Pricing carbon

A study on the most effective carbon tax design for the Netherlands

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Abstract

Carbon pricing is seen as a relatively effective policy instrument to reduce greenhouse gas emissions. The Dutch government announced the introduction of a carbon tax for the industry sector. This research focuses on the level of consideration in the Dutch societal and political debate of important factors that determine the effectiveness of a carbon tax in the Netherlands. The research consists of two phases. First, the effectiveness of eight carbon taxes implemented in the European Union is considered through a meta-analysis. Thereby, the following factors are considered: level of ambition, policy mix, monitoring, reporting and verification system, tax rate, point of enforcement, selection of target group, and redistribution of revenues. The second phase focuses on whether the previously identified most important factors are considered in the Dutch debate. Results show that carbon taxes implemented abroad are mainly effective for the energy sector, manufacturing sector and residential and commercial sector, while a carbon tax for the transport sector often does not lead to emission reduction. Another result is that the Dutch debate is mainly focused on factors as the tax rate and the selection of the target group. Other relevant factors for the effectiveness of the carbon tax, as the policy mix, are not widely discussed. Also, most stakeholder's argumentation appears to be based on normative reasoning instead of empirical causal relationships. It is recommended to intensify the consultations about the introduction of a European carbon tax, since this is preferred by the stakeholders and ensures a level playing field on the European level. Conducting an analysis on the current tax burden of all sectors mentioned in this research is also recommended, as it will give more insight in the gaps of the current tax system and may lead to a fairer distribution of tax burden between different sectors. Future research should focus on ex-post empirical evaluations of carbon taxes.

Key concepts
Carbon tax – carbon pricing – policy making – climate change – greenhouse gases

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List of abbreviations

BAU	business as usual
CCS	carbon capture and storage
CDA	Christen-Democratisch Appèl/Christian Democratic Appeal
CNV	Christelijk Nationaal Vakverbond/National Federation of Christian Trade Unions
CO_2	carbon dioxide
CPB	Centraal Planbureau/Netherlands Bureau for Economic Policy Analysis
D66	Politieke Partij Democraten 66/Democrats 66
DNB	De Nederlandsche Bank
EITE	energy-intensive trade-exposed (firms)
ETS	emissions trading system
EU	European Union
FME	Ondernemersorganisatie voor de technologische industrie/Association for the technological industry
FNV	Federatie Nederlandse Vakbeweging/Netherlands Trade Union Confederation
GDP	gross domestic product
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
Kt	kiloton
MKB	small and medium-sized enterprises
MRV	monitoring, reporting and verification
Mt	megaton
NGO	non-governmental organization
ODE	Opslag Duurzame Energie/Additional Sustainable Energy
PBL	Planbureau voor de Leefomgeving/Dutch Environmental Assessment Agency
PvdA	Partij van de Arbeid/Labour Party
PvdD	Partij voor de Dieren/Party for the Animals
PVV	Partij voor de Vrijheid/Party for Freedom
FvD	Forum voor Democratie/Forum for Democracy
PwC	PricewaterhouseCoopers
SDE+	Stimuleringsregeling Duurzame Energieproductie/Stimulation of Sustainable Energy Production
SDE++	Stimuleringsregeling Duurzame Energietransitie/Stimulation of Sustainable Energy Transition
SGP	Staatkundig Gereformeerde Partij/Reformed Political Party
SP	Socialistische Partij/Socialist Party
tCO_2e	ton of carbon dioxide equivalent
ToC	Theory of Change
VNCI	Koninklijke Vereniging van de Nederlandse Chemische Industrie/Royal Association of the Dutch Chemical Industry
VNO-NCW	Verbond van Nederlandse Ondernemingen & Nederlands Christelijk Werkgeversverbond/Confederation of Netherlands Industry and Employers
VNPI	Vereniging Nederlandse Petroleum Industrie/Netherlands Petroleum Industry Association
VVD	Volkspartij voor Vrijheid en Democratie/People's Party for Freedom and Democracy

1. Introduction

In order to combat climate change, countries have to reduce their GHG (greenhouse gas) emissions. According to the Intergovernmental Panel on Climate Change (IPCC) Synthesis Report (2014), zero net emissions for the end of this century are necessary to stay below the 2°C global warming and, thus, meet the target of the Paris agreement (UNFCCC, 2015). Therefore, most countries have implemented environmental policies to achieve a reduction of GHG emissions.

The Dutch government (2017) aims to reduce its GHG emissions in 2030 with 49% compared to 1990 levels. Current emission levels show that in 2018 the total GHG emissions in the Netherlands were reduced with 2% (CBS, 2019). In this same year, the Dutch business sector reduced its carbon dioxide (CO_2) emissions with 4.4% compared to 2017 (Emissieautoriteit, 2019). This shows that achieving the Dutch national target is not without effort. The PBL Netherlands Environmental Assessment Agency (PBL) (2019a) argued that more action is necessary to achieve the Dutch target of 49% reduction of GHG emissions. Also, the Dutch environmental non-governmental organization (NGO) Urgenda summoned the Dutch government to appear in court to achieve a 25% reduction of GHG emissions in 2020 compared to 1990 levels and won the lawsuit (Urgenda, n.d.), which increases the urgency to act.

In response to these challenges, the Dutch government presented a Climate Agreement (SER, 2019) which includes measures to meet the abovementioned target. One of the most debated measures in this Climate Agreement is the adoption of a carbon pricing instrument, namely a carbon tax for the industry sector (Ministry of Economic Affairs and Climate Policy, 2019).

1.1. Carbon pricing

Carbon pricing is assumed to be an effective manner to cut down CO_2 emissions (Rabe, 2018; Rydge 2015; Scrimgeour et al., 2005). Two options of carbon pricing are possible: an emissions trading system (ETS) and/or a carbon tax. The most common form of an ETS is a cap-and-trade system, which "*imposes a government-established limit on aggregate GHG emissions by specified sources, distributed tradeable allowances (usually one tCO_2e each) approximately equal to the limit, and requires regulated emitters to submit allowances equal to their actual emissions*" (Haites et al., 2018, p.111). The other option, the adoption of a carbon tax is a fiscal policy instrument and imposes a price, set by the government, on "*each metric ton of GHGs emitted, measured as metric ton of carbon dioxide equivalent (tCO_2e), but does not limit overall emissions*" (Haites et al., 2018, p.111).

In theory, a cap-and-trade system sounds promising in order to achieve a GHG emissions reduction. However, several parties argue that the current cap-and-trade system implemented in the European Union (EU), the EU Emission Trading Scheme (EU ETS), does not work optimally, and that additional measures, such as the adoption of a carbon tax on a national level, would be necessary to meet the targets regarding GHG emissions reduction. Also, as mentioned in the Kyoto Protocol (UNFCCC, 1997), the so-called supplementarity principle states that mechanisms on the EU level aiming to reduce GHG emissions, as the EU ETS, should be in addition to domestic efforts. Too much steering on the EU level rather than the domestic level would increase the costs of mitigating carbon emissions, turn out to be ineffective and lead to political resistance from states that are concerned about their independence and competitive position (Haug et al., 2010). This illustrates the space for the implementation of national environmental policies rather than policies on the international scale.

1.2. Problem definition and knowledge gap

The announced adoption of a carbon tax for the industry resulted in a heated debate in Dutch society. Both opponents and proponents tried to communicate their urgent message regarding the potential negative and positive effects of the adoption of the tax and used several routes to channel their perspective, for example through politics and media.

Some countries that participate in the EU ETS, and are therefore comparable to the Netherlands, have previously implemented a carbon tax, based on the carbon content of a commodity. These countries include Denmark, the United Kingdom, Finland, Sweden, Norway, France, Ireland and Iceland.

In order to achieve the most effective design of a carbon tax for the Netherlands, several organizations, as consultancies (PwC, 2019; DNB, 2018; CE Delft, 2018a, 2018b), conducted ex-ante research on the effects of implementing a carbon tax for the industry in the Netherlands, using mainly economic models. In addition, it seems useful to look at international experience, since several countries that participate in the EU ETS already implemented a carbon tax which could have paved the way for the Netherlands. Thus, doing ex-post research on the effectiveness of previously implemented carbon taxes abroad and translating this into concrete recommendations for the Dutch context is missing in the current body of literature.

1.3. Research objective

As explained earlier, there is a desire to connect the Dutch situation with lessons that can be learned from previously implemented carbon taxes abroad. This research will fill the knowledge gap by specifically focusing on factors that determine whether a carbon tax is effective or not and will look at the most effective design for the Netherlands. Therefore, the objective of the research is to contribute to the debate about the most effective design of a carbon tax model in the Netherlands by looking at evaluations of environmental tax models previously implemented in other countries participating in the EU ETS, and investigating the positions of several parties that may influence the implementation and the design of a carbon tax, including the Dutch industry sector and environmental NGOs.

Since the first carbon tax that falls within the scope of this research was adopted in 1990 in Finland (World Bank, 2018), the literature used in this research will be from 1990 onwards. This research contributes to making governance concerning the sustainable energy transition in the Netherlands more effective, and by doing this, it indirectly helps to achieve the target of the Paris Agreement (UNFCCC, 2015) and combat climate change. Policy recommendations will be provided and the results will contribute to the current body of literature.

1.4. Research questions

The central research question resulting from the research objective is the following: "*What essential design parameters for an effective carbon tax can be derived from scientific literature and existing ex-post evaluations of carbon taxes and to what extent are these design parameters considered in the development of a Dutch carbon tax?"*

To answer this question, the theoretical assumptions that form the foundation of the effectiveness of carbon taxes should be considered. Later, a meta-evaluation of the tax models implemented abroad as well as an empirical research on the discourse of stakeholders in the Dutch debate will be executed.

Five sub-research questions are constituted to help answer the central research question. The first question looks at the assumptions found in ecological economics and governance theories on the design and implementation of a carbon tax. The second and third sub-questions are focused on the international scale, considering cases where an environmental tax is implemented and which factors influence the effectiveness of these tax models. In the fourth sub-question, the focus is shifted to the Netherlands and its current political and societal debate. The last sub-question leads to policy recommendations for the Netherlands and looks at the most effective design of the Netherlands, according to the different stakeholders who (in)directly may influence the tax design. The following five sub-research questions will be answered:

1. *"What are the theoretical assumptions regarding the design and implementation of a carbon tax?"*
2. *"What types of carbon taxes are already implemented in countries that are participating in the EU ETS?"*
3. *"Which factors/conditions determine the effectiveness of the existing carbon taxes in reducing CO_2 emissions?"*
4. *"Which assumptions regarding carbon taxation dominate the current political and societal debate in the Netherlands?"*
5. *"What recommendations for the most effective carbon tax design for the Netherlands can be made?"*

1.5. Scientific and societal relevance

From a scientific perspective, experience with carbon taxes abroad can provide lessons for the Dutch government to design and implement an effective carbon tax. As mentioned by Haug et al. (2010) in their research on evaluations of environmental policies in the European Union, there should be more focus on *"the interface between evaluation and its uptake in policy making*". Answering the central research question will fill the research gap and will be supplementary to the current body of literature. This research may later be used by other countries that are planning or developing a carbon tax system as well, while the contextual factors should be considered, since the policy recommendations made in this research are tailored for the Netherlands.

From a societal perspective, questions about the ecological justice of carbon taxes are raised in several countries. There is a debate about who has to pay for environmental damage as a consequence of the deployment of natural capital. From this perspective, getting more insight in the assumptions that form the foundation of the implementation of a carbon tax will be a thorough contribution to the current societal debate. Furthermore, since the research includes a content analysis of the debate in the Dutch parliament as well as interviews with both the industry sector and environmental NGOs, it can be concluded that different societal perspectives will be represented. Since these actors with different position clarify their preference for a specific carbon tax model, more insights are provided in the features of the tax model that are important for a certain interest group. This makes it easier to decide which tax model is most suitable to implement in the Netherlands. Therefore, the results of the research will be applicable to a great extent in societal practices.

1.6. Outline of the report

This paper proceeds as follows. Chapter 2 consists of an overview of background information regarding the current climate- and energy-policies in the European Union and the Netherlands. It elaborates on the carbon pricing systems in order to describe the policy context in where a carbon tax in the Netherlands will be implemented. The third chapter describes the theoretical framework, which is based on ecological economics and governance theories. The research strategy and methods will be described in the fourth chapter, explaining why the chosen strategy is been used. Then, the fifth, sixth and seventh chapters show the results from the conducted research. Hence, the results are separated into three parts. The fifth chapter consists of an overview of the evaluated carbon taxes in other countries in addition to the EU ETS, as a result of the literature study. The sixth chapter describes the information that is derived from the interviews and the analysis of the political debate in the Dutch Parliament. The seventh chapter integrates the two previous chapters in a comparative analysis. Then, a discussion section will elaborate upon the limitations of this research and future research. At the end, the results will be translated into Chapter 9, the conclusion section, answering the central research question and providing (policy) recommendations.

2. Background information

In the following chapter, practical background information concerning the current climate- and energy policies on the European level and the national level of the Netherlands is provided, in order to show the context in which a carbon tax in the Netherlands will be implemented.

2.1. Climate- and energy-related policies in the European Union

2.1.1. European energy production and targets

The European Union has set several climate and energy targets for 2020 and 2030, such as the reduction of GHG emissions with at least 20% in 2020 and 40% in 2030, compared to 1990 levels (European Commission, 2014). In the long term, the 'Roadmap for moving to a competitive low carbon economy in 2050' (European Commission, 2011) presents the EU target for decreasing its domestic GHG emissions by 80% to 95% in 2050, again compared to 1990 levels. An overview of these targets can be found in Table 1. In addition to the EU ETS and carbon taxes, energy taxes and subsidies are implemented to contribute to achieve the emission reductions (Metcalf & Weisbach, 2013).

Table 1. EU GHG emission reduction targets (European Commission, 2014; European Commission, 2011).

European target	**2020**	**2030**	**2050**
Reduction of GHG emission[1]	20%	40%	80-95%

2.1.2. The EU ETS

The EU ETS is one of the main regulations related to climate and energy. All EU member states as well as Iceland, Norway and Liechtenstein participate in this scheme. This system works on a 'cap and trade' principle (European Commission, 2015). A cap is set on the amount of GHG that can be emitted in the whole system. Within this cap, companies can trade their emission allowances. Since the cap and total number of allowances decline over time, total emissions will fall. Hafstead (2019) adds "*allowances can be distributed in a number of ways: they can be directly allocated to firms or facilities (a concept called free allocation of allowances) or sold through auction markets. The limited, government-controlled supply of allowances "caps" the total amount of emissions. Allowances can be traded, and the sales and purchases (supply and demand) of allowances yield a market price for allowances—essentially the price of one ton of* CO_2 *emissions"* (p.1). The ETS covers approximately 45% of the GHG emitted in the EU (European Commission, n.d.), including the electricity sector and some carbon-intensive industries (Metcalf & Weisbach, 2013). However, as briefly mentioned in the Introduction, several parties argue that the EU ETS does not work optimally (Zhang & Wei, 2010). One point of criticism is that negotiations between the European institutions, such as the European Parliament and the European Commission, lead to targets which could make the EU ETS less effective than a carbon tax with a fixed tax rate. The European Environment Agency (2018) writes that the price per allowance in the ETS has varied from around 8 euros to 35 euros per ton of emitted CO_2 from 2005 onwards, which shows that fluctuations in the allowance price are assumed to be relatively normal. These fluctuations reflect the complexity of price dynamics in carbon pricing and could be seen as large risks for enterprises (Zhang & Wei, 2010). Some critique is overcome through the adoption of the Market Stability Reserve (MSR) reform, which addresses the surplus of allowances that led to a relatively low allowance price. The MSR also improves the EU ETS's resilience to shocks by adjusting the supply of allowances (European Parliament, 2015).

2.2. Climate- and energy-related policies in the Netherlands

2.2.1. Dutch energy production and targets

The Netherlands has the biggest natural gas field in the EU, the Groningen gas field. Since its discovering in the 1960s, the Netherlands has been a major producer and exporter of natural gas (OECD, 2019b). However, in the last years the share of natural gas has declined. This was caused by both the transition towards renewable energy sources and the occurrence of earthquakes in the province of

[1] Compared to 1990 levels.

Groningen due to gas exploitation. Still, natural gas was responsible for more than 40% of the primary energy supply in 2017, as is shown in Table 2. Besides its role in the export of natural gas, the Netherlands is a major petroleum hub in Europe (OECD, 2019b).

Table 2. Total primary energy supply in 2017 (OECD, 2019b).

Energy resource	**Total primary energy supply in 2017**[2]
Coal	12%
Natural gas	42%
Oil	38%
Biofuels and waste	5%
Geothermal, solar and wind	2%
Nuclear	1%

As mentioned in the Introduction, Dutch emissions declined in 2018. The rise of the EU ETS price from €8/tCO_2e in January 2018 to approximately €23/tCO_2e in December 2018 could be one of the factors resulting in the reduction of CO_2 emissions in the Netherlands in that year.

The EU targets on GHG emissions reductions for 2020 and 2030 are translated into national targets, which can be found in Table 3. For the Netherlands this means a reduction of non-ETS sector GHG emission by 16% in 2020 compared to 2005 levels (European Parliament, 2009). However, due to the earlier mentioned Urgenda court case, the Netherlands should achieve a GHG emission reduction of 25% in 2020 compared to 1990 levels (Urgenda, n.d.). The EU 2030 target of 40% reduction is tightened by the Dutch government to a reduction of 49% compared to 1990 levels (Government of the Netherlands, 2019). In 2017, the Netherlands was responsible for 4.5% of the total EU emissions. A Dutchman emits 34% more than the average EU citizen, namely 11.3 tCO_2e per habitant, while the average EU emission is 8.4 tCO_2e per habitant (CBS, 2019). Also, since the industry sector only achieved a CO_2 reduction of 1.9% in 2018 (Emissieautoriteit, 2019), additional major steps may be taken.

Table 3. Dutch GHG emission reduction targets (Government of the Netherlands, 2019).

National target	**2020**	**2030**	**2050**
Reduction of GHG emission[3]	25%	49%	95%

Figure 1 below shows the development of CO_2 emissions per sector during the period 1990-1997 relative to a rising gross domestic product (GDP). Since Eurostat (2019) only provides data on the development of the GDP of the Netherlands from 1995 onwards, the black dotted line in Figure 1 starts at this point. However, it can be said that while no carbon tax is implemented in the Netherlands yet, the CO_2 emissions are stagnating or declining compared to the increasing level of GDP. Nonetheless, Figure 2 shows that the absolute CO_2 emissions are increased from 162,428 kiloton (Kt) CO_2 in 1990 to 164,478 Kt CO_2 in 2017. The energy industry, which includes power generation, refineries, oil and gas production and coke ovens, accounts for most emissions relative to all domestic emissions in both 1990 and 2017. In addition, the share of relative emissions caused by the energy sector appears to be increased during the period 1990-1997 (Eurostat, 2019).

[2] Excluding net electricity import.
[3] Compared to 1990 levels.

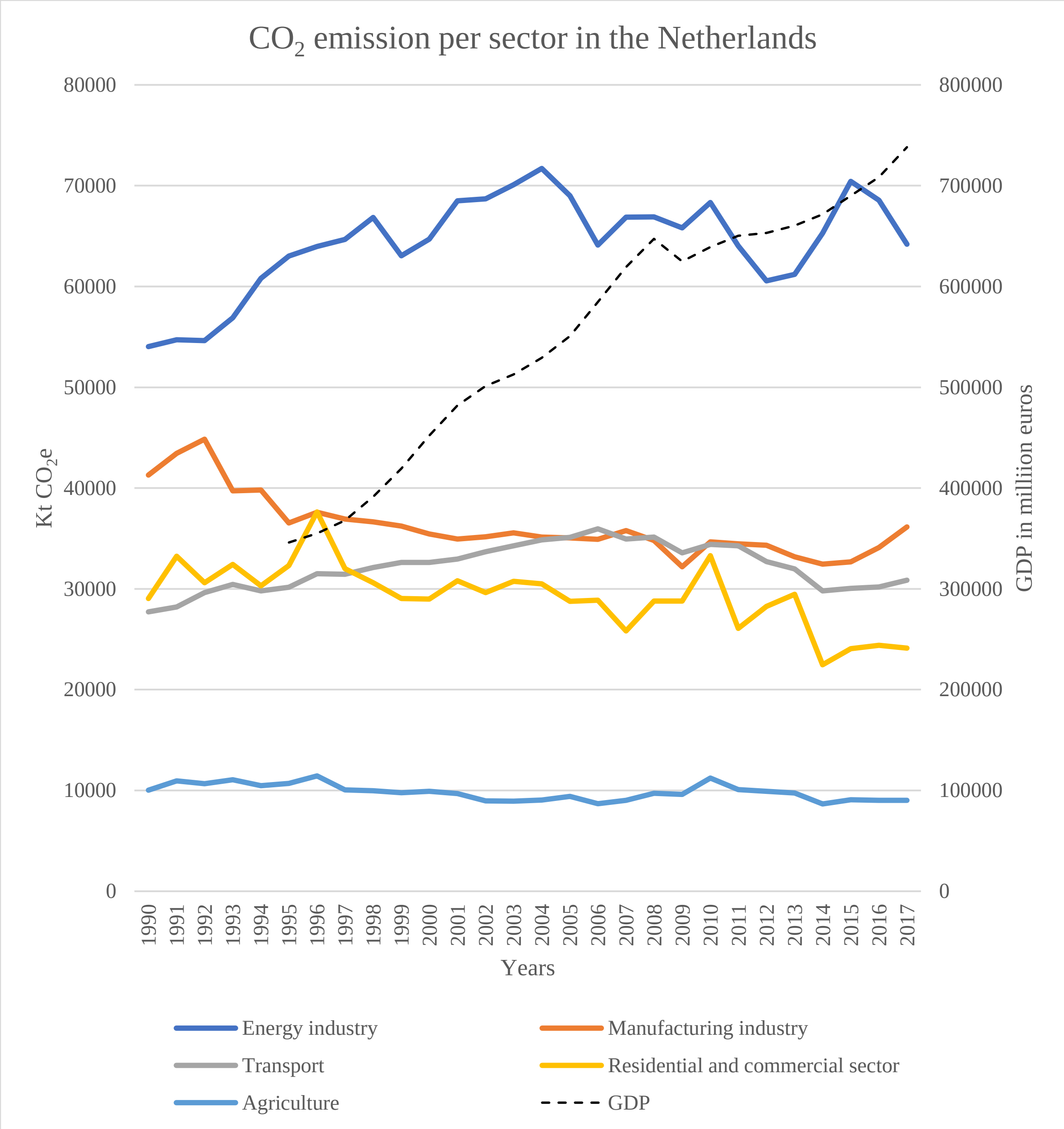

Figure 1. CO_2 emissions per sector and GDP in the Netherlands (Eurostat, 2019)[4]

[4] The same sectors as identified by the EEA (2019a) are used. The emission caused by the energy industry is based on data from fuel combustion in energy industries, including power generation, refineries, oil and gas production and coke ovens (CRF1A1), and fugitive emissions (CRF1B). For the manufacturing industry sector, data from fuel combustion in manufacturing industries and construction (CRF1A2) and from industrial processes and product use (CRF2) is used. The emissions from the residential and commercial sector consist of fuel combustion in commercial and institutional sector (CRF1A4A) and by households (1A4B). Emissions from the transport sector are based emissions from fuel combustion in transport (CRF1A3). The agricultural sector consists of fuel combustion in agriculture, forestry and fishing (CRF1A4C) and agriculture (CRF3). Due to a lack of data for the Netherlands starts the graph representing the GDP development in 1993 (Source: Eurostat, 2019).

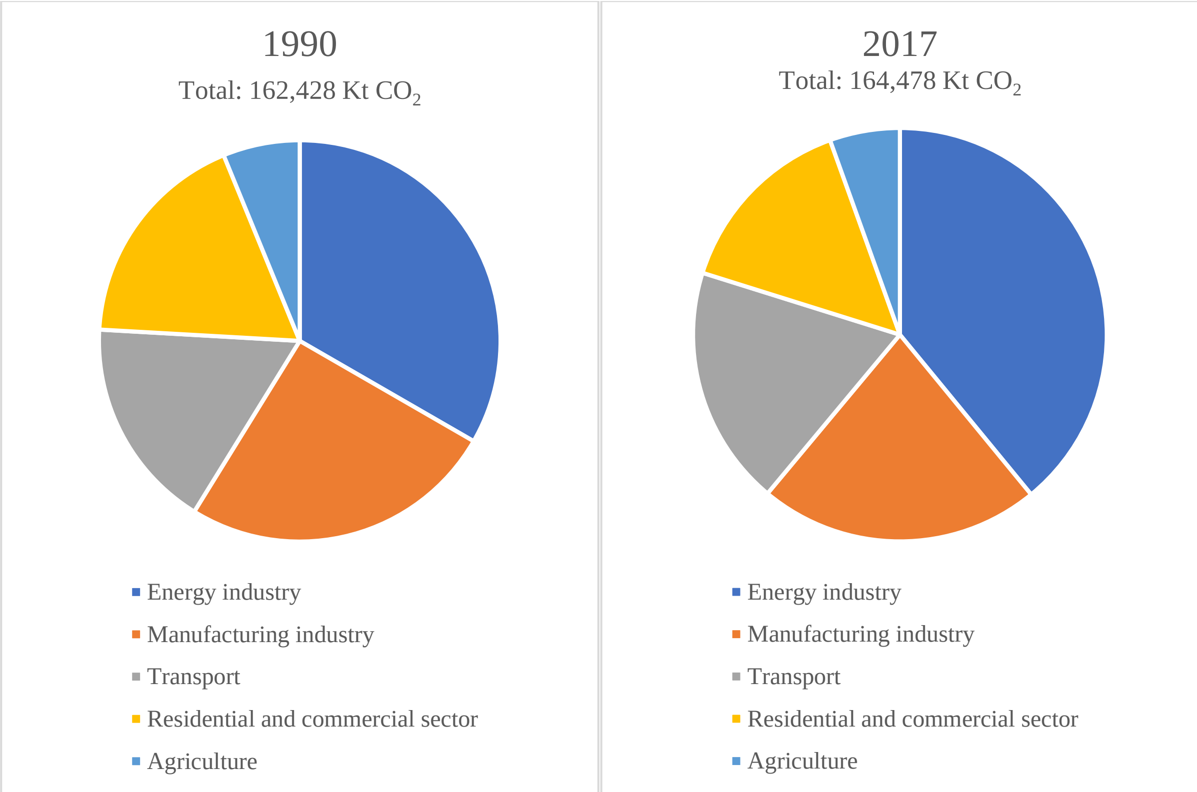

Figure 2. CO_2 emissions per sector related to domestic emissions in 1990 and 2017 in the Netherlands (Eurostat, 2019)

When focusing on the Dutch energy and manufacturing industry it becomes apparent that these sectors emitted approximately 61% of the total domestic CO_2 emissions and consumed 23.4% of the energy in 2016 (EEA, 2018a). The energy supply alone is responsible for more than 40% of the domestic CO_2 emissions, as shown in Figure 2 and Table 4.

Table 4. The Dutch industry and its share of the total domestic CO_2 emissions in 2016 (EEA, 2018a).

Industry sector	**Share of the total domestic CO_2 emissions**
Pulp, paper and wood	1%
Non-metallic minerals	2%
Iron and steel	3%
Food and drink	2%
Energy supply	41%
Chemicals	10%
Other	2%
Total	*61%*

2.2.2. Energy taxes and subsidies

Apart from the international EU ETS, the Netherlands has several national climate- and energy related policies aiming to reduce the GHG emissions. In 1990, the Netherlands adopted a carbon tax. The carbon tax did apply to '*natural gas, electricity, blast furnaces, coke ovens, refinery and coal gas, coal gasification gas, gasoline, diesel and light fuel'* (Sumner, Bird & Dobos, 2011, p.9). However, two years later, this tax was adjusted to a 50/50 energy and carbon tax, based on both the carbon content and energy content of all hydrocarbon fuels, called the Environmental Tax on Fuels. In addition, a Regulatory Tax on Energy was adopted in 1996, which was also based on the carbon and energy content of fuels. This tax was an energy levy on electricity and gas consumption imposed on small and medium-size customers. The tax was abolished in 2005 (IEA, 2014).

In 2008, the Dutch government adopted a Carbon-Based Tax on Packaging to fund a Waste Fund, aiming to meet the target of 65% recycling of used packaging by 2012. However, an evaluation commissioned by the Ministry of Finance concluded that the tax was inefficient and it was subsequently abolished in 2013 (CE Delft, 2010). The Netherlands currently only has an energy tax on electricity and natural gas, which aims to reduce energy consumption and carbon emissions (Metcalf & Weisbach, 2013). De Nederlandsche Bank (DNB) (2018), the Dutch Central Bank, writes that small companies and households are paying a relatively higher energy tax on natural gas than large energy users. This raises questions concerning the ecological justice of the current Dutch tax system.

Concerning other climate- and energy-related policies in the Netherlands, the most important regulations are the SDE+-scheme (Subsidieregeling Duurzame Energieproductie) and the ODE (Opslag Duurzame Energie). The SDE+-scheme is a subsidy that covers the difference between the market price for electricity and the actual price of the production of renewable energy (Visscher, 2018). The ODE is an energy tax that is paid by both households and industry and is added to the market price of the energy consumed. The SDE+-scheme is funded by the revenues from the ODE. These policies will be adjusted in 2020. The Dutch Climate Agreement (SER, 2019) includes an elaboration of the SDE+ to SDE++ (Subsidieregeling Duurzame Energietransitie), which stimulates additional innovations, such as carbon capture and storage (CCS).

2.2.3. Adoption of a carbon tax for the industry

The Dutch Climate Agreement (SER, 2019) also includes a proposal to adopt a carbon tax for the industry. This instrument will be used to achieve a GHG emission reduction of 14.3 megaton (Mt) from the industry in 2030, compared to business as usual (BAU) projections. During the development of the Dutch Climate Agreement, several stakeholders representing several parties, such as industrial associations or environmental organizations, discussed potential policy instruments in order to meet the climate targets. Industrial companies developed the idea of a bonus-malus system, which provides industry companies with subsidies to green their business rather than only paying a tax. Also, left-wing parties PvdA and GroenLinks proposed a carbon tax design with revenue redistribution for low-income households. However, after calculations made by the PBL and CBP, these proposals were deemed not sufficient to meet the climate target or were expected to have a large risk of carbon leakage.

Eventually, the Dutch government, consisting of the political parties VVD, CDA, D66 and ChristenUnie, adopted a definitive carbon tax design. This carbon tax concerns a tax levied on a company's emissions above a certain threshold by the Dutch Emissions Authority (NEa). The tax rate will start at €30/tCO_2e in 2021 and gradually increases to €125-150/tCO_2e in 2030. Here, the EU ETS price is included. In 2020 and 2025, the PBL will do additional research in order to validate whether the tax rate should be adjusted to meet the 14.3 Mt industry target. Levying emissions above a certain threshold aims to prevent for carbon leakage. This threshold is based on the 10% most effective European installations, and will increase over time. The tax is levied on industrial emissions that are also covered by the EU ETS as well as emissions from waste incineration plants (SER, 2019). The monitoring, reporting and verification (MRV) system will be integrated in the current national enforcement strategy. However, further elaboration of this design is in progress. Later in 2020, the bill considering this carbon tax will be submitted to the Dutch parliament for approval. The carbon tax will come into force in 2021 (SER, 2019).

3. Theoretical framework

In this chapter, two main theoretical perspectives on environmental taxation will be addressed, namely ecological economics and governance theories. It is essential to consider both perspectives. On one hand, the economic mechanisms that form the foundation of a carbon tax are presented in the ecological economics literature. On the other hand, governance theories present the public policy making tools to translate these economic mechanisms into policy and eventually behavioral change of target groups. Governance theories also consider the role of interest groups, which may have a substantial influence on policy making, and are therefore important to recognize in research on the effectiveness of a carbon tax. Also, the concept of a Theory of Change will be explained, which will be used as analysis tool. At the end, design parameters influencing the effectiveness of a carbon tax will be discussed. These variables represent features of the carbon tax design, and are derived from ecological economics literature and governance theories.

3.1. Ecological economics

Gowdy and Erickson (2005) argue that the main economic perspective of this century, neoclassical welfare economics, fails as it leads to environmental and social damage, "*including growing income disparity, global climate change and biodiversity loss*" (p.208). They see ecological economics as an alternative as it assumes a balance between raw materials entering the process and waste leaving the process as main idea of economics (Gowdy & Erickson, 2005). Ecological economics is built on the following assumptions: (1) resources are limited and should not be wasted; (2) sustainable economic development should be stimulated and unsustainable economic growth should be discouraged; and (3) environmental consequences of economic goods/services, the so-called externalities, should be included in the price of this good/service (Miller & Spoolman, 2012). These externalities are a key part of ecological economics literature and the internalization of these externalities form the foundation of the principle of carbon pricing.

3.1.1. Pigouvian tax

Externalities can be defined as costs of market transactions that are not included in the traditional costs, which can be positive or negative. In relation to environmental issues mainly negative externalities are mentioned, which create "*side effects that could be harmful to either the general public directly or through the environment, such as pollution generated from the burning of fossil fuels*" (Goldemberg, 2018, p.98). Traditionally, an economy should internalize external environmental costs in order to realize a price that represents the full opportunity costs. However, the negative external costs, the externalities, are often not internalized in the price, resulting in environmental degradation and an unjust paying system (Munda, 2012). Therefore, additional measures in the economics are necessary to include the negative externalities in the price of the polluting service or product. One of the main thinkers on carbon pricing is the economist Arthur Pigou, who developed the idea to use taxes to mitigate the damage caused by externalities, the so-called Pigouvian tax (Pigou, 1920). It directly reflects the marginal damages caused by a specific amount of carbon emitted.

3.1.2. Design of the tax

Often, a carbon tax is levied on fossil fuels determined by their carbon content, e.g. taxation per liter of petrol or per ton of coal. This leads to a higher price for more polluting services or products. Therefore, a carbon tax is based on the *Polluter Pays Principle* (Hammar & Akerfeldt, 2011). For example, the carbon tax introduced in Australia led to an increase of the price for coal, which simultaneously stimulated the depletion of natural gas, which resulted in less GHG emissions compared to the amount of emissions caused by the depletion of coal (Haites et al., 2018). The rate of the tax can be set in various ways. The first option is to set the rate equal to the estimated benefit of reducing GHG emissions by one ton of CO_2, which is called the social cost of carbon. A second option is to set the tax rate that is needed to meet the emission reduction target, studied by economic modelling. Tax rates can also be set based on the preferred amount of revenues collected or the tax rate that is implemented in other states (Haites, 2018).

