysis is carried to address how Denmark, Finland, Norway and Sweden perform on green economy (GE) indicators. According to UNEP (2012), indicators can be useful when measuring progress towards a green economy. An indicator-based analysis allows for comparison between countries and development over time. Various studies have applied indicators to measure progress towards green economies, which will be addressed further under section 3.1.1. To measure progress towards a green economy is challenging, and there are multiple indicators in the economic, environmental and social dimension. The selected indicators for analysis in this paper are based on a literature review of progress indicators on green economy. The indicators are mainly chosen based on the UNEP report "Green economy – Measuring progress towards a green economy" (2012), and from an article on a multi-level evaluation framework to measure progress towards a green economy and evaluate policy instruments to promote GE by Mundaca and Cloughey (2012). The selection of indicators is motivated with regards to the purpose and scope of the thesis, and includes the economic, environmental and social dimension of the green economy. The indicators include:

I. Performance on Global Green Economy Index. Global Green Economy Index (GGEI). GGEI is a composite index of 32 indicators and measures performance and perceptions of 60 countries. The index is built on indicators in four dimensions including Leadership & Climate change, Efficiency Sectors, Markets & Investments, and Environment & Natural Capital. It measures both performance on some indicators, and perceptions by asking experts and practitioners in the field. (Tamanini et al, 2014)

II. Global Competitiveness Index (GCI) 2014-2015 from the World Economic Forum. Measures performance on key indicators for economic competitiveness in 144 countries. (World Economic Forum, 2014)

III. Percentage of renewable energy sources (RES) of gross final energy consumption. Gives an indication of the state of RES compared to EU28.

IV. Human Development Index (HDI). HDI includes twelve dimensions including health, education, incomes, inequality, gender, poverty, employment and vulnerability, human security, trade and financial flows, mobility and communication, environment and demography. (UNDP, 2015)

V. Gini-coefficient, measures the distribution of incomes among individuals, where 0 is absolute equality and 1 is absolute inequality. (OECD, 2015)

VI. Percentage of employees in renewable energy sector. Green jobs can be defined in various ways and based on the definition identified in various sectors. One way is to identify the percentage of employees working in the renewable energy sector, which gives an indication of a share of the green jobs. (EU Commission, 2015)

VII. CO_2 emissions/population, general indicator of the per capita impact, which allows for international comparison. The performance is compared with OECD and non-OECD to analyze the performance in international comparison.

VIII. Energy intensity, measured as Total primary energy supply (TPES)/GDP PPP. The energy intensity gives and indication of how the energy efficiency has developed in relation to the economic development. Data for GDP adjusted to Power Purchasing Parity from IEA (2014) is used to account for different purchasing power and allow for international comparison.

IX. Carbon intensity, measured as CO_2 emissions/Total primary energy supply. Carbon intensity gives an indication of how the carbon profile of the total primary energy supply has developed. The performance is also compared with OECD and non-OECD to analyze the performance in the bigger context.

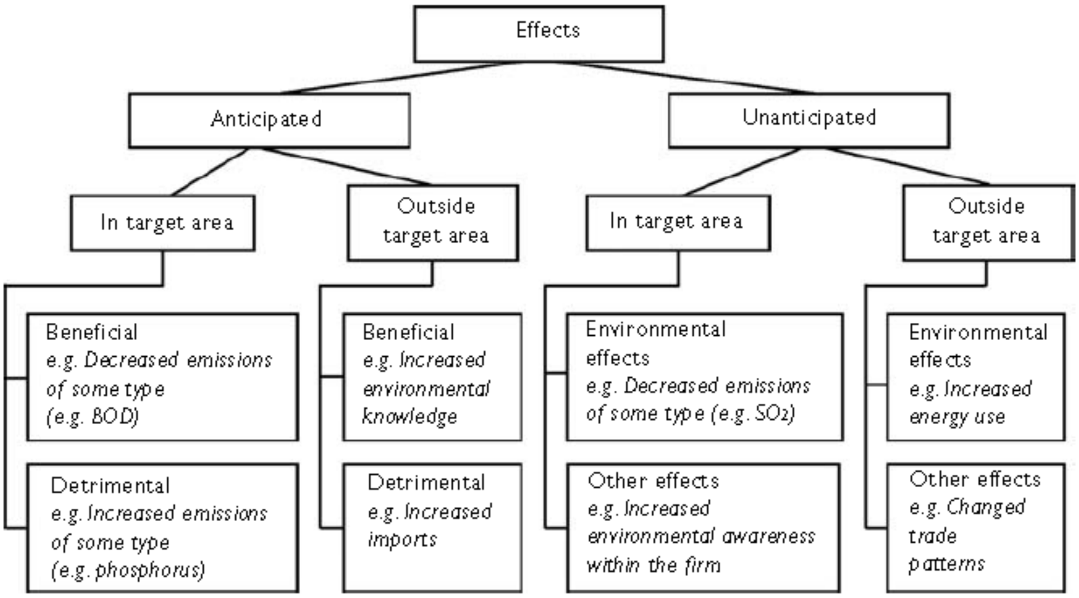
X. Emissions intensity, measured as CO_2 emissions/GDP PPP. Emissions intensity gives an indication of how carbon efficient the economy is. The performance is also compared with OECD and non-OECD to analyze the performance in the bigger context.

Apart from the indicators above, also the Kaya identity (KI) will be analyzed. The KI is a decomposition analysis used to understand the drivers of CO_2 emissions. The KI, is used according to IEA to identify drivers of CO_2 emissions, and expressed as C=P (G/P) (E/G) (C/E), where C= CO_2 emissions, P=population, G=GDP, E=primary energy consumption. According to IEA, the KI expresses "for a given time, CO_2 emissions as the product of population, per capita economic output (G/P), energy intensity of the economy (E/G) and carbon intensity of the energy mix (C/E)" (IEA, 2014). The KI can be used to discuss primary drivers of carbon emissions, according to IEA, however there are also limitations of the KI as there are many more drivers that influence CO_2 emissions and the factors in the KI influence each other. (IEA, 2014)

The analysis of performance on the indicators has been conducted in a horizontal manner, which allows for comparison between the four Nordic countries, OECD and non-OECD. The performance on the selected indicators can give an indication of how "green" the economies are in Nordic countries compared to other countries. However, many more indicators would need to be addressed to fully analyze the progress towards greener economies. For example, the performance on the GE indicator of CO_2 emissions/capita, can give an indication of how carbon taxes have contributed to greener economies. However, the changes in CO_2 emissions cannot be attributed solely to carbon taxation, but is a result of a policy mix and macroeconomic factors, as well as technology, behavioral changes, and weather.

Second, several evaluation criteria are applied to the specific case of carbon taxation across Nordic countries. To that end, a systematic critical review of existing ex-post studies on carbon taxation in Nordic countries is conducted. The review is conducted according to criteria for environmental policy evaluation as suggested by Mickwitz (2003). Criteria for environmental policy evaluation can also be applicable in the evaluation of policy to support a green economy transition (Mundaca and Cloughley, 2012). According to Mickwitz (2003), environmental policy has goals and side effects. Environmental policy can be evaluated based on its achievement in relation to the intended goals of the policy or based on the side effects that were unintended. Mickwitz summarizes anticipated and unanticipated effects in the table below.

Figure 2-1. Classification of effects of environmental policy



Source: Mickwitz, 2003, p. 423

To address the specific performance of carbon taxation across Nordic countries, policy evaluation criteria are applied. Policy evaluation is fundamentally normative in character and evaluation criteria (e.g. environmental effectiveness) are used for normative judgments about the effects of carbon taxation in our case. Three criteria for environmental policy evaluation have been selected, based on a framework from Mickwitz (2003) and an article on how to evaluate policy instruments to promote GE by Mundaca and Cloughey (2012). Based on the above, and considering the aims of a GE to include social equity, reduced environmental impacts, and economic competitiveness, selected criteria include environmental effectiveness, equity and distributional effects, and effects on industry competitiveness.[1] The criteria have been selected with regards to the overall purpose and scope of the thesis.

I. *Environmental effectiveness* refers to the effects that the carbon taxes have had on the level of CO_2 emissions, as the main goal to of carbon taxation is often to influence the levels of CO_2 emissions.

[1] General criteria for evalutation of environmental policy can include relevance, impact, effectiveness, persistence, flexibility and predictability. Economic critera for evaluation can include cost-benefit analysis or cost-effectiveness analysis (if the same benefits could have been achieved for a lower cost). Further, criteria for evaluation that are more social can include legitimacy, transparency, and equity. A side effect can be the influence on industrial competitiveness. (Mickwitz, 2003)

II. *Equity and distributional effects* refers to how large the incomes from the carbon and other environmental taxes are in Nordic countries, how the tax revenues have been used, and how the costs of the carbon tax are distributed between different sectors. This dimension is important, as equity aspects of environmental taxes are highly relevant for their legitimacy.
III. *Effects on industry competitiveness* include effects of the carbon taxes on business/industry sector.

Carbon taxation most often has the main purpose to reduce carbon emissions, and therefore environmental effectiveness and effects on levels of CO_2 emissions is the first criteria. The second criteria are equity/distributional effects, which include the distribution of costs between households and industry, and how tax revenues have been used. Equity is of major importance in the GE policy discourse (UNEP, 2011), for all tax policy, and environmental taxes (Andersen, 2010). The third criterion is effects on industrial competitiveness, with increased competitiveness also being a key element in the GE policy discourse. To promote the industrial competitiveness is not a main goal of carbon taxation, but the design of the carbon taxes in Nordic countries is based on environmental as well as economic considerations. Carbon taxes in Nordic countries are designed to consider effects on industry sector, and therefore it's a relevant criterion to address. Economic competitiveness is also important for a green economy, and most likely a concern for countries that consider the introduction of carbon pricing mechanisms.

Thirdly, the carbon management on a firm level is addressed from a GE perspective. The firm level perspective adds a crucial aspect, as an important part of the green economy is to maintain or even enhance economic competitiveness by introducing regulation and economic incentives. Economic competitiveness is also relevant for carbon taxation, as companies can gain first mover advantages by adopting more sustainable practices, as suggested by Porter (Andersen, 2010). The case study will also highlights the interaction of carbon taxation with other policy instruments, such as EU ETS on a firm level. Background about the case study will be elaborated in section 2.4.

Depending on data availability (from secondary sources), the analysis is mostly qualitative, and partially quantitative.

2.2 Methods for data collection

The study at hand calls for data to be collected from a variety of sources to approximate objectivity and reduce inevitable uncertainty. Methods for data collection include literature review of secondary sources, information from primary sources and interviews. For the analysis on performance on green economy indicators and effects of carbon taxes according to criteria for environmental policy evaluation, information is gathered from:

I. Peer-reviewed articles from academic journals and grey literature on carbon taxation and green economy.
II. Time series data on performance on key energy and economic indicators between 1971-2012, from International Energy Agency (IEA) (2014).
III. Public statistical sources on environmental economics and environmental taxation from all the four Nordic countries and Eurostat.
IV. Country reports to the UNFCCC
V. Interviews (see section 6.1 for list of interviewees)

For the case study on a firm level, the role of carbon taxation and other carbon pricing mechanisms for carbon risk management are investigated through analyzing the following data:

I. Peer-reviewed articles on carbon risk management
II. Data on CO_2 emissions from plants included in EU ETS, 2005-2014, from the Swedish Environmental Protection Agency (Naturvårdsverket, 2015)
III. Annual and sustainability reports
IV. Interviews (see section 6.1 for list of interviewees)

To complement the data of secondary sources, interviews have been conducted with experts on carbon taxation in the Nordic countries as well as general experts on carbon taxation/carbon pricing mechanisms and energy management. The interviews have been semi-structured and conducted over phone. Interviewees include researchers in the field of environmental economics and environmental policy, representatives for international organizations, economic policy research institutes, public committee on environmental objectives, and representatives from industries. Interviewees are listed in section 6.1.

2.3 Carbon taxes in Nordic countries

The tax rate and tax base of the carbon taxes in Nordic countries varies. The table below summarizes the main features of the tax rate, tax base, and the share of GHG emissions that are covered by the carbon taxes.

Table 2-1. Carbon taxes in Nordic countries

Country	% of GHG emissions covered by carbon tax	Carbon tax level, 2014	Tax base
Denmark	45%	DKK 167/t CO_2 (US$31/t CO_2)	Oil, coal, natural gas, electricity. The rate is based on carbon content.
Finland	15%	Heating fuels €30/t CO_2 (US$41/t CO_2) to €35/t CO_2 (US$48/t CO_2) Traffic fuels €60/t CO_2 (US$83/t CO_2)	Energy and CO_2 tax on petrol, diesel, fuel oil, aviation kerosene, coal, natural gas. Designed as an energy tax which also include carbon content.
Norway	50%	NKK 25–419/t CO_2 (US$4–69/t CO_2)	Petrol, diesel, mineral oil, offshore petroleum sector, natural gas, LPG. A special rate is set per fuel.
Sweden	25%	SEK 1076/t CO_2 (US$168/t CO_2)	Fossil fuels for heating, transport and electricity. The rate is based on carbon content of fuels.

Source: Ecofys and World Bank, 2014; Withana et al, 2013

The carbon taxes in Nordic countries have changed continuously since the introduction in the early 1990's. In Denmark, the CO_2 tax has increased since 1992 but remained relatively stable since 2002. Between 2008 and 2015 it was raised by 1,8% annually (Ministry of Climate, energy and building, 2013). In Finland, the tax is designed as an energy and CO_2tax, based on the energy content and carbon content in fuels. The tax base includes transport and heating fuels, whereas fuels for electricity production are exempted, and instead there is an output electricity tax (Withana et al, 2013). In Norway, which has the second highest carbon tax in the world after Sweden, the tax level increased in 2013 for mineral oil and natural gas as well as fuel use in domestic aviation (Ecofys and World Bank, 2014). Sweden has the highest general level of the carbon tax in the world of SEK 1076/t CO_2 (US$168/t CO_2) from 2014 (Ecofys and World Bank, 2014). However the tax only covers 25% of the GHG emissions (ibid. 2014). In Sweden, peat and biofuels are exempt from the carbon tax (Ministry of the Environment, 2014). Since the CO_2 tax was introduced in 1991 along with a large tax reform, and it has been subject to several changes.

2.4 Case study

Two energy intensive Swedish industrial companies have been selected to study how carbon-pricing mechanisms have influenced their environmental management. The companies have been selected, as they are energy intensive and account for a large share of CO2 emissions from the Swedish industry sector.

The first company, LKAB, is a publically owned mining company producing iron ore pellets and fines. In 2014, the company produced around 26Mt iron ore products, of which 77% was exported to steelworks in Europe, and it's the fourth largest iron ore pellets producer in the world. The company is owned by the Swedish state and made a profit of SEK 570 million in 2014. The company is going through a phase with large investments, and plans to open 3 new mines upcoming years. (LKAB Annual and Sustainability Report, 2014)

The second company, SSAB, is a Swedish based steelmaker with production in Sweden, Finland, US, operating in 50 countries, and a leader in high strength steels. The company had sales for SEK 47 billion and a profit of SEK 894 million in 2014. The steel industry accounts for around 4-5% of global CO_2 emissions, and the steel industry has a long history in Sweden. (SSAB Sustainability Report, 2014)

However, the data about the companies is limited, and further research would be needed to address the complexity of drivers and effects of carbon taxation and other carbon pricing mechanisms on the environmental management of the companies.

3 Theoretical framework

3.1 Green economy

The concept of green economy has gained increased popularity since the financial crisis in 2008, but the concept is not new. In the seminal piece "Blueprint for a Green Economy", Pearce et al first established the green economy concept in 1989 (Mundaca and Cloughley, 2012). With the financial crisis in 2008, UNEP established the Green Economy Initiative (GEI). International institutions such as OECD, IMF, World Bank, WTO and UNEP have largely formulated the green economy agenda (Fergusson, 2015). In 2011, UNEP launched the report "Towards a green economy: Pathways to sustainable development and poverty eradication", where sectors that are crucial for the green economy and enabling conditions are identified (UNEP, 2011). The report also includes five scenarios in the "Threshold 21" model with global average data from 1970-2050. The result shows that the most beneficial scenario (G2) is where 2% of global GDP is invested in the green economy. Benefits include higher employment, incomes, low-carbon economies and water security (Fulai, 2013). At the UNCSD in 2012, the "green economy within the context of sustainable development and poverty eradication" was a main theme together with an institutional framework for sustainable development. In the Rio+20 outcome document "The Future We Want", governments gave high priority to the green economy as a means to achieve sustainable development. However, poverty alleviation was established as the biggest challenge. There are various definitions of the green economy concept, and a debate regarding its implications, practical application, and relation to sustainable development, social and environmental justice, and environmental risks. The concept has received interest among policy makers, companies, and academic interest. There is no agreed upon definition of the green economy, and there are several similar, and sometimes synonymous concepts with green economy, including low-carbon economy, green energy economy, clean energy economy, and green growth (Mundaca and Cloughley, 2012).