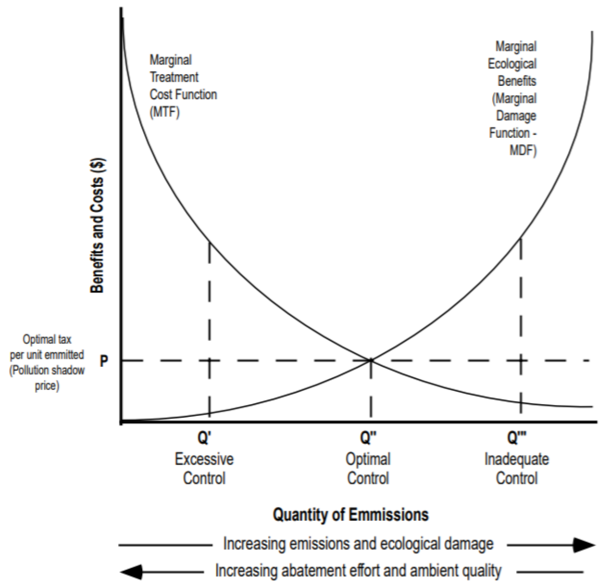

Figure 3. Optimal pollution control and environmental quality (Costanza et al., 1997)

Figure 3 shows the balance between the quantity of emissions and the benefits and costs of the implementation of an environmental taxation system (Costanza et al., 1997). As shown, too much control will lead to increasing abatement effort and ambient environmental quality as well as high costs of control. On the right side of the figure, relatively low control will result in increasing emissions and ecological damage. The optimal control, shown under Q" in the figure, presents the most effective level of the tax.

The main purpose of carbon pricing, or a carbon tax in particular, is to reduce the amount of GHG emissions, which is its environmental effectiveness. Environmental effectiveness consists of two dimensions: the share of the country's GHG emissions covered by the carbon tax, and the net reduction in emissions covered by the instrument. These two dimensions are interlinked, since a relatively bigger share of the GHG emissions covered would lead to a higher net reduction of GHG emissions (Haites et al., 2018). Additional price and revenue effects, such as using the revenues of a carbon tax for emission reducing activities, are difficult to account for when calculating the environmental effectiveness, because these will also interact with other (climate-related) policies and there is a risk of double counting (Haites et al., 2018). Economists often use research models to assess the degree of effectiveness of policy instruments based on ex-ante research, such as computable general equilibrium (CGE) models. These models are based on assumptions about causality rather than on empirical research on the causal relationship between the policy instrument and the outcome itself (OECD, 2016).

One potential consequence of the implementation of a carbon tax which is often mentioned in the literature is carbon leakage. Carbon leakage can be defined as '*the movement of production and emissions to locations with less stringent climate policy*' (Rydge, 2015). Carbon leakage may have consequences for calculating the reduction of GHG emissions as a result of the adopted carbon tax, since GHG emissions in a country that adopted a carbon tax are reduced, but increased in a country with less stringent climate policies. Haites et al. (2018) shows that ex-ante models estimate the effect of carbon leakage as small, varying from 5% to 20% leakage of GHG emissions, while ex-post studies show no evidence of leakage at all. Metcalf and Weisbach (2013) argue that carbon taxes in developed countries lead to an increase of emissions abroad of 15 to 25% of the reductions in the taxing region. Therefore, Haites et al. (2018) use the change in actual emissions subject to the instrument as a way to calculate the environmental effectiveness of carbon taxes. Several studies show that carbon taxes reduce BAU emissions by less than 2% per year (Haites et al., 2018).

Carbon leakage can be reduced by border tax adjustments based on the carbon content of imported or exported goods (Rydge, 2015). However, it is difficult to determine the carbon content of products. One option is to base the border tax adjustment on the carbon that would have been emitted in the country where the product is produced or on the estimates of average emissions in the exporting nation from productions of a given good (Metcalf & Weisbach, 2013).

Besides the tax rate, several other features, such as the point of enforcement and the MRV system, form the tax design (Goulder et al., 2018; Metcalf & Weisbach, 2013; OECD, 2011). Section 3.3 elaborates on these design parameters.

3.1.2. (Dis)advantages of carbon taxation

Coase (1960) criticized the theory of Pigou by arguing that an approach which gives participants the opportunity to negotiate their optimal solution, as the aforementioned cap-and-trade system, would be more efficient, since no third party would be involved. However, critique on the cap-and-trade system is that those negotiations on the caps would not lead to the most effective pricing instrument. Also, the cap-and-trade system produces compliance costs and is therefore less likely to provide a direct link between the market price and the environmental damage (Rabe, 2018). Baumol and Oates (1971) argued that the Pigouvian tax has proven to be rarely feasible, since it is impossible to measure the marginal social damage. More general criticism on carbon pricing, summarized by Rabe (2018), is that carbon pricing is assumed to be an elite advocacy that might promote inequalities. According to the double-dividend hypothesis (Goulder, 1995) however, it is possible to prevent for this regressive nature, since the redistribution of revenues can result in a net welfare benefit. The double-dividend hypothesis states that environmental taxes may offer double benefits: while improving the environment, it also reduces the costs of the taxation system. However, the extent of this double-dividend hypothesis is contested. In addition, Sumner, Bird and Dobos (2011) argue that taxes are an attractive measure in addition to a command and control or a cap-and-trade scheme for emissions that are difficult to regulate. In this case, the carbon tax can be applied to sectors that are not included in the ETS to increase the total percentage of emissions that are covered.

3.2. Governance theories

As earlier explained, the effectiveness of an environmental tax depends on different factors. According to governance theories, effective governance consists of a functional and a procedural aspect (Sørensen & Torfing, 2016). Concerning the functional aspect, the policy should "*solve the problems and satisfy the demands [it is] designed to cope with (goal attainment; problem-solving capacity)"* (p.157). Investigating whether a policy solves the problem and leads to the intended outcome is related to the causal assumptions that are made on which the policy is based. The total of assumptions underlying a policy is called the policy theory. A policy theory can be based on three forms of assumptions or argumentations: (1) final argumentations that consist of a reasoning from an end to a means or vice versa, (2) causal argumentations that have a reasoning from a cause to an effects and vice versa, and (3) normative argumentations that have reasoning from a "*principle to a norm or vice versa, or with an assessment of an existing or expected situation in the light of a principle or norm*" (Hoogerwerf, 1990, p. 289). The actor's assumptions are implicitly or explicitly embodied in oral or written explanation about a policy. Research based on governance theories often includes the assessment of these assumptions and causal relations in terms of whether the policy instrument results to the intended outcome or if this outcome is (partially) the result of other policy instruments or external factors, which is called the causal attribution. Analyzing attribution requires are comparison of the current outcome with a counterfactual, which would have been the situation without the policy intervention (Essama-Nssah, 2013). In comparison to ecological economics, governance theories are therefore more focused on measuring a potential causal relationship between the policy instrument and the outcome, using ex-post research (OECD, 2016).

Furthermore, governance should consist of policy instruments that are both cost-efficient and legitimate (Sørensen & Torfing, 2016). The latter is related to issues of justice and fairness and is therefore seen as more normative. Questions of policy instruments in which all actors, including households and the industry, contribute fairly to the solution to climate change are highly debated. Thus, public acceptance and the role of interest group trying to influence policy making are relevant and often subject of research on the implications of the introduction of policy instruments. Therefore, public acceptance and lobbying as well as public policy making and a theory explaining the performance of groups based on belief systems, called the Advocacy Coalition Framework, will be further explained.

To visualize underlying assumption and theories, the construction of a Theory of Change (ToC) can be used.

3.2.1 Theory of Change

Morra Imas and Rist (2009) define a ToC as "*an innovative tool to design and evaluate social change initiatives*" (p.151). The development of a ToC helps identifying the elements of the implementation of the carbon tax that are necessary to success. Figure 4 shows the causal chain of the ToC, in where the inputs, activities, outputs, outcomes and impacts of a policy will be identified. All steps of the ToC are influenced by the societal environment and vice versa.

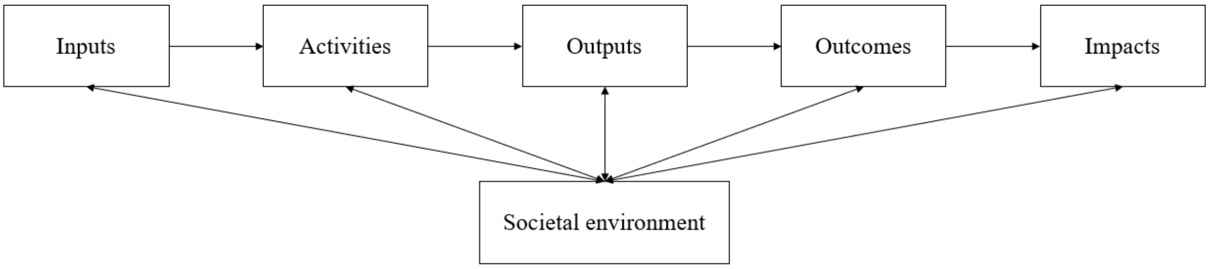

Figure 4. Theory of Change (adjusted from: Morra Imas & Rist, 2009).

3.2.2. Public acceptance and lobbying

It is important for policymakers to understand public perceptions concerning environmental taxes in order to adopt an environmental tax design that receives sufficient public support. Compared to the United States, environmental taxes are highly accepted in Europe, and not only in countries with a relatively green government (Sterner, 2003). Newig and Fritsch (2009) propose to enhance the participation of civil society actors in environmental decision making in order to improve the effectiveness and legitimacy of the process. Carattini, Carvalho and Fankhauser (2018) identify five reasons for aversion to carbon taxes: (1) the perceived costs are too high; (2) the carbon taxes can be regressive; (3) the carbon taxes could damage the general economy; (4) the carbon taxes will not restrain high-carbon behavior; and (5) governments want to implement a carbon tax to increase their revenues.

As stated by Haug et al. (2010), policy makers have to choose between alternative courses of actions. The choice is made in a context of intensive bargaining (Haug et al., 2010). This bargaining context consists of trading off the values of parties with sometimes conflicting interests. In order to gain more insight in the way public policy formation and implementation works and agendas are set, it is important to investigate the role of interest groups. Interest groups may try to influence the level of the environmental taxation, leading to a non-optimal price level which will reduce or increase the mitigating effect of the tax. These groups will try to influence the decision-making in favor of their preferred policy outcome via lobbying. Lobbying is defined as the "*interest groups' contact with—and activities directed at—decision-makers in an attempt to influence public policy*" (Gullberg, 2008). In the past decades, carbon pricing did not receive lots of public and therefore political support, but since the Paris Agreement in 2015, the sentiment has changed in favor of the adoption of carbon pricing (Baranzini et al., 2017). Even many businesses realize that carbon pricing is not a bad option to mitigate climate change. The urgency for mitigation increased due to more prominently visible consequences of climate change, such as more extreme weather events. A survey of EY (2015) concludes that more than 100 executives of large firms worldwide see carbon pricing as a climate policy instrument on the rise. Almost half of the executives states to be in favor of the adoption of a carbon pricing instrument. However, many studies illustrate that policy instruments with a certain level of ambition are degraded before implementation due to powerful lobbies that would otherwise block the implementation of the instrument at all. This lobbying may lead to the inclusion of exemptions from taxation and/or lower tax rates for several industry sectors, in particular for energy-intensive trade-exposed (EITE) firms (Haug et al., 2010; Sterner & Kohlin, 2003). On the other hand, 'green organizations', mainly environmental NGOs, strike against these industry actors in the political area. For instance, in Canada's British Columbia, environmental organizations have successfully stressed the importance of carbon taxation by informing the public about the advantages of carbon taxation and solutions to limit potential drawbacks (Baranzini et al., 2017).

3.2.3. Public policy making

Including the price of environmental damage as a consequence of resource deployment in the market price, thus to internalizing the negative externalities, will be carried out through public policy making. Most literature suggests that public policy making is based on the conventional policy cycle. There are several varieties of this policy cycle, but in this research the following phases will be considered: agenda setting, policy formulation, decision making, implementation, and evaluation (Jann & Wegrich, 2007). During the second phase, the policy formulation, the structure of the policy will be defined, which requires considering several policy options. During this phase, stakeholders and interests groups will try to influence (the design of) the policy. After the policy formulation, the governmental authority is the main actor in the decision making phase. Then, the actual implementation of the policy takes place and at the end, the policy will be evaluated in terms of its effectiveness and success to improve it for future purposes. These phases are "*the result of interactions among a plurality of separate actors with separate interests, goals, and strategies*" (Scharpf, 1978, p.347). Therefore, this research focuses on the influence that interest groups have on the adoption of a policy, which makes considering the motivations behind the actor's actions important.

3.3. Design parameters

As explained above, ecological economics and governance theories stress different aspects concerning carbon pricing. These aspects are related to design parameters that are identified in the literature as determining the effectiveness of a carbon tax (Goulder et al., 2018; OECD, 2011). The following features of the taxation model as well as contextual factors will be considered in this research: the level of ambition, the policy mix, the MRV system, the tax rate, the point of enforcement, the selection of the target group, and redistribution. These theory-based insights led to hypotheses, which will later be tested in case studies.

3.3.1. Design parameter: the level of ambition

The level of ambition can be defined as climate targets that are set for the future. As earlier mentioned, the EU climate target for 2020 is translated into national targets for the European member states (European Parliament, 2009). However, members states could decide to set additional or stricter national climate targets related to GHG emissions. These countries can be seen as more ambitious than European countries that only comply with the European target. More effort is necessary to meet those more ambitious targets, which may lead to the adoption of additional carbon pricing instrument on the national level, as the carbon tax. For analyzing the level of ambition of the case studies, the emission reduction target for 2020 only will be considered, since the long-term targets may still be under development or may be adjusted. This leads to the following hypothesis:

H_1: Setting additional national climate targets is beneficial for the effectiveness of the carbon tax.

3.3.2. Design parameter: the policy mix

The policy mix is defined as the policy instruments that interact together towards the achievement of a specific goal or target (Wilts & O'Brien, 2019). It consists among others of the whole spectrum of taxes and subsidies that are implemented on the local, national and international scale. The entire policy mix should be considered while investigating the carbon tax, since other (non-climate) instruments and policies could influence the effect of the carbon tax (Haites et al., 2018). Rydge (2015) writes that carbon prices and complementary policies should be aligned and integrated within the policy package itself and across the wider economy. This is illustrated in the study of Scrimgeour et al. (2005) on the combination of environmental taxes in New Zealand. They conclude that important trade-offs exist in the implementing of environmental taxes. Here, carbon emissions and fossil fuel consumption declined as a result of implemented environmental taxes, especially due to the carbon and energy taxes rather than the petroleum tax. The carbon tax and energy tax resulted in a decline of the carbon emissions of 18% and 16% respectively, while the petroleum tax reduced these emissions with only 1.9%. The study also shows that implementing additional taxes may have harmful effects on the economy in general, while it would have little beneficial effect on the environment (Scrimgeour et al., 2005).

Also, non-climate policy portfolios can facilitate the implementation of climate policies, as carbon pricing, and thus improve their effectiveness. An example of a success story is Indonesia, where increasing the prices of gasoline, diesel and electricity was combined with a compensation package for low-income households. On the other hand, the reform attempts in Bolivia in 2010 led to riots and civil unrest, which ultimately led to the abandoning of the tax reform (Rydge, 2015). Rydge (2015) concludes that the costs of carbon pricing can rise if divergent carbon prices are put on different parts of the economy, or when fossil fuel extraction and emission reduction is stimulated at the same time.

Marron and Morris (2016) stresses that climate policy is about the policies that remain in place rather than the implementation of new policies aiming to reduce GHG emissions. Long-term climate policies are crucial for decision-making in business environments, which makes it necessary to include the entire policy mix rather than considering the new or adjusted policy solely. Other policies and developments can influence the GHG emission covered by the carbon tax as well (Haites et al., 2018).

Since the implementation of environmental taxes occurs in interaction with the other climate related policies, as the EU ETS, it is important to consider potential overlap or conflicts among the policies. Sorrell and Sijm (2003) investigated the interactions between the EU ETS and other climate policies, including carbon taxes. They distinguished direct and indirect policy interaction, in where direct policy interaction consists of a group that is directly affected by two policies that overlap, and indirect policy interaction means that a group is directly affected by one policy, and indirectly or directly by another policy. Double regulation, which for example occurs when an actor pays for reducing carbon emissions in the EU ETS as well as through the carbon tax, is an example of policy interaction. On the other hand, in the specific case of the ETS, a carbon tax can be used as a supplement, because if the price of an allowance in the ETS is low, the tax rate can be used as 'back-up' to ensure that a minimum price will be paid for the emitted GHG by the ETS participants (Sorrell & Sijm, 2003). The following hypothesis can be derived from the literature and will be tested in the research:

H_2: Aligning and integrating carbon taxes in the whole spectrum of climate and non-climate related policies is beneficial for the effectiveness of a carbon tax.

3.3.3. Design parameter: the monitoring, reporting and verification system

The MRV system is an important tool to gain precise information on the actual amount of emissions and ensure the environmental integrity of a carbon tax (Tang et al., 2018). Haites et al. (2018) argue that most countries already collect taxes on fossil fuels and adding another tax requires to adjust the current MRV system. The broader the scope of the carbon tax, the more administrative complexity. Furthermore, specific legislation and regulations are necessary when introducing a new environmental tax, which include a process of consultation, in where interest groups could try to influence the policy plan.

Haug et al. (2010) conclude that the lack of monitoring and weak enforcement are major barriers in achieving effective implementation of climate policies. The following hypothesis can be derived from the literature and will be tested:

H_3: High quality of the monitoring and enforcement mechanisms of the carbon tax is beneficial for the effectiveness the carbon tax.

3.3.4. Design parameter: the tax rate

Obviously, the tax rate of an environmental tax is an important feature of taxation according to the literature. In the case of a carbon tax, this will be measured with two elements: the rate that the targeted entity has to pay per ton of carbon emitted (tCO_2e) and whether this tax rate increases over time.

Concerning the tax rate level of the carbon tax, as ecological economics literature explains, an important criterion of a carbon tax is its cost-effectiveness: "*reducing emissions at lower cost to society than other forms of regulation"*(Haites et al., 2018, p. 127). The carbon tax rate should be equal to the social marginal damages from producing an additional unit of emissions (Haites et al, 2018; Metcalf & Weisbach, 2013). Therefore, in practice, governments try to meet a specific target of reduced GHG emission with the lowest tax rate possible. However, it is hard to measure the social marginal costs since these will vary over time, depending on contextual factors. Therefore, significant differences between countries are perceptible. For example, the carbon tax of Singapore concerns US$4/$tCO_2e$, while the price level in the Canadian province British Colombia is approximately US$26/t$CO_2$e (World Bank, 2019).

Haites et al. (2018) argue that fossil fuels have a relatively low-price elasticity, which means that relatively high carbon prices are needed to reduce the related emissions, compared to emissions reductions which are covered by an ETS. Haites et al. (2018) conclude that in order to achieve a reduction of GHG emissions from the consumption of gasoline and diesel, a carbon tax should have a significant impact on the retail price of these fuels. The World Bank (2019) states that a minimum tax rate between €40/tCO_2e and €80/tCO_2e by 2020 would be necessary to meet the temperature target of the Paris Agreement. Rydge (2015) writes that ensuring a price floor with a minimum price level per emitted ton of CO_2e provides great certainty and leads to consistent policy signals. This increases the effectivity of the carbon pricing instrument.

Furthermore, several contextual factors, such as technological innovation as well as fossil fuel price changes, can influence the effectiveness of the carbon tax. Several studies show that a carbon tax should therefore be adjusted over time, in order to sustain or increase the emission reduction. The more the tax rate increases over time, the greater emission reductions are expected (Haites et al., 2018). Therefore, the following hypotheses concerning the tax rate can be derived and will be tested in the research:

H_4: A tax rate that has significant impact on the retail price of products is beneficial for the effectiveness of the carbon tax.

H_5: A tax rate that increases over time is beneficial for the effectiveness of the carbon tax, compared to a static tax rate.

3.3.5. Design parameter: the point of enforcement

Another design parameter of the tax is the point of imposing the tax in the supply chain. This determines which entities in the supply chain are responsible for paying the tax. There are several points in the supply chain where the tax can be applied, but three points of taxation are common: upstream, midstream or downstream. The decision on which entities are levied and the administrative and MRV system determine the point of enforcement in the supply chain (Partnership for Market Readiness, 2017a). From the administrative and MRV system perspective it could be argued that imposing the tax at the producers upstream is the most effective, since this leads to the administration of less entities compared to levying all the users downstream. Also, it is important to see if a new tax collection system is necessary in order to collect the revenues, or this can be done with a currently available collection systems.

Regarding the responsibility for entities to pay the tax, the study of Sorrell and Sijm (2003) distinguishes a directly and an indirectly affected target group. Directly affected target groups, such as companies participating in the EU ETS which have to pay the tax upstream or midstream, could pass costs on to an indirectly affected target group. This indirectly affected target group, for example downstream consumers, is then influenced by the behavioral changes that are made by the directly affected target group. It depends on the market situation, the timeframe, the extent to which firms are able to change behavior, and the elasticity of the supply and demand of the market whether the costs will be passed on to an indirectly affected target group.

An ideal carbon tax includes all activities that cause environmental externalities (Metcalf & Weisbach, 2013). There are lots of different sources of GHG emissions with often small contributions. Due to administrative reasons, there are always some emissions excluded which are difficult to measure, such as emissions caused by land use change (LUC) from forests and agriculture. Metcalf and Weisbach (2013) write that "*in deciding where to impose the tax […], one can focus on minimizing collection and monitoring costs while ensuring maximum coverage. In general, imposing the tax upstream (i.e., at the earliest point in the production process) will achieve these goals because (1) there are far fewer upstream producers than there are downstream consumers and (2) the cost will be lower per unit of tax due to economies of scale in tax administration*." (p.11). The following hypothesis can be derived from the literature and will be tested in the research:

H_6: Imposing a carbon tax upstream is more effective than downstream.

3.3.6. Design parameter: the selection of the target group

Another design parameter is the selection of the target group. Here, the entities that are obligated to pay the tax are considered, for example industry sectors or households. The scope of the selected target group is related to the share of domestic CO_2 emissions covered by the tax. The share of emissions covered by carbon taxes globally differs between 3% and 70% (Haites et al., 2018).

Within this selected target group, the tax rate might differ per type of fuel and/or emitting activity. Some sectors might have to pay a lower tax rate than others, depending on their characteristics and the perceptions of the government on the implications of the tax, such as the risk of carbon leakage when industrial companies resettle abroad as a result of the adopted carbon tax. Sorrell and Sijm (2003) argue that tax exemptions or reduced tax rates for industry sectors that are covered by the EU ETS may reduce the economic impacts of double regulation. Exemptions and reduced tax rates compensate for the potential risk of reduced competitive advantage, in order to reduce carbon leakage (Haites et al, 2018), especially for EITE firms. For example, the carbon tax of Canada's province Alberta includes exemptions for oil and gas producers (World Bank, 2019). However, several studies conclude that carbon taxes would be more environmental effective if sectors that are exempted would been levied with the full tax rate (Haites et al., 2018). This leads to the following hypothesis:

H_7: Exempting sectors in a system of carbon taxation will be less beneficial for the effectiveness of a carbon tax.

3.3.7. Design parameter: the redistribution of revenues

Carbon tax revenues can be used in a number of ways. Some governments use the revenues to reduce the public sector debt or spend it on education or health care. Other options are to fund innovation or other climate policies, take (international) climate action or compensate groups that are disadvantaged by a fiscal reform (Rydge, 2015). Carl and Fedor (2016) distinguish three categories, which include the earlier mentioned options. They see green spending as first option, which covers all forms of financial support towards energy efficiency, renewable energy research, development and deployment, and other manners to reduce GHG emissions and adapt to climate change. The second category concerns general funds, where governments do not link the revenues to particular spending programs. Collecting the revenues directly in the general government budget makes the tax relatively easy to administer, compared to using the revenues for funding carbon mitigation programs (Sumner, Bird & Dobos, 2011). The third option is revenue recycling. These revenues are directly returned to the actors that paid the tax as tax rate cuts, tax eliminations or rebates to compensate for the negative macro-economic impacts of levying the carbon tax (Carl & Fedor, 2016). Miller and Spoolman (2012) elaborate upon the latter option and write that ensuring a safety net for low-income groups to reduce the regressive nature of new taxes on essentials such as fuel and food is required to achieve a successful implementation. Marron and Morris (2016) suggest the same options for using revenues, namely offsetting new burdens that a carbon tax places on consumers, producers, communities and the broader economy; supporting additional efforts to reduce the GHG emissions; ameliorating the harms of climate disruption; and funding unrelated public priorities, such as education or health care. They see building political support for the carbon tax and offsetting harms for low-income households as two main goals of the revenues. Furthermore, Marron and Morris (2016) advise to consider wisely the use of revenues for further reductions of GHG emissions, since they argue that policymakers should focus on filling in gaps which can be dismissed by the tax rather than fund measures that are not cost-effective.

The study of Haites et al. (2018) concludes that in 2013, 15% of the revenues generated by all carbon taxes globally was used to support green spending, 28% was used for general revenue and 44% went to tax cuts and rebates. Around 85% of the revenues was used to reduce existing distortionary taxes, including revenue used for the general government budget, rebates and tax cuts (Haites et al., 2018).

Sumner, Bird and Dobos (2011) write that revenue-neutral mechanisms within the carbon tax are used to change the behavior of the customer. An example of a revenue-neutral carbon tax is the case of the Canadian province British Columbia in 2008, which accounted for almost 70% of all emissions. All revenues were returned to the residents in the form of personal or business tax measures, mostly tax reductions. As earlier explained, some theorists are in favor of this double-dividend theory, but this approach may also lower the overall economic impacts of the implementation of the carbon tax itself. Therefore, the following hypothesis will be tested:

H_8: Using the revenues of a carbon tax for low-income groups reduces the regressive nature of carbon taxation and is beneficial for the support base of the carbon tax in society.

3.3.8. Framework of analysis

In order to simplify the analysis, the target parameter and the design parameters can be categorized into clusters. The level of ambition, the policy mix and the MRV system are responsible for target achievement, since the policy mix and MRV system concern the tools to achieve the target, and the level of ambition determines the desire to meet the target. Then, the tax rate and the point of enforcement are elements representing the level of the price of the carbon emitted and are therefore clustered into the category incentive level. The third cluster is the scope, which consists of the selection of the target group as well as the redistribution of the revenues. These elements determine which entities have to pay the carbon tax and which parties receive (financial) support derived out of the revenues in return. Table 5 presents the design parameters, including the clusters and the hypotheses derived from the ecological economics literature and governance theories.

Table 5. Visualization of the clusters, design parameters and related hypotheses, derived from the literature.

Cluster	Design parameter	Hypothesis
Target achievement	Level of ambition	H_1: Setting additional national climate targets is beneficial for the effectiveness of the carbon tax.
	Policy mix	H_2: Aligning and integrating carbon taxes in the whole spectrum of climate and non-climate related policies is beneficial for the effectiveness of a carbon tax.
	MRV system	H_3: High quality of the monitoring and enforcement mechanisms of the carbon tax is beneficial for the effectiveness the carbon tax.
Incentive level	Tax rate	H_4: A tax rate that has significant impact on the retail price of products is beneficial for the effectiveness of the carbon tax. H_5: A tax rate that increases over time is beneficial for the effectiveness of the carbon tax, compared to a static tax rate.
	Point of enforcement	H_6: Imposing a carbon tax upstream is more effective than downstream.
Scope	Selection of the target group	H_7: Exempting sectors in a system of carbon taxation will be less beneficial for the effectiveness of a carbon tax.
	Redistribution of revenues	H_8: Using the revenues of a carbon tax for low-income groups reduces the regressive nature of carbon taxation and is beneficial for the support base of the carbon tax in society.

4. Methods

4.1. Research strategy

The research strategy is visualized in Figure 6 below. A literature study, based on ecological economics literature and governance theories, was used to form a framework of analysis, which is shown as (a) in the figure. This framework of analysis can be seen as the foundation of two pathways.

The first pathway, visualized in blue, consisted of a retrospective meta-evaluation of eight already implemented carbon taxes in countries that are participating in the EU ETS. From this analysis, three main models of a carbon tax were derived, based on similar features of the carbon design, such as the tax rate. This pathway led to insights in the crucial factors and features of the design determining the effectiveness of the tax. These insights were further used in the second pathway.

The second pathway, shown in red in Figure 6, consisted of a discourse analysis focused on the adoption of a carbon tax in the Netherlands. The discourse analysis used a content analysis and interviews to gain insights in different perspectives regarding (the design of) a carbon tax in the Netherlands. Subsequently, these main perspectives were clustered into categories of positions of Dutch stakeholders in order to conclude to what extent these stakeholders incorporate the lessons that could have been learned from the implemented carbon taxes in other European countries.

The two pathways used to find the crucial factors determining the effectiveness of a carbon tax design and the perspectives of the stakeholders on these factors are shown as (b) in Figure 6. The earlier derived crucial factors that determine the carbon tax's effectiveness and the results of the discourse analysis, visualized as (c), will lead to policy recommendations for the implementation of a carbon tax in the Netherlands, shown as (d).

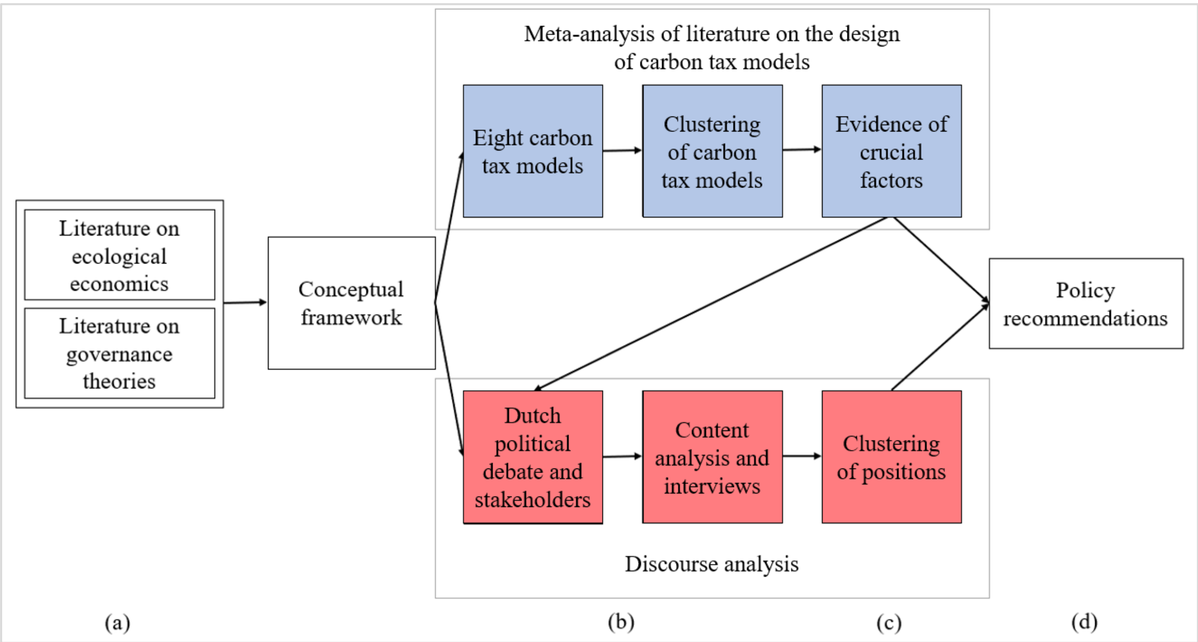

Figure 6. Research framework.

4.2. Literature analysis

To form a conceptual framework, a literature study was carried out. Scientific articles based on ecological economics and governance theories, and more general books on environmental taxes, policy formation and policy implementation were used. Also, the websites Scopus and Google Scholar were used to find peer-reviewed scientific articles. Literature was selected based on their relevance in terms of content and temporality. Most of the literature was found through snowball sampling, especially as reference in other relevant scientific articles.

The literature analysis resulted in a framework of analysis, including relevant design parameters of a carbon tax that determine the effectiveness of the carbon tax. This framework is shown in Table 6.

The framework was later used as format to present the design parameters of the carbon taxes implemented abroad, derived from the meta-analysis of the case studies. Also, this framework was used to illustrate the preferred interpretations of the parameters by the stakeholders in the Dutch debate. The third column represents the status of these parameters of the case studies or the preferred interpretation of the stakeholders.

Table 6. The framework of analysis.

Cluster	Design parameter	Case study / Preference of stakeholder
Target achievement	Level of ambition	
	Policy mix	
	MRV system	
Incentive level	Tax rate	
	Point of enforcement	
Scope	Selection of the target group	
	Redistribution of revenues	

4.3. Meta-analysis of the literature on the design of carbon tax models

4.3.1. Literature study: data collection

The selection of the case studies was based on carbon taxes that were implemented in countries participating in the EU ETS, since this means that this part of the policy mix is comparable to the policy mix of the Netherlands. The carbon taxes analyzed in this research are from Denmark, the United Kingdom, Finland, Sweden, Norway, France, Ireland and Iceland. Strictly speaking, the policy instrument that is implemented in the United Kingdom is not a carbon tax, since the tax rate is not based on the carbon content of the fuel (Metcalf & Weisbach, 2013). However, the United Kingdom implemented a minimum price floor, in addition to the EU ETS, aiming to increase the CO_2-emissions and has therefore similar foundations as the carbon taxes implemented in the other countries analyzed (Leu & Betz, 2016). Switzerland previously implemented a carbon tax as well and has announced to link its own ETS to the EU ETS (European Commission, 2017), but since the harmonization process is still in progress, Switzerland's case will be less comparable to the case of the Netherlands and was therefore not be included in this research. Other countries as Portugal, Spain, Latvia, Poland, Liechtenstein and Slovenia also adopted a carbon tax, but since there is not sufficient literature available on the evaluations of these instruments, these countries are excluded as well (Haites et al., 2018; Leu & Betz, 2016).

Studies from the Organization for Economic Cooperation and Development (OECD), the International Energy Agency (IEA), the World Bank, governmental documents, such as legislation and regulations, of the countries analyzed and scientific literature on evaluations of the carbon taxes are used to form a nuanced and objective picture of the carbon tax design, the policy mix and the effects of the carbon taxes of the case studies.

4.3.2. Literature study: data analysis

The framework of analysis, derived from the literature on ecological economics and governance theories, forms the foundation of the evaluation of the case studies. The case studies were applied to the framework of analysis and this resulted in the identification of some crucial factors that led to an effective carbon tax design. Since there is a lack of evaluative data on the carbon taxes of the case studies, general information regarding the change of CO_2 emissions since the implementation of the carbon tax was used. Due to this lack of data, a causal relationship between the implementation of a carbon tax and a change in CO_2 emissions could not be established. Therefore, other policy instruments that could have contribute to a change of CO_2 emissions, such as energy taxes, were also considered. Then, the carbon taxes were clustered based on their effectiveness: effective carbon taxes, taxes without a clear change of emissions and ineffective carbon taxes. The design parameters of the groups of carbon taxes were analyzed in order to find the most crucial factors for determining the effectiveness of the carbon tax. These crucial design parameters were used to provide recommendations for the design of a carbon tax for the Netherlands.