According to UNEP, a green economy can be defined as an economy that results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP 2011, p. 14). The green economy is resource efficient, low-carbon and socially inclusive, where "growth in income and employment are driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services." (Ibid. 2011, p. 14). According to UNEP, the aim of a green economy is to create economic growth, along with improved environmental quality and social inclusiveness. According to UNEP, the concept of a green economy does not replace the goal of sustainable development, but rather highlights the role of the economy in achieving sustainable development. The transition to a green economy will look different in different countries depending on the natural and human resources available. Enabling conditions for a transition to a green economy includes regulation, subsidies, incentives, and public intervention to spur innovation. According to UNEP, a green economy can result in direct welfare improvements but also contribute to attain future economic growth. (UNEP, 2011)

Critique has been raised to the concept of green economy, that it doesn't give enough attention to social justice, and fails to recognize to economic growth on a finite planet (Bailey and Caprotti, 2014; Wanner, 2015). Discussion has also been raised regarding how to make sure there is a just transition, and how labor unions can contribute to just transition strategy (Stevis and Felli, 2014). According to Ehresman and Okereke (2015), the green economy concept can be analyzed critically for its transformative potential and its relation with sustainable development. Regarding its transformative potential, various definition of the concept exists that are more or less transformative. According to Ehresman and Okereke "mainstream conception of the green economy is entirely misguided insofar as it fails to adjust to the scientific evidence of the limitations of the endless growth paradigm" (2015, p. 19). Faccer et al (2014) identifies three streams of thought within the green economy discourse, the incrementalist with focus on green growth, the reformist with focus on decoupling and dematerialization, and the transformative with focus on steady state economy and de-growth. Also Fergusson (2015) identifies three views of green economy, a strong, transformational and a weak green economy. The tensions in the debate on green economy include the view of ecological limits and carrying capacity, economic growth, valuation and creation of markets for ecosystem services, rebound effects, etc. Critique regarding the transformative potential of the green economy is also raised by Victor and Jackson (2012), that analyses the UNEP report "Towards a green economy: Pathways to sustainable development and poverty eradication", and argue that it's G2 scenario fails to deliver sufficient reductions of CO_2, is based on average global data and doesn't account for the big variations between countries and regions, and is not well developed regarding opportunities for additional investments of 2% of global GDP to a greener economy.

Regarding sustainable development, Fergusson (2015) argues that the sustainable development concept is vague; whereas the green economy is more concrete and easier to operationalize. With regard to sustainable development, three streams of thought can be identified, according to Ehresman and Okereke, where the green economy concept could have a replacing effect, a facilitating effect, or a reinforcing effect for sustainable development. According to Bina (2013), the green economy concept has brought an economization of sustainable development. In "The Future We Want", a green economy is seen as a tool or strategy to reach sustainable development, but according to Bina, the document has failed to deliver the message that something fundamental must change in order to achieve sustainable development.

3.1.1 Measure progress towards a green economy

Measuring progress towards a green economy is a challenge. To measure the progress, there is a need for appropriate indicators on the macro-level and sector-level. Indicators are useful in the process of agenda setting, in designing policy, and in the process of monitoring and evaluating policy. Using conventional macro indicators such as GDP is not sufficient, as these can provide a distorted lens, according to UNEP (2012). Ideally, according to UNEP, would be to evaluate the stocks in natural capital in monetary terms and include these in the national accounts. An attempt to achieve this is developed in the System of Environmental and Economic Accounting (SEEA), and World Bank net saving methods. These methods of Green Accounting and Inclusive Wealth Accounting are available methods and some countries have implemented these (UNEP, 2012).

To measure progress, there are various index, and among these the Global Green Economy Index that is a composite index of 32 indicators, and measures performance and perceptions of 60 countries. The index is built on indicators in four dimensions including Leadership & Climate change, Efficiency Sectors, Markets & Investments, and Environment & Natural Capital (Tamanini, 2014). On firm level there is the NASDAQ OMX Green Economy Index (QGREEN), which is designed to capture performance on sustainability in companies in various sectors (UNEP, 2012). On the EU level, European Commission has developed the iGrowGreen assessment framework based on 70 indicators for 27 Member States in EU since year 2000. The indicators are divided in areas of Environmental tax reform and fiscal consolidation, strengthening market functioning and competitiveness, Boosting new sources of growth, and Climate change and biodiversity. The tool allows for comparison between EU Member States and can help policy-markers to identify challenging areas to reach EU 2020 goals.

UNEP (2012) suggests in the report "Measuring Progress Towards an Inclusive Green Economy", that indicators for measuring progress on green economy can be divided into 1) General indicators for environmental issues and targets, 2) Indicators for green economy policy interventions, and 3) Indicators for green economy impacts on wellbeing and equity. Examples of general indicators for environmental issues could be for climate change, for example Carbon emissions (ton/year), Renewable energy (share of power supply) (%) and Energy consumption per capita (Btu/person). For resource efficiency indicators could be Energy productivity (Btu/USD), Material productivity (ton/USD), Water productivity (m3/USD), CO_2 productivity (ton/USD). Environmental indicators could also include Ecosystem management and Chemicals and waste management. Examples of indicators of green economy policy interventions could be for Green Fiscal Reform, Fossil fuel, water and fishery subsidies (USD or %), Fossil fuel taxation (USD or %), and Renewable energy incentive (USD or %). For policies that aim to Pricing externalities and valuing ecosystem service, suggested indicators could be Carbon price (USD/ton) and Value of ecosystem services (e.g., water provision). Suggested indicators for Green job skill training could be Training expenditure (USD/year and % of GDP) and Number of people trained (person/year). Green economy policy indicators can also be developed in the area of Green investments and Green Public procurement. (UNEP, 2012)

According to UNEP (2012), wellbeing and social equity indicators can include performance on Millennium Development Goals, Human Development Index, Ecological footprint, employment and Gini-coefficient. According to ILO, employment in green sectors or "green jobs" can be defined as "those jobs maintained or created in the transition process towards a green economy that are either provided by low-carbon intensive industries (enterprises) or by industries (enterprises) whose primary output function is to greening economy" (UNEP, 2012, p. 21). To measure employment in the Environmental Goods and Services Sector (EGSS), and Eurostat has developed a method how to define green sectors, investments and employment.

Apart from UNEP, there are other organizations proposing indicators on green economy and green growth. OECD proposes a number of "Green Growth" indicators that includes 1) The socio-economic context and characteristics of growth, 2) Environmental and resource productivity, 3) Natural asset base, 4) Environmental quality of life, and 5) Economic opportunities and policy responses (OECD, 2011). According to the Green Growth Knowledge Platform's (GGKP) report "Moving towards a Common Approach on Green Growth Indicators" (2013), the task of identifying indicators to measure progress on a "complex and multi-dimensional change" is a challenging task and there is not yet any agreement on analytical framework or indicators to monitor green growth and green economy (GGKP, 2013, p. 4). However, GGKP suggests a number of indicators for Environmental and resource productivity/intensity indicators, in the area of energy that could include GDP per unit of TPES and Energy consumption per capita. For carbon, suggested indicators could be GDP per unit of energy-related CO_2 emitted and Renewable energy (% of electricity power generation). Suggested indicators for policy instruments, includes Level of environmentally related tax revenues, Energy pricing (share of taxes in end-use prices), Environmentally related subsidies, Fossil fuel taxation, and Renewable energy incentives (GGKP, 2013, p. 17). Challenges ahead for indicators of green economy, includes harmonization of definitions and measurements to allow for comparability between countries, improving capacity in many countries for collecting data, constructing indicators, increasing transparency of the indicators, and last interpretation and communication on performance on the indicators (GGKP, 2013).

Mundaca and Cloughley (2012) propose a multi-level evaluation framework to measure progress towards a green economy and evaluate policy instruments to promote GE. The framework includes (1) multi-criteria policy evaluation, (2) socio-economic carbon and energy indicators, and (3) genuine savings. Adopted from Mickwitz (2003), the multi-criteria policy evaluation (MCPE) can include various criteria. The socio-economic carbon and energy indicators include energy intensity (TPES/GDP PPP), emissions intensity (CO_2/GDP PPP), and carbon intensity (CO_2/TPES). To find the drivers of carbon emission levels, it can also be useful to analyze the Kaya identity, which builds on the IPAT equation and is used to assess various key aspects that drive CO_2 emission levels. (Mundaca and Cloughley, 2012)

Various studies have also applied indicators to measure progress towards a green economy. Chen et al (2011), applies green economy indicators to assess progress towards sustainable development in Taiwan. Indicators include ecological footprint and an energy analysis. The ecological footprint index allows for comparison between countries and identification of an ecological deficit. The energy analysis includes energy indicators such as total energy use, share of renewable energy, and per capita energy use. The analysis also allows for comparison with other countries. To support the analysis, other indexes are also mentioned, such as Human Development Index, World Bank Genuine savings Index, World Bank World Development Indicators, WWF Living Planet Index, and World Economic Forum's World Competitiveness Index. Other studies that measures progress towards a green economy includes Gibbs and O'Neill (2015) that applies green economy indicators on the UK building sector. Musango et al (2014) has analyzed a transition to a green economy for the South African power sector, Snell and Schmitt (2012) has analyzed electricity companies' contribution to a green economy in the Australian power sector, and Mundaca and Luth Richter (2014) have assessed US programs targeting renewable energy according to green energy economy indicators. Regarding practical application of green economy policy, Faccer et al (2014) concludes that there is only limited information about practical applications of green economy policies and transitions in developing countries.

3.2 Externalities and carbon taxation

Externalities can be regarded as a market failure that can be corrected by introducing taxes that will internalize external costs, and thereby incentivizing change in behavior, technology and investments. CO_2 taxes are beneficial as they allow actors on the market to choose the most cost-effective solution to reduce their CO_2 emissions. Carbon- and energy taxes are considered among the least costly and distortive fiscal policy instruments, and there are many potential co-benefits. (Speck, 2014)

According to Speck (2014), there are two streams of economic theory on carbon taxation. The first streams is according to Pigou, where the tax should be set on a level where the marginal social cost is equal to the marginal benefit from another unit of pollution, and thereby ensure that the social cost of pollution is internalized. It's challenging to estimate the social cost of CO_2 emissions, and some levels are too low to incentivize actors to invest in low carbon energy systems. To create economic incentives for a low carbon development, World Business Council for Sustainable Development, show that a global carbon price of €81-162 per tone CO_2 is necessary to enable a transition to a low carbon economy (WBCSD, 2012). The second stream of economic theory on carbon taxation comes from Baumol and

Oates, and represents a more pragmatic approach where the carbon tax rate should be set in order to meet certain environmental objectives (Speck, 2014). According to Ecofys and World Bank (2014) a recent study shows that USD 35/t CO_2 is an appropriate level, but that a majority of the existing carbon tax schemes is below that level (Ecofys and World Bank, 2014). The expectation is that carbon taxes will contribute to improved energy intensity and carbon intensity (Andersen, 2010).

Although carbon taxes can be ideal according to economic theory with an identical tax rate for all areas, they are, according to Speck (2014), in reality designed in various ways to fit the national context and with consideration to competitiveness and social equity. This is also the case for Nordic countries. Carbon taxes can also be designed in innovate ways, such as the "catch up rate" where the carbon tax level is adjusted according to achievement on emissions targets. Another innovative design feature, is the "carbon floor price" that was introduced in the UK in 2013 of €20 per tone CO_2, with the aim to be increased to €38 in 2020, also for the sector included in the EU ETS. (Speck, 2014)

Regarding the design, carbon taxes can be revenue generating or revenue neutral, and part of tax-shifting programs, environmental tax reforms (ETR) or green tax-shifts. A review of experiences with carbon and energy taxes in selected OECD countries from the Institute for European Environmental Policy Institute shows that most countries consider a number of factors in the design of carbon taxes and that the design varies between countries (Withana et al, 2013). First of all, the objectives of ETR can vary, shift over time, and fulfill multiple objectives. Differences in design of the taxes exist regarding the tax base, the tax rate for various fuels and users, and the evolution of the taxes over time. Exemptions or tax reductions exist in most countries, with regards to competitiveness for the industry sector. Differences also exist regarding how the revenues are used; some countries have used carbon-and energy taxes to reduce taxes on labor, others for fiscal consolidation, or to achieve other environmental objectives. Countries also use different mechanisms to recycle the revenues back into the economy. (Withana et al, 2013)

Carbon taxes can also contribute to co-benefits and reach objectives in other areas, such as fiscal consolidation and to a low-carbon green economy (Speck, 2014; Cotrell et al, 2010; Withana et al, 2013). According to the double dividend hypothesis, environmental taxes can shift the tax burden from labor and capital to pollution and thereby create benefits of increased employment and reduced environmental impact. According to Withana et al (2013), carbon-and energy taxes can also have a positive impact on GDP growth. Other benefits of carbon taxes can be reduction of other environmentally harmful air emissions, increased share of renewable energy, innovation, and diffusion of new technology. ETR and environmental fiscal reforms (EFR) including carbon-pricing mechanisms can also contribute to employment opportunities in low-carbon sectors. A positive impact on employment depends on how the tax revenues are recycled back into the economy.

The largest share of revenues from carbon taxes comes from transport fuels (Cotrell, 2010). Therefore, carbon taxes can have an element of regressivity and affect low-income household most. The regressivity is a common reason for opposition against introduction of environmental taxes. To compensate for the negative effects, revenues can be directed to compensate the groups hit by the negative distributional impacts. However, studies indicate that this is the case for household heating fuels; whereas carbon-and energy taxes for transport fuels can even be progressive (Andersen, 2010). Studies also indicate that value added taxes (VAT) can be more regressive than environmental taxes (Andersen, 2010).

Carbon taxes can have multiple benefits, but cannot guarantee a maximum level of emissions, and can therefore fail to deliver absolute emission reductions. Therefore, carbon taxes and emission trading schemes (ETS) can work in conjunction and complement each other to reach emissions targets. According to Ecofys and World Bank (2014), the discussion on carbon taxes vs. ETS is "defusing". As more countries introduce carbon-pricing mechanisms, taxes or ETS are the most common mechanisms, where a tax can guarantee a price of emissions, and a trading scheme can provide a limit for the emissions through the cap, but prices can be volatile.

Fiscal policy, including carbon taxation, is of central importance to steer towards a green economy (Jones, 2011). Fiscal policy to promote a green economy includes taxes, charges, phasing out environmentally harmful subsidies and getting the prices right. It also includes tax shifts and using revenues to promote a green economy or compensate for distributional effects, and public investments in infrastructure. Green taxation accounts for around 1,7% on average among OECD countries, and has the potential to account for up to 15% of tax revenues (Jones, 2011). According to Jones, fossil fuels are under taxed in many countries and "more rational taxation of fossil fuels, for example, is urgently needed, both to limit climate change and control wider social and environmental costs" (2011, p. 339). Also, in many tax systems exemptions exist for fossil fuels, and according to Jones "raising and systemizing rates across fuel types according to their carbon content, and removing major exemptions, are therefore critical priorities." (2011, p. 340). Challenges with policy design includes regarding pollution as a tax base and to define the tax rate. According to Jones (2011), some studies indicate that the tax level should be around USD 150/tone CO_2 to promote a shift from fossil fuels to renewable energy. Apart from green taxation, reform of environmentally harmful subsidies is a key priority to promote a green economy. With stable fiscal policy, investments that are urgently needed can be encouraged. (Jones, 2011)

3.3 Carbon risk management

Where carbon prices are low or missing, companies increasingly introduce shadow carbon prices, or other methods for carbon risk management, as one expects prices to increase in the future. Around 150 global companies use shadow carbon prices as a tool for strategic decision making, and it's becoming a more common tool for business strategy (Carbon Disclosure Project, 2014).

Organizations face risks with climate change. According to Busch and Hoffman (2007), corporate risk assessments have traditionally focused on "tangible uncertainties" which are easy to quantify. Risks related to resource constraints and prices of fossil fuels can be considered carbon constraints. Despite the fact that many companies face risks related to climate change, it's often not considered a risk factor. Due to the high complexity to estimate the risks and costs of climate change, it's often not integrated in risk management (Busch and Hoffman, 2007). Busch and Hoffman (2007) suggest three steps for companies to deal with carbon risk management. First step is to recognize the importance of the issue and how it affects the company. Second step is to determine the company's exposure to carbon constraints. And third step is to develop a management strategy.

A carbon management system (CMS) can be adopted to reduce carbon emissions and communicate a company's commitment. Tang and Luo (2014) have developed a framework for CMS that contains four perspectives, including carbon governance, carbon operations, emission tracking and reporting, and engagement and disclosure. Within the four dimensions, ten essential elements for a management system are included (see framework of carbon management system elements in appendix 6.2). According to Tang and Luo, companies with a high quality CMS can have bigger success in carbon mitigation.

Carbon governance includes the board function and establishment of a climate committee within the board that that can establish ambitious targets, mobilize resources and develop policies. Another element within the carbon governance is the risk and opportunity assessment where carbon related risks and opportunities are identified according to their significance for the operations. According to Tang and Luo (2014), this risk and opportunities can be regulatory or climate change related, where the most significant risks are often regulatory. Last, it includes staff involvement and engagement for the targets and policies. *Carbon operations* include establishing emissions targets, which is important for developing actions, allocating resources and staff, and communicate the commitments to stakeholders. Another element of carbon operations is policy implementation, where the carbon strategy, policy and actions should be implemented. Last, the carbon operations include supply chain emission control where a cradle-to-grave inventory of the emissions generated by a product or service should be investigated. Emissions generated downstream and upstream in a products value chain might be large, and needs to be considered for effective mitigation. *Emissions tracking and reporting* include carbon accounting, which is a necessary step for estimating the CO_2 emissions. In the carbon accounting, data on GHG emissions is collected and measured, to enable decision-making and third party assurance. Tracking and reporting also includes carbon assurance with audit and third party assurance of the GHG emissions. Last, the carbon management system includes an *Engagement and disclosure perspective*. First, it includes engagement with external stakeholders, which can help the company to improve its success in the CMS. External stakeholders can include non-governmental organizations and government agencies. The engagement and disclosure perspective also includes disclosure and communication, where a high degree of transparency can allow external stakeholders to follow the progress. (Tang and Luo, 2014)

The most relevant element in the context of carbon taxation is the policy implementation, which is a part of the carbon operation perspective. The CMS framework suggested by Tang and Luo (2014) is based on practices in environmental management systems (ISO 14001) and carbon practices. According to Tang and Luo, previous studies have analyzed the benefits, drivers and importance of CO_2 mitigation in companies, "but have not investigated how managers operationalize external pressure and translate incentives into strategic actions to establish a carbon management system (CMS) to cut emissions" (Tang and Luo, 2014, p. 84). Managers can use the CMS framework to implement and improve carbon mitigation strategies.

4 Result and analysis

4.1 General green economy indicators of environmental issues and targets

In the following section, the performance of Denmark, Finland, Norway and Sweden on general green economy indicators of environmental issues and targets will be analyzed. The 10 indicators are selected from the literature review on how to measure progress towards a green economy. The performance on the indicators is analyzed by comparing the performance among the Nordic countries, and in some cases with other areas/countries. The performance on the selected indicators can give an indication of how "green" the economies are in Nordic countries compared to other parts of the world. However, many more indicators would need to be addressed to fully explore the progress towards greener economies in Nordic countries. Also, the reasons why the countries perform as they do on these indicators will only partly be explored.

4.1.1 Performance on indexes, and socio-economic indicators

All Nordic countries score high on the Global Green Economy Index (GGEI) both in perception and performance (Tamanini et al, 2014).

Table 4-1. Performance on the Global Green Economy Index (GGEI), 2014

Country	Perception	Performance
Denmark	2	5
Finland	9	8
Norway	4	2
Sweden	2	1

Source: European Environment Agency, 2014

On the Market and Investments dimension, Denmark scores as a number one on the performance rank and number four on the perception rank of top markets for green investments and development of cleantech markets. Other countries in top of this aspect are United States, China and Germany. Denmark also scores especially high on the Efficiency sector, which is part of the composite index. In the Efficiency Sectors, Norway scores third place both on perception rank and performance rank. According to Tamanini et al (2014), Finland performs well on green economy in Efficiency Sectors and Market and Investments, but is behind the other Nordic countries on the overall index. According to the GGEI report for 2014, Norway scores top 10 despite being an exporter of oil and gas, because it promotes a green economy at home. However, Norway performs below the other Nordic countries in the category Markets and Investments and could improve in that field. Last, Sweden scores high on the GGEI. In Efficiency Sectors, Sweden scores number one both in perception and performance. For Market and Investments, Sweden scores eight place on perception rank and fourth place on performance rank. According to the GGEI 2014 report "Much like Germany, Sweden is a best practice case for how to translate a genuine commitment domestically to green economy into a strong global green reputation" (Tamanini et al, 2014, p. 44). Germany scores as number one on the perception rank. (Tamanini et al, 2014)

Nordic countries also score high at the Global Competitiveness Index (GCI) 2014-2015 from the World Economic Forum. Out of 144 countries, Denmark scores number 13, and is especially high on innovation and sophistication with number 9 out of 144. Finland is number 4 out of 144 countries, and also scores especially high in innovation and sophistication with number 3 out of 144. Norway scores number 11 out of 144, and scores well in the basic requirements of infrastructure, investments, and macro economic conditions with number 6 out of 144. Sweden scores number 10 out of 144, and scores well on innovation and sophistication with number 7 out of 144. (World Economic Forum, 2014)

Both the GGEI and GCI are composite indexes with indicators in dimensions that are relevant for both the environment and the economic competitiveness. The fact that Nordic countries score relatively high on these indexes means that the carbon taxes in place in Nordic countries have not necessarily been negative for the economic competitiveness. However, the situation and economy in Nordic countries are unique and the effects of carbon taxes in other contexts would not be identical.

Another general green economy indicator is the share of renewable energy. The table below summarizes the share of renewable energy sources, and targets for 2020.

Table 4-2. Renewable energy sources (RES) % of gross final energy consumption, 2012

Country	Average share of RES, 2011-2012 EU28, 14%	2020 target EU28, 20%
Denmark	25%	30%
Finland	33%	38%
Norway	65%	68%
Sweden	50%	49%

Source: European Environment Agency, 2014

Among all EU28 countries, the share of renewable energy of gross final energy consumption was 14,1% in 2012, 15,6% for heating and cooling, 23,5% for electricity, and 5,1% for transport fuels. The share of RES of gross final energy consumption in EU28 has grown from 8,5% in 2005. The target for 2020 is 20% RES. Of EU28 countries, Sweden had the highest share of RES in 2011-2012, followed by Latvia, Finland and Austria. The lowest shares of RES in 2011-2012 was found in and Malta (1%), Luxemburg (3 %), followed by Netherlands (4%), United Kingdom (4%), Belgium (6%). Neither Norway nor Iceland are in the European Union, but have the highest share of RES with 65% and 76% respectively. Nordic countries have a higher share of renewable energy than other countries in EU28, according to the European Environment Agency (2014). All Nordic countries also have higher renewable energy targets for 2020 than the EU target. (European Environment Agency, 2014)

One reason for the higher share of renewable energy among Nordic countries can be the fact that these have had carbon taxes in place since the early 1990's. However, it's difficult to establish the correlation between carbon taxes and renewable energy sources, and there are many policy instruments in place that have influenced the share of RES.

Performance on the social dimension of the green economy can be measured by performance on the Human Development Index (HDI), Gini-coefficient and share of green jobs in the work force. The table below summarizes the performance of Nordic countries on these social indicators.

Table 4-3. Performance on socio-economic green economy indicators, Nordic countries

Country	Human Development Index, 2014	Gini coefficient, 2012 OECD average, 0,31	Employment in renewable energy sector, % of total employment, 2012 EU27 average, 0,7%
Denmark	Rank 10	0,25	2,1%
Finland	Rank 24	0,26	1,3%
Norway	Rank 1	0,25	No data
Sweden	Rank 12	0,27	1,1%

Source: UNDP, 2014; OECD, 2015; European Commission, 2015

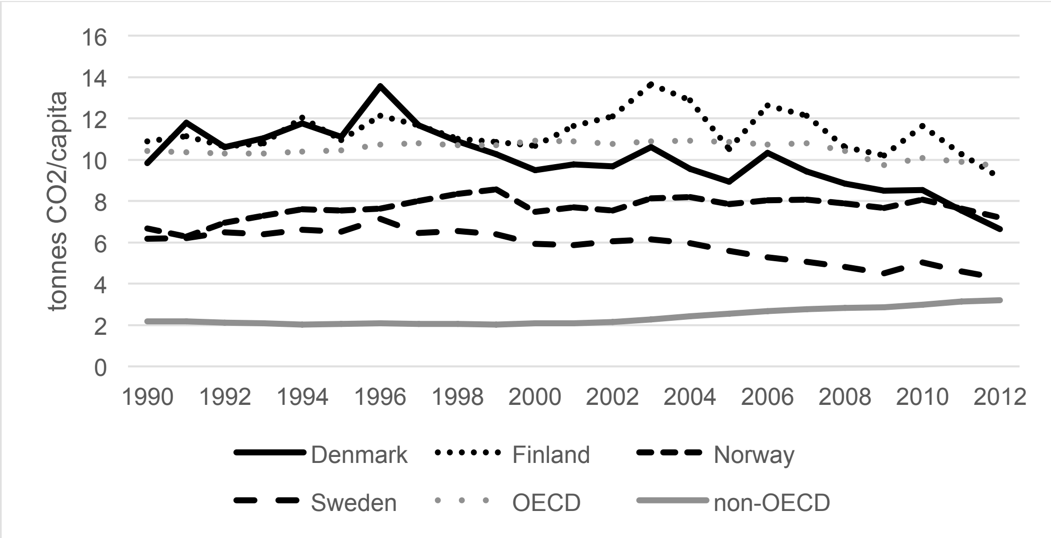
The green economy also entails the social dimension with improved human wellbeing and social equity. Nordic countries perform well on the Human Development Index on top 1-24th rank. The performance of Nordic countries on the HDI stems from the combination of social welfare and GDP per capita, access to education and health care, as well as environmental status, and the other dimensions that is included in the HDI. According to OECD, Nordic countries have more income equality than the OECD average. The reason for this might be that Nordic countries have social safety nets with access to social insurances for unemployment, parental- and sick leave, as well as other economic assistance for people in need.

For green jobs, the share of employees in renewable energy sector is higher in Denmark, Norway and Sweden than in EU27, according to the European Commission (2015). Regarding the green jobs, also other categories could be added, such as jobs in forestry, environmental services, waste sector, etc. However, due to the limited scope of the thesis not all categories of green jobs have been investigated, but only one type that can still give an indication of how many people work in green sectors compared to EU27.

In general, these socio-economic indicators give an indication that Nordic countries perform relatively well on social green economy dimensions. Due to the limited scope of this thesis, the social dimension of the green economy in Nordic countries will not be explored further. To further investigate the progress towards greener economies, also more historical data would be needed, to see the development on the selected indicators. Instead attention will be directed to the development of energy- and economic related indicators for the green economy in the time period 1990-2012, the period when Nordic countries have had carbon taxation in place.

4.1.2 CO_2 emissions per capita

Figure 4-1. CO_2 emissions/capita, Nordic countries, OECD, and non-OECD, 1990-2012



Data source: International Energy Agency, 2014

An important indicator for a green economy and the context of carbon taxation is the CO_2 emissions per capita. On top of the CO_2 emissions, also other GHG emissions need to be added into a CO2e measurement. However, below only CO_2 emissions will be analyzed. The data from IEA contains only data on CO_2 emissions, and not CO_2 equvivalents.

During the period 1990-2012, the per capita CO_2 emissions in OECD have decreased from 10,4 to 9,6 tons CO_2/capita, which is a reduction of around 7%. In non-OECD countries the average CO_2 emissions per capita has increased by 46% from 2,19 to 3,20 tons CO_2/capita in the same time period. All Nordic countries had lower CO_2 emissions/capita than the OECD average in 2012, but significantly higher than the non-OECD average. The comparison with both OECD and non-OECD is relevant as there is an environmental justice aspect on the per capita CO_2 emissions generated in different parts of the world.

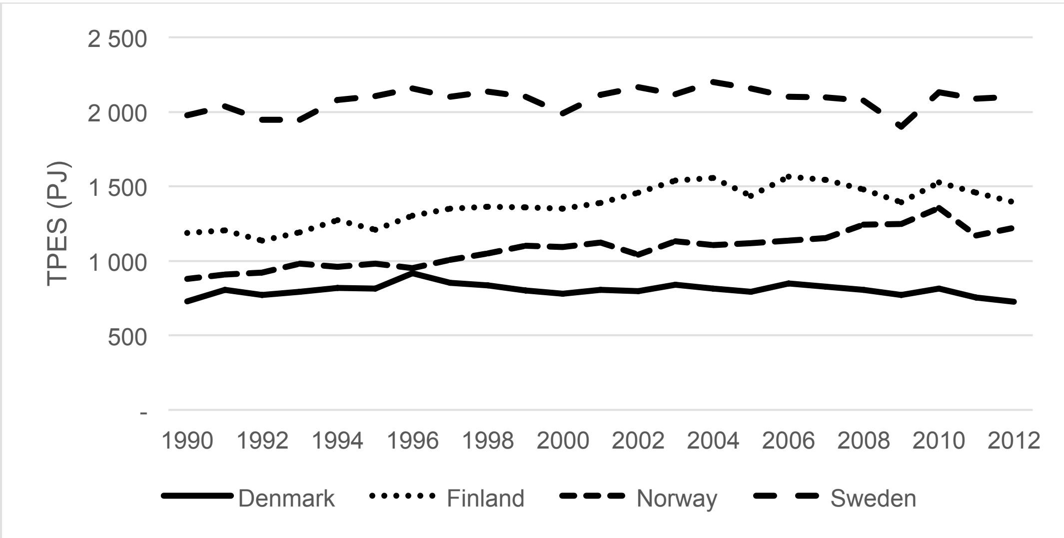
All Nordic countries, apart from Norway have also had a *faster decrease* in CO_2emissions/capita since 1990 than the OECD area. In Denmark, the CO_2 emissions per capita have decreased of around 32% from 9,8 to 6,6 tons CO2/capita between 1990-2012. In Finland, the CO_2 emissions/capita in Finland have decreased around 16% from 10,9 to 9,1 tons CO_2/capita in 2012. In Sweden, the CO_2 emissions per capita has decreased around 31% from 6,1 tons to 4,2 tons CO_2/capita between 1990-2012. One of the reasons behind the faster reduction of CO_2 emissions per capita in Nordic countries compared to OECD can be the carbon taxation that will be explored further in section 4.2.

In Norway, the CO_2 emissions per capita has *increased* around 8% from 6,6 tons to 7,2 tons CO_2/capita between 1990-2012. As shown in the analysis of performance on the Kaya identity in section 4.1.6, drivers behind the increase of CO_2 emissions in Norway include growth in population and GDP. The CO_2 emissions increased during the 1990's and decreased since 1999. Still, the CO_2 emissions per capita in Norway are lower than average per capita emissions for all OECD countries.

The sources and levels of CO_2 emissions vary between the Nordic countries. According to IEA (2014), the biggest source of CO_2 emissions in Denmark and Finland comes from electricity and heat production, followed by road transport. In Norway, the biggest source of CO_2 emissions comes from transport sector followed by the energy use in energy industry. In Sweden, the largest source of CO_2 emissions comes from road transport followed by manufacturing industry (IEA, 2014, see appendix 6.2). The sources of CO_2 emission can also influence the impacts of carbon taxation as the elasticity of demand varies between different sectors. Among the Nordic countries, Finland had the highest CO_2 emissions/capita in 2012, followed by Norway, Denmark and Sweden. Norway and Sweden has the most low-carbon electricity production but high CO_2 emissions from industry and transport sector, while Denmark and Finland still has a high share of fossil fuels in electricity and heat production.

4.1.3 Energy intensity

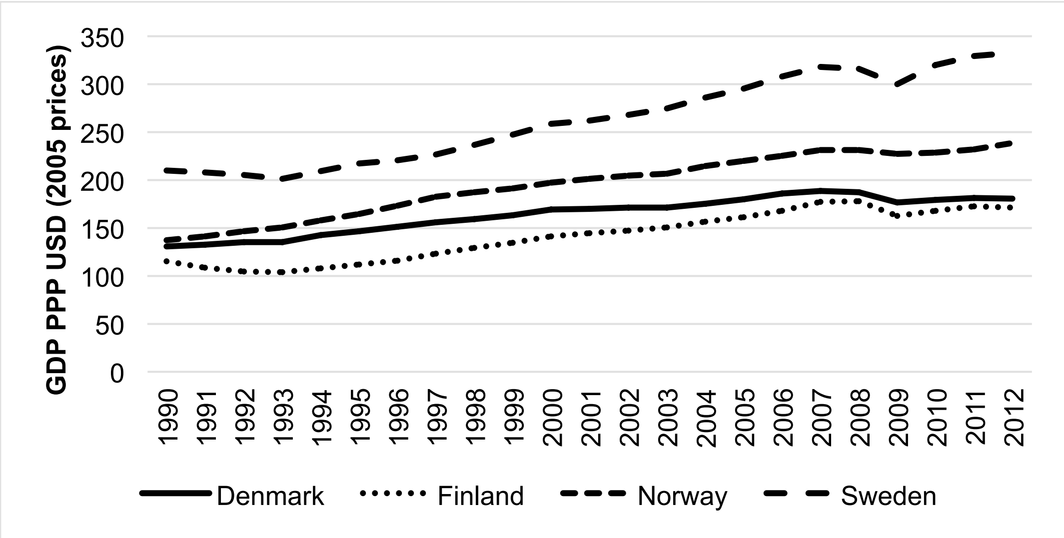
Figure 4-2. Total primary energy supply, Nordic countries, 1990-2012



Data source: International Energy Agency, 2014

The TPES has increased in all Nordic countries, apart from Denmark, between 1990-2012. Only Denmark had a decrease in its TPES by 0,1% since 1990, whereas Finland had an increased primary energy supply by 17%, Norway by 39%, and Sweden by 6%. The increase in total primary energy supply reflects the increase in production and consumption in the same period. Norway had the largest increase in TPES, which can be related to the increase in GDP growth. Even though the TPES and GDP increased in the period, the energy intensity in all Nordic countries has improved, which will be analyzed further below.

Figure 4-3. GDP PPP, Nordic countries, 1990-2012, USD (2005 prices)



Data source: International Energy Agency, 2014

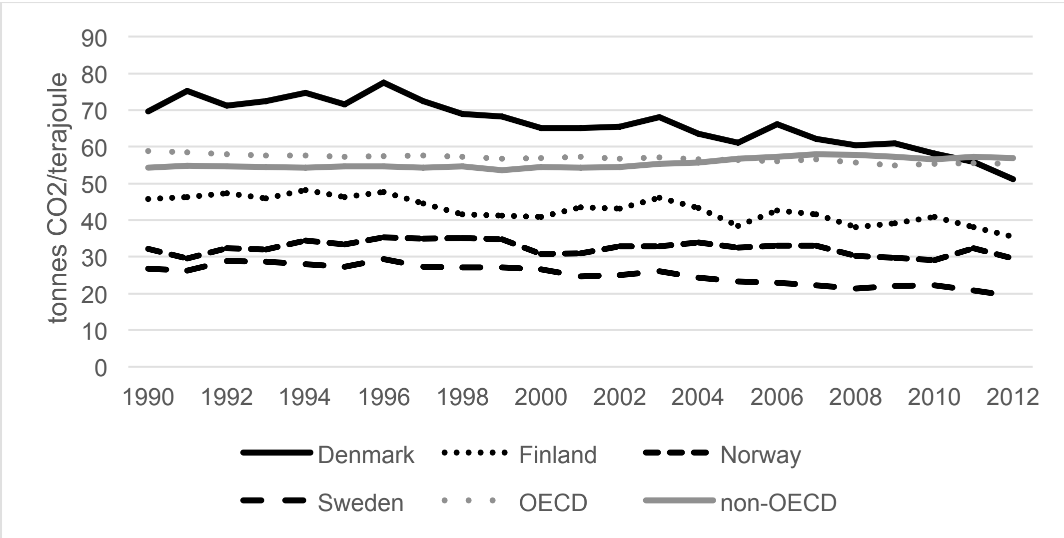
In the same period, the GDP PPP has increased in the Nordic countries. In Denmark, the GDP PPP has increased by 36% between 1990-2012 from 132,5 to 180,6 billion USD. In Finland, the GDP PPP has increased by 48% in the same period from 115,4 to 171 billion USD. Also in Sweden, the GDP PPP has increased by 58% from 210,2 to 332,5 billion USD. Norway have had a 73% increase of its GDP PPP in the period from 137,3 to 238,5 billion USD. Behind the big increase in GDP in Norway, is among other factors an increase in oil and gas extraction during the 1990's. The increase in GDP has also been the main driver of increased CO_2 emissions, as shown in the analysis of the Kaya identity in section 4.1.6.