4.4. Discourse analysis

4.4.1. Content analysis: data collection

The focus was shifted from national carbon taxes in other EU countries to the implementation of the Dutch carbon tax. In order to evaluate the debate about the implementation of a carbon tax in the Netherlands, the content analysis included (opinion) articles from Dutch newspapers, several reports of consultancy bureaus on carbon taxation, and the transcripts of debates related to the carbon tax in the Dutch parliament. Three types of political debates were analyzed: two roundtable discussions, three technical briefings and four plenary debates. A complete list of the debates analyzed in this research, including the topics and participants can be found in Appendix B.

Regarding the analysis of the articles, 92 (opinion) articles published across the whole spectrum from progressive to conservative national newspapers, such as *De Volkskrant*, *De Telegraaf*, *Het Financieele Dagblad*, and *Trouw*, were included. Opinion articles were considered as well, since these represent the perspectives of a specific group of scientists, such as economists, or CEOs of multinational industrial companies. In addition, opinion articles can be used by stakeholders to frame the subject of carbon taxation in their advantage. Thus, these data represent the perspectives of several stakeholders, political parties and other organizations, since the perceptions of these groups are covered in the articles. An overview of the newspaper articles analyzed can be found in Appendix A. Only data published between September 2018 and August 2019 were included, since the decision making on the carbon tax took place during this period.

The articles, the reports, the stenographs of the plenary debates and the transcripts of roundtable discussion and technical briefings were analyzed in NVivo in order to extract the perspectives of the political parties, stakeholders and other organizations, such as DNB. Figure 7 visualizes how this content analysis, as part of the discourse analysis, represents the perspectives of the different parties involved in the societal debate.

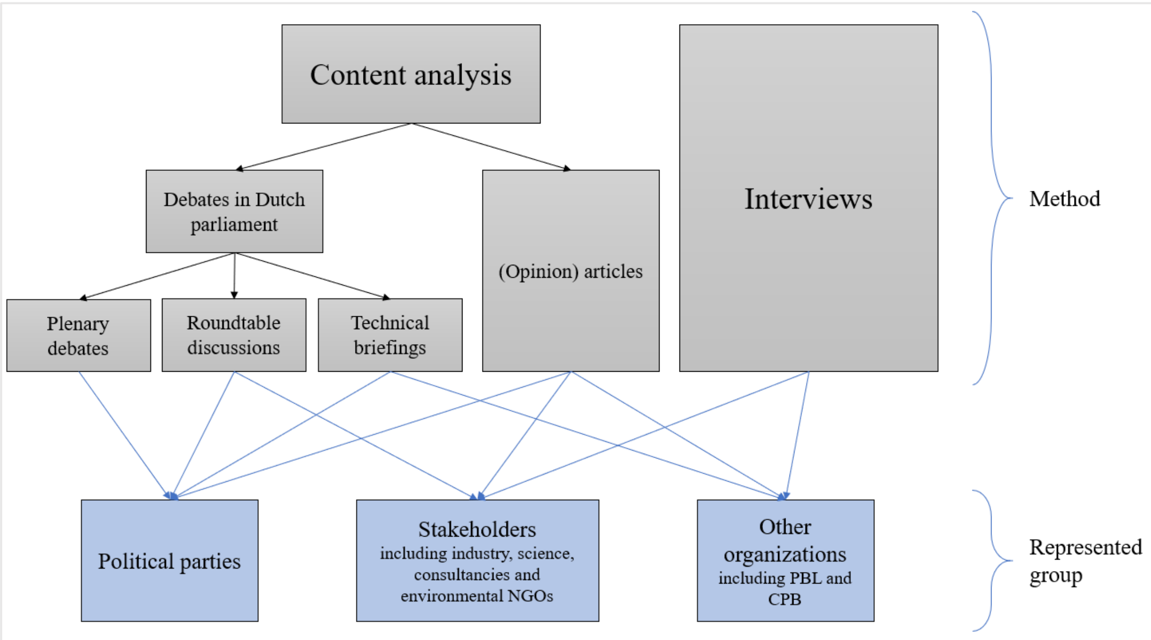

Figure 7. Discourse analysis.

4.4.2. Interviews: data collection

The OECD (2011) shows that interviews and firm-level analyses can provide strong supplementary information. Therefore, ten interviews were included in this research to gain more in-depth knowledge about the positions of stakeholders and how to optimize environmental taxation in order to stimulate sustainable innovations. Employees working in both the industry sector and environmental NGOs were interviewed, since it was expected that these stakeholders would have conflicting positions concerning the carbon tax. In addition, scientists and government officials were questioned in order to provide a more balanced perspective regarding the adoption of a carbon tax. Some of these respondents attended the earlier mentioned roundtable discussions or technical briefings in the Dutch parliament. Others, such as the economists, published scientific or newspaper articles on the Dutch carbon tax. Figure 7 visualizes how the interviews, as part of the discourse analysis, represent the perspectives of the different parties involved in de societal debate.

The recruitment of interviewees took place through Publieke Zaken, which is a public affairs bureau for organizations in the energy and climate sector. It has a widespread network in this sector since it works for both industry businesses and environmental NGOs, which makes it relatively easy to contact stakeholders. The respondents were contacted through email and some of were referred by colleagues who are more familiar with the topic.

The interviews had a semi-structured character, which is efficient and leaves space for the interviewees to stress certain aspects of the interview. The topic list used during the interviews and an overview of the interviewees and the related organizations can be found in Appendix C and D respectively. During the interviews, the respondents were questioned on their preferences regarding the design parameters of a carbon tax. These design parameters are presented in the framework of analysis, as earlier mentioned.

4.4.3. Content analysis and interviews: data analysis

The research material consists of the (opinion) articles, reports, transcripts of debates in the Dutch parliament, and transcripts of the interviews. Including methodological triangulation in the research leads to verifying or rejecting of the data, which ensures the internal validity (Verschuren & Doorewaard, 2010). During the analysis in NVivo, cases were created that represent the stakeholders in the debate, such as the chemical industry and individual political parties. First, the statements made in the data were connected to the cases that made these statements.

Before the qualitative analysis was conducted, codes derived from the ecological economics literature and governance theories, so-called sensitizing concepts, were created in NVivo. During the analysis itself, new, so-called emerging codes, were added to the existing collection, depending on whether new relevant issues were mentioned. The pieces of data that were connected to the individual cases were later connected to these codes. The list of cases and codes can be found in Appendix E.
The analysis had an iterative nature, because the analysis moved from collection to analysis and vice versa, until the point of saturation was reached (Marshall, 1996). In addition, a logbook was kept to record the progress made during the research.

The main output of the discourse analysis was a table with an overview of the perspectives of the stakeholders on the different design parameters of a carbon tax, which were derived from the framework of analysis. Later, these perspectives were clustered, since some organizations or persons appear to have overlapping perspectives regarding the design parameters of the carbon tax.

Lastly, the perspectives of these stakeholders were used to provide recommendations for the design of the carbon tax that will be implemented in the Netherlands.

4.5. Ethical issues

Regarding the interviewees, *informed consent* was guaranteed through an informed consent form. Also, the interviewees were in advance informed about the purpose of the research, the length of the interview, the procedures, and eventually the recording of the interview. The records and transcripts of the interviews were carefully saved to ensure that others had no access to the data. The data gained were only used for this research and were not disseminated for other purposes. After the interviews, member checks are done, in which the respondents review and evaluate the interpretation of the data and may suggest changes. Member checks improve the credibility of the research (Anney, 2014). The respondents were treated with respect, were not younger than 18 years, and were not obligated to answer the questions. The interviews were anonymized if the interviewees preferred this.

At the end of the research, respondents had the opportunity to receive a summary with the main conclusions from the research or the entire research report.

5. Results 1: International evidence

5.1. Results: Case studies

As explained in the Method section, the analysis consists of two pathways. In this chapter, the results of the literature analysis of the case studies of countries that have already implemented a carbon tax in addition to the EU ETS will be given. These case studies will be clustered in a few main models, based on the earlier identified design parameters determining the effectiveness of the carbon tax.

It is almost impossible to compare all other taxes that are part of the domestic policy mix in the countries analyzed, since these are diverse and broad. Therefore, the different instruments that are part of the policy mix should be used to illustrate the context in which the carbon tax is implemented. More detailed information on the energy resources and consumption of the case studies can be found in Appendix F.

5.1.1. Denmark

Denmark adopted a carbon tax in 1992, called the *Kuldioxidafgift*. Initially, the carbon tax was only applied to households, but later the industry sector was covered as well. The purpose of the Danish carbon tax is to stimulate the consumption of less CO_2 intensive energy and to increase climate change awareness (Weishaar, 2018).

The European Union decided that Denmark should reduce its non-ETS sector GHG emissions in 2020 by 20% compared to 2005 levels (European Parliament, 2009). The Danish government has not set a stricter climate target related to GHG emissions for 2020 (Danish Energy Agency, n.d.).

Design of the carbon tax

The Danish carbon tax is applied to fossil fuels, including oil, gas, coal and electricity, for the industrial, residential and commercial sectors. The tax rate is set per ton of carbon emitted, but this can be converted to rates per unit, e.g. per liter gasoline, as is shown in Table 7 below. Table 7 also shows that the tax increased over time for all fuels, while the current tax rate is set on €23/tCO_2e (World Bank, 2019). The rate depends on the user and type of fuel, for example, road transport is taxed with the highest rates (OECD, 2018). The tax covers 40 to 50% of the domestic GHG emissions (World Bank, 2019; Haites et al., 2018).

Table 7. Tax rate of the carbon tax in Denmark (IEA, 2019)

From	To	Heavy fuel oil (DKK/tonne)	Light fuel oil (DKK/1000l)	Automotive diesel (DKK/l)	Gasoline (DKK/l)	Natural gas (DKK/MWh)
01.01.05	31.12.05	288	243	0.243	0.220	
01.01.06	31.12.06	288	243	0.243	0.220	16.2
01.01.07	31.12.07	288	243	0.243	0.220	16.5
01.01.08	31.12.08	293	247	0.247	0.224	16.5
01.01.09	31.12.09	298	252	0.252	0.228	16.8
01.01.10	28.10.10	493	413	0.413	0.373	28.7
29.10.10	31.12.10	493	413	0.413	0.355	28.7
01.01.11	31.05.11	502	420	0.420	0.361	29.2
01.06.11	31.12.11	502	420	0.391	0.361	29.2
01.01.12	31.12.12	511	428	0.399	0.367	29.8
01.01.13	31.12.13	520	435	0.405	0.374	30.3
01.01.14	31.12.14	529	443	0.413	0.381	30.8
01.01.15	31.12.15	539	451	0.420	0.388	31.4
01.01.16	31.12.16	543	455	0.423	0.391	31.6
01.01.17	31.12.17	547	457	0.426	0.393	31.8
01.01.18	31.12.18	549	460	0.428	0.395	31.9
01.01.19	now	556	465	0.433	0.400	n.a.

During the introduction of the carbon tax, companies publicly presented themselves to be in favor of the carbon tax, while they also requested their trade associations to advocate against it. This can be explained by the idea that companies want to be seen as sustainable. This paradox was overcome by earmarking funds for the district heating system and supporting the natural gas market as well as providing tax exemptions for industrial companies. Initially, the industry had to pay a maximum of 50% of the full tax rate, but this was increased with the adoption of the Green Energy Package in 1996 (Weishaar, 2018; Partnership for Market Readiness, 2017b). In 2009, the threshold for energy-intensive companies was reduced (Weishaar, 2018). Currently, industries covered by the EU ETS are exempted from the tax for process and power generation, except for fuels used for the production of district heating. The energy-intensity industry sectors that are not covered by the EU ETS are exempted, which is similar to the provision of free allowances in the EU ETS (World Bank, 2014). The carbon tax rate for light industrial companies is higher than the rate for heavy industrial companies (Lin & Li, 2011). Also, the Danish government offers a 25% tax reduction if a company agrees with an energy saving agreement proposed by the Ministry of Transportation and Energy (Leu & Betz, 2016). The carbon tax is ultimately paid downstream by the users, but collected midstream by the distributors. The Central Customs and Tax Administration is responsible for collecting the taxes. Companies must have meters to measure the amount of fuels used for production processes and space heating. These meters are standardized by the Danish Energy Regulatory Authority and the Ministry of Trade and Industry. Companies that have signed an energy saving agreement have to report annually (Partnership for Market Readiness, 2017b).

Regarding other related policy instruments, Denmark has an energy tax that is also applied to the same fuels, as well as to fossil waste in the industry, residential and commercial sectors (OECD, 2018). Simultaneously with the adoption of the carbon tax, the rate of this previously implemented energy tax was decreased, since the government decided to maintain the taxation rate for fossil fuels (Sumner, Bird & Dobos, 2011). In addition to the carbon tax for companies, the Green Energy Package implemented in 1996 also includes a SO_2 tax and energy taxes on space heating. In 2005, the energy tax was increased again, since the carbon tax was decreased.

The study of Carl and Fedor (2016) shows that approximately 5 to 10% of the revenues of the Danish carbon tax are used for green subsidies, such as business energy efficiency subsidies. Around half of the revenues are transferred to the government's general budget. The initial idea of the revenues of the Danish carbon tax was to reduce the government's overall reliance on labor taxes. The rest of the revenues, 45% of the revenues are used to return money "*to the population through individual or business tax rate cuts, tax eliminations, or rebates in order to offset, in aggregate, the negative macroeconomic impacts of higher energy costs under a carbon price*" (Carl & Fedor, 2016, p.51; Andersen, 2010), as for reducing personal income tax and the employer social security contributions. The Danish government highlights that households and industries should pay for their own transition since cross-subsidization between households and industry should be avoided (Weishaar, 2018). Thus, the revenues of the Danish carbon tax are mainly used to raise funds to finance an income tax reduction (Weishaar, 2018) and the tax appears to have a regressive nature (Wier et al., 2005).

Effects of the carbon tax

According to evaluative studies, the tax led to a reduction of per capita emission of 15% during the period 1990-2005 and a reduction of industrial CO_2 emissions by 23% during the 1990s (Sumner, Bird & Dobos, 2011). Another study (Haites et al., 2018) found that the carbon tax led to an annual reduction of the taxed emissions of 2.31% during the period 1994-2016. The reduction of emissions is mainly caused by the replacement of coal as main energy source for the industry to renewable energy. Because coal was the main energy source for energy production, it was relatively easy to green the energy supply by replacing it by renewable energy sources. Also, the use of revenues for the industry sector was a major indirect factor leading to the reduction of CO_2 emissions per capita in Denmark (Lin & Li, 2011).

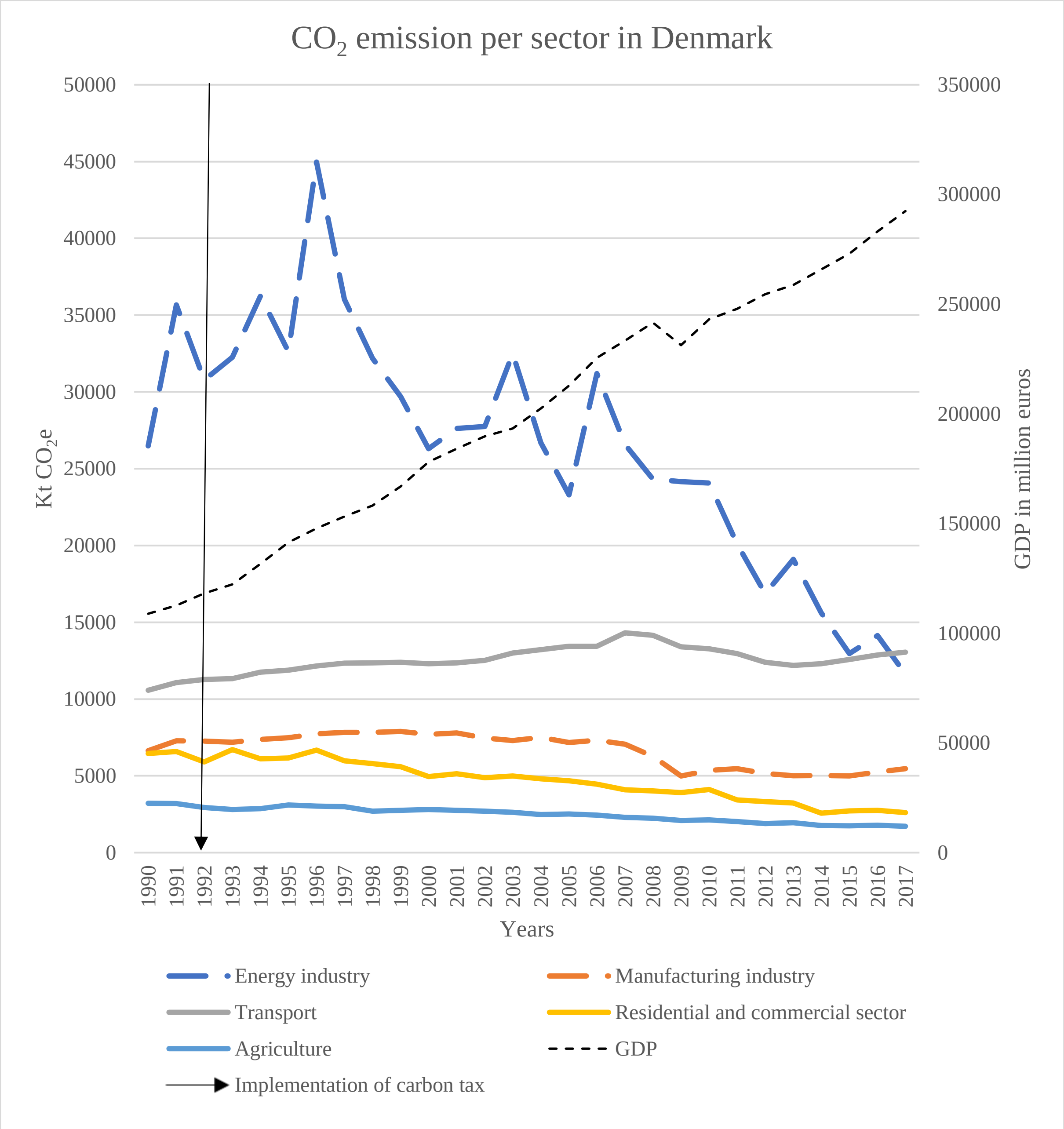

Figure 8. CO_2 emission per sector and GDP in Denmark (Eurostat, 2019). A solid line represents a sector that is fully covered by the carbon tax and a dashed line represents a sector that is partially covered[5]

Since the implementation of the carbon tax in 1992, the emissions from the energy industry, manufacturing industry, residential and commercial sector and agriculture have declined. However, it is not possible to attribute this reduction to the implementation of the carbon tax only. The dashed lines of the energy and manufacturing industries in Figure 8 illustrate that these sectors are almost completely exempted from the tax. For the manufacturing industry and the residential and commercial sector, a slightly declining trend is visible. This is interesting because a lot of companies in the manufacturing industry are exempted from the carbon tax, since they already participate in the EU ETS. However, an

[5] The same sectors as identified by the EEA (2019a) are used for all case studies. The emission caused by the energy industry is based on data from fuel combustion in energy industries, including power generation, refineries, oil and gas production and coke ovens (CRF1A1), and fugitive emissions (CRF1B). For the manufacturing industry sector, data from fuel combustion in manufacturing industries and construction (CRF1A2) and from industrial processes and product use (CRF2) is used. The emissions from the residential and commercial sector consist of fuel combustion in commercial and institutional sector (CRF1A4A) and by households (1A4B). Emissions from the transport sector are based emissions from fuel combustion in transport (CRF1A3). The agricultural sector consists of fuel combustion in agriculture, forestry and fishing (CRF1A4C) and agriculture (CRF3) (Source: Eurostat, 2019).

increasing trend is visible for the transport sector, where the emissions increased over the period 1992-2017, while road transport is even taxed with the highest tax rate. This could be caused by an increasing population, demanding more transport, and the challenge of greening the transport sector. The black dotted line represents the GDP development, showing a significant increase during the period 1992-2017.

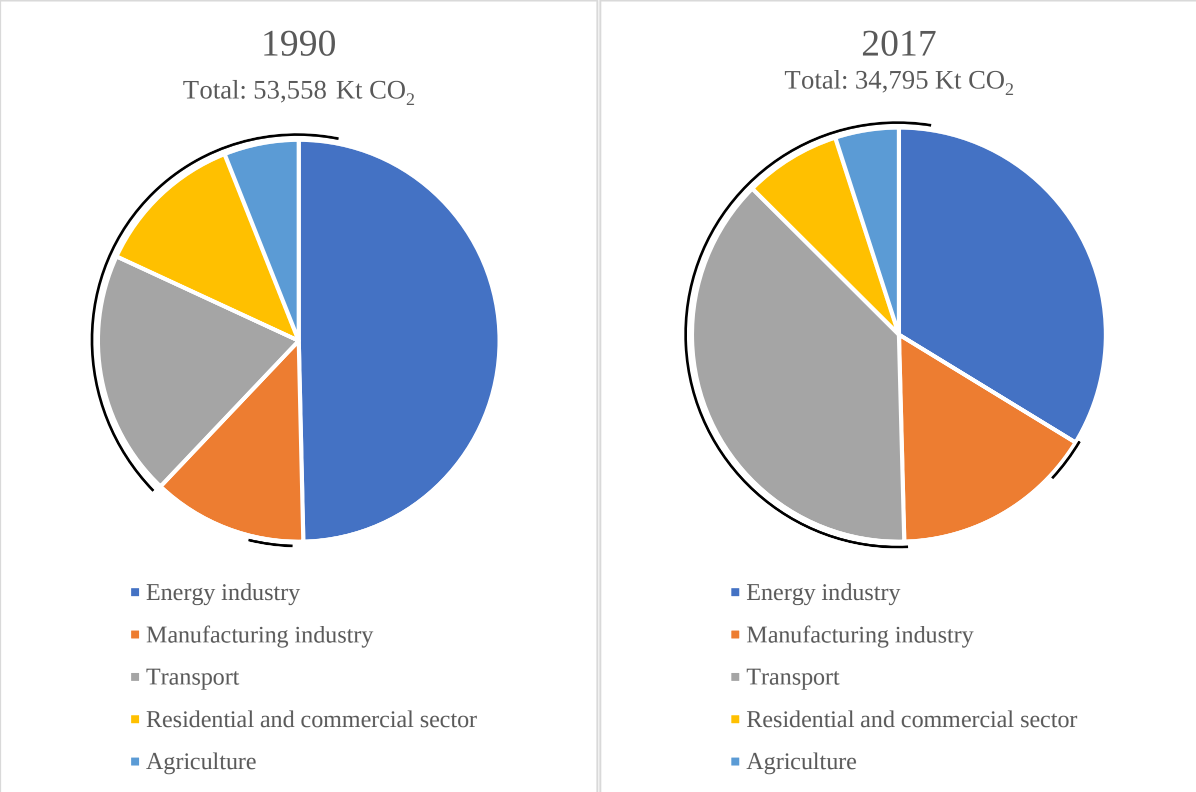

Figure 9. CO_2 emission per sector related to domestic emissions in 1990 and 2017 in Denmark (Eurostat, 2019). The black line visualizes the share of the sectors that are covered by the carbon tax[6]

Figure 9 above shows that the absolute domestic emissions decreased from 53,558 Kt CO_2 in 1990 (before the implementation of the carbon tax) to 34,795 Kt CO_2 in 2017 (after its implementation). The black line visualizes the sectors that are covered by the Danish carbon tax and illustrates that these sectors were responsible for relatively more CO_2 emission after the carbon tax's implementation than before its adoption. However, it should be mentioned that some parts of the sectors get exempted, such as the manufacturing and energy industry that participate in the EU ETS.

Table 8. Design parameters and effectiveness of case study Denmark

Cluster	Design parameter	Case study Denmark
Target achievement	Level of ambition	EU target of 20% reduction of GHG emissions in 2020, compared to 2005 levels
	Policy mix	Industrial emissions covered by the EU ETS are exempted; carbon tax is harmonized with energy tax; Green Energy Package (1996) includes also a SO_2 tax and an energy tax on space heating
	MRV system	Companies must have meters accounting for the amount of fuel used; the Central Customs and Tax Administration collects the tax.
Incentive level	Tax rate	Annual increased with €0.48 on average to €23/tCO_2e in 2019
	Point of enforcement	Tax on emissions; ultimately paid downstream by users and collected midstream by the distributors

[6] The black line representing the sectors that are covered by the carbon tax is indicative due to exemptions within the sectors.

Scope	Selection of the target group	Applied to oil, gas, coal and electricity in industry, residential and commercial sectors; seems that companies have higher rates, but exemptions still exist; 40-50% of GHG emissions are covered
	Redistribution of revenues	40-45% goes to the general budget, 45% is recycled to the industry or households and approximately 5-10% is invested in green technologies through subsidies; cross-subsidization between households and industry should be avoided
Effectiveness of the carbon tax		According to evaluations of the Danish carbon tax, an annual reduction of CO_2 emissions of 2.61% between 1994 and 2016 and the replacement of coal by renewables are observed. Figure 8 shows that since the implementation of the carbon tax in 1992: • CO_2 emissions from energy industry declined with 62.2% in 2017; • CO_2 emissions from the manufacturing industry declined with 24.7% in 2017; • CO_2 emissions from the transport sector increased by 15.8% in 2017; • CO_2 emissions from the residential and commercial sector declined with 55.8% in 2017; • CO_2 emissions from agriculture declined with 41.6% in 2017, while the GDP almost tripled in the same period. However, it is not clear to which extent these effects on emissions can be attributed to the carbon tax solely.

5.1.2. The United Kingdom

In 2013, the United Kingdom (UK) adopted a Carbon Price Floor (CPF) on fossil fuels used to generate electricity, such as coal. This instrument is part of the UK Climate Change Levy (CCL), which is adopted in 2001 (Hirst, 2018). Strictly speaking, the CPF is not a carbon tax, since the tax rate is not based on the carbon content of the fuel (Metcalf & Weisbach, 2013). The purpose of this tax is to encourage the transition to a low carbon economy (Hirst, 2018) by providing a stable carbon price signal for the electricity generation sector covered by the EU ETS, especially since the EU ETS allowance price can be unstable (World Bank, 2014).

The European Union decided that the United Kingdom should reduce its non-ETS sector GHG emission with 16% by 2020 compared to 2005 levels (European Parliament, 2009). In addition, the United Kingdom has set a national climate target for 2020: a reduction of GHG emission by 37%. However, this percentage is compared to 1990 levels, rather than 2005 levels (Committee on Climate Change, n.d.).

Design of the carbon tax

The CPF is applied to fossil fuels used for electricity generation and is levied in Great Britain, including England, Scotland, and Wales, but Northern Ireland is exempted (World Bank, 2014). The tax itself is paid midstream by electricity generators (Partnership for Market Readiness, 2017a). Approximately 20 to 30% of the UK's GHG emission is covered by the CPF (World Bank, 2019).

The tax rate is updated annually and calculated as the difference between the allowance price of the EU ETS and the CPF target, which started with approximately €18/tCO_2e in 2013 and would increase linearly to €35/tCO_2e in 2020 (World Bank, 2014). However, the government decided in 2014 to cap the CPF target at €21/tCO_2e until 2020 (Haites et al., 2018), because the UK was afraid of harming the competitive advantage of the energy intensive industry.

As previously mentioned, the CPF is part of the broader CCL, which also covers other products, such as natural gas, LPG and solid fuels. The Climate Change Levy applies to commercial and industrial uses only, thus households, transportation, and non-energy uses are exempt (IEA, 2019). Table 9 shows the tax rate of the CCL, which includes the CPF. It shows that the tax rates are increased since the implementation of the CCL in 2001. However, the tax rates are here expressed per unit of fuel rather than per ton of CO_2e emitted.

In order to pay the tax, electricity generations must register with HM Revenue and Customs, report several aspects, such as equipment and facility performance, and maintain records on tax payments. If they are not able to comply to this, the HM Revenue and Customs can charge penalties or bring criminal charges (Partnership for Market Readiness, 2017b). The tax evasion rate of 2% can be seen as low (Haites et la., 2018).

In 2017, the UK government received £1 billion, approximately €1,2 billion, from the revenues of the CPF. All revenues are used in the UK Treasure, which is the governmental general budget (Hirst, 2018).

Table 9. The tax rate of the CCL, including the CPF, in the UK (IEA, 2019).

Climate change levy

From	To	Natural gas (GBP/MWh)	Coal (GBP/tonne)	Electricity (GBP/MWh)	Automotive LPG (GBP/tonne)
01.04.01	31.03.07	1.50	11.70	4.30	9.600
01.04.07	31.03.08	1.54	12.01	4.41	9.850
01.04.08	31.03.09	1.59	12.42	4.56	10.18
01.04.09	31.03.11	1.64	12.81	4.70	10.50
01.04.11	31.03.12	1.69	13.21	4.85	10.83
01.04.12	31.03.13	1.77	13.87	5.09	11.37
01.04.13	31.03.14	1.82	14.29	5.24	11.72
01.04.14	31.03.15	1.88	14.76	5.41	12.10
01.04.15	31.03.16	1.93	15.12	5.54	12.40
01.04.16	31.03.17	1.95	15.26	5.59	12.51
01.04.17	31.03.18	1.98	15.51	5.68	12.72
01.04.18	31.03.19	2.03	15.91	5.83	13.04
01.04.19	now	3.39	26.53	8.47	21.75

The UK's future trajectory concerning climate governance is less predictable than for the other case studies, since Brexit may lead to a significant change in the regulations concerning climate and energy. The government announced that the EU ETS will no longer apply to UK industry in case of a 'no-deal' Brexit (Department for Business, Energy & Industrial Strategy, 2019). The UK's government states that companies should be prepared for leaving the EU ETS, which may have consequences for the risk of loss of registry access. However, the industry should plan to comply with GHG emission MRV requirements as well as a new Carbon Emissions Tax after Brexit (Department for Business, Energy & Industrial Strategy, 2019), in order to meet the legally binding reduction of GHG emissions under the Climate Change Act. In 2018, the government announced to be willing to introduce a temporary carbon tax, which in case of a no-deal Brexit will be applied to all stationary installations that were previously covered by the EU ETS (except for aviation) (World Bank, 2019; Department for Business, Energy & Industrial Strategy, 2019). This new, temporary Carbon Emissions Tax that will be implemented in case of a no-deal Brexit, will have a rate of approximately €19/CO_2e "*emitted over an installation's emissions allowance, which would be based on the installation's free allocation under the current EU ETS*" (World Bank, 2019, p.43). In addition, the UK's government develops long-term carbon pricing options, such as the establishment of a UK ETS that is linked to the EU ETS. Other options are the introduction of a standalone UK ETS, remaining part of the EU ETS or the development of a long-term carbon tax (World Bank, 2019). Nevertheless, since agreements between the EU and the UK on carbon pricing after Brexit still should be made, there is uncertainty for (international) companies covered by the CPF.

Effects of the carbon tax

There are mixed perspectives on the effectiveness of the CPF. On one hand, the CPF has led to a reduced international competitive position of UK companies. Also, household energy bills increased on average by £14 per year in 2014 and will increase with approximately £30 in 2020 and £70-80 in 2030. On the other hand, energy bills of companies remained stable and the instrument is still approved by environmental organizations and many power companies (Hirst, 2018). Before the implementation of this tax, electricity was approximately 30-40% generated with coal plants, while this was reduced in 2016 to less than 5% (Hirst, 2018). The carbon tax changed the 'merit order': the "*sequence in which generating units that use different fossil fuels are used*" (Haites et al., 2018, p.151), by making coal-fired unites costlier than gas-fired units. Natural gas was used as alternative fuel for coal. Also, the minimum price level provides certainty for businesses and results in more consistent policy signals (Rydge, 2015), while this may change due to Brexit.

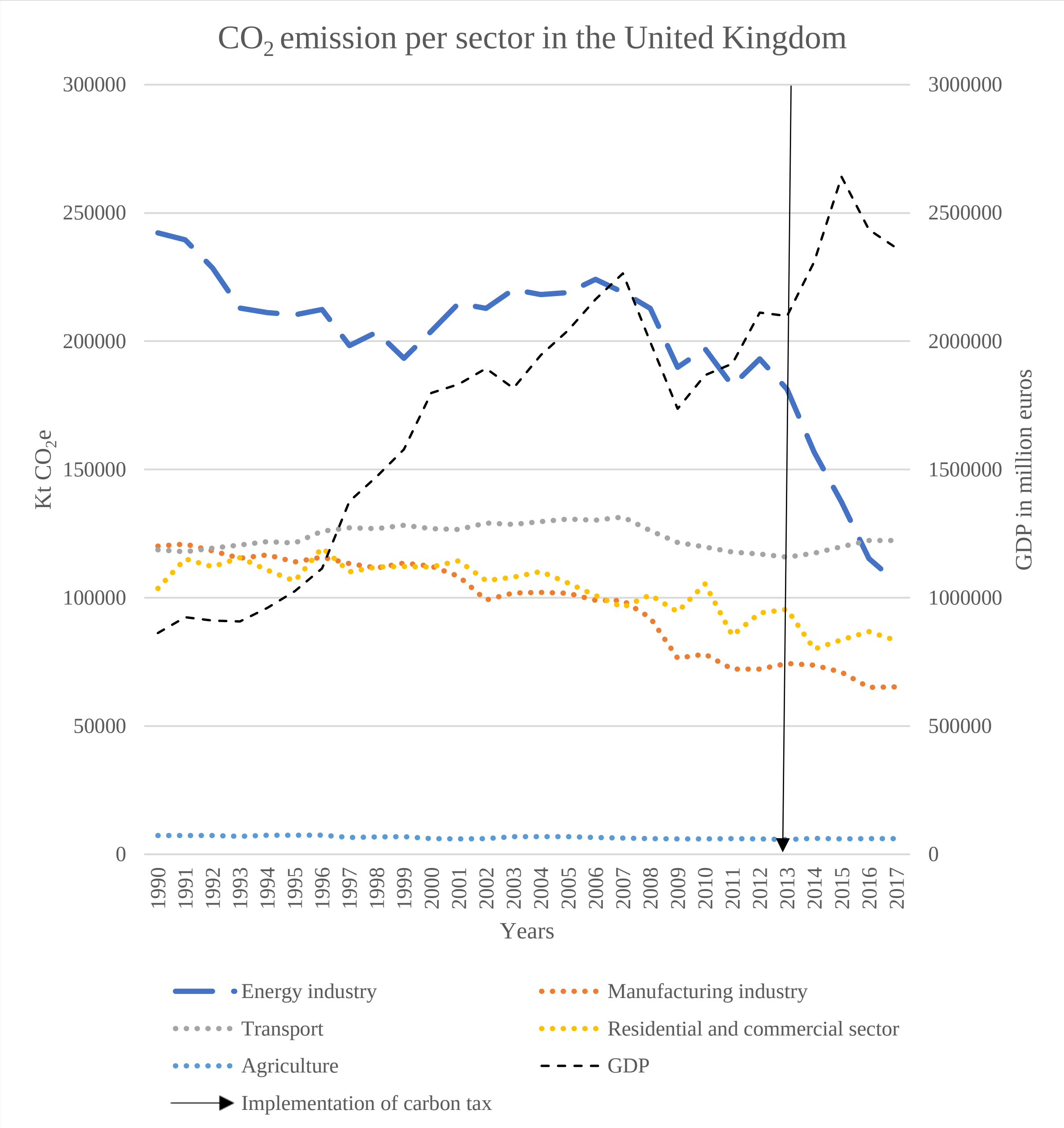

Figure 10. CO_2 emission per sector in the UK (Eurostat, 2019). A dashed line represents a sector that is partially covered by the carbon tax and a dotted line represents a sector that is not covered

The implementation of the CPF in 2013 is visualized with the black arrow in Figure 10. Since only electricity production is covered by the CPF, Figure 10 shows all lines that are not covered by the CPF as dotted, except for the energy industry which includes electricity production. After the implementation in 2013, the emissions of the energy sector decreased rapidly. This shows that the CPF meets it aim since it targets electricity generation. Figure 11 below shows that the absolute CO_2 emissions declined from 598,610 Kt before the implementation of the CPF (in 1990) to 384,937 Kt and after its implementation (in 2017) and that the share of the covered sectors under the CPF is declined, as stated by the government (Hirst, 2018).