Although the TPES and GDP PPP have increased in all Nordic countries between 1990-2012, the *energy intensity* measured as the TPES/GDP PPP has decreased. Factors behind can be improved energy efficiency, increased service sector, and other structural changes. Denmark had the most energy efficient economy in 2012 with 4 PJ/GDP PPP, followed by Norway with 5,1 PJ/GDP PPP, Sweden with 8,1 PJ/GDP PPP, and Finland with 8,1 PJ/GDP PPP. One reason for Denmark being the most energy efficient economy is because it has less heavy industry than the other Nordic countries. The fastest decrease of energy intensity in the period 1990-2012 has occurred in Sweden where the energy intensity has been reduced by 32% since 1990, followed by Denmark with 25%, Finland and Norway with 20%. The high rate of improved energy intensity in Sweden and Denmark means that these countries have improved their energy efficiency.

To what extent carbon taxes have been a driver for the improved energy efficiency in Nordic countries will partly be explored further below. However, the energy efficiency is influenced by many factors, such as energy and carbon taxes, energy prices, economic development, technological developments in industry, fuel standards in the transport sector, information about energy efficiency, incentives on energy efficiency for industry and households. Many more factors also influence the energy intensity of the economy, and due to the limited scope of this thesis, the full complexity behind the drivers for energy efficiency will not be explored in detail in this thesis.

4.1.4 Carbon intensity

Figure 4-4. Carbon intensity, Nordic countries, OECD, and non-OECD, 1990-2012, tons CO_2 emissions/TPES (terajoule)



Data source: International Energy Agency, 2014

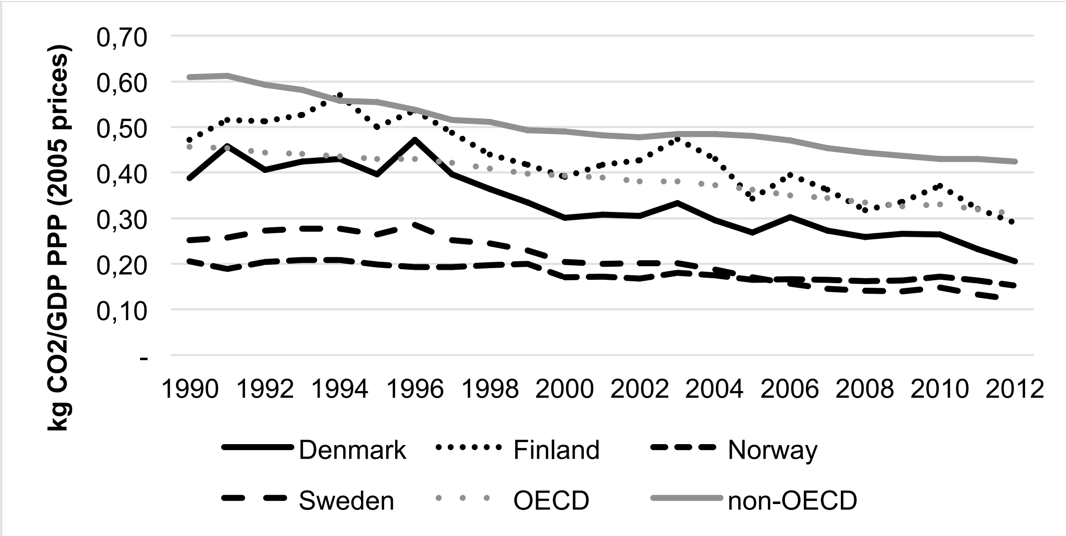
The carbon intensity reflects the share of fossil fuels in the energy mix, and is an interesting indicator in the context of understanding how carbon taxes have been a driver for greener economies and more low-carbon energy mixes. In the OECD area, the carbon intensity has decreased by 5% from 58,8 to 55,3 tons CO_2/TJ between 1990-2012. In the non-OECD area, the carbon intensity has increased by 4,9% from 54,2 to 56,9 tons CO_2/TJ. All Nordic countries have had a faster reduction of the carbon intensity between 1990-2012 compared with the OECD area.

In Denmark, the carbon intensity has decreased by 26% from 69,7 to 51,1 CO_2/TJ between 1990-2012. In 1990, Denmark had higher carbon intensity than the other countries, OECD and non-OECD, but reduced its carbon intensity gradually since 1996. The reason for the high carbon intensity in Denmark was the high share of coal and oil in the energy mix. Since 1996, Denmark has reduced its carbon intensity and moved closer to average for all OECD and non-OECD countries with a carbon intensity of around 55 tons CO_2/TJ. Also Finland has had relatively high carbon intensity since the 1990's, but has made progress and reduced by 22% from 45,8 to 35,4 tons CO_2/TJ between 1990-2012. In Sweden, the carbon intensity has decreased by 28% from 26,7 to 19,2 tons CO_2/TJ between 1990-2012. Sweden thereby has the lowest carbon intensity of the Nordic countries, followed by Norway. However, Norway has had the slowest decrease in carbon intensity of the Nordic countries. In Norway, the carbon intensity has decreased slower than the other Nordic countries, by 8 % from 32,2 to 29,6 tons CO_2/TJ in the period. One reason for the slow decline in Norway can be the fact that fossil fuels mainly are used in transport and industry sector, where there has been a strong growth in Norway.

In 2012, all Nordic countries had a lower carbon intensity than the OECD and non-OECD average. Since 1990, all the Nordic countries have also had a faster decrease of carbon intensity than the OECD area. The role of the carbon taxes for this development will be explored further in section 4.2.

4.1.5 Emissions intensity

Figure 4-5. Emissions intensity, Nordic countries, OECD, non-OECD, 1990-2012, CO_2 emissions/GDP PPP, (USD, 2005 prices)



Data source: International Energy Agency, 2014

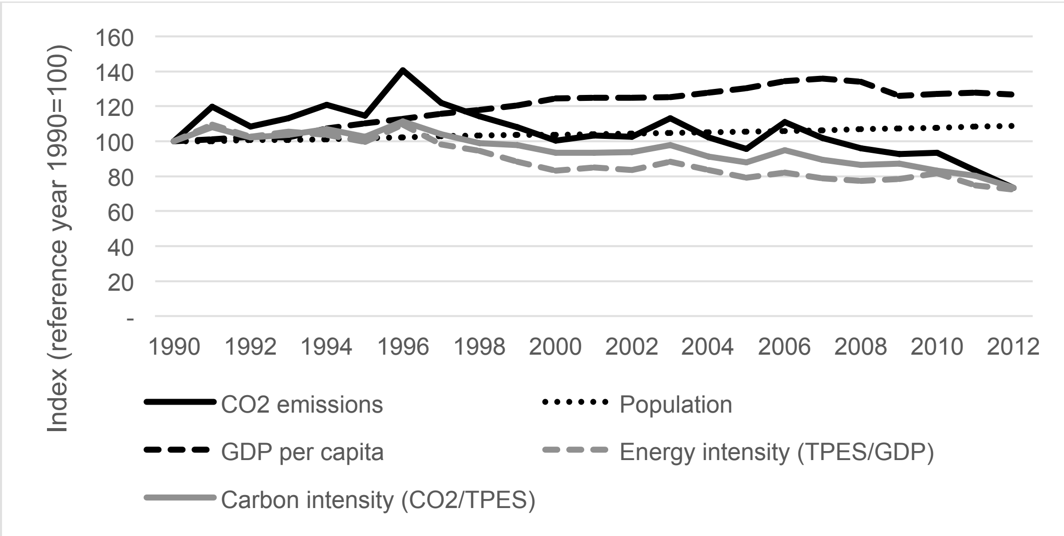
Emissions intensity is another important green economy indicator, as it reflects the CO_2 emissions/GDP. In the OECD area, the emissions intensity improved by 31% between 1990-2012, from 0,45 to 0,31 kg CO_2. In the non-OECD area, the emissions intensity also improved by 31% from 0,61 to 0,41 kg CO_2/GDP PPP. All Nordic countries had lower emissions intensity than the OECD and non-OECD area in 2012. Denmark, Finland and Sweden have also had a faster decrease of the emissions intensity than the OECD and non-OECD area between 1990-2012.

In Denmark, the emissions intensity decreased by 54% from 0,46 to 0,21 kg CO_2/GDP PPP between 1990-2012. The emission intensity of GDP PPP is therefore lower in Denmark than the total for all OECD and non-OECD countries. In Finland, the emissions intensity decreased by 43% from 0,51 to 0,29 kg CO_2/GDP PPP between 1990-2012. The carbon intensity is around the same as average for OECD countries, but lower than for non-OECD countries. The relatively high emission intensity in Finland reflects the high CO2 emissions/capita in relation to the size of the economy. In Sweden, the emissions intensity has decreased by 53% from 0,26 to 0,12 kg CO_2/GDP PPP between 1990-2012. Norway is the only country that have had a slower decrease in emissions intensity than the other Nordic countries, OECD and non-OECD. The emissions intensity has decreased by 21% from 0,21 to 0,15 kg CO_2/GDP PPP between 1990-2012. However, Norway has the lowest emissions intensity after Sweden of all the countries and areas compared above, due to its high GDP per capita and low-carbon electricity production.

4.1.6 Kaya identity

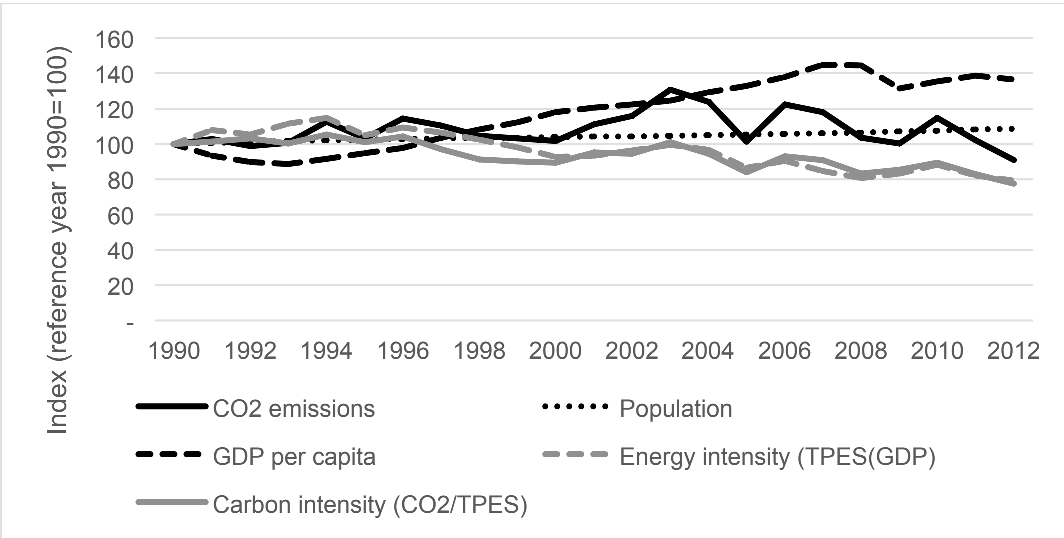
The Kaya identity shows the drivers for CO_2 emissions. According to the IEA data, the drivers for *lower* CO_2 emissions in Denmark, Finland and Sweden are improved energy-and carbon intensity, whereas population and GDP growth have been drivers for higher CO_2 emissions. In Norway, the CO_2 emissions have increased during the period 1990-2012, and the Kaya identity shows that GDP and population growth have been drivers for the increased emissions, whereas energy-and carbon intensity have been drivers for reduced emissions. The figures below illustrate the development of the Kaya identity for the Nordic countries between 1990-2012.

Figure 4-6. Kaya identity, Denmark, 1990-2012



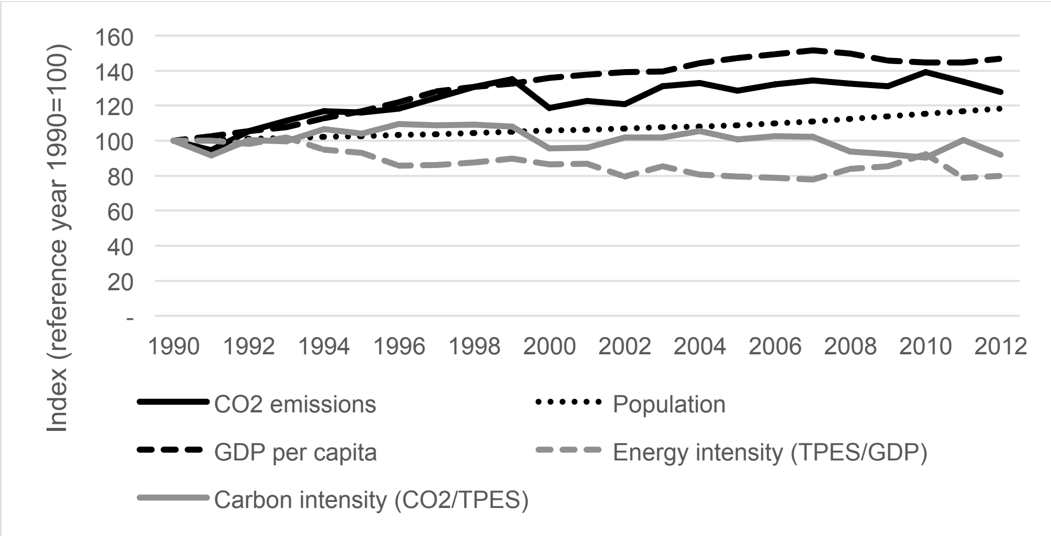
Data source: International Energy Agency, 2014

Figure 4-7. Kaya identity, Finland, 1990-2012



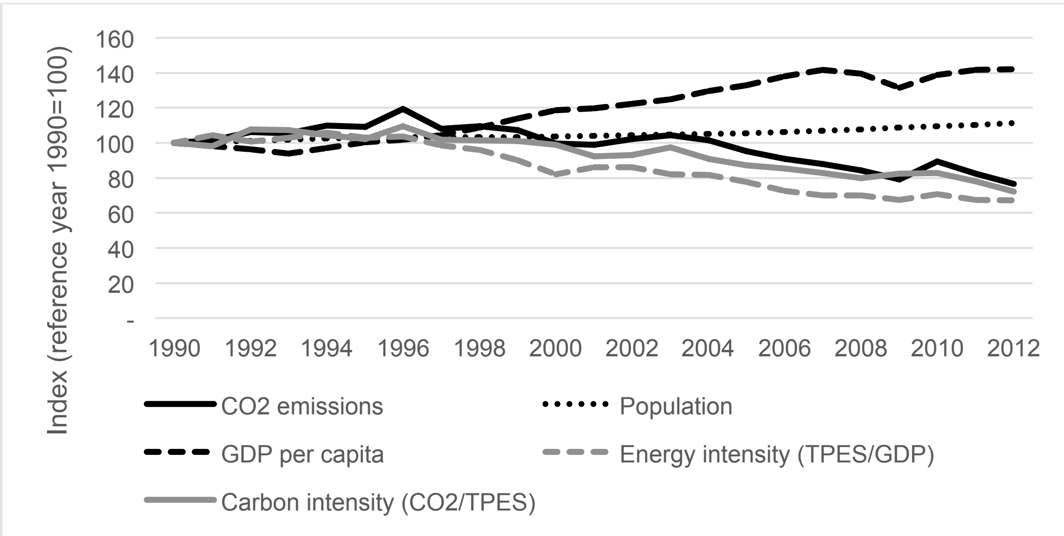
Data source: International Energy Agency, 2014

Figure 4-8. Kaya identity, Norway, 1990-2012



Data source: International Energy Agency, 2014

Figure 4-9. Kaya identity, Sweden, 1990-2012



Data source: International Energy Agency, 2014

To summarize the sections above, Nordic countries all perform relatively well on the selected green economy indicators. At the GGEI, Nordic countries score high in terms of efficiency and markets and investments, but without undermining the economic competitiveness. At the GCI, Nordic countries also score relatively well on key indicators for economic competitiveness. Further, Nordic countries all have a higher share of RES as a % of gross final energy consumption, which is another important green economy indicator. For socio-economic indicators, Nordic countries all score high on the HDI and its many dimensions of human development. The social dimension of the green economy also includes the income equality, where Nordic countries have a lower income inequality than the OECD average measured as a Gini-coefficient, according to OECD. Last, Denmark, Finland and Sweden also have a higher share of employees working in the renewable energy sector than EU27, according to the European Commission.