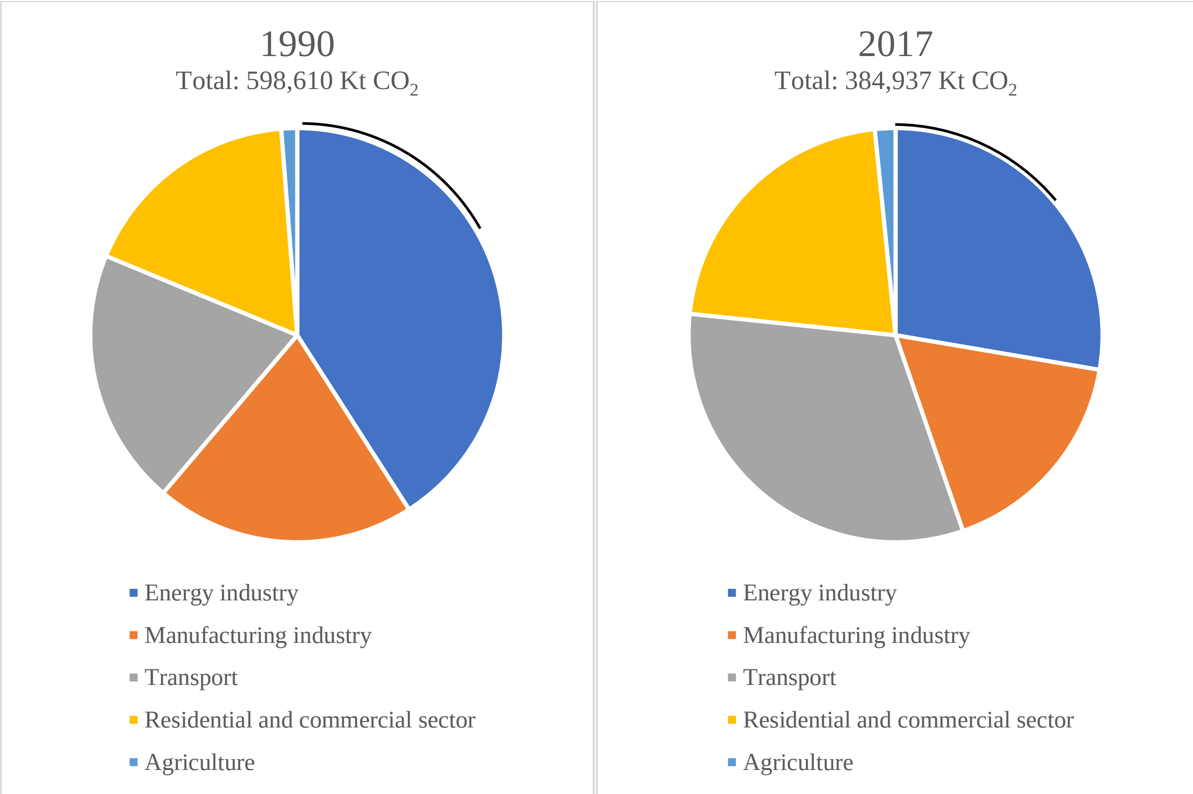

Figure 11. CO_2 emission per sector related to domestic emissions in 1990 and 2017 in the UK (Eurostat, 2019). The black line visualizes the share of the sectors that are covered by the carbon tax [7]

Table 10. Design parameters and effectiveness of case study United Kingdom.

Cluster	Design parameter	Case study United Kingdom
Target achievement	Level of ambition	EU target of 16% reduction of GHG emissions in 2020, compared to 2005 levels; national target of 37% GHG emissions reduction in 2020 compared to 1990 levels
	Policy mix	Applied in addition to the EU ETS and is part of the broader Climate Change Levy; Brexit may complicate the system
	MRV system	Electricity generators must register with HM Revenue and Customs, report and maintain records on tax payments; penalties can be charged in case of failure of payment; Brexit may complicate the MRV system
Incentive level	Tax rate	Difference between the price of the EU ETS allowances and the annual increasing CPF; CPF increased annually with €1.80 on average to €21/tCO_2e in 2019
	Point of enforcement	Tax on emissions; paid midstream by electricity generators
Scope	Selection of the target group	Fossil fuels used for electricity generation; 20-30% of GHG emissions are covered
	Redistribution of revenues	All revenues are transferred to the general budget
Effectiveness of the carbon tax		Literature shows mixed perspectives: the carbon tax led to a reduced competitive position, but changed the merit order in favor of natural gas rather than coal. Figure 10 shows that since the implementation of the CPF in 2013, CO_2 emissions from the energy industry declined with 41.5% in

[7] The black line representing the sectors that are covered by the carbon tax is indicative due to exemptions within the sectors.

2017, while the GDP increased with more than 10% in the same period. However, it is not clear to which extent this effect on emissions can be attributed to the carbon tax solely.

5.1.3. Sweden

In 1991, the Swedish government introduced a carbon tax, the so-called *Koldioxidskatt*, in addition to an already existing energy tax (Hammar & Åkerfeldt, 2011). The Swedish government stresses that the carbon tax is based on the *Polluter Pays Principle* (Government Offices of Sweden, 2019). The carbon tax aims to reduce the consumption of fossil fuels and CO_2 emissions (Partnership for Market Readiness, 2017b). Sweden should have reduced its non-ETS sector GHG emissions by 17% by 2020 compared to 2005 levels (European Parliament, 2009). In addition to this European target, the Swedish government aims to reduce its total domestic GHG emissions by 40% in 2020 compared to 1990 levels (Swedish Environmental Protection Agency, 2019).

Design of the carbon tax

The Swedish carbon tax applies to all energy products, except electricity. The tax rate of the carbon tax has increased gradually from €24/tCO_2e in 1991 to €112/tCO_2e in 2019 (Government Offices of Sweden, 2019; World Bank, 2019), which makes it the highest carbon tax rate globally. This increase of the tax rate is shown in Table 11 and aims to achieve cost-effective emission reductions.

The carbon tax is levied on all fossil fuels determined by their carbon content (Government Offices of Sweden, 2019). In order to prevent for carbon leakage, the Swedish government initially applied absolute tax exemptions or reduced tax rates for industrial facilities (Hammar & Åkerfeldt, 2011). Harmonization between on one hand fulfilling of environmental objectives and on the other hand considering the risk of carbon leakage is considered to be one of the main principles of the Swedish carbon tax.

Table 11. Tax rate of the carbon tax in Sweden (IEA, 2019)

CO_2 tax *(Koldioxidskatt)*

From	To	Automotive diesel (SEK/l)	Gasoline (SEK/l)	Natural gas (SEK/Mm^3)	Coal (SEK/tonne)
01.01.00	31.12.00	1.058	0.86	792	920
01.01.01	31.12.01	1.527	1.24	1144	1329
01.01.02	31.12.02	1.798	1.46	1346	1564
01.01.03	31.12.03	2.174	1.77	1628	1892
01.01.04	31.12.04	2.598	2.11	1946	2260
01.01.05	31.12.05	2.609	2.12	1954	2270
01.01.06	31.12.06	2.623	2.13	1965	2282
01.01.07	31.12.07	2.663	2.16	1994	2317
01.01.08	31.12.08	2.883	2.34	2159	2509
01.01.09	31.12.09	3.007	2.44	2252	2617
01.01.10	31.12.10	3.013	2.44	2256	2622
01.01.11	31.12.11	3.017	2.44	2259	2625
01.01.12	31.12.12	3.100	2.51	2321	2697
01.01.13	31.12.13	3.093	2.50	2316	2691
01.01.14	31.12.14	3.088	2.50	2313	2687
01.01.15	31.12.15	3.218	2.60	2409	2800
01.01.16	31.12.16	3.204	2.59	2399	2788
01.01.17	31.12.18	3.237	2.62	2424	2817
01.01.18	30.06.18	3.292	2.66	2645	2865
01.07.18	31.12.18	2.191	2.57	2465	2865
01.01.19	now	2.236	2.62	2516	2924

Formerly, combined heat and power (CHP) plants covered by the EU ETS were exempted from the carbon tax, but since a tax reform in 2018, CHP emissions are being taxed at 11% of the full tax rate. In addition, non-ETS industry sectors that were initially exempted have to pay the full tax rate since 2018 (World Bank, 2018). These developments show a step-by-step process to reduce carbon tax exemptions in Sweden. The Swedish government argued that "*the removal of these tax rebates would better align its policy with the polluter pays principle, lead to a more cost-effective instrument, and improve the transparency of the taxation system*" (World Bank, 2015, p.46). However, industrial companies participating in the EU ETS are still entirely exempted (Government Offices of Sweden, 2019). The major taxed sectors in Sweden are natural gas, gasoline, coal, light and heavy fuel oil, LPG and home heating oil (World Bank, 2018). Approximately 40-50% of the total GHG emissions in Sweden are covered by the carbon tax (World Bank, 2019; Haites et al., 2018).

The implementation of a carbon tax is seen as relatively easy by the Swedish officials, since it is a high-taxed country, which means that existing revenue collecting systems are in place (Criqui, Jaccard & Sterner, 2019). The tax is paid upstream by producers and importers and midstream by distributors. Some pass the cost on to downstream users (Partnership for Market Readiness, 2017a). The tax system has low administrative costs, around 0.1% of the revenues from the energy and carbon taxes, and still ensures monitoring and control (Carl & Fedor, 2016; Hammar & Åkerfeldt, 2011), which results in a carbon tax evasion rate of less than 1% (Haites et al., 2018; World Bank, 2015). The National Tax Authority collects the tax revenues (Ecofys, 2018). The anti-climate lobby in Sweden is small because there are no large fossil-fuel-producing companies, which made the implementation of a carbon tax relatively easy (Criqui, Jaccard & Sterner, 2019).

Considering the broader policy package, which also includes an increase of the energy tax and a reduction of labor taxes, shows a green tax shift reform between 2001 and 2006 (Ackva & Hoppe, 2018; Hammar & Åkerfeldt, 2011). At the same time when the carbon tax was implemented in 1991, the energy tax was decreased, resulting in lower costs for industrial companies that were exempted from the carbon tax (Ackva & Hoppe, 2018).

The revenues that are collected as a result of the carbon tax are transferred to the general budget, which can be used for specific purposes, such as tax relief for low-income groups (Government Offices of Sweden, 2019; OECD, 2019c).

Effects of the carbon tax

The Swedish carbon tax is seen as a success story. Since the introduction of the tax in 1991, the GDP of Sweden is increased with 78% and the GHG emissions are decreased with 26% in 2017 (Government Offices of Sweden, 2019; Eurostat, 2019), while usually there is a positive correlation between the growth of the economy and the amount of GHG emission. Regarding the effect of the carbon tax, it has the strongest effects on sectors that are levied with the full tax rate. Especially the residential and commercial building sector experienced an enormous transformation. The introduction of the carbon tax had led to a rapid increase of the use of biomass in district heating, while biomass is exempted from paying the tax (Hammar & Åkerfeldt, 2011; Sterner & Kohlin, 2003). Also, Ecofys (2018) found strong evidence that the Swedish carbon tax led to a reduction of emissions caused by road transport by approximately 10%. This is a remarkable percentage, since decarbonizing transport is a considerable challenge. However, it should be mentioned that a high carbon tax rate may be ineffective when the abatement opportunities, such as CCS and hydrogen, are very expensive. Ecofys (2018) highlights that Sweden’s abundant and affordable green electricity facilitated the reduction of emissions to a great extent.

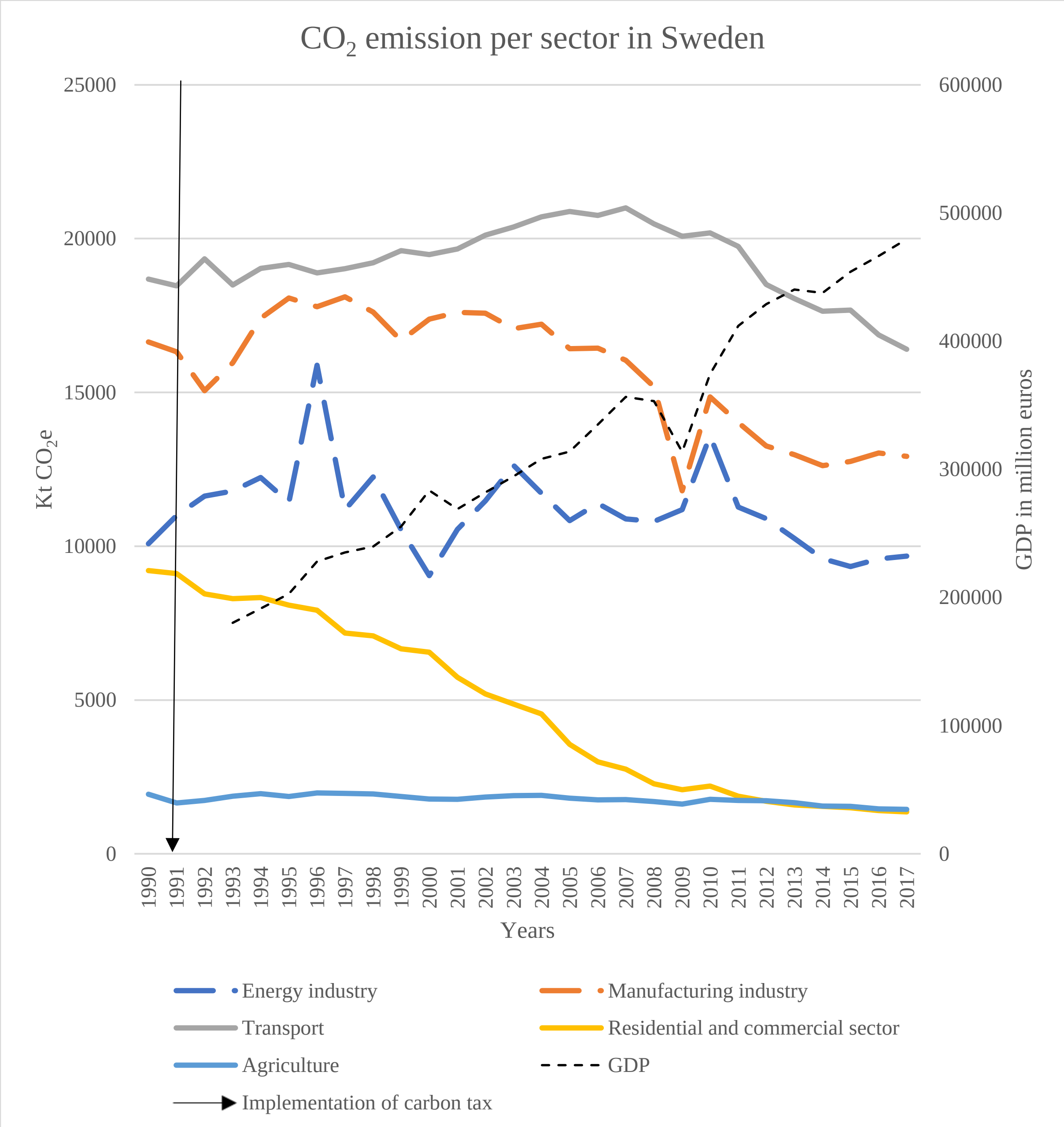

Figure 12. CO_2 emission per sector in Sweden (Eurostat, 2019). A solid line represents a sector that is fully covered by the carbon tax and a dashed line represents a sector that is partially covered[8]

As shown in Figure 12 above, the emissions of all sectors declined during the period 1990-2017. Since the industry is largely exempted, these graphs are dashed. Even with those exemptions, the emissions caused by the energy and manufacturing industry sector are declined since the carbon tax's implementation by approximately 12% and 20.8% respectively (Eurostat, 2019). The emissions from the energy sector are low compared to other case studies, which can be explained by the relatively considerable share of carbon-free nuclear energy for electricity production (see Appendix F). It should be said that the most prominent decline in emissions caused by the manufacturing sector is visible after 2008, which may be related to less production as a result of an economic crisis, also shown in the decrease of the GDP in Figure 12. Thus, external factors, as economic crises, can be even more influential on emission reduction than the implementation of a carbon tax.

[8] Due to a lack of data for Sweden starts the graph representing the GDP development in 1993 (Eurostat, 2019).

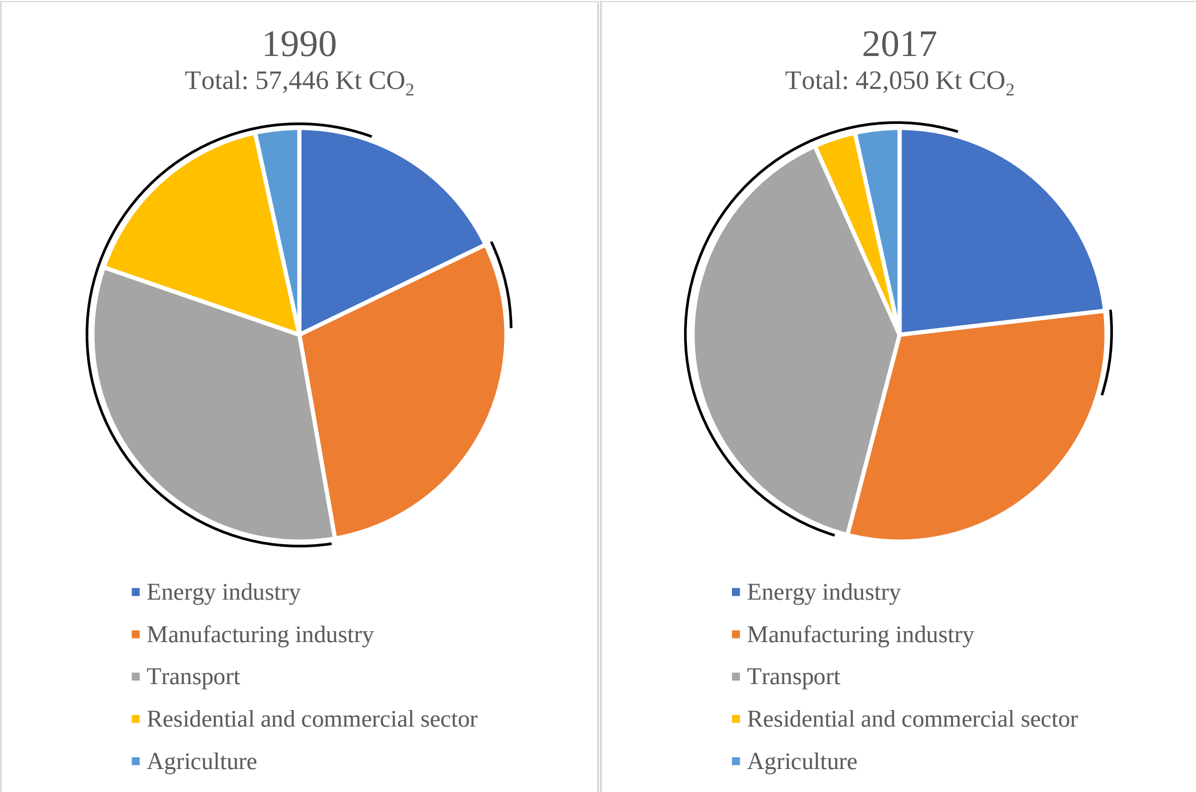

Figure 13. CO_2 emission per sector related to the domestic emissions in 1990 and 2017 in Sweden (Eurostat, 2019). The black line visualizes the share of the sectors that are covered by the carbon tax[9]

The absolute domestic emissions declined in the period 1990-2017 from 57,446 Kt CO_2 to 42,050 Kt CO_2, as shown in Figure 13. The figure also shows that the relative share of emissions of the sectors covered by the carbon tax seems to be slightly less after the implementation (in 2017) than before implementation of the tax (in 1990). This is mainly due to the rapid decline of emissions in the residential and commercial sector. Exempting the industry results in the fact that mainly car owners are responsibility for the main part of the revenues. Since the industry is responsible for a large share of the domestic emissions, but the most taxes are paid by households rather than industrial companies, the *Polluter Pays Principle* is not achieved with the implementation of this policy instrument.

Table 12. Design parameters and effectiveness of case study Sweden

Cluster	Design parameter	Case study Sweden
Target achievement	Level of ambition	EU target of 17% reduction of non-EU ETS sector GHG emissions in 2020, compared to 2005 levels; national target of 40% reduction of GHG emissions in 2020 compared to 1990 levels
	Policy mix	Companies covered by the EU ETS are exempted; the carbon tax is implemented in addition to other energy taxes
	MRV system	Relatively easy and cheap due to an already existing revenue collecting system; the National Tax Authority collects the revenues; monitoring and control is ensured
Incentive level	Tax rate	Annual increased with €3.14 on average to €112/tCO_2e in 2019, which is the highest price globally
	Point of enforcement	Tax on emissions; paid upstream by producers and importers, and midstream by distributors; sometimes passed on to downstream users
Scope	Selection of the target group	All sectors are levied, but tax exemptions for industrial facilities exist; 40-50% of GHG emissions are covered

[9] The black line representing the sectors that are covered by the carbon tax is indicative due to exemptions within the sectors.

	Redistribution of revenues	The revenues are transferred to the general budget, which is mainly used for lowering income taxes
Effectiveness of the carbon tax		According to the literature, the carbon tax led to a reduction of GHG emissions by 26% in 2017 as well as economic growth are achieved; mainly car owners are responsibility for the revenues, which conflicts the Polluter Pays Principle Figure 12 shows that since the implementation of the carbon tax in 1991: • CO_2 emissions from energy industry declined with 12% in 2017; • CO_2 emissions from the manufacturing industry declined with 20.8% in 2017; • CO_2 emissions from the transport sector declined with 11.2% in 2017; • CO_2 emissions from the residential and commercial sector declined with 85.1% in 2017; • CO_2 emissions from agriculture declined with 12.8% in 2017, while the GDP more than doubled in the same period. However, it is not clear to which extent these effects on emissions can be attributed to the carbon tax solely.

5.1.4. Norway

Norway adopted a carbon tax in 1991, the so-called *CO2-avgift*. Later, the country adopted other carbon taxes as well. Norway is not part of the EU, but participates in the EU ETS since 2008 (European Commission, 2015). Effectiveness and cost-effectiveness are two key criteria in the development of Norwegian environmental policies. Also, the *Polluter Pays Principle* is stressed by the Norwegian Ministry of Climate and Environment (2018). In this analysis, two Norwegian carbon taxes will be considered: the CO_2 tax on mineral oil and the tax on CO_2 emissions in petroleum activities.

Since Norway is not part of the European Union there are no European climate targets set for this country. The Norwegian government aims to reduce its domestic GHG emissions with 30% by 2020, compared to 1990 levels (Norwegian government, 2019).

Design of the carbon tax

In 1991, the Norwegian government implemented a carbon tax on mineral oil, petrol and petroleum extraction on the continental shelf. However, since 2008, the emissions caused by the extraction of petroleum are also included in the EU ETS. In 2010, natural gas and LPG were added to the scope of the carbon tax. Bioethanol, biodiesel and hydrogen are not covered by the carbon tax. Thus, the carbon tax applies to all consumption of mineral oil, gasoline and natural gas oil products, natural gas and coal (IEA, 2019). In 2008, when becoming part of the EU ETS, Norway reduced its carbon tax for the petroleum industry in order to remain the same tax rate as before participation in the EU ETS. While Norway increases annually all of its tax rates for the effect of inflation (Haites et al., 2018), the carbon tax was further increased in 2013 for some uses to compensate for a lowered EU ETS price (OECD, 2019b). The trend of the increasing tax rate of the carbon tax is visualized in Table 13 below, showing the full tax rate of the carbon tax for different fuels. These tax rates are given per unit of fuel, rather than per ton of CO_2e. During the last years, the carbon tax has gradually expanded and equalized across uses. Approximately 60 to 70% of all domestic GHG emissions are covered by the carbon tax (World Bank, 2019; Norwegian Ministry of Climate and Environment, 2018). Currently, the tax rate varies between €3/tCO_2e and €54/tCO_2e, depending on the type of fossil fuel and use (World Bank, 2019).

The offshore petroleum industry and domestic aviation have to pay the highest tax rate on top of their participation in the EU ETS. The offshore petroleum is levied with the highest rate in order to stimulate the use of electricity generated onshore with hydropower (World Bank, 2014). Other industry sectors participating in the EU ETS are (partly) exempted to ensure their competitive position, including fishery, freight and passenger transport in domestic shipping (OECD, 2019b; Norwegian Ministry of Climate and Environment, 2018; Leu & Betz, 2016; World Bank, 2014). The exemptions for the industry sector are one of the main features of the Norwegian carbon tax. The collection of the general CO_2 tax is done by the Norwegian Tax Administration, while the Norwegian Petroleum Directorate is responsible for the administration of the CO_2 tax on petroleum activities. The tax is levied upstream and midstream. This means that for petroleum activities, oil and gas companies operating upstream on the continental shelf are levied and that suppliers after collection from downstream users are levied midstream (Partnership for Market Readiness, 2017b). Petroleum companies are obligated to measure, report and ultimately pay the tax. Interest should be paid in case of late payments and fines or imprisonment could be subjected to individuals or companies that fail to pay (Partnership for Market Readiness, 2017b).

Table 13. Tax rate of the carbon tax in Norway (IEA, 2019)

CO_2 tax *(CO_2-avgift)*

From	To	Heavy fuel oil (NOK/tonne)	Light fuel oil (NOK/1000l)	Automotive diesel (NOK/l)	Gasoline (NOK/l)	Automotive LPG (NOK/kg)	Natural gas (NOK /Sm^3)	Coal (NOK/tonne)
01.01.91	31.12.91				0.600			
01.01.92	31.12.92				0.800			
01.01.93	31.12.93				0.800			400
01.01.94	31.12.94				0.820			410
01.01.95	31.12.95	415	415	0.415	0.830			415
01.01.96	31.12.96	425	425	0.425	0.850			425
01.01.97	31.12.97	435	435	0.435	0.870			435
01.01.98	31.12.98	445	445	0.445	0.890			445
01.01.99	31.12.99	460	460	0.460	0.920			460
01.01.00	31.12.00	470	470	0.470	0.940			470
01.01.01	31.12.01	480	480	0.480	0.720			480
01.01.02	31.12.02	490	490	0.490	0.730			490
01.01.03	31.12.03	500	500	0.500	0.750			500
01.01.04	31.12.04	510	510	0.510	0.760			500
01.01.05	31.12.05	520	520	0.520	0.780			500
01.01.06	31.12.06	530	530	0.530	0.790			500
01.01.07	31.12.07	540	540	0.540	0.800			500
01.01.08	31.12.08	550	550	0.550	0.820			500
01.01.09	31.12.09	570	570	0.570	0.840			500
01.01.10	31.12.10	580	580	0.580	0.860	0.650		500
01.01.11	31.12.11	590	590	0.590	0.880	0.660	0.440	500
01.01.12	31.12.12	600	600	0.600	0.890	0.670	0.450	500
01.01.13	31.12.13	610	610	0.610	0.910	0.680	0.460	500
01.01.14	31.12.14	880	880	0.620	0.930	0.990	0.660	500
01.01.15	30.06.15	900	900	1.090	0.950	1.010	0.670	500
01.07.15	31.12.15	900	900	1.090	0.950	1.230	0.820	500
01.01.16	31.12.17	920	920	1.120	0.970	1.260	0.840	500
01.01.17	31.12.17	1200	1200	1.200	1.040	1.350		
01.01.18	31.12.18	1330	1330	1.330	1.160	1.500		
01.01.19	now	1350	1350	1.350	1.180	1.520		

Norway implemented several other environmental taxes, such as a tax on HFCs and PFCs, a road usage tax, a tax on lubrication oil, a SO_2 tax and a tax on NO_x emissions (Partnership for Market Readiness, 2017b).

The revenues of the general carbon tax are transferred to the national budget. The revenues from the petroleum industry are transferred to a special pension fund, the Global Government Pension Fund, which is used to finance the rising public pension expenditures and invests in petrochemical companies (OECD, 2019c; Sumner, Bird & Dobos, 2011). However, the Norwegian government announced to phase out this fund in order to stimulate the investments in renewable energy projects rather than in the petrochemical industry.

Effects of the carbon tax

The effects of the implementation of the carbon tax in Norway are highly debated, since the amount of absolute GHG emissions during the period 1991-2008 was increased with 15% (Sumner, Bird & Dobos, 2011). Haites et al. (2018) conclude that the adoption of a carbon tax in Norway had hardly no effect on the change of CO_2 emissions. The production of oil and gas has almost doubled since 1990 and led to an increase of GHG emissions from 8 to 14.2 million tons in 2018 (Statistics Norway, 2019). However, it should be considered that almost all oil and gas is exported and these emissions may be attributable to the foreign importer. Figure 14 below shows a clear picture: CO_2 emissions from the energy industry, manufacturing industry and transport have not declined since the implementation of the carbon tax, and have even substantially increased by 81.5%, 8.1% and 26.7% respectively (Eurostat, 2019). Figures 14 and 15 show that both the absolute and relative emissions of the energy industry, which includes the emissions from the (offshore) petroleum industry, are increased since the implementation of the carbon tax, even while this sector pays the highest carbon tax. This increase of emissions can be explained as a result of tax exemptions and the relatively inelastic demand in the industry (Bruvoll & Larsen, 2004). The reduction in emissions after 2008 in Figure 14 may be caused by the economic crisis, which led to less production and thus less emission of CO_2.

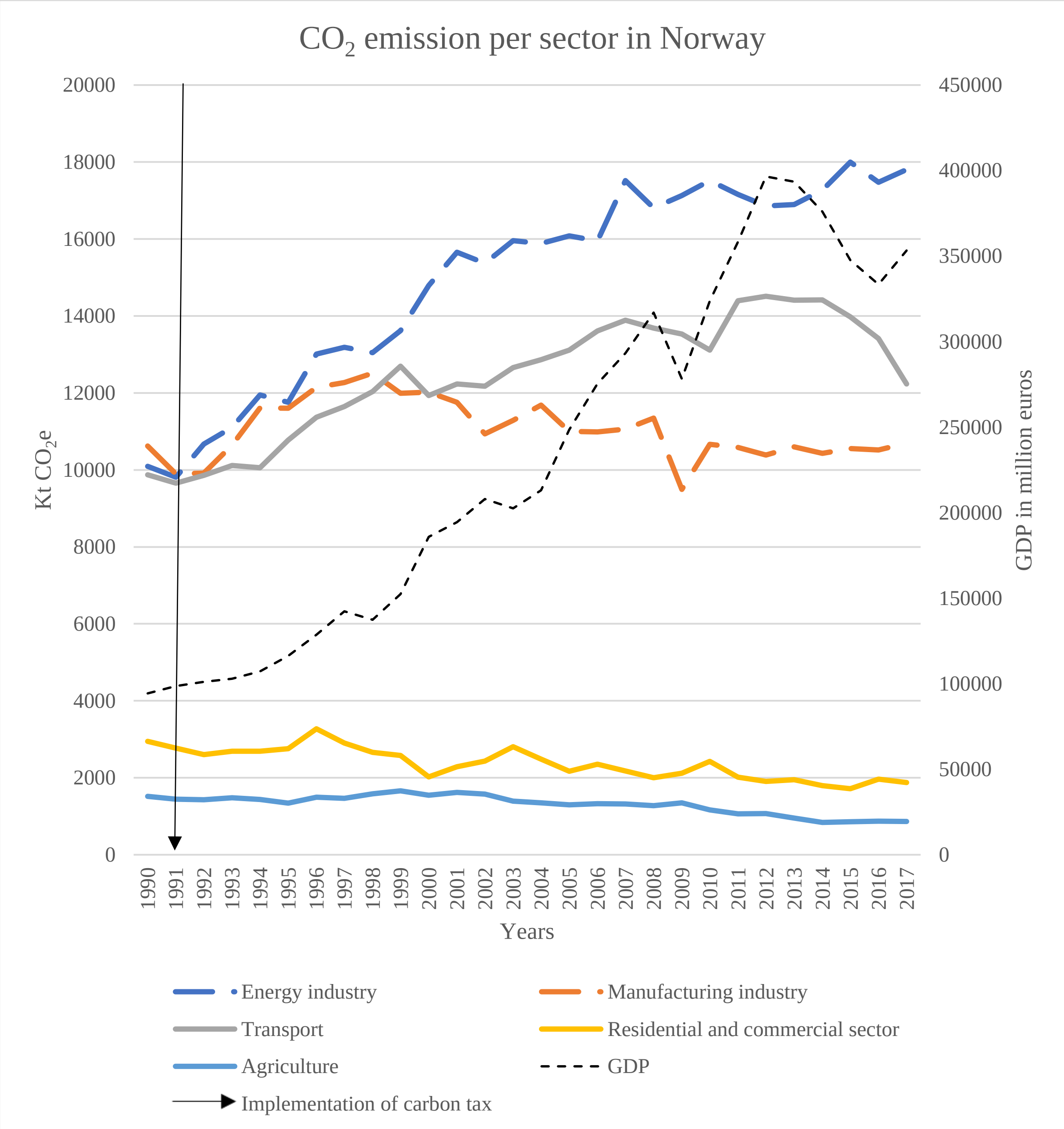

Figure 14. CO_2 emission per sector in Norway (Eurostat, 2019). A solid line represents a sector that is fully covered by the carbon tax, a dashed line represents a sector that is partially covered and a dotted line represents a sector that is not covered.

On the other hand, it should be said that the GDP increased more than the emissions. Also, the carbon tax is responsible for technological innovations, such as CCS in industrial aquifers and replacing gas turbines by electricity from an onshore power grid (Norwegian Ministry of Climate and Environment, 2018; Sumner, Bird & Dobos, 2011; Sterner & Kohlin, 2003), and an improvement of energy efficiency in the industry. The study of Gavenas, Rosendahl and Skjerpen (2015) shows that the increasing carbon tax led to a decrease of the emission intensity of the petrochemical sector in 2012 by approximately 55 kg CO_2 per toe extracted, compared to a global average of 130 kg CO_2. The Norwegian Ministry of Climate and Environment (2018) reports that in 2000, CO_2 emissions caused by the petrochemical sector were estimated to be two million tons less than without the implementation of a carbon tax.

However, it is difficult to calculate or estimate the effect of the carbon tax on the consumption of products and thus on the emissions, since other tax instruments, such as a road usage tax for petrol, contribute to increased retail prices, which may result in less consumption.

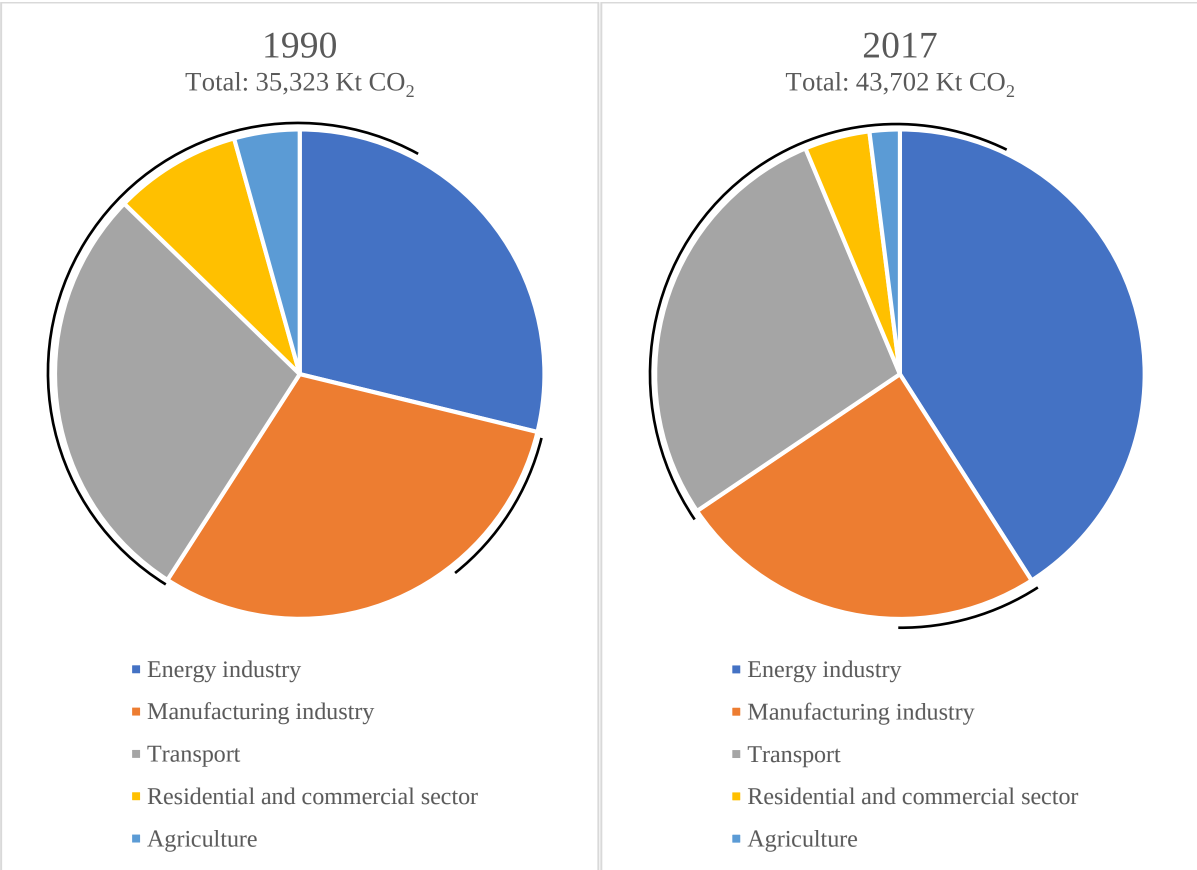

Figure 15. CO_2 emission per sector related to domestic emissions in 1990 and 2017 in Norway (Eurostat, 2019). The black line visualizes the share of the sectors that are covered by the carbon tax[10]

Figure 15 shows that the relative share of the emissions covered by the carbon tax is declined in the period 1990-2017. However, since the manufacturing and energy industries are largely exempted, these are not fully considered. The absolute domestic CO_2 emissions increased significantly from 35,323 Kt in 1990 to 43,702 Kt in 2017.

Table 14. Design parameters and effectiveness of case study Norway

Cluster	Design parameter	Case study Norway
Target achievement	Level of ambition	National target of 30% GHG emissions reduction in 2020 compared to 1990 levels
	Policy mix	Companies participating in EU ETS are exempted; carbon tax rates are adjusted to the price of EU ETS allowances; Norway has several other environmental taxes, including a SO_2 tax and a tax on HFCs and PFCs
	MRV system	The Norwegian Tax Administration collects general revenues and acts in case of failure of payment; the Norwegian Petroleum Directorate administrates revenues from petroleum activities

[10] The black line representing the sectors that are covered by the carbon tax is indicative due to exemptions within the sectors.

Incentive level	Tax rate	Annual increased with €0.34 on average to €3/tCO_2e and €54/tCO_2e (varies per fossil fuel and purpose) in 2019
	Point of enforcement	Tax on emissions; upstream for petroleum activities and midstream for fuels
Scope	Selection of the target group	Mineral oil, petrol, natural gas and LPG, but exemptions for several industrial sectors and processes; 60-70% of GHG emissions are covered
	Redistribution of revenues	General revenues are transferred to the national budget; revenues from petrochemical activities are transferred to the Global Government Pension Fund, but this fund will be phased out
Effectiveness of the carbon tax		According to literature, absolute emissions increased by 15% between 1991 and 2008 and tax exemptions and price-inelastic demand lead to an unsuccessful carbon tax; especially the energy sector increased its emissions; on the other hand, the tax encouraged innovation and energy intensity decreased Figure 14 shows that since the implementation of the carbon tax in 1991: • CO_2 emissions from energy industry increased by 81.5% in 2017; • CO_2 emissions from the manufacturing industry increased by 8.1% in 2017; • CO_2 emissions from the transport sector increased by 26.7% in 2017; • CO_2 emissions from the residential and commercial sector declined with 32.3% in 2017; • CO_2 emissions from agriculture declined with 39.8% in 2017, while the GDP tripled in the same period. However, it is not clear to which extent these effects on emissions can be attributed to the carbon tax solely.

5.1.5. Finland

In 1990, Finland was the first country that adopted a carbon tax, the so-called *Hiilidioksidivero/ Koldioxidskatt*. The Finnish carbon tax is implemented to improve environmental conditions and to prepare for a potential European energy tax. Other purposes of the tax are to partially offset tax reductions elsewhere and to achieve the national and European climate and energy targets for 2030 and 2050 (Partnership for Market Readiness, 2017b). Finland has to reduce its GHG emissions from non-ETS sectors by 16% by 2020 compared to 2005 levels, according to the European Union (European Parliament, 2009). The Finnish government adds that EU ETS companies should reduce their CO_2 emissions by 21% by 2020 compared to 2005 levels (Finnish government, 2019).

Design of the carbon tax

The Finnish carbon tax applies to all consumers of fossil fuels. Only electricity production, commercial aviation and commercial yachting are exempted (Leu & Betz, 2016).

Currently, the tax rate is approximately €63/tCO_2e for transport fuels and €53/tCO_2e for other fossil fuels. Table 15 shows the increase of the tax rate from 2011 until 2019. However, for fuels and natural gas, this rate is provided per unit of fuel, rather than per ton of CO_2e. The table shows that in 2016, the tax rate for heavy and light fuel oil and coal is further increased than in the previous years. The purpose of this increase is to improve the competitive position of peat and natural gas compared to coal and to encourage the use of biomass and low emission heating fuels (World Bank, 2016).

Table 15. Tax rate of the carbon tax in Finland (IEA, 2019)

CO_2 tax *(Hiilidioksidivero/Koldioxidskatt)*

From	To	Heavy fuel oil (EUR/1000l)	Light fuel oil (EUR/1000l)	Automotive diesel (EUR/l)	Gasoline (EUR/l)	Natural gas (EUR/MWh)	Coal (EUR/tonne)
01.01.11	31.12.11	97.20	80.00	0.0000	0.1166	5.94	72.37
01.01.12	31.12.12	97.20	80.00	0.1590	0.1400	5.94	72.37
01.01.13	31.12.13	113.40	93.40	0.1590	0.1400	6.93	84.43
01.01.14	31.12.14	113.40	93.40	0.1861	0.1625	6.93	84.43
01.01.15	31.12.15	142.50	117.40	0.1861	0.1625	8.71	106.14
01.01.16	31.12.16	174.90	144.00	0.1861	0.1625	10.69	130.26
01.01.17	31.12.17	187.80	154.70	0.1990	0.1738	11.48	139.91
01.01.18	now	200.80	165.40	0.1990	0.1738	12.28	149.56

Industrial companies, including firms participating in the EU ETS, is the main target group of the Finnish carbon tax. Until 1996, the carbon tax did not include any exemptions and in order to ensure the international competitive position of the Finnish energy intensive companies the tax rate was relatively low (Weishaar, 2018). Currently, several exemptions exist, for example for fuels for refineries and feedstock. Approximately 30-40% of the domestic GHG emissions are covered by this tax (World Bank, 2019; PwC, 2019).

In first instance, the tax would be based on the carbon content only and was charged at €1.12/tCO_2e. The tax was adjusted in 1997 and 2011 and consists now of a combined carbon and energy tax (Sumner, Bird & Dobos, 2011; Leu & Betz, 2016). The Finnish carbon tax is closely related to other energy taxes. Besides an energy and carbon tax, there is also an electricity tax, which is based on the output (Partnership of Market Readiness, 2017b). When the Finnish carbon tax was introduced, the excise tax rate was reduced in order to remain the same retail price for fossil fuels. This means that the carbon tax only has an effective price signal for the consumer if the increase of the carbon tax rate is higher than the reduction of the excise tax rate (Haites et al., 2018). Simultaneously with the adoption of the carbon tax, another tax levied on fossil fuels, namely the excise tax, was decreased (Haites et al., 2018). The Finnish carbon tax is levied downstream as an excise tax. The Finnish Tax Administration is the responsible authority for the collection of the carbon tax's revenues (Partnership for Market Readiness, 2017b).

The World Bank (2019) states that Finland is greening its tax system by reforms that increase the carbon tax rate and lower income taxes and social security contributions. The government does this by "*gradually strengthening the carbon tax component in the energy tax and shifting the tax burden to higher carbon fuels*" (World Bank, 2019, p.38). The Finnish carbon tax revenues are not earmarked and fully transferred to the general budget. A part of the revenues is used to reduce personal and local income taxes and employer social security contributions (Carl & Fedor, 2016; Sumner, Bird & Dobos, 2011).

Effects of the carbon tax

There are almost no recent evaluations of the Finnish carbon tax found. Since the carbon tax is combined with an energy tax it is difficult to conclude whether the effects on emissions are the result of the implementation of the carbon tax, the energy tax or other policy instruments (Partnership for Market Readiness, 2017b). A study (Institute for European Environmental Policy, 2013) estimated that the combined energy and carbon tax led to a reduction of CO_2 emissions of 7% and a reduction of fuel consumption of 4.8% between 1990 and 1998.

Figure 16 shows the development of emissions caused by different sectors. The energy and manufacturing sectors are (largely) exempted from paying the carbon tax and therefore visualized with dashed lines. Since the implementation of the carbon tax in 1990, the emissions caused by the manufacturing industry declined by 35.8% (Eurostat, 2019). Around 2008, Figure 16 shows a decline of emissions from the manufacturing and energy industries and to a less extent from the transport and residential and commercial sectors. This may be due to an economic crisis, which probably led to less production and less emissions. The GDP also decreased during that period.

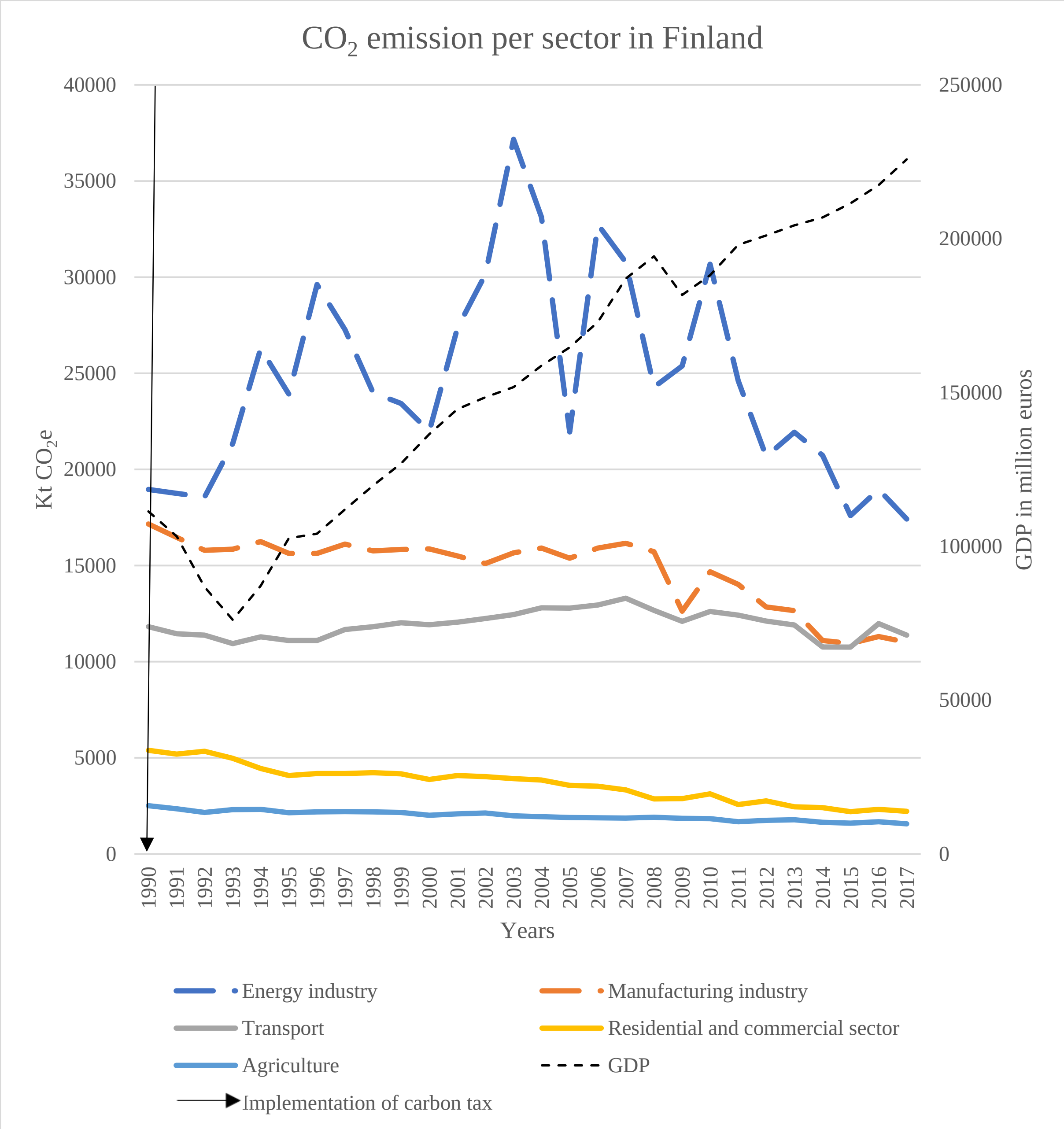

Figure 16. CO_2 emission per sector in Finland (Eurostat, 2019). A solid line represents a sector that is fully covered by the carbon tax, a dashed line represents a sector that is partially covered and a dotted line represents a sector that is not covered.

Figure 17 below shows that the relative share of sectors covered by the carbon tax as well as the absolute CO_2 emissions decreased during the period 1990-2017. The Finnish carbon tax covers all sectors, but has exemptions. Therefore, the energy and manufacturing industries are partly covered with the black line in this figure. This shows that the relative emissions of the residential and commercial sector decreased since the implementation of the carbon tax, while the relative emissions from the energy industry increased.

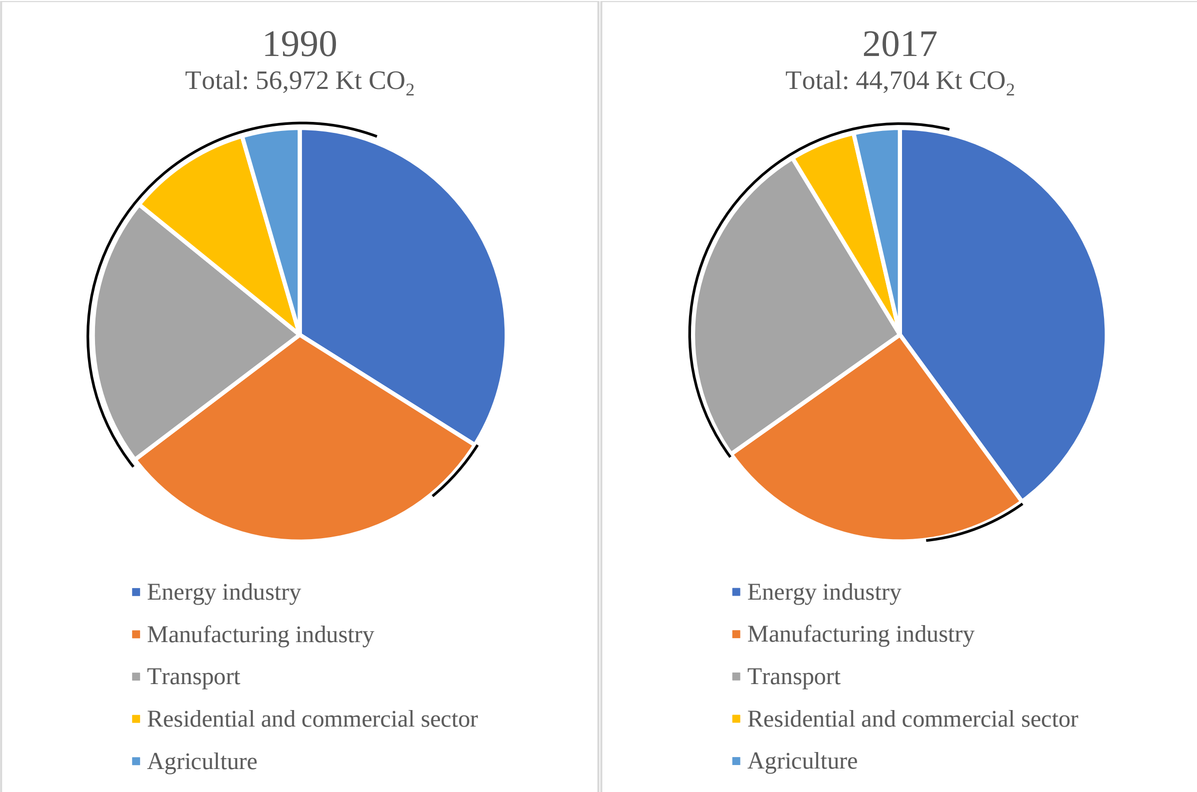

Figure 17. CO_2 emission per sector related to domestic emissions in 1990 and 2017 in Finland (Eurostat, 2019). The black line visualizes the share of the sectors that are covered by the carbon tax [11]

Table 16. Design parameters and effectiveness of case study Finland

Cluster	Design parameter	Case study Finland
Target achievement	Level of ambition	EU target of 16% reduction of non-EU ETS sector GHG emissions in 2020, compared to 2005 levels; national target of 21% reduction of GHG emissions in 2020 compared to 1990 levels for EU ETS-companies
	Policy mix	Carbon tax rate is related to the excise tax rate; companies participating in EU ETS are exempted
	MRV system	The Finnish Tax Administration collects the revenues
Incentive level	Tax rate	Annual increased with €1.96 on average to €63/tCO_2e for transport fuels and to €53/tCO_2e for other fossil fuels in 2019
	Point of enforcement	Tax on emissions; levied downstream as an excise tax
Scope	Selection of the target group	All sectors are taxed, but large exist, but large exemptions for industrial companies exist; 30-40% of GHG emissions are covered
	Design parameter: redistribution of revenues	All revenues are transferred to the general budget; tax system is greened by reforms that increase the carbon tax rate and lower income taxes and social security contributions
Effectiveness of the carbon tax		Literature shows that the energy and carbon tax led to a reduction of CO_2 emissions of 7% between 1990 and 1998. Figure 16 shows that since the implementation of the carbon tax in 1990:

[11] The black line representing the sectors that are covered by the carbon tax is indicative due to exemptions within the sectors.

	• CO_2 emissions from energy industry declined with 8.1% in 2017; • CO_2 emissions from the manufacturing industry declined with 35.8% in 2017; • CO_2 emissions from the transport sector declined with 3.7% in 2017; • CO_2 emissions from the residential and commercial sector declined with 58.8% in 2017; • CO_2 emissions from agriculture declined with 37.5% in 2017, while the GDP more than doubled in the same period. However, it is not clear to which extent these effects on emissions can be attributed to the carbon tax solely.

5.1.6. France

The French carbon tax, which is a part of the *Taxes interieures sur la consummation des produits énergétiques* (Domestic consumption tax on energy products), was introduced in 2014 (IEA, 2019). The tax was part of a more general energy tax reform (Partnership for Market Readiness, 2017b). France has to reduce its GHG emissions caused by non-ETS sectors by 14% in 2020 compared to 2005 levels (European Parliament, 2009). The French government has not set additional national targets in terms of GHG emissions for 2020.

Design of the carbon tax

The French carbon tax is a component of the internal consumption tax on energy products. This component is added in 2014 on the use of natural gas, heavy fuel oil and coal that is not covered by the EU ETS. The tax is levied for the whole economy, but heavy industry, electricity producers, shipping, aviation, freight transport and public transport are exempted (Partnership for Market Readiness, 2017b).

In 2015, the French government adopted the Law on the Energy Transition to Green Growth and extended the tax to transport fuels and heating oil (Leu & Betz, 2016). Currently, the carbon tax covers around 30 to 40% of all domestic GHG emissions (World Bank, 2014; World Bank, 2019).

The tax rate started with €7/tCO_2e in 2014 (World Bank, 2014). The Law on the Energy Transition to Green Growth includes a trajectory for the carbon tax rate to rise annually with €8.5/tCO_2e to, ultimately, a tax rate of €100/tCO_2e in 2030 (World Bank, 2015; World Bank, 2016). Haites et al. (2018) argue that rapidly increasing tax rates of more than 30% per year are probably not sustainable. Table 17 shows the increase of the tax rate of the internal consumption tax on energy product, which includes the carbon tax. This table shows the tax rates per unit of fuel, rather than per ton of CO_2e. While the tax rate increased from €7/tCO_2e in 2014 to €44.6/tCO_2e in 2019 with the intention to increase it further the coming years (World Bank, 2019), the French government also increased the tax on diesel. The producers of food and energy produces transmitted the costs to their customers, illustrating the regressive nature of the tax. As a result of increasing oil prices worldwide and the increased taxes, the price of diesel increased with 0.25 cents within one year. This led to social protests in November 2018, called the *gilets jaunes*, consisting of dissatisfied inhabitants wearing yellow vests, whose demonstrations had caused more than two hundred victims and a lot of damage. As a result, the tax rate in 2019 remained at the 2018 rate of €44.6/tCO_2e, and following national consultations, a further increase in the coming years is unlikely (World Bank, 2019). Thus, the French carbon tax received low public acceptance (Metcalf & Weisbach, 2013).

The tax is paid upstream by the producers and importers and midstream by the distributors (Partnership for Market Readiness, 2017a). The Ministry of Finance and Public Accounts collects the carbon tax revenues. In case of failure of payment, the government uses charges, fines and the potential for filing criminal charges (Partnership of Market Readiness, 2017b).

Table 17. Tax rate of the carbon tax in France (IEA, 2019).

Internal consumption tax on energy products
(Taxe intérieure de consommation sur les produits énergétiques - TICPE)

From	To	High sulphur fuel oil (EUR/tonne)	Low sulphur fuel oil (EUR/tonne)	Light fuel oil (EUR/1000l)	Automotive diesel (EUR/l)	Gasoline (EUR/l)
07.01.92	14.01.93	21.16	0	0	0.257	0.436
15.01.93	14.04.93	21.43	0	0	0.265	0.443
15.04.93	11.07.93	21.45	0	0	0.268	0.446
12.07.93	20.08.93	23.14	0	0	0.268	0.489
21.08.93	31.11.93	23.14	0	0	0.311	0.489
01.12.93	10.01.94	23.14	0	0	0.311	0.489
11.01.94	10.01.95	23.14	0	0	0.324	0.507
11.01.95	10.01.96	23.51	0	75.46	0.329	0.549
11.01.96	10.01.97	23.92	0	76.86	0.349	0.568
11.01.97	10.01.98	24.38	0	78.45	0.358	0.577
11.01.98	10.01.99	24.67	0	79.44	0.371	0.589
11.01.99	10.01.00	18.49	0	80.14	0.381	0.589
11.01.00	31.12.00	18.49	0	80.54	0.392	0.589
01.01.01	30.09.00	18.57	18.57	80.54	0.367	0.589
01.10.00	28.02.01	18.57	18.57	31.07	0.367	0.564
01.03.01	31.12.01	18.57	18.57	42.52	0.377	0.564
01.01.02	20.07.02	18.50	18.50	42.52	0.376	0.574
21.07.02	10.01.04	18.50	18.50	56.60	0.392	0.589
11.01.04	31.12.06	18.50	18.50	56.60	0.417	0.589
01.01.07	07.02.08	18.50	18.50	56.60	0.426	0.602
08.02.08	31.12.10	18.50	18.50	56.60	0.428	0.606
01.01.11	19.01.12	18.50	18.50	56.60	0.437	0.611
20.01.12	28.08.12	18.50	18.50	56.60	0.440	0.613
29.08.12	31.12.11	18.50	18.50	56.60	0.410	0.583
01.12.12	10.12.12	18.50	18.50	56.60	0.420	0.593
11.12.12	20.12.12	18.50	18.50	56.60	0.425	0.598
21.12.12	10.01.13	18.50	18.50	56.60	0.430	0.603
11.01.13	21.01.13	18.50	18.50	56.60	0.440	0.613
22.01.13	15.01.14	18.50	18.50	56.60	0.439	0.613
16.01.14	31.12.14	21.90	21.90	56.60	0.441	0.613
01.01.15	31.12.15	45.30	45.30	56.60	0.481	0.631
01.01.16	31.12.16	68.80	68.80	96.30	0.511	0.648
01.01.17	31.01.17	95.40	95.40	118.90	0.547	0.660
01.01.18	now	139.50	139.50	156.20	0.5940	0.6829

Initially, the revenues of the carbon tax were for 38 to 100% used for the funding of green subsidies, namely the "green energy transition plans". The share of this proportion varied per year. The remaining part of the revenues was transferred to the general government budget (Carl & Fedor, 2016). However, it seems that the protests led to an adjusted redistribution of the revenues. In 2016, €3 billion of the total revenues of €3.8 billion was used as a tax credit for businesses. Later, €1.7 billion of the revenues was earmarked to an energy transition account, which largely compensates industries for the higher costs associated with using renewable energies for electricity generation (OECD, 2019c). In addition, the government now uses a part of carbon tax revenues to cut labor and corporate taxes and provide financial assistance for low-income households on their energy bill. While the French government does not earmark revenues, which means that all revenues are transferred to the general budget, the reform was accompanied by some support for the energy transition, including support for alternatively-source vehicles and tax credit to households improving energy efficiency of their residence (World Bank, 2019)

Effects of the carbon tax

There is a lack of data on the effect of the French carbon tax on emissions, as the implementation took place only six years ago. However, the study of Gloriant (2018), based on an ex-ante approach, states that the carbon tax led to a reduction of 0.6 to 1.7 Mt in the transport sector in 2017. The study consists also of an ex-post approach, but due to a small number of observations during the period 2014-2017, a robust conclusion cannot be provided. The French government expected to reduce its CO_2 emissions from the transport sector with 1 Mt and from the buildings sector with 2 Mt in 2017 (Partnership for Market Readiness, 2017b).

General data on emissions for France during the period 1990-2017 show that CO_2 emissions are not declined since the adoption of the carbon tax in 2014, as is visible in Figure 18 below. This could be due to the fact that the energy and manufacturing industries are fully exempted and the transport sector is partially exempted.

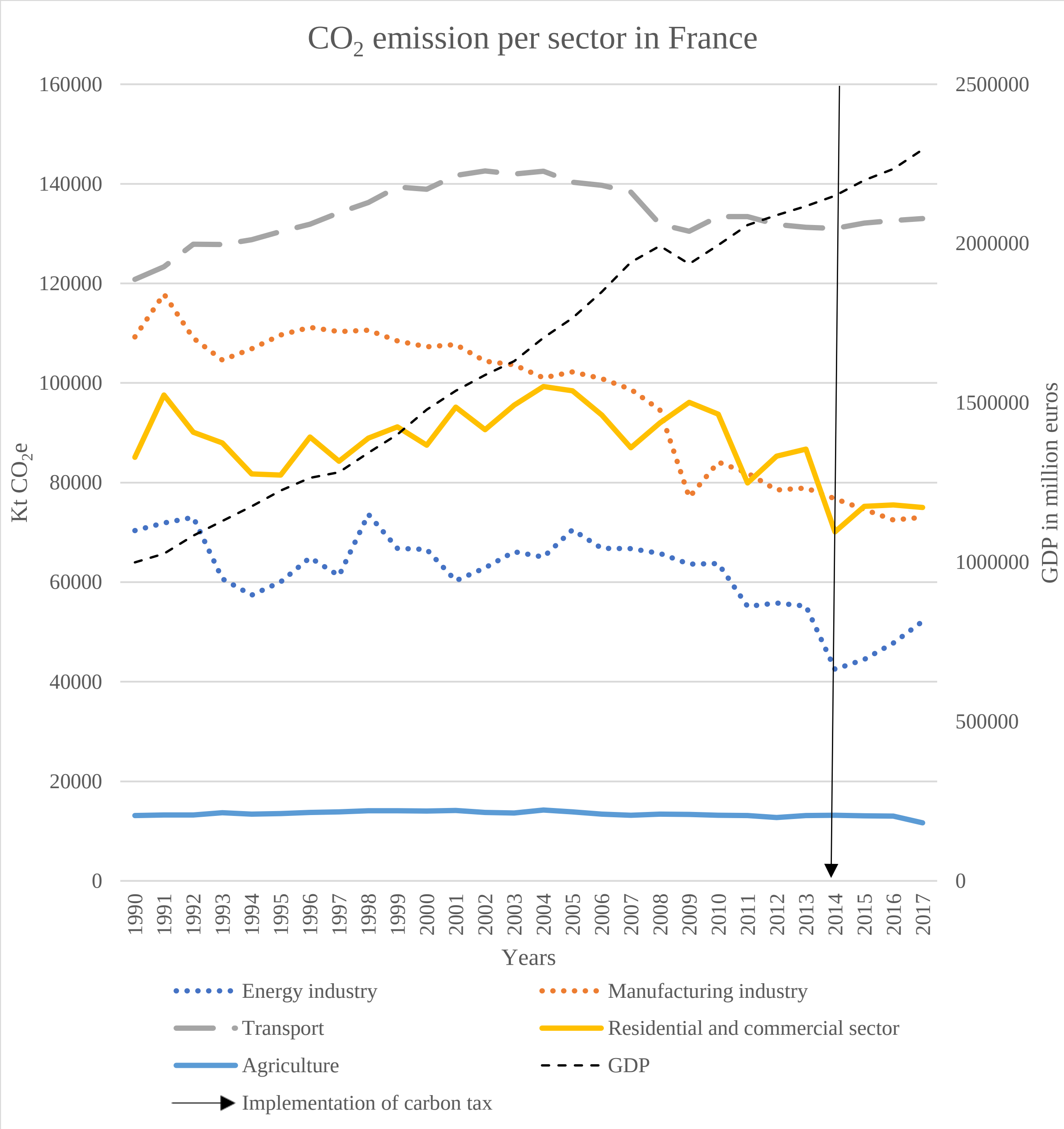

Figure 18. CO_2 emission per sector in France (Eurostat, 2019). A solid line represents a sector that is fully covered by the carbon tax, a dashed line represents a sector that is partially covered and a dotted line represents a sector that is not covered.

In France, total domestic emissions declined during the period 1990-2017, as shown in Figure 19. According to a study of Criqui, Jaccard and Sterner (2019), this decline of total domestic CO_2 emissions is caused by stabilization of consumption, including electricity consumption, increasing oil and gas prices, the economic crisis in 2008 and the introduction of environmental policies, such as the 2005 Energy Act and its related policies and measures. Figure 19 also shows that the share of emissions of the sectors covered by the carbon tax is remained equal during this period. Since the transport, energy industry and manufacturing industry are (largely) exempted, those sectors are not totally covered with the black line. This means that a large part of the tax is paid by the residential and commercial sector, which illustrates that the carbon tax still faces challenges regarding tax equality between industry and households and public acceptance (Partnership for Market Readiness, 2017b). The French carbon tax illustrates the importance of 'just taxation' and shows that underestimating potential redistribution effects could even threaten the existence of the carbon tax.