On the green economy indicators with focus on energy and environment, analysis of data from the IEA (2014), shows that all Nordic countries had lower CO_2 emissions/capita than the OECD average in 2012, but significantly higher CO_2 emissions/capita than the non-OECD average. Further, the analysis shows that all Nordic countries, apart from Norway have also had a *faster decrease* in CO_2 emissions/capita since 1990 than the OECD area.

The analysis of the *TPES and GDP PPP* shows that the TPES and GDP PPP have increased in all Nordic countries (with the exception of TPES which has decreased slightly in Denmark) between 1990-2012, and the strongest increase of TPES and GDP PPP has occurred in Norway with an increase of 73% in GDP in the period. But although the TPES and GDP PPP has increased, the energy intensity measured as the TPES/GDP PPP has *decreased by 20-32%* and the energy efficiency of the economy thereby improved. Denmark is the most energy efficient country of the four, and Sweden has had the fastest decrease in energy intensity. Regarding carbon intensity, the analysis of the data from IEA shows that all the Nordic countries have had a faster reduction of the carbon intensity (8-28%) between 1990-2012 compared with the OECD area (5%). Regarding emissions intensity, the analysis shows that it is lower among all Nordic countries compared to OECD and non-OECD, and it has decreased faster in Denmark, Finland and Sweden (43-54%), compared to OECD and non-OECD (31%), whereas Norway has had a slower decrease of the emissions intensity (21%) between 1990-2012.

Last the analysis of the Kaya identity for the Nordic countries shows that drivers for higher CO_2 emissions in Norway is population and GDP growth, and drivers for lower CO_2 emissions in Denmark, Finland and Sweden are improved energy-and carbon intensity.

The relatively good performance on the indicators above indicate that Nordic countries perform better than the OECD area in terms of CO_2 emissions/capita, carbon intensity, and emissions intensity. The Nordic countries have also improved their energy intensity in the period. The purpose of the thesis is to contribute to increase understanding of how/to what extent carbon taxes has been a driver of greener economies in Nordic countries. When the performance on green economy indicators have been established, the next section will deal with the second research question *What is the environmental effectiveness, distributional effects and effects on industrial competitiveness of carbon taxes in Denmark, Finland, Norway and Sweden?* in order to understand the influence of carbon taxes on the development in Nordic countries.

4.2 Assessment of carbon taxes

4.2.1 Environmental effectiveness

As shown in section 4.1.2 (figure 4.1), data from IEA (2014) on CO_2 emissions/population shows that during the period 1990-2012, Denmark, Finland and Sweden has had a larger decrease of CO_2 emissions than the whole OECD area (7%). CO_2 emissions have been reduced fastest in Denmark (32%), followed by Sweden (31%) and Finland (17%). In Norway however, the CO_2 emissions/capita have increased by 8% between 1990-2012. All Nordic countries had lower CO_2 emissions/capita than the OECD average in 2012, but significantly higher than the non-OECD average.

But to what extent can these reductions of CO2 emissions be attributed to carbon taxes in Nordic countries? Ex-post studies that have attempted to attribute changes in GHG emissions to carbon taxes will be addressed below.

The largest ex-post study on the effects of carbon-energy taxation is the so-called Competitiveness Effects of Environmental Tax Reforms (COMETR) study for the European Commission DG Research and DG Taxation and Customs Union (Andersen et al, 2007). In the study, the effects of environmental tax reforms in 7 EU countries (Denmark, Finland, Germany, Netherlands, UK, Slovenia and Sweden) have been analyzed. The study has estimated the impacts of carbon-and energy taxes in the E3ME model from Cambridge Econometrics. The model is based on empirical time-series data in 40 sectors, and estimates the effects on fuel consumption and CO_2 emissions. However, it's very challenging methodologically to attribute changes to one tax and the results can only be a "best guess" (Andersen, 2010). The effects have been estimated by developing two scenarios, one baseline scenario with various key indicators on GDP, energy intensity and GHG emissions. The baseline scenario have then been compared with a counterfactual "what if" scenario without the carbon-and energy taxes, and everything else equal. The two scenarios were then compared and the difference is the estimated effects of the carbon-energy taxes. The time period investigated is 1994-2004, and with a projection up to 2012. The result shows that GHG emissions were lower in 6 countries as a result of the ETR, and the biggest effects were found in the countries with the highest taxes, Finland and Sweden. According to the study, ETR had contributed to reduced GHG emissions by 3,1% in average by 2004. The largest impact could was found in Finland with a reduction of 5,9% of GHG emissions. The study also estimated the effects on fuel demand, where the effects of ETR were also biggest in Finland and Sweden and had reduced fuel demand by around 4-5% in 2004. (Andersen et al, 2007; Barker et al, 2009)

As shown in section 4.1.2, Denmark has had a large decrease of CO_2 emissions/capita between 1990-2012, a larger decrease than the other Nordic countries and the whole OECD area. In Denmark, the carbon tax has contributed to reduced CO_2 emissions and improved energy efficiency together with other energy taxes (Ministry of Climate, energy and building, 2013). The reason is that the taxes has kept down energy consumption and kept fossil fuel prices relatively high (Sovacool, 2013; Wier et al, 2005). According to Sovacool (2013), it is expected that the CO_2 emissions would be at least 10% higher without the carbon and energy taxes.

As shown in section 4.1.2, the emissions have decreased by 16% between 1990-2012. According to the Ministry of Environment and Statistics Finland's National Communication report to UNFCCC (2013), the carbon and energy tax has been a key instrument for attaining Finland's climate and energy goals. A government-working group assessed environmental taxation in 1999 and found that the carbon and energy taxes had reduced emissions by 7% between 1990-1999, and due to ETR in Finland, fuel use was estimated to be 4,8% lower than without energy and carbon tax (Withana et al. 2013). In the study by Lin and Li, the carbon tax has been most environmentally effective in Finland among the Nordic countries plus Netherlands with regards to effects of CO_2 emissions/capita. According to Lin and Li, the CO_2 emission/capita are 1,69% lower due to the carbon part in the carbon and energy tax in Finland than it would have been without the tax (Lin and Li, 2011).

According to IEA (2014), the CO_2 emissions/capita in Sweden have been reduced by 31% between 1990-2012, and the emissions were the lowest of all Nordic countries in 2012. According to Sweden's Sixth National communication on Climate change to the UNFCCC (Ministry of the Environment, 2014), the carbon and energy taxes have been key instruments to reduce CO_2 emissions since 1990. To estimate the impacts of the CO_2 tax and other economic instruments, the NC6 report from Sweden has used the MARKAL-NORDIC energy system model. In the model, two scenarios have been compared based on 1990 policies and 2013 policy instruments. According to the NC6 from Sweden, the modeling results show that emissions could have been 14MtCO2e (around 25%) higher in 2010 with the policy instruments from 1990, mainly from the electricity and heating sector and the difference is mainly because coal would have been more common with the 1990 policy instruments. Also older studies show the impacts of the CO_2 tax. A study by Swedish Energy Agency from 1994 shows that CO_2 emissions were 3-5% lower in 1994 than it would have been without the CO_2 tax (Andersen, 2004; Swedish Energy Agency, 1994). It's clear that the carbon tax have had an effect in Sweden and contributed to lower CO_2 emissions, but not established exactly how big the effect is. The carbon tax is connected with other incentives, and its difficult to establish how high the CO_2 emissions would have been without it (Samakovlis, personal communication, June 23, 2015).

As shown in section 4.1.2, Norway had an increase in CO_2 emissions/capita in the period 1990-2012 by 8%. However, the carbon tax can still have had an influence, as emissions could have been even higher without the tax. A modeling study by Bruvoll and Larsen (2004) shows that reduced energy intensity and changes in the energy mix contributed to a 14% reduction of CO_2 emissions in the time period compared to a scenario without the active climate policy, but that the carbon tax contributed to only 2,3% of that reduction (in the period 1990-1999). An older study by Larsen and Nesbakken (1997) show effects of CO_2 emissions and CO2 taxes between 1987-1994, where the CO2 tax contributed to a reduction of CO_2 emissions by 3-4 percent between 1991-1993 in the sectors included in their analysis.

As shown in section 4.1.6, the Kaya identity for Nordic countries shows that decreased energy-and carbon intensity has been a driver for lower CO_2 emissions, and studies about the effects of carbon taxation confirms that.

Although Norway has had an absolute increase of CO_2 emissions/capita between 1990-2012, the carbon taxation has still had an effect and contributed to a relative improvement compared to a situation without the tax. Hydropower accounts for around 95% of Norway's electricity production, and therefore the carbon taxation has mainly affected other sectors. Norway improved its energy intensity by 20% between 1990-2012, and was the second most energy efficient country after Denmark in 2012 of the four Nordic countries in this study (IEA, 2014). Bruvoll and Larsen (2004) finds in their ex-post analysis that there has been a significant reduction in CO_2 emissions/GDP like in most OECD countries during the time period. According to IEA (2014) the emissions intensity reduced by 21% between 1990-2012, and in the same period the GDP PPP increased by 73%. According to Bruvoll and Larsen (2004), the change in emissions intensity in Norway can be attributed to lower energy intensity, change in the energy mix and lower process emissions. In Norway, the carbon tax has had extensive effects on the oil and gas sector, which has adopted more energy efficient technology (Andersen, 2004; Larsen and Nesbakken, 1997; Bruvoll and Larsen, 2004). During the 1990's, the petroleum-producing sector in Norway accounted for around 25-30% of domestic CO_2 emissions, and CO_2 emissions in Norway increased between 1990-2000 mainly due to increased activities in the oil and gas sector. But due to the carbon tax, emissions per produced unit are lower than it would have been without the tax (Andersen, 2004). According to Bruvoll and Larsen (2004), 0,8% of the emission reductions in their modeling scenario came from the offshore sector, and 1,5%, from the onshore sector. The tax effect comes from reduced energy intensity, mainly due to more efficient technology in the petroleum-producing sector, and from reduced energy use. Also in Sweden, the CO_2e emissions have decreased in the industry sector by around 32% for combustion between 1990-2013 (combustion accounts for 60 % of GHG emissions in industry, and processes for the rest) (Naturvårdsverket, 2014). But modeling in the MARKAL NORDIC tool shows that "the effect of economic instruments on combustion-related emissions in this sector would have been somewhat greater, or at least as great, if 1990 policy instruments had been retained. The difference in emissions between the 1990 and current instruments scenarios is consistently small" (Ministry of Environment, 2014, p. 50). In other words, the carbon tax in Sweden seems to have had a limited effect on the combustion emissions in the industry sector.

Regarding the effects of the carbon tax in Norway, Bruvoll and Larsen, argues, "In light of the belief that the carbon taxes have been both considerable and pioneering, these results might seem surprising" (2004, p. 501). The small effects of the carbon tax can be explained by the extensive exemptions for industry and fishing in Norway during the time period, and the inelastic demand in the sectors where the carbon tax is effective, according to Bruvoll and Larsen. A more recent study by Lin and Li (2011) of the environmental effectiveness of carbon taxes in Denmark, Finland, Norway, Netherlands and Sweden, shows that the CO_2 tax has had no significant effect on CO_2 emissions per capita in Norway. Lin and Li (2011) have done a review of environmental effectiveness of carbon taxation in Nordic countries plus the Netherlands, and modeled the effects on CO_2 emissions/capita. Based on their review of ex-post studies on effects on CO_2 emissions/capita, they conclude that some of the studies show an effect of the carbon taxes, and other shows that the effects of the taxes are limited. The result in their study shows that the biggest effect of the carbon tax can be found in Finland. According to Lin and Li, the effects of a carbon tax depend on the tax rate, the scope of exemptions and how the revenues are used. One reason for the limited effects of carbon taxes is due to the many exemptions that the countries have implemented in order to mitigate the negative effects on competitiveness for energy intensive industry.

Carbon taxes have also had effects on the energy sector, together with other policy instruments. Denmark has managed to transition from almost 100% dependence on imported fuels in the 1970's to become a net-exporter of fuels and electricity. The country has increased its self-sufficiency in energy from only 5% in 1980 to 121% in 2010, and is considered among the most energy secure countries (Sovacool, 2013). The CO_2 emissions in Denmark have been reduced through improved energy efficiency and increased share of renewable energy (Ministry of Climate, energy and building, 2013). Behind the reduction, there is a mix of policies, such carbon and energy taxes, promotion of wind-energy, investments in combined heat and power (CHP) and district heating (DH), and energy efficiency (Sovacool, 2013). Effects of the energy policy in Denmark include lower energy intensity, lower carbon and emissions intensity, enhanced competitiveness, and improved energy security through increased diversification and distributed generation (Sovacool, 2013). Regarding energy efficiency, Denmark has put much effort into investments and promotion of CHP and DH, which is a main element of improved energy efficiency and increased share of renewable energy. In 1973, oil accounted for 90% of the TPES in Denmark, and through various policy measures, fuel use for electricity generation switched from 90% oil in 1970's to 95% coal in 1981. In 1997, legislation was passed to stop new coal power plants from being built. According to Wier et al (2005), the CO_2 tax has resulted in a reduction of energy use by 10% between 1993-1997. CO_2 emissions in have also been reduced through increased share of renewable energy. Denmark have had an increase in wind power and biomass, along with a more distributed generation (DG) (Sovacool, 2013). Behind the growth of wind power is a consistent strategy, with introduction of Feed-in-tariffs (FIT) in 1979 and investments in research and development of small-scale wind power (Sovacool, 2013). Also, biomass share of TPES has doubled since 1990, to 69% of RES in 2012 (ibid. 2013).

According to Sweden's Sixth National communication on Climate change to the UNFCCC (Ministry of the Environment, 2014), the emission reductions can be explained by the reduced GHG emissions in the energy sector. And emissions in the energy sector have decreased due to an increased use of renewable fuels since 1990. The impact from production of electricity and district heating can mainly be attributed to the economic instruments in place, energy and CO_2 tax, the electricity certificate scheme and the EU ETS, according to the Ministry of the Environment (2014). For electricity and heat production, the Ministry of Environment shows that energy and carbon taxes have been important factors in the development for the sectors. Studies by the Swedish EPA (Naturvårdsverket, 2003) also shows that the carbon and energy tax have contributed to the large expansion of bioenergy in Sweden in the 1990s. This is especially the case for district heating production, where a shift of fuels has been made from fossil fuels to bioenergy (Nilsson et al, 2004). Also older studies confirms this picture, where "the most striking effects of the carbon dioxide tax can be found in the district heating sector", with increased use of biofuels instead of coal (Bohlin, 2008, p. 287). Other effects of the carbon taxation apart from shifting fuels for district heating production, includes changed heating systems in houses with independent heating systems (Naturvårdsverket, 2003). Due to the price increase on heating oil and other policies, there has been an increase in heat pumps from 11 % of the small houses in 1992 to 18 % in 2000, and a continued increase after (Naturvårdsverket, 2003). Also in Norway, the carbon tax has contributed to a changed energy mix, where households have replaced fossil heating fuels with electricity in Norway (Larsen and Nesbakken, 1997).

For the transportation sector, the emissions remain unchanged since the 1990's, in Sweden and an estimation is that the energy and CO_2 tax has decreased the demand for fuels by 2% in 2010 compared to a scenario where 1990 policies would have remained the same (Naturvårdsverket, 2003). According to the COMETR study (Andersen et al, 2007), the ETR in Sweden has been estimated to reduce fuel demand by 6% until 2012. In Norway, the carbon tax have also had an influence on the transportation sector, where it has given incentives for more energy efficient cars and together with other policy instruments promoted more electric vehicles, but in total the emissions from the transport sector has increased due to growth in number of vehicles and transportation (Soyland, personal communication, August 21, 2015). The limited effect on the transport sector is likely due to the relatively inelastic demand of transport fuels. The carbon taxation will be one of many important instruments to promote a decarbonization and electrification of the transport sector. However, the carbon tax will have to change in order to contribute to achievement of goals for 2030 and 2050 in Sweden (Samakovlis, personal communication, June 23, 2015).

The environmental effectiveness of carbon taxes can be influenced by various factors, such as the tax rate, the scope of exemptions and how the revenues are used (Lin and Li, 2011). Common for the carbon taxes in Nordic countries is that they are not only designed to be environmentally effective, but also consider other policy objectives. In theory the ideal environmentally effective carbon tax should be equal for all users and fuels. But in practice the rates have been subject to various changes for users and fuels in all Nordic countries. The reason for the differentiated rates has been motivated to maintain economic competitiveness or to prevent risks for carbon leakage. A uniform tax would be more environmentally effective, but the differentiated rates have been introduced to make the taxes cost-effective with regards to the overall effects on the economy and the risk of carbon leakage. Nordic countries have also all adjusted the carbon taxes with the introduction of EU ETS, to prevent double incentives and unfair competition within EU.

The Nordic experience shows that carbon taxes have been environmentally effective in combination with other policy instruments, including energy and environmental taxes, public investments in district heating infrastructure, regulations, and other incentives for households and industry. For countries that wish to introduce carbon taxes, it's therefore useful to consider the portfolio of policy instruments that has been used to achieve the improvements on green economy indicators.

4.2.2 Equity and distributional aspects

As shown in Table 2.1, the carbon taxes in Nordic countries cover around 15-50% of total GHG emissions, according to Ecofys and the World Bank (2014). As CO_2 emissions account for a larger share of the GHG emissions than 15-50%, Nordic countries have not fully implemented the polluter pays principle (PPP) for CO_2 emissions with the carbon tax. One explanation for the limited environmental effectiveness of carbon taxes in Nordic countries can be related to their limited coverage of GHG emissions.

Another equity and distributional aspect of the carbon taxes in Nordic countries, is that environmental taxes as a whole are generally around the same level as the EU28 average. Apart from the taxes in the table below, Nordic countries have other market-based instruments, which are revenue neutral for the state, such as the Electricity Certificate System, which is used to support electricity from renewable RES in Sweden and Norway. The table below gives an indication of the level of environmental taxation in Nordic countries compared with EU28, and the share of energy taxes paid by households.