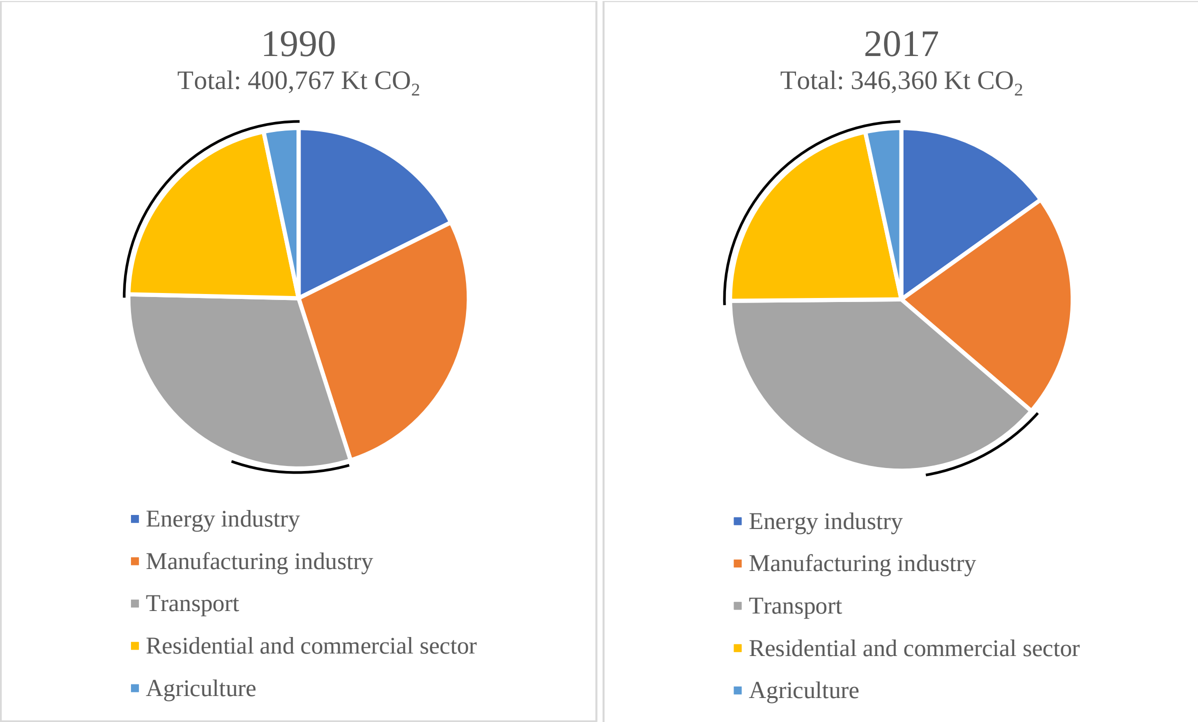

Figure 19. CO_2 emission per sector related to domestic emissions in 1990 and 2017 in France (Eurostat, 2019). The black line visualizes the share of the sectors that are covered by the carbon tax [12]

Table 18. Design parameters and effectiveness of case study France

Cluster	Design parameter	Case study France
Target achievement	Level of ambition	EU target of 14% reduction of non-EU ETS sector GHG emissions in 2020, compared to 2005 levels
	Policy mix	Companies participating in EU ETS are exempted; also raised the tax on diesel, resulting in significant price increases
	MRV system	The Ministry of Finance and Public Accounts collects revenues; failure of payment results in charges, fines and the potential for filing criminal charges
Incentive level	Tax rate	Annual increased with €7.52 on average to €44.6/tCO_2e in 2019, but will not further increase during the coming years
	Point of enforcement	Tax on emissions; paid upstream by the producers and importers and midstream by the distributors
Scope	Selection of the target group	Exemptions for large share of transport sector and industrial companies; 30-40% of GHG emissions are covered
	Redistribution of revenues	Initially to green subsidies, now transferred to general budget and used to cut labor tax and provide support for low-income households
Effectiveness of the carbon tax		There is not enough data for robust evaluations, but increased prices led to low public acceptance. Figure 18 shows that since the implementation of the carbon tax in 2014: • CO_2 emissions from the transport sector increased by 1.5% in 2017; • CO_2 emissions from the residential and commercial sector increased by 7% in 2017;

[12] The black line representing the sectors that are covered by the carbon tax is indicative due to exemptions within the sectors.

	• CO_2 emissions from agriculture declined with 11.4% in 2017, while the GDP increased with approximately 7% in the same period. However, it is not clear to which extent these effects on emissions can be attributed to the carbon tax solely.

5.1.7. Ireland

The government of Ireland implemented the first carbon tax in 2010, namely the Natural gas carbon tax (NGCT) (IEA, 2019; Leu & Betz, 2016). Three years later, the Solid fuel carbon tax (SFCT) came into force as well (IEA, 2019). The European Union decided that Ireland has to reduce its GHG emissions from the non-ETS sectors by 20% by 2020 compared to 2005 levels (European Parliament, 2009). The Irish government has not set an additional national GHG reduction target for 2020.

Design of the carbon tax

Obviously, the NGCT applies to natural gas, while the SFCT applies to coal and other solid fossil fuels (OECD, 2019d). In addition, there is also a Mineral oil tax (MOT) implemented in Ireland on fossil fuels. However, since only a small part of the charge of this tax is based on the amount of CO_2 emitted (Irish Tax and Customs, 2019), this tax is not considered in this study.

Regarding the carbon taxes, several exemptions are provided, such as for natural gas and coal used for electricity generation. Installations having a specific 'greenhouse gas emissions permit holders declaration' get a reduced rate or a full exemption, while biomass defined as "*any solid fuel product with a biomass content of 30 per cent or more*" is fully relieved (IEA, 2019; Irish Tax and Customs, 2019). Companies participating in the EU ETS also receive partial or full exemptions on the tax paid for coal, peat products coke products and natural gas (OECD, 2019d). Agriculture is also largely exempted (Partnership for Market Readiness, 2017a). Approximately 40 to 50% of the domestic GHG emissions of Ireland are covered by these carbon taxes (World Bank, 2019).

The taxes have an equal tax rate, which increased from the initial rate of €10/tCO_2e, to €20/tCO_2e in 2014. The government increased the rate to €26/tCO_2e on 8 October 2019 for transport fuels, and has announced to increase it for solid fuels from 1 May 2020 onwards (Citizens Information Board, 2019). Table 19 below shows the trend of an increasing tax rate since the implementation of the taxes. The Office of Revenue Commissioners is responsible for collecting the carbon tax revenues. Suppliers of natural gas or solid fossil fuels are liable for payment (Partnership for Market Readiness, 2017b). Suppliers must register annually to obtain the necessary licensing, use equipment that appropriately measures the amount of fuel and maintain documents regarding the fuel sales. If a taxpayer fails to pay, enforcement action can be taken, including civil proceedings (Irish Tax and Customs, 2019).

Table 19. Tax rate of the carbon taxes in Ireland (IEA, 2019)

Natural gas and solid fuel carbon tax

From	To	Natural gas (EUR/MWh)	Coal (EUR/tonne)
01.05.10	30.04.10	2.77	
01.05.12	30.04.13	3.70	
01.05.13	30.04.14	3.70	26.33
01.05.14	now	3.70	52.67

In 2016, €434 million was collected from the Irish carbon taxes (OECD, 2019c). Almost all revenues of the carbon taxes are transferred to the government's general budget. Initially, the carbon tax should be revenue-neutral, but due to the significant public deficit the government decided to use the revenues to pay off the national debt (Partnership for Market Readiness, 2017a). Approximately 12.5% of the revenues is earmarked annually for the funding of green subsidies, especially for resident energy efficiency measures (Carl & Fedor, 2016).

Effects of the carbon tax

There is a lack of ex-post studies on the effectiveness of the Irish carbon taxes in order to adequately evaluate the instruments. An ex-ante study from the Irish Economic and Social Research Institute (de

Bruin, Monaghan & Yakut, 2019) shows that the carbon tax will not be sufficient to meet the European climate target for 2030. Regarding public acceptance, the Irish carbon tax appears to be a good example of public engagement in the developing of taxation system, since a detailed stakeholder process before the implementation resulted in high accepted tax system (Convery, Dunne & Joyce, 2013).

Considering all Irish emissions during the period 1990-2017 shows that most emissions initially increased, but are now decreasing. Figure 20 shows that the carbon tax resulted in a decline of CO_2 emissions from agriculture and the residential and commercial sector of 23.2% and 23.5% respectively. Several exemptions for agriculture, the energy and the manufacturing industries are provided, such as for natural gas and coal used for electricity generation. These sectors are therefore visualized with dashed lines in Figure 20. Also the emissions from the energy sector declined after the implementation, but this trend already started before the implementation in 2010. The absolute and relative emissions caused by the residential and commercial sector are decreased since the implementation, as shown in Figures 20 and 21). Comparing the emissions before implementation of the carbon tax (in 1990) and after its implementation (in 2017) shows that the emissions from the transport sector are increased.

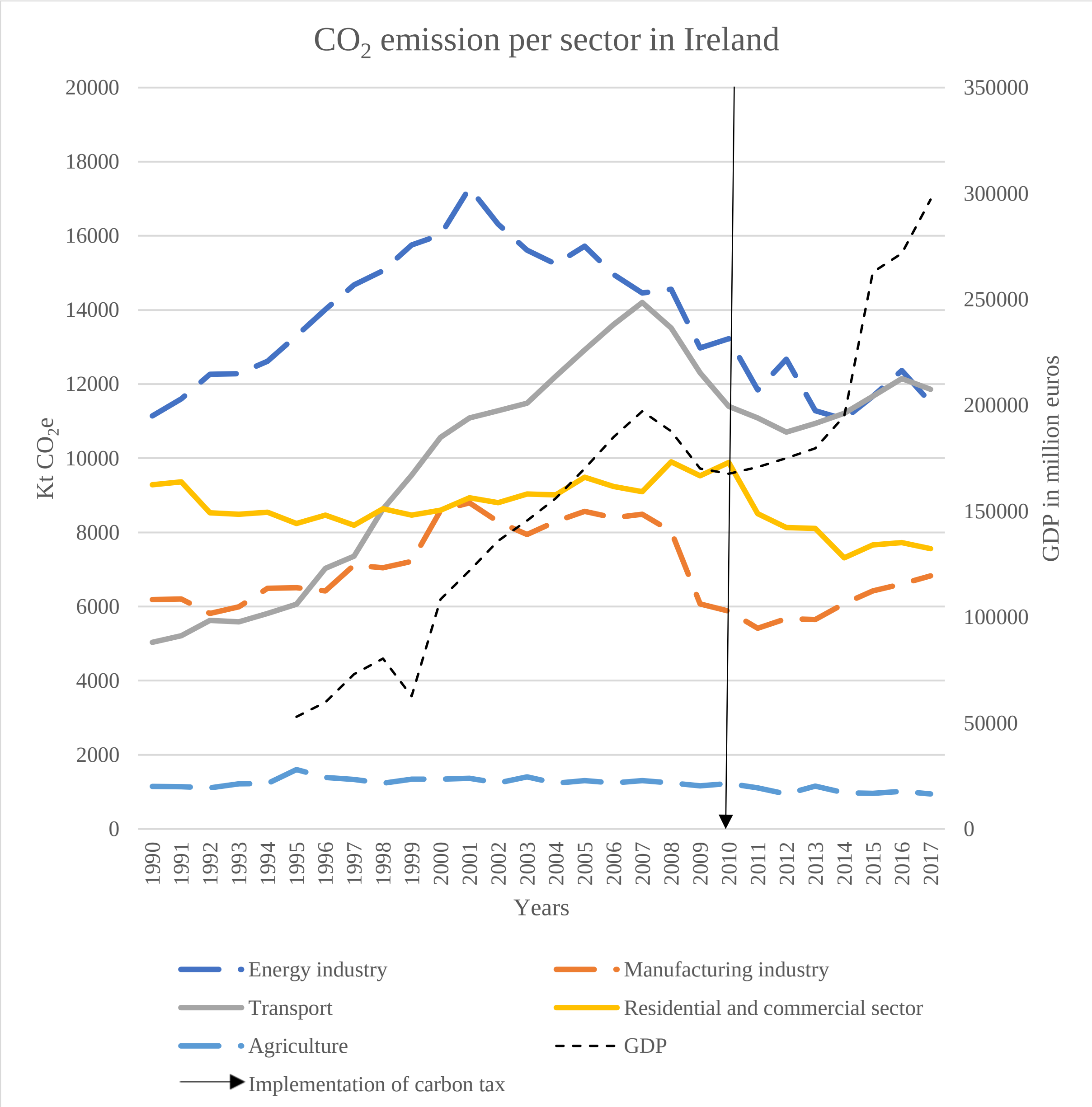

Figure 20. CO_2 emission per sector in Ireland (Eurostat, 2019). A solid line represents a sector that is fully covered by the carbon tax and a dashed line represents a sector that is partially covered[13]

[13] Due to a lack of data for Ireland starts the graph representing the GDP development in 1995 (Eurostat, 2019).

Figure 21 shows that the absolute domestic emissions increased from 32,891 Kt CO_2 in 1990 to 38,728 Kt CO_2 in 2017. Also, the relative share of emissions from sectors covered by the carbon tax slightly increased during the period 1990-2017. The sectors agriculture, energy industry and manufacturing industry are not (fully) covered by the black line, since large parts are exempted.

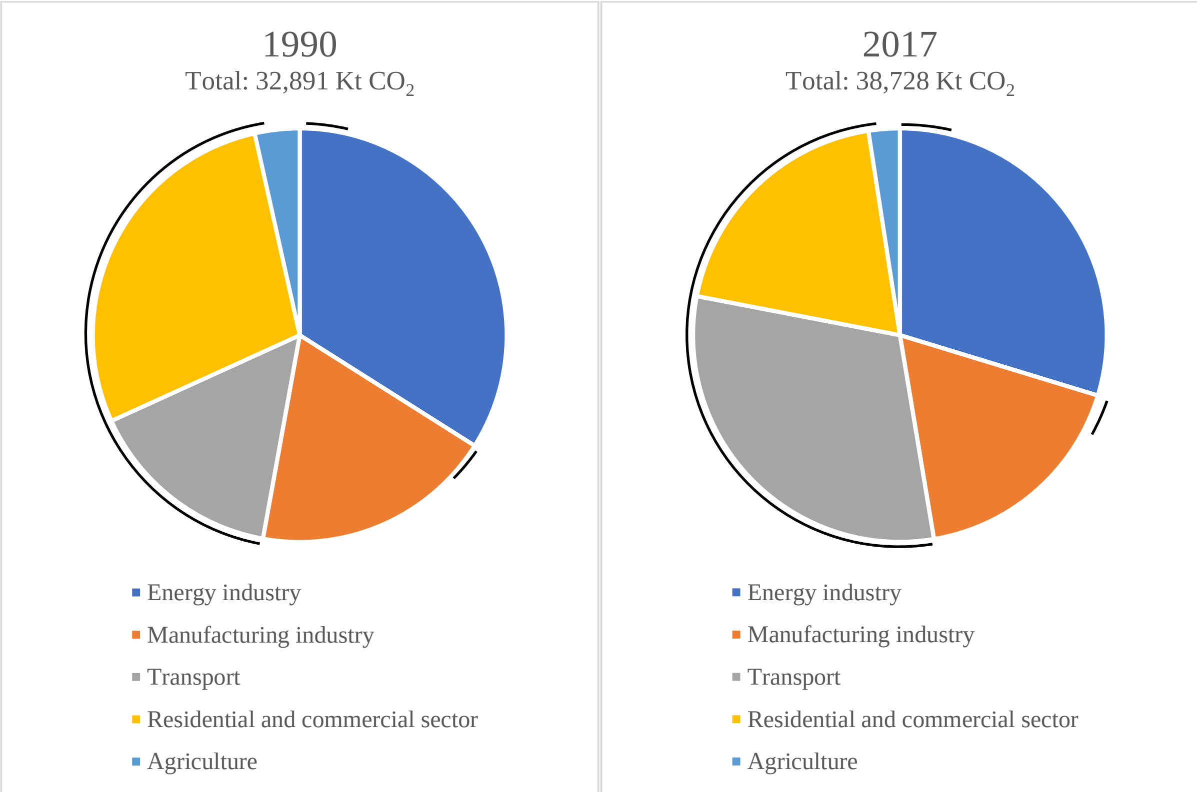

Figure 21. CO_2 emission per sector related to domestic emissions in 1990 and 2017 in Ireland (Eurostat, 2019). The black line visualizes the share of the sectors that are covered by the carbon tax [14]

Table 20. Design parameters and effectiveness of case study Ireland

Cluster	Design parameter	Case study Ireland
Target achievement	Level of ambition	EU target of 20% reduction of non-EU ETS sector GHG emissions in 2020, compared to 2005 levels
	Policy mix	Companies participating in EU ETS are exempted
	MRV system	The Office of Revenue Commissioners collects revenues; enforcement action occurs if payment fails
Incentive level	Tax rate	Annual increased with €0.55 on average, to €20/tCO_2e in 2019; will increase to €26/tCO_2e in 2020
	Point of enforcement	Tax on emissions; the supplier is liable for payment
Scope	Selection of the target group	Applied to natural gas and solid fossil fuels; some industrial companies, agriculture and fuels for electricity generation are exempted; 40-50% of domestic GHG emissions are covered
	Redistribution of revenues	Almost all revenues are transferred to the general budget, but approximately 12,5% is used for green subsidies

[14] The black line representing the sectors that are covered by the carbon tax is indicative due to exemptions within the sectors.

Effectiveness of the carbon tax	There is a lack of data; carbon tax will not be sufficient to meet the EU 2030 climate target; seems to lead to a small reduction of emissions caused by the residential and commercial sector; but high public acceptability. According to Figure 20, since the implementation of the carbon tax in 2010: • CO_2 emissions from energy industry declined with 13.1% in 2017; • CO_2 emissions from the manufacturing industry increased by 16.3% in 2017; • CO_2 emissions from the transport sector increased by 4.1% in 2017; • CO_2 emissions from the residential and commercial sector declined with 23.5% in 2017; • CO_2 emissions from agriculture declined with 23.2% in 2017, while the GDP more than doubled in the same period. However, it is not clear to which extent these effects on emissions can be attributed to the carbon tax solely.

5.1.8. Iceland

In 2010, Iceland adopted a carbon tax, the *Kolefnisgjald á fljótandi jarðefnaeldsneyti* (Carbon tax on carbon of fossil origin). Iceland is not part of the EU, but participates in the EU ETS (European Commission, 2015). Initially, the carbon tax would be into force until the end of 2012, but the government decided to continue and even expand the scope of the instrument. The Icelandic government mentions that pricing GHG emissions in the economy is seen as a long-term instrument (Icelandic Ministry of the Environment and Natural Resources, 2018b). Since Iceland is not a European member state, the EU has not set any emission reduction targets for this country. However, the Icelandic government want to reduce its domestic GHG emissions with 20% by 2020 compared to 1990 levels (EEA, 2017).

Design of the carbon tax

The carbon tax in Iceland covers all types of liquid or gaseous fossil fuels, including LPG, gas diesel oil, motor gasoline and heavy fuel oil (Icelandic Ministry of the Environment and Natural Resources, 2018a). The carbon tax concerns the transport and energy industry sectors, but firms covered by the EU ETS are exempted. Approximately 20 to 30% of the Islandic domestic GHG emissions are covered by this tax (World Bank, 2019). Together with the EU ETS, around 90% of the domestic CO_2 emissions are priced (Icelandic Ministry of the Environment and Natural Resources, 2018b)

The current tax rate is approximately €28/tCO_2e (World Bank, 2019). Iceland raised its tax rate at one- or two-year intervals (Haites et al., 2018). The carbon tax rate will increase with 10% by 2020, which is part of the Climate Action Plan 2018-2030 and includes measures to reach the target of carbon neutrality by 2040. These changes in the tax rate aim to phase out fossil fuels in the Icelandic transport sector (World Bank, 2019). The carbon tax is levied on importers and producers of fossil fuels upstream and the responsible authority for assessing and collecting the carbon tax revenues is the Directorate of Customs (Partnership for Market Readiness, 2017b). The revenues of the carbon tax are fully transferred to the government's general budget. There are no measures in terms of revenue redistribution noted (Partnership for Market Readiness, 2017b; Carl & Fedor, 2016).

Other environmental policies that are implemented in addition to the carbon tax include an excise tax on diesel fuel, recycling fees and a carbon-related excise tax on vehicle purchases (Partnership for Market Readiness, 2017b).

Effects of the carbon tax

No evaluations on the carbon tax of Iceland are found or completed yet (Partnership for Market Readiness, 2017b; Leu and Betz, 2016). For determining the effect of the carbon tax, the period of analysis is key, since the Icelandic GHG emissions increased by 26.3% between 1990 and 2012, but decreased by 4% in the period 2010-2012 (Partnership for Market Readiness). A critical remark is that it is not clear to what extent the carbon tax contributed to this decrease. The Icelandic government (Icelandic Ministry of the Environment and Natural Resources, 2018b) argues that there are signs that the emissions in some sectors covered by the carbon tax decrease.

Figure 22 presents the development of CO_2 emissions and GDP during the period 1990-2017. The transport and energy industry are covered by the carbon tax, but since the energy industry is largely exempted, this sector is visualized with a dashed graph. The implementation of the carbon tax in 2010 has not led to an evident decline of CO_2 emissions in the transport sector. The emissions from the energy industry declined with 26.4% since the implementation (Eurostat, 2019). However, a considerable decline of emissions can be seen in 2008, which will be a result from the economic crisis, including the collapse of Icesave bank which led to a significant decrease of the GDP.

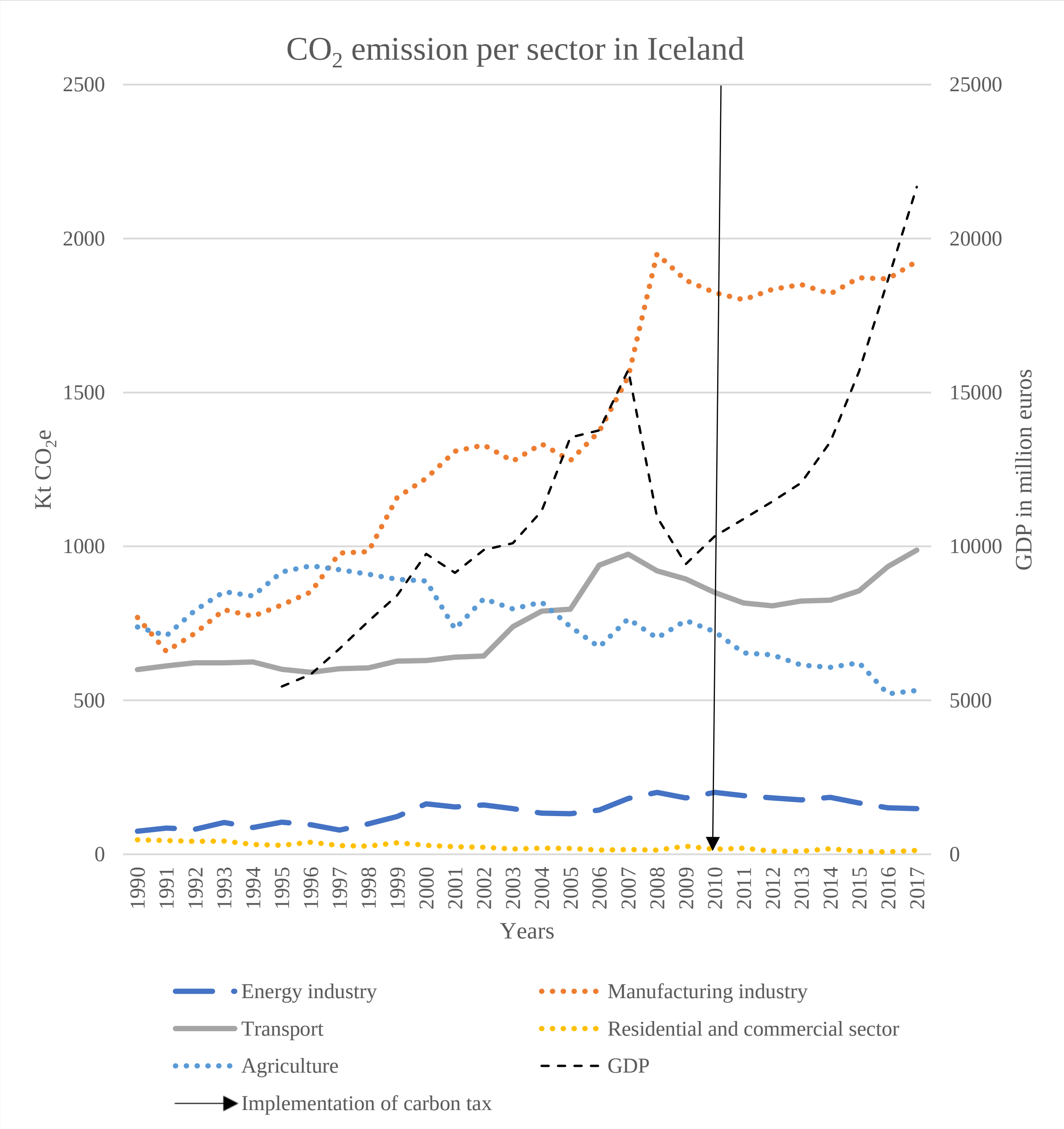

Figure 22. CO_2 emission per sector in Iceland (Eurostat, 2019). A solid line represents a sector that is fully covered by the carbon tax, a dashed line represents a sector that is partially covered and a dotted line represents a sector that is not covered[15]

[15] Due to a lack of data for Iceland starts the graph representing the GDP development in 1995 (Eurostat, 2019).

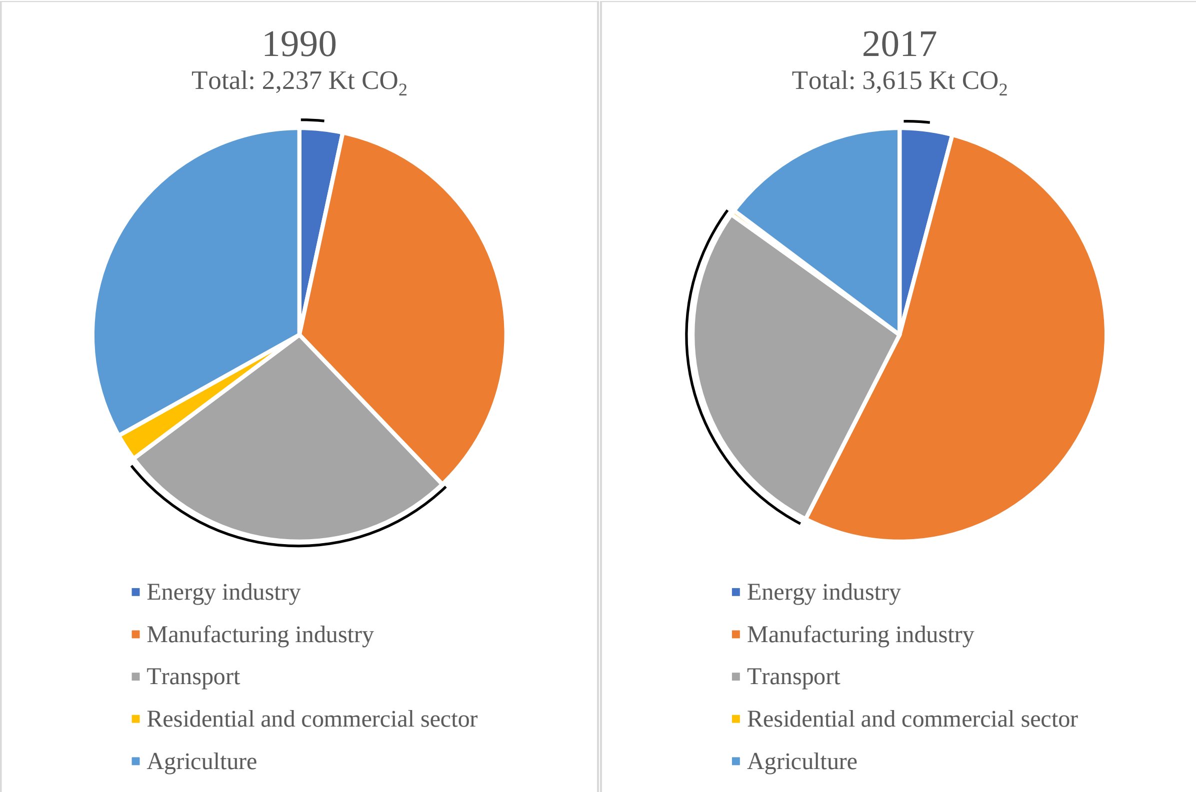

Figure 23. CO_2 emission per sector related to the domestic emissions in 1990 and 2017 in Iceland (Eurostat, 2019) The black line visualizes the share of the sectors that are covered by the carbon tax[16]

The absolute domestic emission is significantly increased during the period 1990-2017, as shown in Figure 23. However, it should be noted that the carbon tax is implemented in 2010, and therefore its effect on emissions will not be fully visible in this figure. It also shows that the share of emissions from the transport sector and agriculture remained almost equal before implementation of the carbon tax (in 1990) and after its implementation (in 2017).

Table 21. Design parameters and effectiveness of case study Iceland

Cluster	Design parameter	Case study Iceland
Target achievement	Level of ambition	National target to reduce GHG emissions by 20% in 2020 compared to 1990 levels
	Policy mix	Industrial companies participating in the EU ETS are exempted; other environmental policies include an excise tax on diesel fuel and a carbon-related excise tax on vehicle purchases
	MRV system	The Directorate of Customs assesses and collects the revenues
Incentive level	Tax rate	Annual increased with €2.33 on average to €28/tCO_2e in 2019
	Point of enforcement	Tax on emissions; levied on importers and producers of fossil fuels upstream
Scope	Selection of the target group	Mainly the transport and energy industry sectors are covered; but large exemptions exist; 20-30% of GHG emissions are covered
	Redistribution of revenues	All revenues are transferred to the general budget

[16] The black line representing the sectors that are covered by the carbon tax is indicative due to exemptions within the sectors.

Effectiveness of the carbon tax	There is a lack of data, however, emissions from sectors covered by the tax seem to stabilize Figure 22 shows that since the implementation of the carbon tax in 2010: • CO_2 emissions from energy industry declined with 26.4% in 2017; • CO_2 emissions from the transport sector increased by 16.2% in 2017, while the GDP more than doubled in the same period. However, it is not clear to which extent these effects on emissions can be attributed to the carbon tax solely.

5.2. Overview of case studies

An overview of abovementioned case studies, their design parameters and the effectiveness of the carbon taxes is presented in Table 22.