Table 4-4. Environmental taxation in Nordic countries

Country	Environmental taxes % of GDP in 2013 (EU28 average 2,44%)	Environmental taxes % of revenues from taxes and social contributions (EU28 average 6,3%)	Households share of energy taxes, %
Denmark	4,23%	8,85%	60%
Finland	2,92%	6,65%	35%
Norway	2,25%	No data	46%
Sweden	2,36%	5,51%	44%

Source: Eurostat, 2015

Environmental and energy taxes include carbon taxes, and therefore gives an indication of the revenues and distributional aspects of carbon taxes as well. According to Eurostat (2015), Denmark has among the highest environmental taxes in EU28 as a percentage of tax revenues. Finland and Denmark had higher share of environmental tax revenues of GDP in 2013 compared to EU28, whereas Norway and Sweden had lower shares of environmental tax revenues than the average for EU28. Environmental taxes as a percentage of total revenues from taxes and social contributions were highest in Denmark, followed by Finland, which both are above the EU28 average. Sweden had lower environmental tax revenues as a percentage of total tax revenues than the average in EU28. In contrast to what might be expected, not all Nordic countries have high environmental taxation.

According to Eurostat, households pay almost 60% of energy taxes in Denmark, compared to 35% in Finland. The distributional aspects of who pays the environmental and energy taxes, can contribute to their legitimacy in society. It can also contribute to their environmental effectiveness. As shown in section 4.2.1, the carbon and energy tax seem to have been most effective in Finland, which could have a correlation with the fact that households in Finland pay only 35% of the energy tax. According to a study by the Swedish National Audit Office (2012), private households generates 19% of the GHG emissions in Sweden, but pay more than 50% of the climate related taxes (including CO_2 tax). Business sector, which according to the Swedish National Audit Office, generates 81% of the GHG emissions, pay less than 50% of the climate related taxes. And although the general level of the CO_2 tax is high (around 1050 SEK/tonne in 2011), the actual average tax paid was 422-551 SEK/tonne between 2003-2009, due to the extensive number of exemptions from the CO_2 tax (Riksrevisionen, 2012).

Regarding the distribution of costs between households and other sectors, it has been shown above that households carry a large share of energy taxation in Denmark, Sweden and Norway. One of the reasons is that Nordic carbon taxes all have various excemptions within the carbon taxation for users and fuels. The excemptions have been introduced to protect economic competitiveness and prevent carbon leakage. OECD has identified the reductions of the general level of the CO_2 and energy tax as "fossil fuel subsidies" (OECD, 2013). Among the identified subsidies, there are also exemptions from the CO_2 tax. However, due to the limited scope of this thesis, the exemptions will not be analyzed in depth.

Another distributional aspect of the carbon taxes is how large the tax revenues are, how the revenues are used, if the taxes are revenue neutral, and if the countries have seized any potential double dividend benefits. The table below gives an estimate of revenues from carbon taxes in Nordic countries.

Table 4-5. Incomes from carbon taxes, 2013

Country	Carbon tax revenues, 2013	GDP, 2013	% GDP, 2013
Denmark	5 762 (DKK million), CO_2 tax, 2013	1 589 (DKK billion)	0,36%
Finland	Total environmental tax revenues 5,8 (EUR billion), 2013 Of which 40% from transport sector 2 303 (EUR million) from motor gasoline and diesel, 2013 1 598 (EUR million), other energy products, 2013	170 (EUR billion)	
Norway	4 913 (NOK million) from tax on CO_2 emissions 4 387 (NOK million) from tax on CO_2 emissions on emissions in petroleum sector	2 176 (NOK billion)	0,42%
Sweden	24 042 (SEK million), CO_2 tax, 2013	3 261 (SEK billion)	0,73%

Source: Statistics Denmark, 2015; Statistics Finland, 2015; Statistics Norway, 2015; Statistics Sweden, 2014a

Of the Nordic countries, Denmark has used the carbon tax revenues most effectively to enhance the energy and climate policy. According to Harrison (2010), double dividend and multiple benefits of ETR have had more impact in Denmark than in other countries. At an early stage, revenues from the carbon tax were used to promote energy savings and investments in district heating (Harrison, 2010). And revenues from the CO_2 tax from industry were earmarked for energy conservation projects in businesses. The reuse of revenues was a transitional measure used in Denmark for the first years after the introduction of carbon taxation, and around 10-20% of tax revenues were used for transitional measures in companies (Andersen, personal communication, August 19, 2015). Also according to Lin and Li (2011), Denmark has been most effective in recycling the revenues from the carbon tax among Nordic countries plus Netherlands. According to Andersen (2010), the carbon taxes in Nordic countries are mainly revenue neutral, where the taxes have been financed by reduced taxes on labor (in Finland and Sweden), and reduced social insurance contributions (in Denmark). The revenue neutrality is an important aspect for the legitimacy of environmental taxation (Andersen, 2010).

Another equity and distributional aspect of carbon taxes is their role as a significant tax revenue streams and the low transaction costs related to their administration. In Finland, the revenues from the carbon tax part of the energy and carbon tax were around EUR 500 million in 2010, which accounts for 15% of total energy tax revenues (Withana et al, 2013). When the carbon and energy taxes were reformed in 1997, the aim of the ETR was not to make it revenue neutral, however, state income taxes and social contributions were lowered at the same time (Withana et al, 2013). In Norway, the petroleum sector contributed with almost 47% of the carbon tax revenues (4,3 billion NOK in 2013), according to Statistics Norway (2015). The large incomes from carbon taxes from the petroleum sectors, reflects the fact that the petroleum sector accounts for a large share of the CO_2 emissions in Norway. Sweden has the highest revenues from carbon taxes among the Nordic countries, because the level of the CO_2 tax is higher in Sweden than the other Nordic countries, and the population and economy larger. According to Statistics Sweden, the total environmental taxes in Sweden generated 89 046 million SEK in 2013, of which the CO_2 tax accounted for 27% and the energy taxes (on fuels and electricity) accounted for 46%. For the CO_2 tax specifically, Statistics Sweden shows that in 2012, private consumption accounted for almost 36% of the carbon tax incomes, followed by service providers, commodity producers, and transport/logistics sector (Statistics Sweden, 2014b). Manufacturing industry contributed with only 7% of the CO_2 tax revenues in 2012, and the heat and electricity utilities with 5%. The division of which sector pay the CO_2 tax does not account for which actors pays the tax, but is an estimation of the contributions based on the energy use and carbon intensity of the energy use in that sector (Statistics Sweden, 2014b). A related benefit with carbon taxes compared to ETS, which is relevant for the equity and distributional aspects, are the low transaction costs. In Sweden, it has been shown that the carbon tax has low administrative costs compared to the total tax revenues. The biggest costs for administration comes from the administration of the exemptions and refunds from the tax (Naturvårdsverket and Energimyndigheten, 2006).

Another equity aspect of carbon taxation is the effect on households. As shown in section 3.2 on carbon taxation, environmental taxes can be regressive as they are the same for all households. Not many studies on this aspect among households have been found for Nordic countries. One study by Wier et al (2005) shows that the carbon tax is regressive in Denmark, and effects low income households in the countryside harder than urban households. One way to understand the distributional effects on households from carbon taxes is to study electricity prices for households, and compare with EU28. According to Eurostat (2015), the average electricity price in EU28 (second half of 2014) was around EUR 0,210/kWh. Denmark had around 50% higher electricity prices for households than the average EU28, whereas Norway, Finland and Sweden had the same or lower electricity prices. Of all EU28 countries, Denmark had the highest share of taxes, levies and VAT on the electricity price in 2014, with 56,8% of the final electricity price. The limitation of looking at electricity prices to understand the effects of carbon taxation on households is that the Nordic countries have a relatively high share of RES and nuclear power in the energy mix for electricity production, and therefore the effects of carbon taxes are not extensive. Also, a large part of the electricity is exempt from carbon taxes due to overlapping with EU ETS. However, it can still give an indication of electricity prices for households in countries with carbon taxes.

4.2.3 Effects on industrial competitiveness

In the period 1990-2012, the GDP PPP has grown by 36-73% in the Nordic countries, compared to 60% for all OECD countries (IEA, 2014). Denmark, Finland and Sweden has had a slower economic development than OECD, wheras Norway has had a faster economic development. According to the COMETR study (Andersen et al, 2007), the carbon-energy taxes in Europe have not had a negative impact on the competitiveness and economic performance (GDP) of the countries in the study. However, industry competitiveness is just one of many factors that influence the general economic development, and the main focus of the following section is how the carbon tax has affected industry competitiveness.

One of the main design features of the CO_2 tax in Sweden and other Nordic countries is the many exemptions (according to OECD, fossil fuel subsidies, OECD, 2013). Therefore the economic impacts of the carbon tax might not have been as extensive as they would have been if the carbon taxes had been designed according to the theoretically ideal environmentally effective carbon taxes.

The design of the CO_2 tax in Denmark has included reductions and reimbursements for industries since its introduction. In 2004, energy taxes were reorganized to make them more transparent and the CO_2 tax was reduced, but the overall tax burden remained the unchanged. Before 2014, energy intensive industries could be exempt from carbon tax in exchange for voluntary agreements, but that possibility was abolished in 2013 (Ecofys and World Bank, 2014). In Finland, the carbon tax has been changed several times since the introduction. The tax was initially low but with few exceptions (Andersen, 2004). According to Vehmas (2004), the CO_2 tax in Finland has had various differentiations directed to certain fuels, purposes and user groups. In 1994-1996 the CO_2 tax was changed into a combined CO_2 and energy tax, with exemptions for natural gas and peat. In 1997, the tax base shifted from the production to the consumption side of energy. The CO_2 tax was removed from electricity generation and instead levied on electricity consumption, a change related to the liberalization of the electricity market. Also, the CO_2 tax on light fuel oil was increased. In 1998, extensive refund system was introduced for industry for CO_2 and electricity taxes. In 2011, the CO_2 and energy tax went through major changes again (Ministry of Environment and Statistics Finland, 2013). According to the Norwegian Ministry of Climate and Environment (2014), Sixth National Communication under UNFCCC, the structure of the carbon tax has remained the same since its introduction in 1991. The tax differs between some products and users. Along with the introduction of the CO_2 tax in 1991, Norway also introduced a CO_2 tax for offshore oil and gas production. Norway has exemptions in carbon taxation for inland metallurgical industry and for the agricultural sector (Norwegian Ministry of Climate and Environment, 2014). In Sweden the CO_2 tax level was the same for all users until 1993. But in 1993 when the energy and CO_2 tax was increased, the manufacturing industry received a reduction and had to pay only 25 % of the general level. In 1997, the energy and CO_2 tax was raised as a part of a "green tax shift" with shifting burden from labor taxes to environmental taxes. Until 2011, manufacturing industry, agricultural sector and forestry industry paid in average only 21 % of the general CO_2 tax level for fuels. The rationale for lower CO_2 tax rates for industry is due to competitiveness and risk of carbon leakage (Finansdepartementet, 2014). Due to the several exemptions and deductions, Brännlund and Lundgren conclude, "This elaborate tax scheme is quite non-transparent except to the well initiated" (2010, p. 63).

With the introduction of EU ETS in 2005, Nordic countries have adjusted their carbon taxes to avoid double policy incentives for the trading sector. The price of allowances in the EU ETS is significantly lower than the carbon taxes in Nordic countries, and therefore the effects on carbon emissions needs to be studied further. It's beyond the scope of this thesis to analyze that in detail. However, some aspects will be addressed due to the effects of industrial competitiveness. Since 2010, the CO_2 tax in Denmark was adjusted to the EU ETS to avoid double policy incentives, and since 2013 large waste incineration plants have been exempt from CO_2 tax (Ministry of Climate, energy and building, 2013). Fuels for district heating are covered by carbon tax although the CHP plants are also included in EU ETS. The industry and business outside the EU ETS pays the same level of CO_2 tax as the price of allowances in EU ETS. In Norway, a national ETS was introduced in 2005 covering 11% of the GHG emissions, and in 2008, Norway became a part of the EU ETS, which covers around 40% of GHG emissions (Norwegian Ministry of Climate and Environment, 2014). As of 2014, operators in EU ETS are partially exempted, apart from offshore petroleum sector that is also paying carbon tax. In Sweden, industries and CHP producers in the EU ETS have partly been exempted from the CO_2 tax from 2011 and 2013 (Finansdepartementet, 2014).

Before 2014, energy intensive industries in Denmark could be exempt from carbon tax in exchange for voluntary agreements, but that possibility was abolished in 2013. According to Andersen (2004), there are various ex-post studies about the CO_2 tax in Denmark, regarding the effects on industry sector. Shopley and Brasseur (1996 in Andersen, 2004) have studied the effects of carbon taxation on a management level, and show that companies in the study had reduced energy consumption by 20% without negative impacts on employment etc. Other studies by Bjorner and et al (1998) have studied effects of carbon taxation on 5000 industrial companies representing 90% of industrial energy consumption, and found that companies with voluntary agreements and reduced tax rates had reduced energy consumption by 13% instead of 8% if the standard tax rate would have been applicable. Also a study by the Danish Energy Agency (1999) shows that CO_2 emissions among industrial companies with voluntary agreements had reduced their emissions by 1,7% in 1999, and that the CO_2 tax had helped the companies to focus their actions on energy efficiency measures (Andersen, 2004). Further, Denmark has been good at revenue recycling and using up to 20% of the incomes from the carbon tax to support energy efficiency projects in industry. Danish industry had an improvement of energy intensity by 30% between 1990-2000 (Andersen, 2010; Andersen, 2004).

Carbon taxes can influence electricity prices for industry sector and thereby the economic competitiveness compared to other countries. According to Eurostat (2015), the average electricity price in EU28 was EUR 0,120/kWh in second half of 2014 for industrial consumers. All Nordic countries had lower electricity prices for industrial consumers, with between EUR 0,05-0,10/kWh. The level of fossil fuel use in manufacturing industry could also influence industry competitiveness. The profiles of CO_2 emissions in Nordic countries are different. According to IEA (2014), the CO_2 emissions from manufacturing industries in Denmark accounted for less than 10% of total CO_2 emissions in 2012, 17% in Finland, 19% in Norway, and 20% in Sweden. (Eurostat, 2015; See appendix 6.2, IEA, 2014)

Studies indicate that productivity and growth has increased in Swedish industry between 1991-2004, despite the CO_2 tax. Brännlund et al (2014), have modeled the effects of the CO_2 tax for the Swedish manufacturing industry between 1991-2004. The research is based on data of productivity development of various manufacturing industry sectors, as well as the CO_2 emissions, and expenses for CO_2 tax between 1991-2004. The result show that the Swedish manufacturing industry was 45 % less carbon intensive in 2004 compared to 1991, that the CO_2 emissions had decreased by 10 %, and productivity had increased by 35 %, and the CO_2 tax was a significant reason for that (Brännlund et al, 2014). In all sectors, Brännlund et al (2014) have found an absolute decoupling between productivity and CO_2 emissions, which means that the CO_2 emissions have decreased in absolute terms at the same time as productivity has increased. Only in the paper and pulp industry, there was a relative decoupling, according to the study, where the CO_2 emissions increased but at a slower rate than the increase in production. Based on the research, Brännlund et al conclude that a CO_2 tax is an effective way to lower emissions in all sectors. However, the positive effect of the CO_2 tax in Sweden can also be viewed from the perspective of the limited use of fossil fuels and availability of bioenergy and hydro in Swedish industry (only 3% of costs used for fossil fuels in Swedish manufacturing industry). According to Brännlund et al, "This means that carbon taxation not necessarily have a negative impact on productivity in industrial production" (2014, p. 855). In Denmark the carbon tax has become a tool to promote renewable energy, energy efficiency, and CHP. The GDP has kept growing despite the high energy taxes, and the wind-power industry has contributed to enhanced competitiveness (Sovacool, 2013). According to Andersen (2004), the effects of the carbon tax in Denmark includes a fuel switch away from coal and a use of the tax revenues from the carbon tax to support energy efficiency. However, buildings and transport accounts for the largest part of energy use in Denmark, and therefore the effects of a carbon tax could be different in a country with heavy industry (Andersen, personal communication, August 19, 2015). In Norway the carbon tax has been a driver for companies to consider emission reductions, like the case of carbon capture and storage (CCS) in the Sleipner field where expenses for carbon emissions have been saved by storing 1 million tons of CO_2 (Soyland, personal communication, August 21, 2015). To what extent the carbon tax has been a driver for innovation is beyond the scope of this thesis, but should be researched further.

Another benefit of carbon taxation is the predictability for actors on the market to plan for future investments. Compared to increased fuel prices, Brännlund et al (2014) conclude that a CO_2 tax is more beneficial as it has a "signal" effect for future prices. Also in Norway, the carbon taxation have created predictability for the future, and allowed for actors on the market to plan ahead (Soyland, personal communication, August 21, 2015). Predictability of future prices is especially important for industrial actors that need to make large investments in new technology to reduce their GHG emissions.

The differentiation in carbon taxes to protect economic competitiveness and prevent carbon leakage is also relevant from a green economy perspective. A study by Godal and Heltsmark (2001) shows the advantages and disadvantages of uniform carbon taxes across sectors, and concludes that there are *political barriers* to implement uniform carbon taxes. According to Kasa (2000), the development of the carbon tax in Norway can be analyzed based on the policy network barriers, where some mainland metallurgical industries were exempt from the carbon tax during the 1990's due to strong organized interest groups. Kasa argues further that its possible to show a strong affinity between policy makers and energy intensive industries, and that these networks contributed to abandon the introduction of a broader CO_2 tax in 1998 (Kasa, 2000). These political economy aspects of carbon taxation can be studied in all countries to find how actors with vested interests and policy networks can influence environmental and energy taxation.

4.2.4 Carbon taxation and carbon risk management

The last dimension of the effects of carbon taxes that will be investigated is the effect on a firm level. Carbon taxation can be a driver of an effective carbon management system, as discussed in section 3.3. Two energy intensive companies (LKAB and SSAB) with a large share of the industrial CO_2 emissions were selected for interviews and review of sustainability reports.

In 2014, LKAB emitted 675 214 tons of CO_2, according to the register of plants in the EU ETS from the Swedish Environmental Protection Agency, and has increased by 17% since 2008 (Naturvårdsverket, 2015). The emissions accounted for 3,4% of all the CO_2 emissions in the EU ETS sector in Sweden. The largest share of the emissions comes from the sintering process, where coal and oil is used as fuels. LKAB is also one of the single largest energy users in Sweden, and account for 1,5% of the total electricity use (LKAB Annual and Sustainability Report, 2014). According to the Annual and Sustainability Report for 2014, 10% of the company's expenses go to energy, and therefore energy use is of strategic importance to the company. In the energy mix used by the company, coal accounts for 28%, diesel oil 2%, fuel oil 16%, and electricity 54%. Of the CO_2 emissions, 55% comes from coal, 2% from diesel oil, 26% from fuel oil, and 2% from electricity. The company has a long-term goal to phase out oil and coal from the production. As energy is of strategic importance for LKAB, the company has among other initiatives invested in a Wind power company, improved its efficiency through freight transport on rail to the ports in Narvik and Lulea, invested in Eco driving programs, and participated in a public programme for energy efficiency in collaboration with the Swedish Energy Agency and other energy intensive industries (LKAB Annual and Sustainability Report, 2014).

Environmental goals of the company include reducing the energy consumption from 160 kWh/tonne in 2011, to 130 kWh/tonne in 2020, and reduce CO_2/tonne product from 27 kg to 17 kg in 2020 (LKAB, Strategy for Sustainable Development 2013-2020, 2012; LKAB Annual and Sustainability Report, 2014). The board has adopted the goals (Granberg, personal communication, September 10, 2015). Further, the company aims to launch new climate smart pellets in 2017. The company has ambitions to be leading the market in the development of new pellets, which are more energy efficient to produce and can contribute to more energy efficiency in steel production. In the Annual and Sustainability report for 2014, the company has conducted a materiality analysis together with stakeholder groups to identify the significant sustainable development issues. Among the significant issues identified in the materiality analysis, environmental emissions and resource efficient use of materials have been identified. (LKAB, Annual and Sustainability Report, 2014)

LKAB has been a part of the EU ETS since the start, and thereby does not pay CO_2 tax for fuels used in the process. Due to the large energy use of the company, it imports fuels (including diesel oil) to Sweden, and is obliged to pay carbon tax for fuels that are not used in the process, such as diesel oil for transportation. LKAB is thereby subject both to the carbon tax and the EU ETS. LKAB has received free allowances in the EU ETS until 2017, and thereby the EU ETS have not been a strong incentive to reduce carbon emissions so far (Granberg, personal communication, September 10, 2015). Drivers for the environmental work at LKAB include directives from the owner, the public ownership of the company, and goals set by the board. Barriers for the reduction of CO_2 emissions from the company are economic and technological (Granberg, personal communication, September 10, 2015).

SSAB emitted 9,6 million tons CO_2 in 2014 globally, and most of the emissions comes from the process of transforming iron ore to steel in a blast furnace process, where coke and coal is used. Issues that have been identified as significant aspects include efficient use of raw materials and energy, air emission reductions of carbon dioxides, nitrogen oxides, sulphur oxides and other particulate matter. (SSAB Sustainability Report, 2014; SSAB, 2013)

SSAB's targets for 2019 include reducing CO_2 emissions by 200 000 tons, reduce purchase of fuels and electricity by 300 GWh, and improved use of rest products (SSAB, 2015). Barriers to achieve the targets are a mostly technological challenge that requires large investments (Hirsch, personal communication, August 21, 2015). According to the Swedish Environmental Protection Agency, SSAB emitted 2,9 million tonne CO_2 in Sweden 2014 (from plants in Oxelösund, Luleå, Borlänge and Finspång), which account for around 15% of the CO_2 emissions in the EU ETS sector in Sweden in 2014 (Naturvårdsverket, 2015). SSAB also owns 50% of Lulekraft AB where gases from the steel making process are combusted to produce heat and electricity, which emits another 2 million tonne CO_2, and the total total CO_2 emissions from SSAB in Sweden were 5,059 million tonne CO_2 in 2014. SSAB has received free allowances in EU ETS for the trading period 2013-2020, because of the risk for carbon leakage and international competition, but around 10% lower allowances than the actual CO_2 emissions (Hirsch, personal communication, August 21, 2015). The time horizon for investments in new technology in the steel industry is around 30-40 years, and according to Hirsch, energy manager at SSAB, the EU ETS gives predictability only for around 10 years (Hirsch, personal communication, August 21, 2015). Regarding the carbon tax as an economic incentive, metallurgical processes have mainly been exempt from carbon tax, and therefore the carbon tax has not been applicable for most of the CO_2 emissions from SSAB (ibid. 2015).

Both companies fulfill many of the elements for an effective carbon management system as suggested by Tang and Luo (2014) and discussed in section 3.3. Regarding carbon operations, both companies have established emissions targets and communicated the commitments with stakeholders through Annual and sustainability reports. The companies have also gone further in the reporting and identified significant environmental aspects in collaboration with stakeholders though materiality analysis as required by the Global Reporting Initative. The companies have also done well in emissions tracking and reporting through carbon accounting. And last, the companies have done well in engagement and disclosure, by providing transparency in the Annual and sustainability reports, and through engagement with stakeholders.

However, based on the data above, it seems as if carbon taxation and EU ETS as policy instruments have had a limited effect on the carbon mitigation strategies of the two companies. But the scope of the data above is very limited, and much more research would be needed to understand the complexity of the carbon/environmental management systems in the companies.

The design of the carbon tax in Sweden has exempted metallurgical processes and thereby a large share of the CO_2 emissions from energy intensive industries. With the introduction of

EU ETS, the industries have also to a large extent received free allowances, due to the risk of carbon leakage, and thereby both the carbon tax and the EU ETS has been weak economic incentives for mitigation of CO_2 emissions. The EU ETS also doesn't give a long-term signal of the future carbon price, which is a weakness for actors on the market that face large and long-term investments. Drivers for the environmental work at LKAB and SSAB include requirements from customers and owners, commitment from the boards, reducing energy costs, and an ambition to be leading in resource efficiency. Barriers include technological development and the need for large investments. However, the data is too limited to draw any final conclusions, and more research is needed on a company level to understand how carbon-pricing mechanisms have influenced environmental management on a firm level in Nordic countries.

5 Conclusions

Carbon taxation is considered as one of many important policy instruments to drive and promote a greener economy. With the urgent need for deep emission cuts, increased resource efficiency and job creation, there has been an increasing interest to know to what extent carbon taxes have the potential to drive a green economy. For countries with interest to introduce carbon taxation to create greener economies, knowledge about the experiences of carbon taxation in Nordic countries can be useful. The purpose of this thesis has been to contribute to increase the understanding of how/to what extent carbon taxes has been a driver of greener economies in Nordic countries.

In order to fulfill the purpose, questions have included (1) how do Denmark, Finland, Norway and Sweden perform on selected green economy indicators? (2) What is the environmental effectiveness, equity and distributional effects and effects on industrial competitiveness of carbon taxes in Denmark, Finland, Norway and Sweden? (3) How do carbon taxation and other carbon pricing mechanisms influence carbon risk management on a company level? As whole, the findings of this thesis reveal that progress towards a green economy cannot solely be attributed to carbon taxes. Other factors such as the portfolio of policy instruments, weather patterns, economic development, technological alternatives, have also influenced the GE performance and certainly the levels of CO_2 emissions. However, and to some extent, findings also reveal that carbon taxation has contributed to the performance on the addressed indicators.

The first question was how do Denmark, Finland, Norway and Sweden perform on selected green economy indicators? The first level of analysis shows Nordic countries as top performers when it comes to selected Green Economy indicators. Nordic countries perform well on relevant green economy indexes such as GGEI, GCI, and have a higher share of RES than the average within EU28. On socio-economic green economy indicators, Nordic countries performed well on the HDI, have a lower Gini-coefficient than the OECD average, and have a higher share of employees working in the renewable energy sector than the EU28. In the period 1990-2012, Nordic countries have generally performed better than the OECD area in terms of CO_2 emissions/capita, carbon intensity, and emissions intensity. The Nordic countries have also improved their energy intensity in the period. The GDP PPP growth in the Nordic countries has been similar or lower (except in Norway) than in the OECD area in the period 1990-2012, despite the carbon taxes in place. All the Nordic countries have the same or lower per capita CO_2 emissions than OECD average, but still higher than the non-OECD average. The relative improvements since 1990 and compared with the OECD average, makes Nordic countries perform well as green economies, but with regards to the level of CO_2 emissions per capita that are required to achieve deep emission cuts, Nordic countries still have a long way to go.

The second question of this thesis was what is the environmental effectiveness, equity and distributional effects and effects on industrial competitiveness of carbon taxes in Denmark, Finland, Norway and Sweden? Regarding *environmental effectiveness*, the ex-post studies that have been reviewed shows that carbon taxes have been key policy instruments to achieve climate and energy goals, and have been effective in combination with other policy instruments, such as energy taxes, other environmental taxes, investments, and regulations. Carbon taxes in Denmark, Sweden, Finland and Norway have contributed to absolute and relative reductions of CO_2 emissions by incentivizing more efficient technology, change of fuels for heat and power production, and reduced demand for transport fuels. Some studies show that the carbon tax effect on CO_2 emissions is significant, whereas other studies show that the effects are limited. A common feature of carbon taxes in Nordic countries is the use of differentiated rates and exemptions for different fuels and users. Studies indicate that this have made the taxes less environmentally effective. However, its likely that without the carbon taxes in place, the performance on the green economy indicators would have been worse. Regarding the *equity and distributional effects of carbon taxation,* it has been shown that environmental taxation is higher in Denmark and Finland than EU28. Also, households pay a large share of the energy taxes in Denmark, Sweden and Norway. As households pay a large share of the taxes, there is an element of regressivity, which is highlighted as a downside of environmental taxation in the academic literature. This can also be the case for carbon taxes, but few studies have been found regarding the distributional effects on households. Another aspect of the distributional effect is how the revenues from the carbon tax are used. Among the Nordic countries, Denmark has used the carbon tax revenues most proactively to further enhance environmental policy objectives. Further, Sweden has the largest incomes from carbon taxes, due to the fact that Sweden has the highest general level of the carbon tax globally and have a larger economy than the other Nordic countries. Last, it has been shown that the transaction costs of the carbon tax are low in relation to the tax revenues. Regarding the *effects of carbon taxation on industry competitiveness*, it has been shown that the development of GDP PPP has been around the same or lower among Nordic countries (with the exception of Norway), as for the OECD area between 1990-2012, despite the carbon taxes in Nordic countries. Some studies for Denmark and Sweden indicate that industry competitiveness have not been undermined despite the carbon tax. However, all Nordic countries have applied differentiated carbon taxes, and also adjusted the taxes to the EU ETS. The energy mix of Nordic countries also influence the carbon tax' cost-effectiveness and effects on industry sector. For instance, Sweden had the biggest reductions of CO_2 emissions in the 1970's and 1980's, with the expansion of nuclear power. For other countries introducing a CO_2 tax, the level of dependency of fossil fuels in industry is therefore of importance for the expected outcome and cannot necessarily be expected to be as good as in Sweden (Brännlund et al, 2014).

The third question of this thesis was how do carbon taxation and other carbon pricing mechanisms influence carbon risk management on a company level? Based on a review of Sustainability reports and interviews with energy managers from LKAB and SSAB, it has been suggested that EU ETS and the carbon tax seem to have had a limited effect on the mitigation of CO_2 emissions, but much more research would be needed to understand the complexity of the environmental management in the companies.

Based on the findings, a few *policy learnings* can be drawn regarding the use of carbon taxation to promote a greener economy. *First*, carbon taxes in Nordic countries have not been designed according to the theoretically ideal carbon taxes. Rather, they have a number of exemptions for various fuels and users to protect economic competitiveness or other objectives. These exemptions have decreased the environmental effectiveness of the taxes. For countries that want to introduce more environmentally effective carbon taxes, uniform rates can be applied for all sectors. However, with regard to the risk for carbon leakage, which could undermine the mitigation potential of the policy from a global perspective. *Second*, carbon taxes in Nordic countries have not undermined other policy objectives, such as economic competitiveness. Instead, they might have contributed to improve the economic competitiveness in combination with other policy instruments, such as the promotion of wind energy in Denmark, and development of CCS technology in Norway. For countries that want to improve their economic competitiveness by supporting improved energy efficiency, lower emissions intensity, improved carbon intensity, and the innovation potential in the industry and energy sector, a carbon tax can be one of many potential policy instruments. *Third*, carbon taxes can contribute with significant tax revenues, as shown by the Nordic experience, where incomes from the carbon taxes accounted for 0,36-0,73% of GDP in 2013. With a tax base that includes fuels used in industry, transportation fuels, heating and electricity production, the tax base is significant to raise incomes that can be used to either enhance the climate and energy policy, of for other purposes. However, research shows that revenue neutrality is as important for the legitimacy of environmental taxation, and therefore the potential to reduce other taxes can be considered when carbon taxes are introduced. The equity aspects of the carbon taxes also need to be considered, to prevent an unequal distribution of the costs. *Fourth*, a related benefit to the revenue potential of carbon taxes is that the transaction costs are low in relation to the total tax revenues, and therefore it's an attractive option for all countries with institutional capacity to raise environmental and energy taxes. In Sweden, it has been shown that the biggest costs are related to administration of the tax exemptions and reimbursements. Carbon taxes can also be designed so that importers of fuels pay the tax, which makes it easy to enforce as the number of actors that import fuels to a country are limited. *Fifth*, another benefit of carbon taxation is that it creates predictability for the actors on the market. Predictability about future prices of CO_2 emissions is an important factor for decision making on new low-carbon infrastructure and technology. For industries that face large investment decisions and investments in R&D, a predictable and high price of CO_2 emissions could contribute to investments in low-carbon options. *Sixth*, experience from Nordic countries shows that the carbon taxes have been changed continuously since the early 1990's. Even if the tax is introduced at a low level that doesn't cover the social cost of CO_2 emissions and only cover some sectors of the society, the tax can be adjusted with time. *Seventh*, experiences of carbon taxation in Nordic countries show that carbon taxes have been effective in combination with other policy instruments, including energy and environmental taxes, public investments in district heating infrastructure, regulations, and other incentives for households and industry. Therefore its important to look at the whole portfolio of instruments used to improve the performance on green economy indicators.

Last, some conclusions can be made regarding the need for *further research* of carbon taxes to promote greener economies. Based on the interviews conducted for this thesis with researchers in the field of environmental economics and experts in the field of carbon taxation, some needs for further research on carbon taxation in Nordic countries have been identified. These includes the effects of overlapping policy instruments such as carbon taxes and EU ETS, effects on economic competitiveness, carbon taxation as a driver for innovation, and the problem of carbon leakage due to increased carbon taxation. The needs for further research also includes distributional effects of carbon taxation based on original data, due to the many exemptions for various sectors in Nordic countries (Andersen, personal communication, August 29, 2015). Other needs for further research include the role of carbon taxation to achieve a low carbon transition in transport sector (Samakovlis, personal communication, June 23, 2015). Further, there is a need for research on how the carbon tax interacts with other environmental policies, the effects of removing exemptions, and what would be the effects on carbon taxation if there were fundamental changes in society.

Some reflections can also be made regarding the *methodological challenges* to establish the effects of the carbon taxation. A general challenge for all environmental policy evaluation is the impact or attribution problem where the evaluation needs to answer the questions to what degree the impact has been influenced by the policy under evaluation (Mickwitz, 2003). To deal with the attribution problem, triangulation of methods can be deployed. Estimating the effects of carbon taxation is considered very challenging (Andersen, 2010). Various methods can be used, mainly econometric models with rich empirical data that compares actual developments with a hypothetical scenario without the tax. One way to estimate the effects is also to study effects on industry, where the elasticity of demand is high (Samakovlis, personal communication, June 23, 2015). However, the estimates can only be a "best guess" (Andersen, 2010). Also, when a particular policy is evaluated, other policies and factors needs to be considered and the results have to be analyzed in the overall *policy context* (Mickwitz, 2003). This is certainly the case for carbon taxation, which effects needs to be evaluated together with other policies, such as energy taxation, as well as economic incentives and regulations for renewable energy and energy efficiency. Due to the limited scope of this thesis, only secondary ex-post studies have been reviewed, but nevertheless the methodological challenge of attribution remains.

There is a *momentum* for carbon pricing mechanisms and the number of countries with carbon taxation has increased in recent years. Carbon pricing mechanisms are crucial for countries that want to adapt green economy policies. For countries that are interested to introduce carbon taxes, experiences from Nordic countries can be interesting for effective design and implementation. Carbon taxes have served Nordic countries well, without undermining the economic competitiveness, and have an important role to play also for future climate policy. However, experience from Nordic countries show that carbon taxes alone cannot deliver deep emission cuts, but needs to be complemented with other policies and needs to be designed in a way that is environmentally effective.