Table 22. Case studies, the design parameters and the effectiveness of the carbon taxes (World Bank, 2019; OECD, 2019a; Haites, 2018)

Cluster	**Target achievement**			**Incentive level**		**Scope**		
Design parameter	**Level of ambition**	**Policy mix**	**MRV system**	**Tax rate in 2019**	**Point of enforcement**	**Selection of target group**	**Redistribution of revenues**	**Effectiveness of the carbon tax**
Denmark	EU target of 20% reduction of GHG emissions in 2020 compared to 2005 levels	Industrial emissions covered by the EU ETS are exempted; carbon tax is harmonized with energy tax; Green Energy Package (1996) includes also a SO2 tax and energy tax on space heating	Companies must have meters accounting for the amount of fuel used; the Central Customs and Tax Administration collects the tax	Annual increased with €0.48 on average, to €23/tCO_2e in 2019	Tax on emissions; ultimately paid downstream by users and collected midstream by the distributers	Applied to oil, gas, coal and electricity in industry, residential and commercial sectors; exemption still exist; 40-50% of GHG emissions are covered	40-45% goes to the general budget, 45% is recycled to the industry or households, and approximately 5-10% is invested in green technologies through subsidies; cross-subsidization between households and industry should be avoided	An annual reduction of CO_2 emissions of 2.61% between 1994-2016 and replacement of coal by renewables. For the period 1992-2017: CO_2 emissions from energy industry declined with 62.2%; CO_2 emissions from manufacturing industry declined with 24.7%; CO_2 emissions from transport increased by 15.8%; CO_2 emissions from residential and commercial sector declined with 55.8%; CO_2 emissions from agriculture declined with 41.6%, while GDP almost tripled
United Kingdom	EU target of 16% reduction of GHG emissions in 2020 compared to 2005 levels; national target of 37% GHG emissions reduction in 2020 compared to 1990 levels	Applied in addition to the EU ETS and is part of the broader Climate Change Levy; Brexit may complicate system	Electricity generators must register with HM Revenue and Customs, report and maintain records on payments; penalties can be charged in case of failure of payment; Brexit may complicate system	Difference between EU ETS allowance price and the annual increasing CPF; CPF increased annually with €1.80 on average to €21/tCO_2e in 2019	Tax on emissions; paid midstream by electricity generators	Fossil fuels used for electricity generation; 20-30% of GHG emissions are covered	All revenues are transferred to the general budget	Mixed perspectives: the carbon tax led to a reduced competitive position, but changed the merit order in favor of natural gas rather than coal. For the period 2013-2017: CO_2 emissions from energy industry declined with 41.5%, while GDP increased with more than 10%
Sweden	EU target of 17% reduction	Companies participating in EU	Easy and cheap due to an already	Annual increased with	Tax on emissions; paid	All sectors are levied, but tax	All revenues are transferred to the	Reduction of domestic GHG emission by 26% in 2017. For the period 1991-2017:

	of non-EU ETS sector GHG emissions in 2020 compared to 2005 levels; national target of 40% reduction of GHG emissions in 2020 compared to 1990 levels	ETS are exempted; carbon tax is implemented in addition to other energy taxes	existing revenue collecting system; the National Tax Authority collects the revenues; monitoring and control is ensured	€3.14 on average to €112/tCO_2e in 2019, which is the highest price globally	upstream by producers and importers, and midstream by distributor; can be passed on to downstream users	exemptions for industrial facilities exist; 40-50% of GHG emissions are covered	general budget, which is mainly used for lowering income tax	CO_2 emissions from energy industry declined with 12%; CO_2 emissions from the manufacturing industry declined with 20.8%; CO_2 emissions from transport declined with 11.2%; CO_2 emissions from the residential and commercial sector declined with 85.1%; CO_2 emissions from agriculture declined with 12.8%, while GDP more than doubled
Norway	National target of 30% GHG emissions reduction in 2020 compared to 1990 levels	Companies participating in EU ETS are exempted; carbon tax rates are adjusted to price of EU ETS allowances; several other environmental taxes, including a SO_2 tax and a tax on HFCs and PFCs	The Norwegian Tax Administration collects general revenues and acts in case of failure of payment; the Norwegian Petroleum Directorate administrates revenues from petroleum activities	Annual increased with €0.34 on average to €3/tCO_2e and €54/tCO_2e (varies per fossil fuel and purpose) in 2019	Tax on emissions; upstream for petroleum activities and midstream for fuels	Mineral oil, petrol, natural gas and LPG, but exemptions for several industrial sectors and processes; 60-70% of GHG emissions are covered	General revenues are transferred to the general budget; revenues from petrochemical activities are transferred to the Global Government Pension Fund, but this fund will be phased out	Tax exemptions and price-inelastic demand led to an unsuccessful tax; the tax encouraged innovation and led to lower energy intensity. For the period 1991-2017: CO_2 emissions from energy industry increased by 81.5%; CO_2 emissions from manufacturing industry increased by 8.1%; CO_2 emissions from transport increased by 26.7%; CO_2 emissions from residential and commercial sector declined with 32.3%; CO_2 emissions from agriculture declined with 39.8%, while GDP has tripled
Finland	EU target of 16% reduction of non-EU ETS sector GHG emissions in 2020 compared to 2005 levels; national target of 21% reduction of GHG emissions in 2020 compared to 1990 levels for	Carbon tax rate is related to the excise tax rate; companies participating in EU ETS are exempted	The Finnish Tax Administration collects the revenues	Annual increased with €1.96 on average to €63/tCO_2e for transport fuels and to €53/tCO_2e for other fossil fuels in 2019	Tax on emissions; levied downstream as an excise tax	All sectors are taxed, but large exemptions for industrial companies exist; 30-40% of GHG emissions are covered	All revenues are transferred to the general budget; tax system is greened by reforms that increase the carbon tax rate and lower income taxes and social security contributions	CO_2 emissions are reduced with 7% between 1990 and 1998. For the period 1990-2017: CO_2 emissions from energy industry declined with 8.1%; CO_2 emissions from the manufacturing industry declined with 35.8%; CO_2 emissions from transport declined with 3.7%; CO_2 emissions from the residential and commercial sector declined with 58.8%; CO_2 emissions from agriculture declined with

	EU ETS-companies							37.5%, GDP has more than doubled.
France	EU target of 14% reduction of non-EU ETS sector GHG emissions in 2020 compared to 2005 levels	Companies participating in EU ETS are exempted; also raised the tax on diesel, which resulted in significant price increases	The Ministry of Finance and Public Accounts collects revenues; failure of payment results in charges, fines or the potential for filing criminal charges	Annual increased with €7.52 on average to €44.6/tCO_2e in 2019, but will not further increase during the coming years	Tax on emissions; paid upstream by the producers and importers and midstream by the distributors	Exemptions for large share of transport sector and industrial companies; 30-40% of GHG emissions are covered	Initially to green subsidies, now transferred to general budget and used to cut labor tax and provide support for low-income households	Lack of data, but increased prices led to low public acceptance; for the period 2014-2017: CO_2 emissions from transport increased by 1.5%; CO_2 emissions from the residential and commercial sector increased by 7%; CO_2 emissions from agriculture declined with 11.4%, GDP increased by 7%
Ireland	EU target of 20% reduction of non-EU ETS sector GHG emissions in 2020 compared to 2005 levels	Companies participating in EU ETS are exempted	The Office of Revenue Commissioners collects revenues; enforcement action occurs if payment fails	Annual increased with €0.55 on average, to €20/tCO_2e in 2019; will increase to €26/tCO_2e in 2020	Tax on emissions; the supplier is liable for payment	Applied to natural gas and solid fossil fuels; some industry, agriculture and fuels for electricity generation are exempted; 40-50% of GHG emissions are covered	Almost all revenues are transferred to the general budget, but approximately 12,5% is used for green subsidies	Lack of data; carbon tax not sufficient to meet 2030 climate target; high public acceptability. For the period 2010-2017: CO_2 emissions from energy industry declined with 13.1%; CO_2 emissions from the manufacturing industry increased by 16.3%; CO_2 emissions from transport increased by 4.1%; CO_2 emissions from the residential and commercial sector declined with 23.5%; CO_2 emissions from agriculture declined with 23.2%; GDP has more than doubled
Iceland	National target to reduce GHG emissions by 20% in 2020 compared to 1990 levels	Industry participating in EU ETS is exempted; other environmental policies include an excise tax on diesel fuel and a carbon-related excise tax on vehicle purchases	The Directorate of Customs assesses and collects the revenues	Annual increased with €2.33 on average to €28/tCO_2e in 2019	Tax on emission; levied on importers and producers of fossil fuels upstream	Mainly transport and energy industry sectors are covered but large exemptions exist; 20-30% of GHG emissions are covered	All revenues are transferred to the general budget	Lack of data, emissions from sectors covered by the tax seem to stabilize; for the period 2010-2017: CO_2 emissions from energy industry declined with 26.4%; CO_2 emissions from transport increased by 16.2%, GDP has more than doubled

5.3. Clustering of tax models

In order to simplify the analysis, the eight carbon tax case studies will be clustered into three groups. This clustering is based on the effectiveness of the carbon taxes. There is little literature on the reduction of GHG emissions caused by the implementation of carbon taxes in Europe (Haites et al., 2018). Therefore, the focus is on the observed change in CO_2 emissions since the implementation of the carbon tax until 2017. A direct relation between the emission change and the implementation of the carbon tax is difficult to prove, since other policy instruments as well as external factors, such as economic crises, could be influential on the emissions. However, there are indications that the emission change and carbon taxation are related. Table 23 provides an overview of the effectiveness of the abovementioned carbon taxes. The "total" row presents the change of CO_2 emissions between 1990 and 2017. Also, it shows for each case study the change in CO_2 emissions between the year of implementation of the carbon tax and 2017, for the sectors analyzed. It should be noted that since the implementation of the carbon tax, the GDP of all case studies increased significantly.

Furthermore, the table shows that the energy and manufacturing industry are (partially) exempted in all case studies. The case studies show that implementing a carbon tax can be effective for reducing GHG emissions caused by agriculture and the residential and commercial sector. Also, the emissions from the energy and manufacturing industry can be reduced by implementing a (reduced) tax rate. Only the France carbon tax has not led to reductions in the residential and commercial sector, but this can be explained by the excessive increased tax rate. Based on this data, three groups of carbon taxes can be identified.

Table 23. Overview of the effectiveness of the carbon taxes per sector (data from Eurostat, 2019).

Case study	Total (change between 1990 and 2017)	Energy industry (emission change between year of implementation and 2017)	Manufacturing industry (emission change between year of implementation and 2017)	Transport (emission change between year of implementation and 2017)	Residential and commercial sector (emission change between year of implementation and 2017)	Agriculture (emission change between year of implementation and 2017)
Sweden	- 26.8% - 15,396 Kt	- 12% - 1,321 Kt	- 20.8% - 3,403 Kt	- 11.2% - 2,063 Kt	- 85.1% - 7,751 Kt	- 12.8% - 212 Kt
Finland	- 21.5% - 12,268 Kt	- 8.1% -1,534 Kt	- 35.8% - 6,152 Kt	- 3.7% - 440 Kt	- 58.8% - 3,170 Kt	- 37.5% - 942 Kt
United Kingdom	- 37.7% - 213,673 Kt	- 41.5% - 75,171 Kt				
Denmark	- 35% - 18,763 Kt	- 62.2% - 19,143 Kt	- 24.7% - 1,793 Kt	+ 15.8% + 1,783 Kt	- 55.8% - 3,295 Kt	- 41.6% - 1,220 Kt
Iceland	+ 61.6% + 1,378 Kt	- 26.4% - 53 Kt		+ 16.2% + 138 Kt		
Ireland	+ 17.7% + 5,837 Kt	- 13.1% - 1,727 Kt	+16.3% + 956 Kt	+ 4.1% + 464 Kt	- 23.5% - 2,327 Kt	- 23.2% - 285 Kt
France	- 13.6% - 54,407 Kt			+ 1.5% + 1,986 Kton	+ 7% + 4,923 Kt	- 11.4% - 1,495 Kt
Norway	+ 23.7% + 8,379 Kt	+ 81.5% + 7,993 Kt	+ 8.1% + 802 Kt	+ 26.7% + 2,575 Kt	-32.3% 895 Kt	- 39.8% - 574 Kt

- Sector fully covered by carbon tax and shows a reduction of CO_2 emissions
- Sector partially covered by carbon tax and shows a reduction of CO_2 emissions
- Sector fully covered by carbon tax and shows an increase of CO_2 emissions
- Sector partially covered by carbon tax and shows an increase of CO_2 emissions
- Sector fully covered by carbon tax and shows no clear result regarding CO_2 emissions
- Sector partially covered by carbon tax and shows no clear result regarding CO_2 emissions
- Sector not covered by carbon tax

The first group consists of case studies that can be defined as not effective because the emissions have increased since the implementation of the carbon tax or the tax has led in other negative consequences that question the functioning of the carbon tax. The case study of Norway is a clear example of this, since the absolute emissions increased since the implementation of the carbon tax. Also, France is part of this group, as the implementation of the carbon tax led to a significant increase of transport fuel prices, which resulted in the rise of the *gilets jaunes*. The lack of public support for the French carbon tax even put the tax's existence at stake.

The second group consists of case studies where the emissions have declined since the implementation of the carbon tax and can therefore be seen as effective. The carbon tax implemented in Sweden, Denmark, United Kingdom and Finland can be seen as effective, because the emissions caused by multiple sectors are reduced since the tax's implementation. Sweden can be seen as a frontrunner since it achieved the most reduction. Swedish carbon tax can be summarized as: easy and cheap to administer and resulting in great emissions reduction as well as economic growth. Also, the Finnish and Danish carbon tax have reduced emissions as a result, but these are less significant as the Swedish tax. For the United Kingdom, the CPF shows that a substantially different tax design could also result in a (small) reduction of emissions and a stable policy signal for companies participating in the EU ETS.

Case studies without a clear effect of the carbon tax on the emissions (yet) form the last group. The case studies Ireland and Iceland fall under this category, since their carbon taxes are recently implemented and lack sufficient evaluative data. While this is also the case for France, the social protests and a frozen tax rate result in a categorization of this carbon tax in the first group. Table 24 presents the groups of carbon taxes based on their effectiveness.

Table 24. Effectiveness of carbon taxes

Effectiveness of the carbon tax	Mainly effective	Mainly effective	Mainly effective	Mainly effective	No clear result	No clear result	Mainly ineffective	Mainly ineffective
Case study	Sweden	Finland	United Kingdom	Denmark	Iceland	Ireland	France	Norway

Legend: green = Mainly effective; red = Mainly ineffective; white = No clear result

To get insight into the influence of the design parameters on the effectiveness of the carbon taxes, the earlier proposed hypotheses will be discussed.

5.3.1. Target achievement: level of ambition, policy mix and MRV system

Regarding the level of ambition, the United Kingdom, Sweden and Finland has implemented an additional national GHG reduction target for 2020, and also have an effective carbon tax. Comparing Table 23 and Table 25 shows that there seems to be a relation between the effectiveness of the taxes and the implementation of additional national GHG emission targets for 2020. Thus, it can be said that the following hypothesis: H_1: *Setting additional national climate targets is beneficial for the effectiveness of the carbon tax;* can be confirmed.

Table 25. Level of ambition of case studies

Additional climate target for 2020	Additional national GHG emission target for 2020	Additional national GHG emission target for 2020	Additional national GHG emission target for 2020	No additional national GHG emission target for 2020	Not part of EU: only a national GHG emission target for 2020	No additional national GHG emission target for 2020	No additional national GHG emission target for 2020	Not part of EU: only a national GHG emission target for 2020
Case study	Sweden	Finland	United Kingdom	Denmark	Iceland	Ireland	France	Norway

Legend: green = Additional national GHG emission target for 2020; red = No additional national GHG emission target for 2020; white = Not part of EU: only a national GHG emission target for 2020

Regarding the policy mix, it is clear that all case study countries implemented the carbon tax in addition to other environmental policies, such as energy taxes. All case studies aligned their tax rates with the tax rates of other taxes or subsidies. Therefore, it is not possible to confirm or invalidate the following hypothesis: H_2: *Aligning and integrating carbon taxes in the whole spectrum of climate and non-climate* *related policies is beneficial for the effectiveness of a carbon tax;* since there is no comparison with a case where the carbon tax is not aligned with other climate policies.

For all case studies, a MRV system is present. However, the case studies cannot provide an adequate comparison of the MRV systems, because the relation between the MRV system and the effectiveness of the carbon tax is not measured in the evaluations considered in the case studies. Therefore, the following hypothesis: *H_3: High quality of the monitoring and enforcement mechanisms of the carbon tax is beneficial for the effectiveness the carbon tax;* can neither be confirmed nor invalidated. However, implementing the carbon tax in Sweden was relatively effortless, since there was already an existing taxation system in place. Since this is the case for all European countries, it is obvious to argue that the MRV system for the countries analyzed would not have worked counteracting to the effectiveness of the carbon tax.

5.3.2. Incentive level: tax rate and point of enforcement

Concerning the tax rate, Sweden, with the most successful carbon tax, has the highest tax rate, as shown in Figure 24. There seems to be a positive relationship between the effectiveness and high tax rates. Besides Sweden, only Finland and France have a tax rate higher than €40/tCO_2e, which exceed the carbon price that is necessary to achieve the Paris Agreement target of increasing the global average temperature with maximum 2°C above pre-industrial levels (World Bank, 2019; Haites et al., 2018). Except for France, which will be considered later, the high tax rates of Sweden and Finland and their effective carbon taxes show that *H_4: A tax rate that has significant impact on the retail price of products is beneficial for the effectiveness of the carbon tax* can be confirmed.

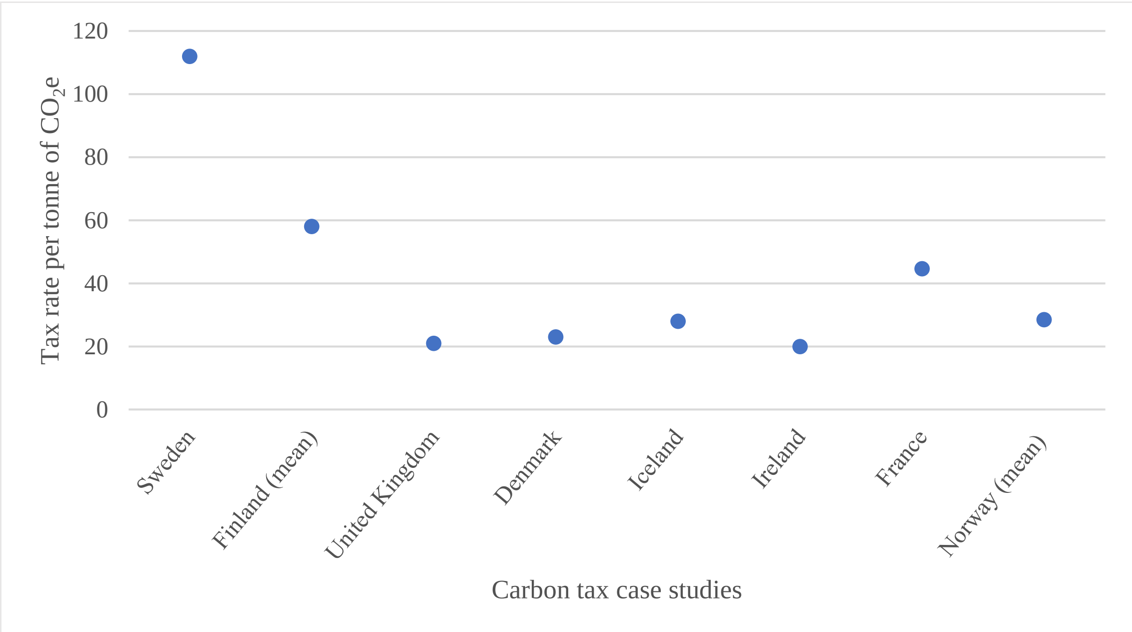

Figure 24. Tax rates of carbon tax case studies in 2019 (World Bank, 2019)[17]

Since the implementation of the carbon taxes, all tax rates gradually increased. However, some increased with a relatively high rate, as France, which is shown in Figure 25. Since all case studies increased their tax rate over time, and no case study with stable tax rate was considered, *H_5: A tax rate that increases over time is beneficial for the effectiveness of the carbon tax, compared to a static tax rate,* can neither be confirmed nor invalidated based on this research. However, the tax rate of the most effective carbon tax, namely Sweden, increased annually with more than €3/tCO_2e, which is considerably more than the other case studies, except for France, which tax rate increased excessively. It should be mentioned that some of the case studies have gradually increased their tax rate for a relatively short period, for example Ireland and France, since these carbon taxes were implemented in 2010 and 2014 respectively.

[17] For the UK, this tax rate is the rate of the Carbon Price Floor.

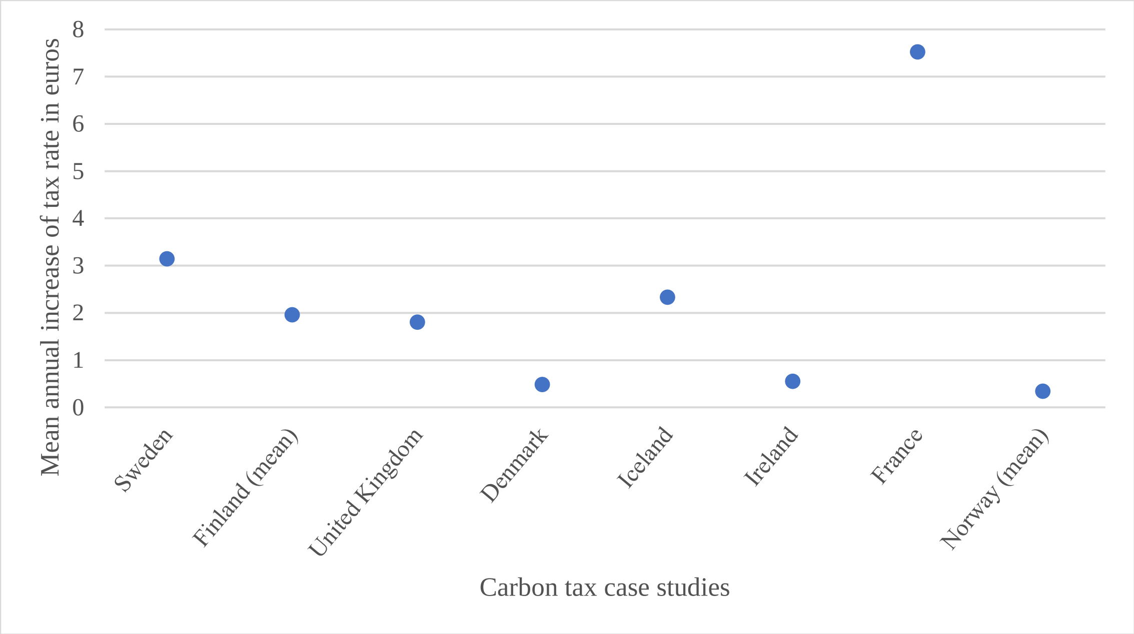

Figure 25. Mean annual increase of tax rate in euros (World Bank, 2019)

Regarding the point of enforcement, there is no clear effect of the point of enforcement on the effectiveness of the carbon taxes. Most carbon taxes impose their taxes upstream or midstream, but as mentioned by Sorrel and Sijm (2003), some costs can be passed on from directly affected target groups to indirectly affected target groups. Even while the carbon tax is imposed upstream and the producers are thus the directly affected target group, the case of Sweden shows that (some) costs are passed on to users, which makes them the indirectly affected target group. This may be harmful for the carbon tax's public support since this may lead to an increased retail price of the product, depending on the elasticity of the supply and demand (Sorrel & Sijm, 2003). However, since the Swedish carbon tax is successful, the transfer of costs to downstream users appear to be no crucial element influencing the effectiveness of the carbon tax design. Therefore, *H_6: Imposing a carbon tax upstream is more effective than downstream*, cannot be confirmed. Thus, the point of enforcement of the carbon tax does not play an important role on the effectiveness of the carbon tax.

5.3.3. Scope: selection of target group and redistribution of revenues

Regarding the selection of the target group, all carbon taxes are applied to almost exclusively non-ETS emissions, except for the United Kingdom's CPF. As shown in Figure 26 below, the most effective carbon taxes do not have the highest percentage of domestic GHG covered by their carbon taxes. Surprisingly, the ineffective carbon tax of Norway has the highest percentage of domestic GHG emissions covered by its carbon tax, while the effective Swedish carbon tax has a lower percentage of emissions covered. Thus, *H_7: Exempting sectors in a system of carbon taxation will be less beneficial for the effectiveness of a carbon tax*, cannot be confirmed, since the case of Norway shows that a highest percentage of GHG emissions covered by the carbon tax does not imply an effective carbon pricing instrument.

On the other hand, Table 23 shows that the selection of the target group is an important design parameter. The emissions from the transport sector appear to be not declined since the implementation of the carbon taxes in all case studies, except for Sweden. For the residential and commercial sector as well as agriculture, emissions have declined since the implementation of carbon taxes. Also, for the energy and manufacturing industries, emissions have declined, even while these sectors are often (partially) exempted. Therefore, the effectiveness of a carbon tax is highly dependent on the selection of the target sector.

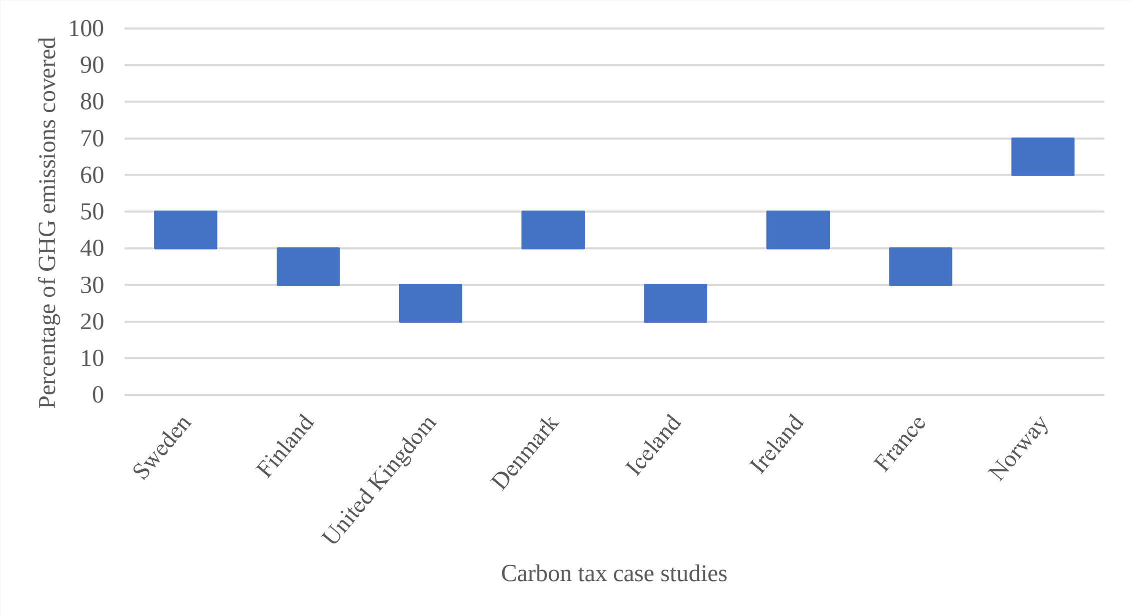

Figure 26. Scope of carbon taxes as percentage of GHG emissions covered (World Bank, 2019)

Regarding the use of revenues, Figure 27 shows that most case studies transfer their revenues to the government's general budget. However, while the revenues are transferred to the general budget, those revenues are often indirectly used to lower income taxes and social security contributions, as is stressed by the governments of Finland and Sweden. Based on Sweden and Finland, which have relatively effective carbon taxes and stress the urgency to use the revenues to lower income taxes and social security contributions, H_8*: Using the revenues of a carbon tax for low-income groups reduces the regressive nature of carbon taxation and is beneficial for the support base of the carbon tax in society* can be confirmed. In addition, France shows that using revenues for investments in green innovations contributed to a low support base and even social protests. Currently, the French government (partially) uses the revenues to cut labor tax and support low-income households. Thus, not using revenues for social contributions could be harmful for the effectiveness of the carbon tax. However, this parameter is not as crucial for the effectiveness as other parameters such as the tax rate.

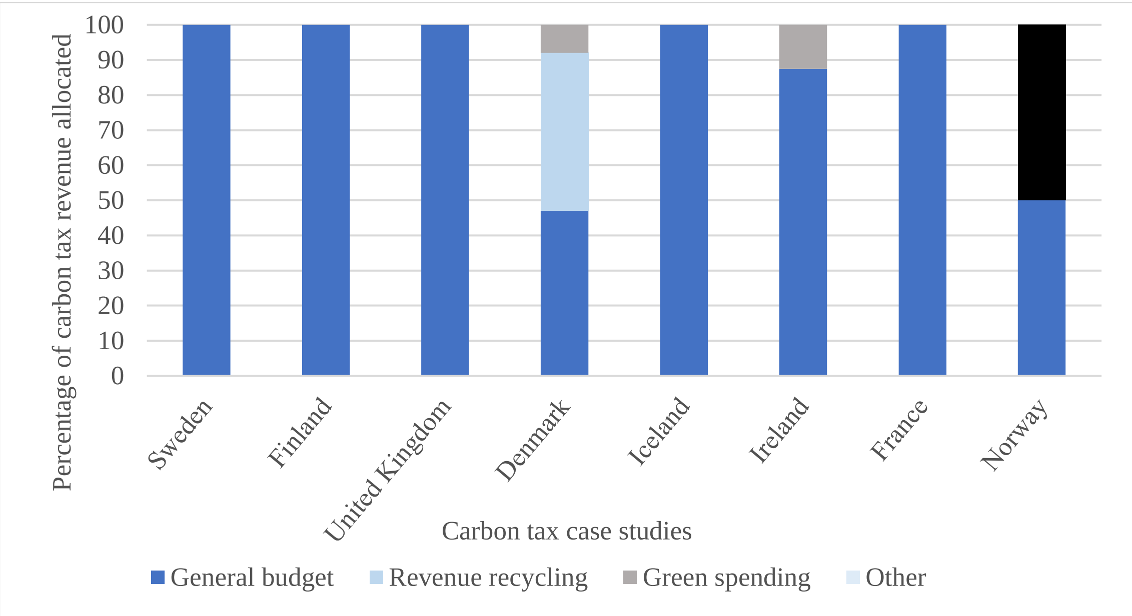

Figure 27. Carbon tax allocation (adjusted from Burke, Byrnes & Fankhauser, 2019; Carl & Fedor, 2016)[18]

[18] For Norway, the share of revenues transferred to the general budget and transferred to the Global Government Pension Fund are not clear. Thus, the revenue share for Norway is only a rough attribution of this tax shift based upon incomplete date.

5.4. Conclusions based on international evidence

Obviously, it depends on the definition of effectiveness which carbon taxes are seen as effective. Considering a reduction of CO_2 emissions shows that the carbon taxes of Sweden, Denmark and Finland as well as the CPF of the United Kingdom have the most effective design.

Concerning the design parameters, the tax rate appears to be the most influential parameter for the effectiveness of a carbon tax. As shown by the carbon tax of Sweden, the higher the rate, the more emissions are reduced. However, other factors may contribute to the influence of the tax rate on the effectiveness. The carbon tax of France shows that the tax rate should not be increased too much in a relatively short time period. The tax rates of the Norwegian carbon tax are lower than the Swedish tax rate, but also relatively high compared to other countries. Nevertheless, Norway's relatively high CO_2 emissions from the petroleum industry and natural gas extraction, as world's major oil and natural gas exporter, explain the growth of emissions per capita. Apparently, even levying the petroleum industry with the highest carbon tax rate is not sufficient to reduce its emissions. Thus, the amount of fossil industry appears to be influential as well.

Regarding the selection of the target group, the percentage of GHG emissions that is covered by the carbon tax is not as important as expected, since Figure 25 shows that Norway has the highest scope, while this carbon tax cannot be seen as successful. On the other hand, the type of sectors that are taxed is important for an effective carbon tax design, as shown in Table 23. This table also shows that all industrial sectors are (partially) exempted. Therefore, the risk of carbon leakage was not heavily debated in the case studies. Greening the transport sector will be more challenging than greening the energy and manufacturing industry and the residential and commercial sector, due to the availability of more CO_2 reducing technologies for these target groups. However, launching cheaper electric vehicles as carbon-free alternatives for internal combustion engine vehicles could contribute to a reduction of CO_2 emissions in the transport sector as well.

The point of enforcement appears to be not as influential on the carbon tax's effectiveness as other factors, such as the tax rate. This is due to the fact that often when a carbon tax is imposed upstream, the costs are passed on to the downstream users. Thus, the retail price of the product increases. There was no evidence that imposing a carbon tax on a certain point, for example downstream, would be easier because of already existing tax collecting systems.

Using the revenues of the carbon tax for low-income groups could be beneficial for the support base of the carbon tax, as shown by the case studies of Finland, Sweden and France. However, the use of revenues has no significant impact on the effectiveness of the carbon tax, since most case studies transfer the revenues to the general budget, while large differences in effectiveness of the carbon taxes exist.

For all case studies, the carbon tax rates were adjusted to the tax rates of other taxes, and can thus be seen as well integrated in the policy mix. Since there is no comparative case study that has not integrated its carbon tax in the policy mix, this research cannot provide conclusions about the importance of the integration on the effectiveness (H_2). This is also the case for determining the effects of the MRV system (H_3) and the increased tax rate over time (H_5). Due to a lack of case studies without a probably adequate functioning MRV system and a stable tax rate as comparison, this study can neither confirm nor falsify these hypotheses. However, the properly functioning MRV systems of the successful carbon tax of Sweden and the CPF of the United Kingdom show that a well-functioning MRV system may support the effectiveness of the carbon taxes. If the MRV system of one of the case studies would be insufficient, this may be harmful for the carbon tax's effectiveness, but no signs were found that this is the case. Table 26 below provides an overview of the importance of the design parameters for an effective carbon tax, according to the case studies analyzed.

In addition to the design parameters mentioned earlier, public acceptance appears to be of significant importance for the effectiveness of the carbon tax. The case of France can be used as an example for what happens if the tax rate is increased significantly in a short time period, while the case of Ireland shows that involving stakeholders in the decision-making process could lead to more public acceptance. Also, external effects, such as the economic recession in 2008, seem to affect the reduction of emissions to a greater extent that the carbon tax itself, as supported by the study of Haites et al. (2018).

Table 26. Importance of carbon tax design parameters for the effectiveness, according to the case studies

Design parameters	Importance for the carbon tax's effectiveness	Explanation
Level of ambition		Effective carbon taxes have set national targets in addition to EU targets
Policy mix		Lack of comparative case study without aligned policy mix
MRV system		Lack of comparative case study without well-functioning MRV system
Tax rate		Effective carbon taxes have higher tax rates (except for France)
Point of enforcement		No clear effect on effectiveness, since some effective carbon taxes have different points of enforcement
Selection of target group		The percentage GHG emissions covered is not important, but which sectors are levied is important for the carbon tax's effectiveness
Redistribution of revenues		Effective and ineffective carbon taxes transfer the revenues to the general budget, but some effective carbon taxes stress to use the revenues for low-income groups to reduce the regressive nature

Important parameter

Medium important parameter

Less important parameter

Not clear due to lack of data or opposite comparative carbon tax

6. Results 2: Carbon tax in the Netherlands

6.1. Results: Discourse analysis

The discourse analysis consists of an analysis of 92 (opinion) articles in Dutch newspapers, reports from governmental research institutes and consultancies as well as interviews with several stakeholders. One of the opinion articles is a position paper from a group of economists. They specify why a carbon tax should be implemented in the Netherlands and how this instrument should be designed. Table 27 shows how often particular actors or sectors are mentioned in the newspaper articles. This illustrates which actors have played a prominent role in the debate on carbon taxation in the Netherlands.

Table 27. Actors or sectors mentioned in the newspaper articles (excl. governmental organizations)[19]

Actor or sector	Type of actor/organization	Amount of articles
Economists	Scientists	30
Tata Steel	Steel company	28
VNO-NCW	Business association	21
Environmental organizations	NGO	19
Dow	Chemical company	12
Greenpeace	NGO	11
Shell	Petrochemical company	11
Dutch industry	Business sector	11
MKB	Business sector	8
Sabic	Chemical company	7
Yara	Chemical company	6
Milieudefensie	NGO	6
(Petro)chemical industry	Business sector	6
Natuur & Milieu	NGO	5
Port of Rotterdam	Company	5
Zeeland Refinery	Petrochemical company	5
BP	Petrochemical company	5

Furthermore, the reports on the implications of the adoption of a carbon tax in the Netherlands are written by the consultancy bureaus CE Delft and PriceWaterhouseCoopers (PwC). Also a study of DNB and a policy brief from the PBL and the CPB Netherlands Bureau for Economic Policy Analysis (CPB), two governmental organizations, are included in the research.

Concerning the political perspective, three types of debates in the Dutch parliament are considered: two roundtable discussions, three technical briefings and four plenary debates. Most of these meetings covered the topic of the Dutch Climate Agreement, which includes the implementation of a carbon tax for the industry. In roundtable discussions, several stakeholders inform members of parliament (MPs) of their perspective on a specific topic and the politicians got the opportunity to question them in return. One roundtable discussion included for example consultancy bureau CE Delft, three environmental NGOs, industrial companies, and several research institutes and professors representing the scientific point of view on the role of the industry in the Climate Agreement. The adoption of a carbon tax was the main subject of this meeting. During technical briefings, government officers provide MPs with more technical information on a certain subject. Again, after the presentations by the government officials, the MPs can question them. During the three technical briefings, government officials from the PBL and the CPB presented their research on the potential implications of the Climate Agreement, including on the introduction of a carbon tax. Lastly, the plenary debates are meetings for politicians solely, but clarify differences between the perspectives of the political parties and potential common ground.

The analysis of the discourse analysis of the (opinion) articles in Dutch newspapers and political debates as well as the interviews shows that the role of the industry within the debate is very apparent. Within the political debates, most parties are in favor of the introduction of a carbon pricing instrument,

[19] Only actors or sectors that are mentioned in at least five articles are considered.

but not a carbon tax for the industry per se, while a few political parties even question the urgency to act against climate change and to reduce emissions.

Regarding the interviews, all respondents mention the urgency to act against climate change and to reduce carbon emissions. Also, all prefer the implementation of a carbon pricing instrument globally or on the EU level rather than on the national level. They also consider the risks of carbon leakage and losses of companies or employment in the Netherlands as a result of the adoption of a national carbon tax. However, changes can be found in the prioritization of these issues, as well as on the preferences considering the design of a carbon tax.

Due to the great amount of data derived from the newspaper articles, political debates and interviews, the perspectives on the design parameters of a carbon tax in the Netherlands are clustered in three main coalitions, which are described below.

6.1.1. Coalition 1: Industry

The first coalition consists of industrial companies and their associations. The carbon tax may have the most effect on the steel and chemical industry sectors, which can be seen as the most important actors within this coalition. The reasoning of this coalition is visualized in the Theory of Change in Figure 28.