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6.1 Interviews

Eva Samakovlis, Head of Unit, Environmental Economics, National Institute of Economic Research, phone interview, 2015-06-23

Stefan Nyström, Head of Unit, Miljömålsberedningen, interview, 2015-08-28

Runar Brännlund, Professor, Environmnetal Economics, Umeå University, phone interview, 2015-06-24

Svend Soyland, Senior Advisor, Nordic Energy Research, phone interview, 2015-08-21

Nicolai Prytz, Carbon pricing analyst, Climate change policy team, World Bank, phone interview 2015-08-20

Mikael Skou Andersen, Professor, Department of Environmental Science, Aarhus University, phone interview, 2015-08-19

Tomas Hirsch, Energy manger, SSAB, phone interview, 2015-08-21

Johan Granberg, Energy manager, LKAB, phone interview, 2015-09-10

Appendix

6.2 Carbon management system elements

Carbon Governance Perspective

Elements		Purposes	Proxy variables
1	Board function	To develop overall climate change strategy and policy	*ClimateCommittee*
2	Risk and opportunity assessment	To identify and assess carbon risk and opportunity	*RiskAssess*
3	Staff involvement	To motivate staff and enhance awareness of climate change issues	*INCENTIVE*

Carbon Operation Perspective

Elements		Purposes	Proxy variables
4	Emissions target	To set up a mitigation target that is consistent with carbon strategy	*TARGET*
5	Policy implementation	To enforce carbon policy by prioritising reduction actions and allocating resources to achieve targets	*CarbonProgram*
6	Supply chain emission control	To reduce supply chain emissions	*CustomerGHGAvoid*

Emission Tracking and Reporting Perspective

Elements		Purposes	Proxy variables
7	Carbon accounting	To keep track of carbon inventory and emissions footprint	*GHGAccounting*
8	Carbon assurance	To increase the reliability of carbon data and information	*GHGAudit*

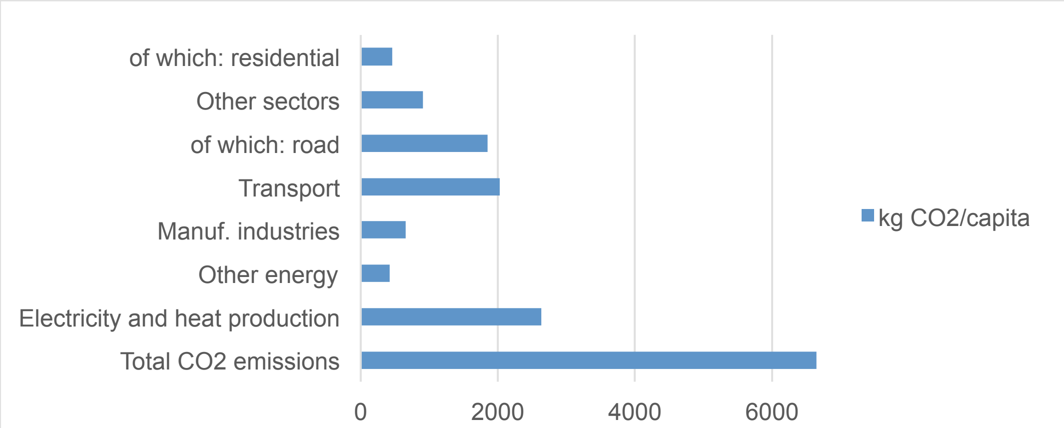
Engagement and Disclosure Perspective

Elements		Purposes	Proxy variables
9	Engagement with stakeholders	To strengthen the link with stakeholders	*PolicyEngage*
10	Disclosure and communication	To increase the transparency of mitigation activities and outcomes	*DISCLOSE*

Source: Tang and Luo, 2014, p. 92

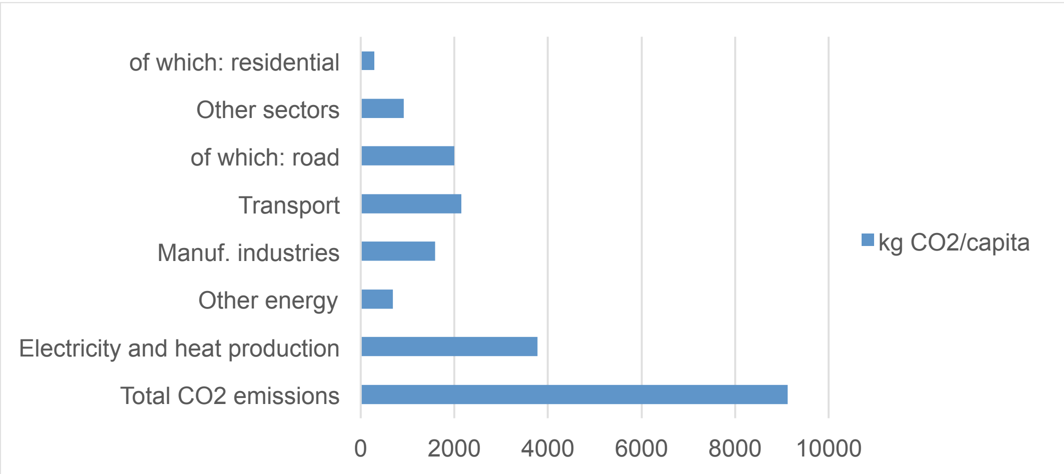
6.3 Per capita CO_2 emissions by sector, 2012

Figure 0-1. Per capita CO_2 emissions by sector, Denmark, 2012



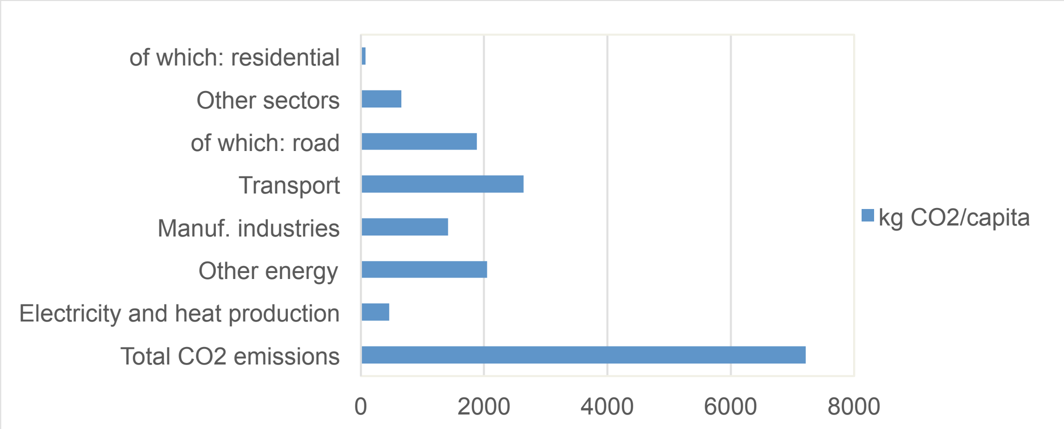
Data source: IEA, 2014

Figure 0-2. Per capita CO_2 emissions by sector, Finland, 2012



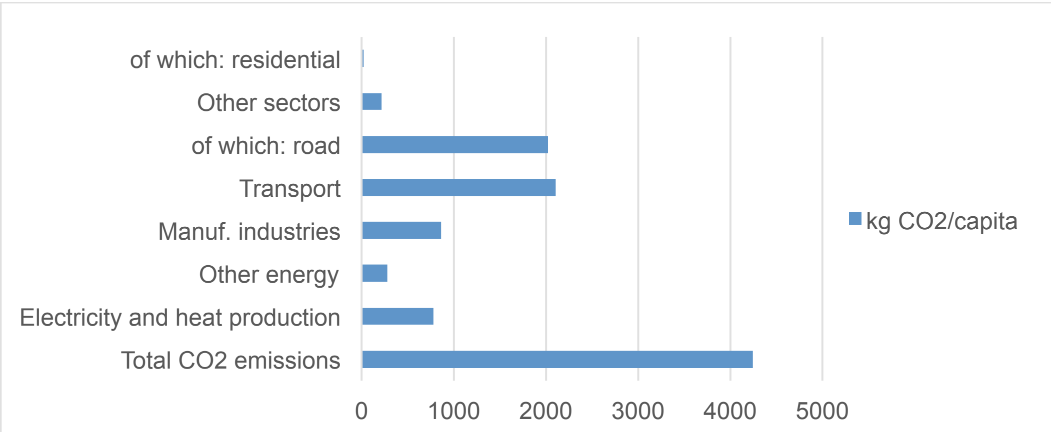
Data source: IEA, 2014

Figure 0-3. Per capita CO_2 emissions by sector, Norway, 2012



Data source: IEA, 2014

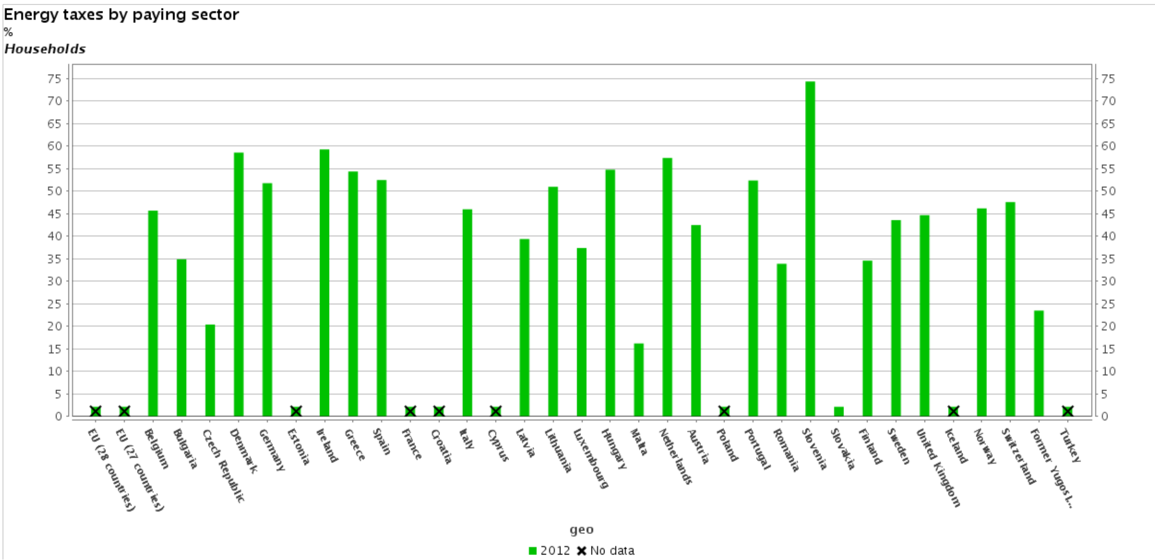
Figure 0-4. Per capita CO_2 emissions by sector, Sweden, 2012



Data source: IEA, 2014

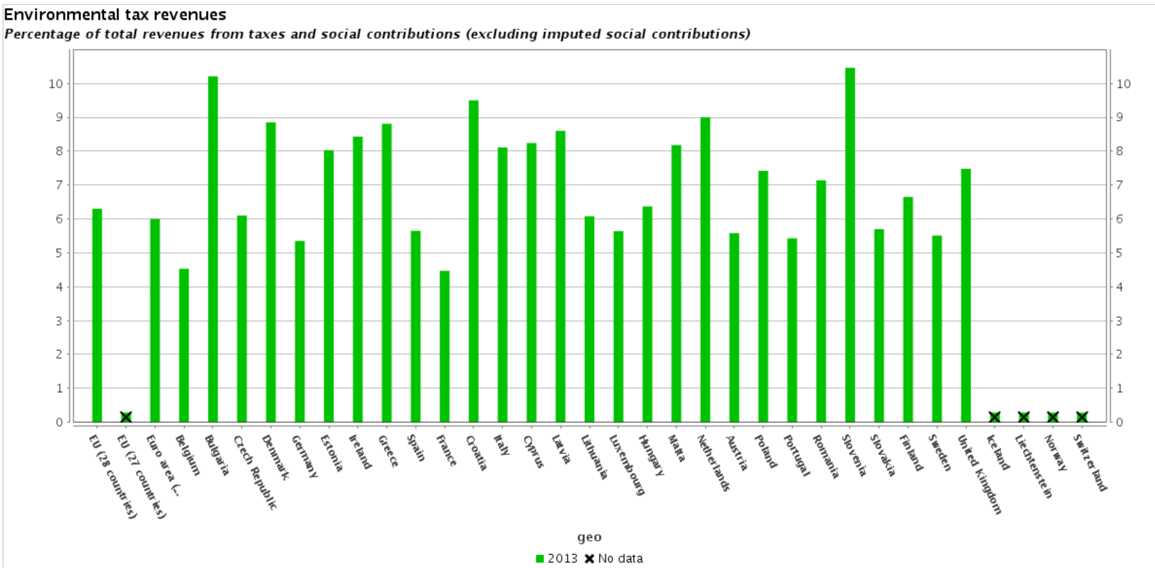
6.4 Environmental tax revenues, 2013, EU 28

Figure 0-5. Energy taxes by paying sector, EU28, 2013



Source: Eurostat, 2015

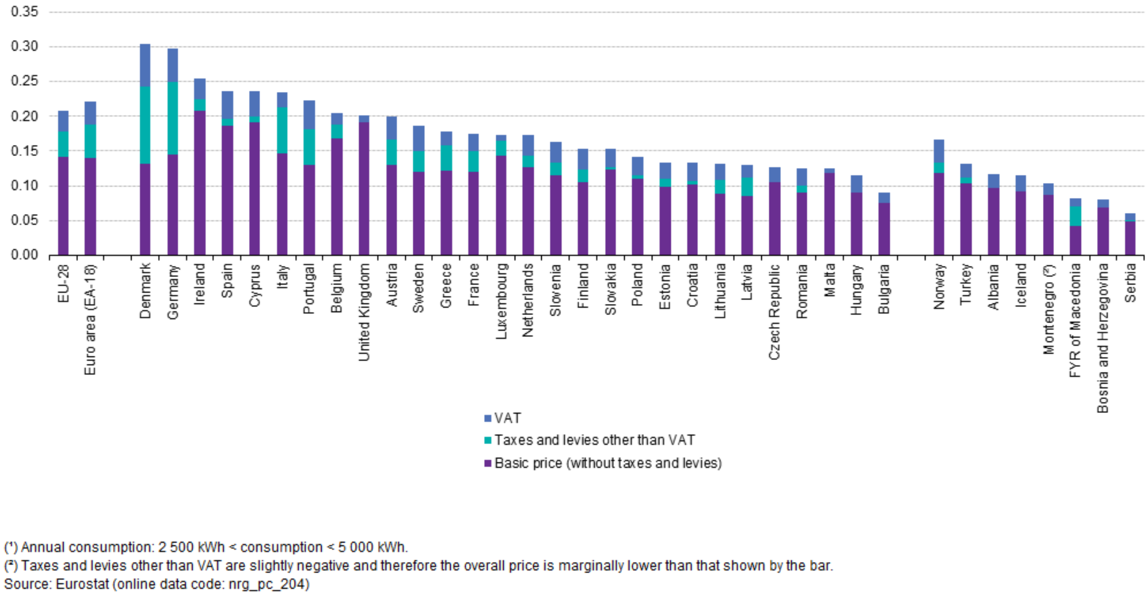
Figure 0-6. Environmental tax revenues, EU28, 2013



Source: Eurostat, 2015

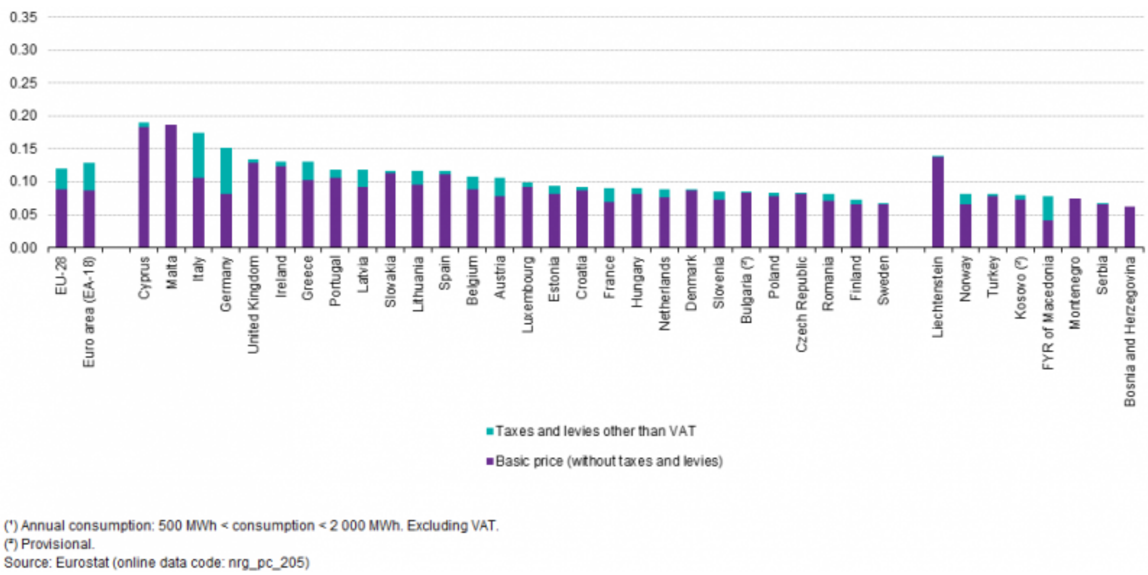
6.5 Electricity prices for households and industry, 2014, EU28

Figure 0-7. Electricity prices for household consumers, second half of 2014, EU28



Source: Eurostat, 2015

Figure 0-8. Electricty prices for industrial consumers, second half of 2014, EU 28



Source: Eurostat, 2015