Regarding the effectiveness of the carbon tax, the industry sees meeting the climate target as a goal. Several industrial companies committed themselves to the targets of the Paris Agreement. In addition, this coalition stresses that the adoption of a carbon tax should have no negative influence on the level playing field. The companies argue that a decreased competitive position would lead to a loss of employment, bankruptcy, or (partially) resettling abroad. The industry sector highlights that the climate target should be met, but also stresses that the international competitive position should be preserved, but this statement is not based on any causal relationships. This coalition bases its reasoning mainly on normative arguments. They often refer to a report of PwC, which highlights the risk of harming the international competitive position if a carbon tax will be adopted. This report is based on mainly ex-ante research, which uses assumptions about the Dutch future situation. This report also considers some countries that already implemented a carbon tax, such as Sweden, but the industrial companies themselves do not refer to these case studies. The issue of a weakened competitive position is also mentioned by the other coalitions, but they argue that the Dutch business climate is not based on national fiscal policy instruments solely, since the implementation of a carbon tax should be seen in a broader business context, and is not as valuable as presented by the industry coalition.

Some industrial companies highlight potential opportunities regarding the energy transition. This sector aims to focus more on long-term climate targets rather than the mid-term target for 2030, since the current investments are mainly done for 2030 and therefore not useful for technologies necessary to meet the 2050 target. The lobbyist of a chemical company stresses that the twelve biggest emitters, including several chemical companies and steel company Tata Steel, were relatively united and suggested the adoption of a bonus-malus system. This system implies that companies develop an own CO_2 reduction plan. They are obligated to execute the intended measures included in the plan and other measures with a payback time of less than five years. A subsidy is available for the unprofitable top of the investments. In case the company does not implement the measures, a penalty should be paid, which depends on the price of EU ETS allowances. The price rate of the penalty is not further discussed. Other design parameters of this system, including the redistribution of revenues and the MRV system, are not elaborated. However, the PBL calculated that this system will not be sufficient to meet the climate targets. Due to its (legal) complexity, this system was rejected (PBL Netherlands Environmental Assessment Agency, 2019b).

For the implementation of a bonus-malus system as well as for a carbon tax, the revenues should be used to invest in sustainable, innovative technologies, according to all industry actors. The key point of the association for the chemical industry, the VNCI, is that the SDE+(+) subsidy is a necessary instrument to add to a carbon tax as an incentive to ensure that the energy transition takes place. The lobbyist of Tata Steel argues that "using revenues for the general budget is capital dissipation". He argues that transferring the revenues to the general budget instead of directly investing it in sustainable technologies leads to the risk that not the full amount is invested in the energy transition. However, at the same time, some industry actors are critical on revenue recycling to the industry because of the complexity, since it would be difficult to determine which companies would receive which amount of money in return. Table 28 below shows the preferred design parameters concerning the carbon tax for this coalition.

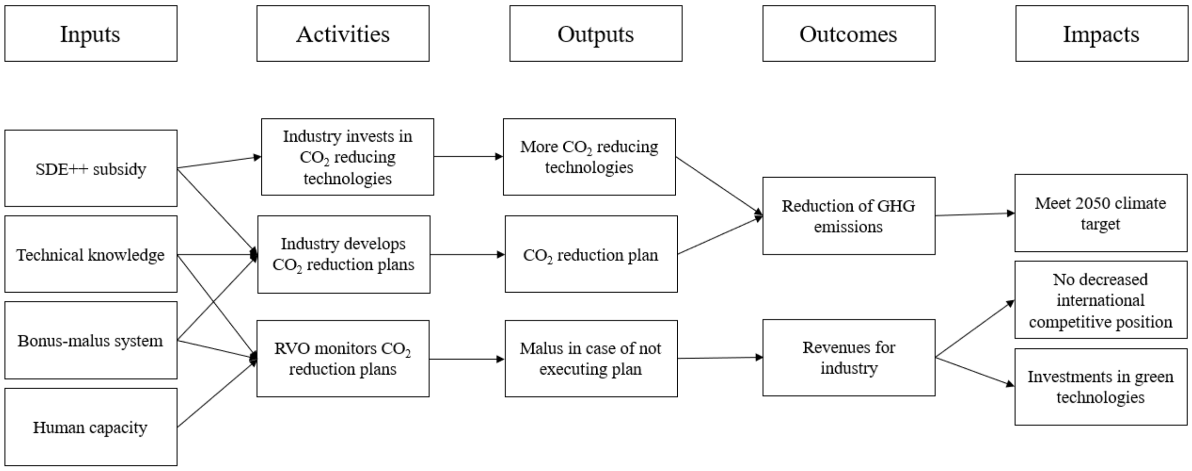

Figure 28. Theory of Change based on assumptions from coalition 1: Industry

Table 28. Preferred target and design parameters of coalition 1: Industry

Cluster	Design parameter	Coalition 1: Industry
Target achievement	Level of ambition	Focus on the climate target for 2050 rather than 2030; minimize risk of a decreased international competitive position; green technologies should be further developed
	Policy mix	Retaining the SDE+(+) subsidy to overcome the price difference with the EU ETS is necessary, it will bridge the gap between the price of CO_2 reducing alternatives and the EU ETS
	MRV system	Companies develop CO_2 reduction plans, which should be approved by the Netherlands Enterprise Agency (RVO); PBL supervises the emission reductions (as proposed in bonus-malus system)
Incentive level	Tax rate	A penalty as part of the bonus-malus system is not further discussed
	Point of enforcement	Tax on emissions; but tax on the product instead of on emissions could be interesting
Scope	Selection of the target group	If only implemented in the Netherlands, there should be exemptions for companies participating in the EU ETS
	Redistribution of revenues	Revenues should be returned to the industry sector; however due to the complexity of revenue recycling, the bonus-malus system is a better option

6.1.2. Coalition 2: Environmental organizations, 71 economists, PvdA and GroenLinks

Another coalition consists of the environmental organizations, the 71 economists who wrote an opinion article about the adoption of a carbon tax for the industry in the Netherlands, and the political parties PvdA and GroenLinks, which both proposed a specific design of carbon tax for the industry. The reasoning of this coalition can be found in the Theory of Change in Figure 29 below.

The environmental organizations were united in the green coalition during the consultations on the Climate Agreement. This illustrates their overlapping perspectives. The head of the department Climate and Energy of the environmental organization Greenpeace says that on a certain point during the consultations, all parties, including political parties that were initially not pleased such as VVD and CDA, were in favor of the carbon tax, except for the industrial companies. In general, the left political parties have a similar position to the environmental organizations, aiming to equally distribute the burden of the energy transition between the industry and the households.

The environmental organization Milieudefensie appears to have a slightly more outspoken opinion concerning redistribution than the others. Milieudefensie and the economists favor a so-called ‘carbon dividend’, where households receive the revenues of the carbon tax in order to ensure public support for the policy instrument. Therefore, transparent governmental policies are key. Milieudefensie suggests to use climate policy to organize redistribution in society. While the labor union does not have an explicit focus on the parameters of the design of the carbon tax, they also note that a fair distribution of the benefits and burdens should be a main priority.

They see a carbon tax with a tax rate of €10-20/tCO_2e as sufficient to start with, because they want to prevent for carbon leakage. In addition, this tax rate will be enough to finance the energy transition for the industry, assuming that the industry needs 1 billion euros until 2030 for this.

Interesting enough, the 71 economists who wrote the opinion article in the newspaper have a slightly different perspective than the economists working for governmental organizations as DNB and the PBL. For example, the EU ETS is seen as successful by economists working for DNB and the PBL, while professor Dirk Schoenmaker, one of the initiators of the opinion article, sees the EU ETS as too unpredictable, volatile and unmanaged. An economist working for the PBL argues that the letter of these economists is on one hand an important sign to Dutch politics to deal with climate change through fiscal instruments, but on the other hand does it not consider the Dutch current policy mix sufficiently.

This coalition based its arguments mainly on normative assumptions. They stress the *Polluter Pays Principle* and aim to divide the costs of the energy transition equally among households and industry, which can be seen as a normative point of view. This is illustrated by the statement of Milieudefensie that the industry should pay for its own transition. They highlight the issue of climate justice. In addition, Milieudefensie uses causal arguments when referring to other carbon taxes that are perceived as both effective and equitable, such as the carbon taxes in Canada, Ireland and Switzerland. Milieudefensie argues that a carbon tax is a neoliberal principle since it is a fiscal pricing instrument, and while the organization genuinely is against neoliberal principles, this instrument is perceived as efficient. This statement shows that the organization also considers causal relations, since it goes beyond its own normative principles, against neoliberalism, and favors the adoption of a neoliberal carbon tax. Table 29 summarizes the issues that should be achieved in order for the carbon tax to be effective as well as the favored design parameters of the carbon tax.

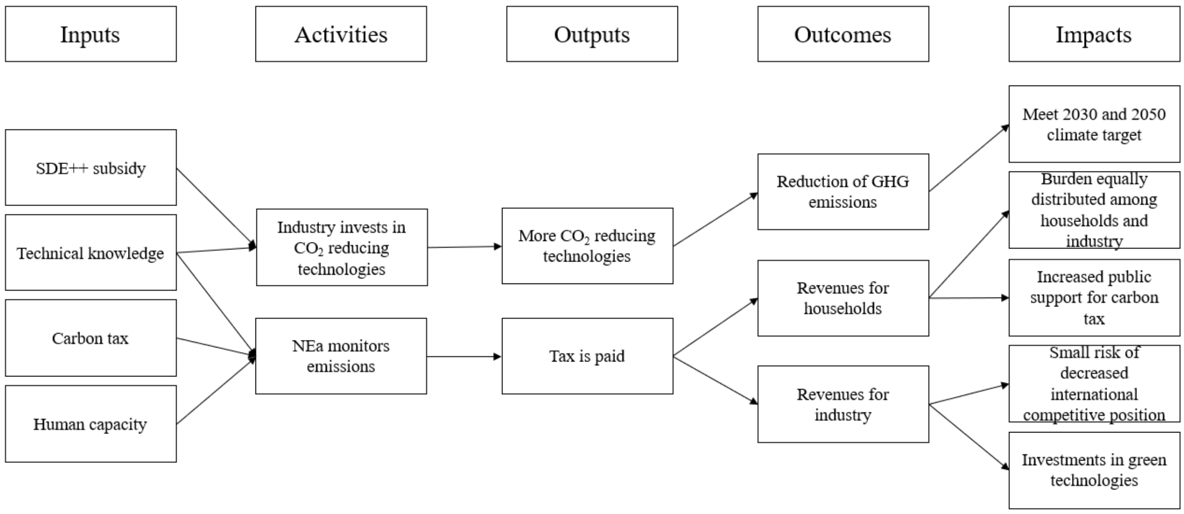

Figure 29. Theory of Change based on assumptions from the coalition 2: Environmental organizations, 71 economists, PvdA and GroenLinks[20]

[20] Currently, the NEa (Dutch Emissions Authority) monitors emissions caused by companies participating in the EU ETS companies. It is assumed that this organization will remain responsible for the monitoring in case of the adoption of a carbon tax for industrial companies that participate in the EU ETS.

Table 29. Preferred target and design parameters of coalition 2: Environmental organizations, 71 economists, PvdA and GroenLinks

Cluster	Design parameter	Coalition 2: Environmental organizations, 71 economists, PvdA and GroenLinks
Target achievement	Level of ambition	Targets of 49% CO_2 reduction in 2030 and 95% in 2050 should be met; more balanced contribution of the industry and households: industry should pay for its own transition; minimize the risk of reduced international competitive position
	Policy mix	EU ETS does not work properly, thus a national carbon tax should be added needed; households are currently paying too much for their energy tax compared to industry
	MRV system	NEa monitors the emissions
Incentive level	Tax rate	Starting with a tax rate of €10/tCO_2e to €20/tCO_2e
	Point of enforcement	According to the *Polluter Pays Principle*, a carbon tax on emissions is more fair than a tax on the products
Scope	Selection of the target group	Economic-wide; eventually the transport and agricultural sectors could be included as well
	Redistribution of revenues	Partly used to invest in green technologies for the industry, partly used as tax cuts for households to gain public support, and partly used to support employees working in fossil industry to get new jobs/retraining; some stress that climate policy should lead to a redistribution in society

6.1.3. Coalition 3: PBL, CE Delft and DNB

The last coalition consists of the governmental organizations PBL and DNB and the consultancy CE Delft, which all studied the effectiveness and efficiency of carbon tax designs for the industry in the Netherlands. They are therefore seen as more neutral than the other two coalitions, which have interests concerning the adoption and design of the carbon tax, both on the achievement of climate targets and profit issues. The economists working for the PBL and DNB argue that their studies are relatively similar.

This coalition sees carbon pricing as an effective and efficient policy instrument leading to the reduction of CO_2 emission. Since it sees the EU ETS as a successful carbon pricing instrument, an extension of the scope of the ETS is favored instead of the adoption of a new carbon pricing instrument. An economist of the PBL argues that adding a minimum price for the EU ETS would be a better option to improve carbon pricing within the EU than introducing a new carbon tax. An economist of DNB suggests to extend the scope of the EU ETS. Also, existing policies, such as the energy tax and the tax on fuels for transport, should be considered in de political and societal debate on carbon taxation. These policy instruments may be adjusted when a new carbon tax is introduced.

The optimal tax rate, given the emission reduction target, depends on the development of new technologies, such as CCS, and the availability of subsidy. The economist from the PBL states that a uniform price for all companies would in theory be the "optimal pricing instrument", but this may not be advisable since the Netherlands has an open economy. He argues that the government should take into account the impact on the international competitiveness, which is particularly relevant for the ETS-sector as additional carbon pricing may lead to carbon leakage. A subsidy on emission reducing investments, accompanying the carbon tax, could reduce the risk on carbon leakage. If there is enough subsidy available, a tax rate of several tens of euros in 2030 would be sufficient. If this is not the case, the tax rate could be increased to €90-165/tCO_2e in 2030. Thus, the tax rate depends highly on the amount of subsidies. A relatively high tax rate does not require a lot of subsidies, while in the case of generously provided subsidies, the tax rate may be relatively low. DNB made calculations with a tax rate of €50/tCO_2e, which would increase over time. This tax rate is not their preferred rate, but they only show that this tax rate would have no harmful consequences for the Dutch economy. CE Delft's director sees a tax rate of €10-20/tCO_2e as feasible starting point. To achieve climate neutrality, the tax rate should be around €150/tCO_2e, depending on the price of technologies. However, he stresses that a carbon tax is a short-term solution, since Dutch society should be transitioning towards a so-called 'Vergoeding Externe Kosten' (VEK), which includes a carbon price instrument on the product rather than on the emissions. This VEK is seen as interesting by other parties, however, this system may be difficult to implement, since it requires a monitoring and reporting system of emissions of all products, including products that are produced abroad. Pricing emissions leads to an incentive at the production upstream, thus where the pollution takes place, which is consistent with the Polluter Pays Principle. Thus, while the views within this coalition generally overlap, there is disagreement on this point.

The economists from the PBL and DNB argue that the revenues could be returned to the industry to prevent for carbon leakage. However, as increased public support for climate policies is also important, they argue that a part of the revenues could also be used for households rather than for the industry solely. However, since this are the interviewees' personal statements rather than perspectives of the organizations they represent, this argumentation is visualized as grey in Figure 30. DNB stresses that the administrative costs of a carbon tax should be low.

The arguments used by this coalition are based on their own scientific research. They used economic models to determine the potential effectiveness of measures on the achievement of the targets. However, the empirical foundation of these models requires particular attention, as at the more detailed level relations in the model cannot always be based on empirically determined causal relationships. For example, the PBL states in its background document on the calculations for the concept Climate Agreement that *"there is no empirical evidence that supports a quantification of the companies' response to the proposed policy measures*." (PBL Netherlands Environmental Assessment Agency, 2019c, p.14). Table 30 summarizes the characteristics of the preferred carbon tax and its main goals according to this coalition.

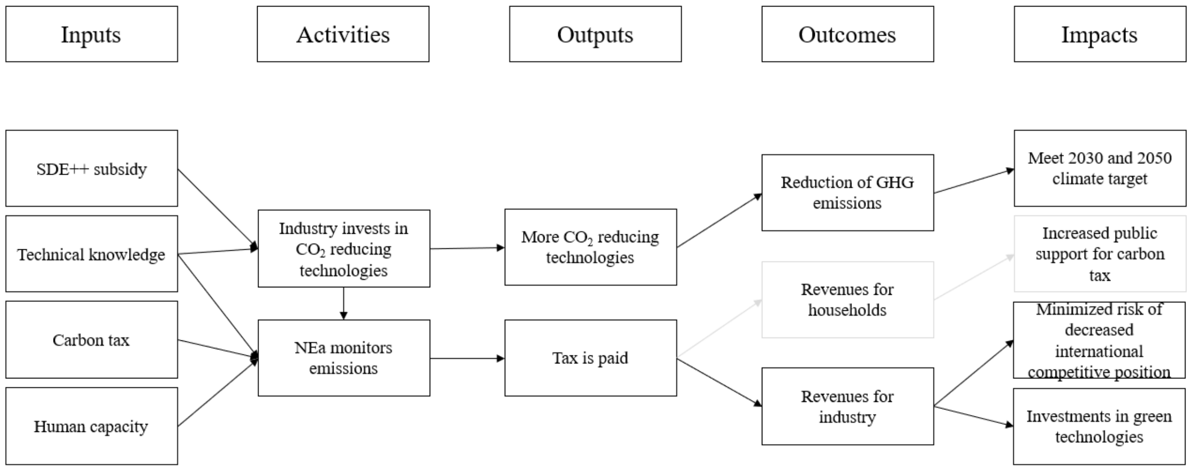

Figure 30. Theory of Change based on assumptions from the coalition 3: PBL, CE Delft and DNB.[21]

Table 30. Preferred target and design parameters of coalition 3: PBL, CE Delft, DNB

Cluster	Design parameter	Coalition 3: PBL, CE Delft and DNB
Target achievement	Level of ambition	The targets of 49% CO_2 reduction in 2030 and 95% in 2050 should be met; take into account the risk of reduced international competitive position
	Policy mix	When considering the introduction of a carbon tax, it is important to consider existing policies (e.g. energy taxes and EU ETS) and other externalities (e.g. air pollution and spillover effects of innovation); currently a degressive taxation system exists; adapting current energy taxation could be a way to implement a new carbon pricing instrument; preferred way may be by optimizing the EU ETS, e.g. by adding a minimum price or extending the scope

[21] Currently, the NEa (Dutch Emissions Authority) monitors emissions caused by companies participating in the EU ETS companies. It is assumed that this organization will remain responsible for the monitoring in case of the adoption of a carbon tax for industrial companies that participate in the EU ETS.

	MRV system	NEa monitors emissions; low administrative costs
Incentive level	Tax rate	Depends on the price of alternative CO_2 reducing options, such as CCS and (green) hydrogen, and the availability of subsidy (could be limited to several tens of euros in 2030 if there is enough subsidy available)
	Point of enforcement	Tax on emissions is the most effective (PBL and DNB); CE Delft sees a carbon tax as short-term solution and prefers the VEK as long-term solution
Scope	Selection of the target group	Economy-wide would be the best option; uniform price for all companies would result in the "optimal price" but may not be feasible due to international trade; should pay attention to ETS-companies
	Redistribution of revenues	Revenues could be returned to the industry to reduce the risk of carbon leakage; a part of the revenues could be used as compensation for low-income groups for support base

6.2. Conclusions based on the discourse analysis

Considering the decision-making of the Dutch Climate Agreement, which includes the discussion about the carbon tax for the industry, is a very interesting issue, since the Dutch government gave lots of room for the stakeholders to propose their preferred design of a carbon tax, such as the bonus-malus system proposed by the industrial sector. However, it can be discussed whether this consultation process will result in the most effective carbon tax design and whether all parties involved are represented in a fair way, including households.

In this societal and political debate, the roles of industrial companies on one side and environmental organization on the other side were clearly present. In addition, consultancies and governmental research institutes as the PBL, CE Delft and DNB were responsible for nuancing the debate.

Interesting, all three coalitions identified base their reasoning on mainly normative arguments. Coalition 3: PBL, CE Delft and DNB used models to investigate the relationship between design parameters and the potential effectiveness of a carbon tax in the Netherlands, but on the more detailed level relations in these model cannot always be based on empirically determined causal relationships. In addition, Coalition 1 based its normative reasoning mainly on retaining the existing situation and therefore aiming to minimize the risk of carbon leakage, while Coalition 2 used normative arguments that are based on an expected situation (Hoogerwerf, 1990), namely an equally distributed burden for households and industry.

It can be said that the societal and political discussion considers not all design parameters that were identified in the literature. In the discussion about the Dutch carbon tax, most attention went to the parameters tax rate and redistribution of the revenues. These design parameters were most often mentioned by the interviewees, in the political debates and in the newspaper articles. Also, the policy mix is stressed during the interviews, but is not often mentioned in political debates or in the newspaper articles.

Coalition 1 and 2 mentioned the importance to meet the climate targets and to change or retain the current policy mix. While Coalition 1 highlighted the importance of continuing the SDE+-subsidy, Coalition 2 argued that households are currently unevenly burdened by a high energy tax rate, compared to the tax rate for industrial users. Also, these coalitions have not elaborated upon the MRV system and the point of enforcement parameters, as presented in Table 31. According to the interviewees, this is due to the fact that the Dutch EU ETS companies already report their emissions to the Dutch emission authority (NEa) and will probably also be part of the target group of the Dutch carbon tax.

The tax rate was more often mentioned by Coalition 2 than by Coalition 1. The industry favored a bonus-malus system and has not proposed a certain tax rate. Coalition 2 did mention a preferred tax rate and supported their statement with though-out reasoning. The discussion about the selection of the target group was mainly about potential exemptions, and not about including other sectors besides the industry. The redistribution of revenues was often mentioned by all coalitions, while the perspectives on this vary to a great extent.

Coalition 3 had a completely different role in the debate on carbon taxation than the other coalitions, namely providing information on the most effective design of a carbon tax, and took therefore no political perspective. Due to this, the design parameter level of ambition was not very often mentioned by the third coalition, as the research institutes have no own perspective on this. This coalition stressed the urgency to consider the current policy mix.

Also, Coalition 2 and 3 both referred to some classical critics regarding the carbon tax, namely the regressive nature of the carbon tax and the perspective on the carbon tax as instrument promoting inequalities (Rabe, 2018). They stressed that the regressive nature of the carbon tax should be compensated with other policies, supporting low-income households.

Interesting, the carbon tax design proposed by the Dutch government after the consultations with the stakeholders is a different variant than mentioned in the stakeholder consultations. Section 7.2. will further elaborate upon this.

Table 31. Importance of parameters according to the coalitions, based on the discourse analysis

Design parameters	**Coalition 1: Industry**	**Coalition 2: Environmental organizations, 71 economists, PvdA and GroenLinks**	**Coalition 3: PBL, CE Delft and DNB**
Level of ambition	[orange]	[green]	[orange]
Policy mix	[green]	[green]	[green]
MRV system	[red]	[red]	[red]
Tax rate	[orange]	[green]	[green]
Point of enforcement	[red]	[red]	[orange]
Selection of target group	[orange]	[orange]	[orange]
Redistribution of revenues	[green]	[green]	[green]

[green] Important parameter
[orange] Medium important parameter
[red] Less important parameter

7. Results: Comparative analysis

7.1. Comparison of international evidence and Dutch debate

In the discourse analysis, the stakeholders did not refer to the carbon taxes implemented abroad frequently. In the debates in the Dutch parliament, the carbon tax of Sweden was sometimes mentioned as an example of a well-functioning carbon tax. However, it should be noted that the successful tax of Sweden is not comparable with the carbon tax proposal of the Dutch government, since the Swedish carbon tax includes several exemptions for industrial companies, especially for EU ETS companies, while those industrial companies will be the target group of the Dutch carbon tax.

In addition, some interviewees mention the case of France as example that a rapidly increasing tax rate could be harmful for public support. This statement is supported by the study of Carattini, Carvalho and Fankhauser (2018), that identifies too high perceived costs as a reason for aversion to carbon taxes. Therefore, some parties argue that revenues should be (partly) used to support low-income household groups. The case study Ireland shows how involving stakeholders in decision making could increase the public support of a carbon pricing instrument. For the Netherlands this is interesting since a lot of stakeholders were involved during the consultations for the potential carbon tax. However, as the discourse analysis shows, mainly industrial companies, environmental organizations and research institutes were present. Most interviewees are very critical on this stakeholder approach of the Dutch government, since they argue that households were not represented in the consultations. However, it can be assumed that political parties would represent the citizens, but still some signs exist that the public involvement in the consultations could have been improved.

Considering the design parameters, Table 32 shows that the tax rate, which appears to be important for the effectiveness of a carbon tax system, is also mentioned by the coalitions as important feature. However, there is some discrepancy between the importance of other parameters, as shown by the case studies, and the perspectives of the stakeholders classified in coalitions. The meta-analysis of the case studies illustrates that it is important which sectors are covered by the carbon tax. For example, countries that levy a carbon tax on the residential and commercial sector achieve more reduction of GHG than when they levy a carbon tax on the transport sector. Interesting, all coalitions see this parameter as medium important, since they expressed their perspectives on the provision of exemptions for some industrial companies, such as companies participating in the EU ETS. However, they have not elaborated upon the inclusion of other sectors besides the industry sector in the carbon tax. Furthermore, it seems that the coalitions focus on the redistribution of revenues, while international evidence shows that this design parameter is of minor importance. Both countries with effective and countries with ineffective carbon taxes transferred the revenues directly to the general government budget. Nevertheless, the most effective carbon tax case studies stress that they use the revenues (indirectly) for supporting low-income households. In contrast, some stakeholders in the debate in the Netherlands focused on returning the revenues to the industry, since this would be the targeted group. However, returning revenues to the industry is not found to be an important issue for the case studies, but it should be noted that the industry is not the main target group of the carbon taxes abroad.

The comparison of the importance of the policy mix and MRV system according to the case studies and coalitions will not be further elaborated, since there was no clear conclusion about their importance on the effectiveness due to a lack of case studies with different features.

Table 32. Comparison of importance of design parameters according to case studies and discourse analysis

Design parameters	Importance of design parameter according to case studies (see Chapter 5.4.)	Importance of design parameter according to Coalition 1 (see Chapter 6.2)	Importance of design parameter according to Coalition 2 (see Chapter 6.2)	Importance of design parameter according to Coalition 3 (see Chapter 6.2)
Level of ambition				
Policy mix				
MRV system				
Tax rate				
Point of enforcement				
Selection of target group				
Redistribution of revenues				

Important parameter

Medium important parameter

Less important parameter

Not clear due to lack of data or opposite comparative carbon tax design

Thus, it can be noted that in the Dutch societal and political discussion the tax rate and the redistribution of revenues were the most mentioned parameters. International evidence shows that the tax rate can be seen as the crucial factor determining the effectiveness of the carbon tax, which will be no surprise. Nevertheless, also the selection of the target group, especially the sector(s) that are taxed, and the level of ambition are important for an effective carbon tax.

7.2. Comparison with carbon tax design from the Dutch government

As explained in Chapter 2, the current Dutch carbon tax design concerns a tax levied on the company's emissions above a certain threshold. The tax rate starts at €30/tCO_2e in 2021 and increases to €125-150/tCO_2e in 2030, including the EU ETS price (SER, 2019). The MRV system will be integrated in the already existing national enforcement strategy. However, since the carbon tax design is not totally elaborated yet, it is difficult to compare this with the preferred tax designs of the stakeholders.

It can be said that a carbon tax on emissions above a certain threshold, the so-called "avoidable emissions", is unique. Several interviewees mentioned that officers of the Dutch Ministry of Economic Affairs and Climate Policy have considered the effectiveness of carbon taxes abroad while developing this proposal. However, this proposal is different than the carbon taxes implemented abroad, since industrial emissions as well as emissions from waste incineration plants are the target of the Dutch carbon tax (SER, 2019), while the industrial sector is often exempted in other (European) countries. The interviewees also said that other European countries keep up with the developments in the Netherlands and see the Netherlands as a frontrunner that puts a price tag on industrial emissions solely. This is interesting, since the Netherlands has relatively high emissions and even increased its absolute CO_2 emissions during the period 1990-2017, as shown in Figure 2. Thus, the Netherlands lags behind the rest of Europe on the achievement of climate targets.

Furthermore, it seems odd that while the Dutch government took a considerable amount of time for stakeholder consultations, the final idea consists of a carbon tax design that is not based on the proposed ideas of the stakeholders. Thus, it is not exactly clear where this proposal, and especially the idea of a certain threshold comes from.

8. Conclusion and recommendations

The implementation of the carbon tax for the industry in Netherlands has led to a heated debate. The Dutch government gave several stakeholders the opportunity to get involved in the policy making, which resulted in an interesting case for research. Industrial companies, consultancies, environmental NGOs and other parties have been involved in this process. Since some European countries already have implemented a carbon tax, these case studies of carbon taxes provide useful insights in crucial elements that determine the effectiveness of a carbon tax. Therefore, the following research question is answered:

"*What essential design parameters for an effective carbon tax can be derived from scientific literature and existing ex-post evaluations of carbon taxes and to what extent are these design parameters considered in the development of a Dutch carbon tax?"*

The case studies show that the level of ambition, the tax rate and the selection of the target group were the most influential design parameters for determining the effectiveness of the carbon taxes implemented in the case studies. Also, the redistribution of revenues appears to be an important design parameter of a carbon tax, but not the most crucial factor for its effectiveness. The importance of the MRV system as well as the policy mix could not be determined, due to a lack of case studies without a properly functioning MRV system and well-aligned policy mix to compare with. International evidence shows that an effective carbon tax has a high tax rate, which does increase more than approximately 3/tCO_2e per year in order to ensure public acceptance. Also, the selection of the target group is important, since the carbon taxes abroad are mainly effective for the energy industry, manufacturing industry, residential and commercial sector and agriculture. Implementing a carbon tax for the transport sector has not led to a reduction of CO_2 emissions in all case studies, except for Sweden. This could be explained by the limited carbon-free alternatives for transport up to now, compared to CCS and hydrogen as CO_2 reduction options for the industry and residential sector.

Several insights from this research lead to recommendations for the development of a carbon tax in the Netherlands.

First, the meta-analysis of the carbon taxes shows that most of the current European carbon taxes are not sufficient to meet the Paris Agreement target. Therefore, tax rates need to be adjusted on a more regular basis in order to compensate for inflation and technological innovations. Nowadays, the scale and frequency of the changes of tax rates are not sufficient to stimulate further emission reductions. Therefore, several stakeholders have proposed to further invest in harmonizing the European carbon taxes, which minimizes the risk of industrial companies leaving to other (European) countries and thus the risk of carbon leakage. The Dutch government is already in consultation with other European countries to discuss a potential multinational carbon tax. However, the risk of carbon leakage for industrial companies, which is the main barrier for implementing carbon taxes on the national scale, would be removed by a European carbon tax. The risk of carbon leakage is not as heavily debated in other European countries as in the Netherlands, since other countries have exemptions for industrial companies to ensure the international competitive position. Thus, the first recommendation following from this research is to intensify the multilateral negotiations between European member states. Here lies an opportunity for the Minister of Economic Affairs and Climate Policy as well as his colleague at the Ministry of Finance and the Dutch representatives in the European Union. Even while the interviewees have very different perspectives on the design of a carbon tax, European cooperation is seen as valuable by all of them. This shows that there is extensive public support in the Netherlands for a European carbon tax, which could increase the tax's effectiveness.

Second, the societal and political debate on carbon taxation in the Netherlands focuses on some design parameters, such as the tax rate, that are important for determining the effectiveness of a carbon tax. However, there are some parameters not often mentioned, which appear to be essential as well, such as the level of ambition and the selection of the target group. The Dutch debate has focused on a few design parameters in particular, such as the tax rate or the redistribution of revenues, and some particular groups in society, such as the steel industry. In addition, the stakeholders influencing the decision-making based their arguments on mainly normative reasoning rather than on empirical arguments. Even governmental bureaus studying the expected effectiveness of a potential carbon tax, such as the PBL, which are value-free and nuanced, use economic models of which the empirical foundation at the more detailed level cannot always be ensured.

Since it is not clear to what extent the Dutch government considered the carbon taxes implemented abroad, more empirical research on those carbon taxes could provide insights in the crucial factors that determine the effectiveness of a carbon tax. Some interviewees were in favor of particular carbon taxes in Canadian provinces. The Ministry of Economic Affairs and Climate Policy as well as the Ministry of Finance could take the lead in conducting research on the effectiveness of carbon taxes beyond the scope of this study, including countries that do not participate in the EU ETS.

Also in light of this debate, the lack of attention for a broader meta-analysis of multiple target groups and all design parameters is an omission. A priori choices, such as the industry as sole target group, have prevailed during the societal and political discussion, while there was little room for empirical arguments, such as the inclusion of other sectors as well. This point is highlighted by the meta-analysis of carbon taxes in other European countries, which shows that a carbon tax is mainly effective for the energy industry, manufacturing industry, residential and commercial sector and agriculture. This leads to another recommendation for the Dutch government. It would be useful to carry out a full analysis of the tax burden of all target groups in Dutch society, such as households and several different companies, which could be done by the Ministry of Finance. After this analysis, it is more clear which groups have already internalized their externalities and which groups emit more than they pay. The creation of rational policy on tax burden for all target groups in the Netherlands should be key.

Lastly, transparency and clear communication about the establishment of the carbon tax itself and the use of its revenues is vital. The case studies, especially the cases of France and Ireland, show that public support of a carbon pricing instrument is essential. It is crucial for sufficient public acceptability that the use of revenues is well-explained. Therefore, publishing annual reports at publicly available websites can be an instrument to inform society on the functioning of the carbon tax.

All of these recommendations could be used for other countries that are planning to implement a carbon tax on the national scale as well. For the Netherlands, other environmental issues appear to unveil, even while this carbon tax dossier is not completely closed. These recommendations can also be beneficial for those new environmental policy dilemmas, such as the current nitrogen problem.

9. Discussion

This study used a research method that is mainly based on governance theories rather than ecological economics, since it considered the effectiveness of already implemented carbon taxes abroad through ex-post research (OECD, 2016). This is another method than used by governmental agencies that support the development of the carbon tax in the Netherlands, since these ex-ante methods are mainly based on economic assumptions. Therefore, this study can be seen as supplementary to studies based on ex-ante methods.

Several limitations have to be considered while looking into the results of this research. First, due to a lack of evaluations of some case studies, it was difficult to conclude which design parameters resulted to which degree of effectiveness. Also, most of the carbon taxes analyzed were often adjusted. An example of this is the use of revenues of the carbon tax in France. These revenues were redistributed differently after the social protests. Such adjustments obstruct a proper evaluation since most evaluations were based on the carbon tax before the adjustments. Another critical remark on the identification of the design parameters of the carbon tax is that it can be difficult to see these parameters as detached components, while they together form a coherent policy instrument. The effectiveness of a carbon tax is not only determined by changing one design parameter, because the parameters are related and therefore influence each other. For example, increasing the tax rate could be beneficial for the effectiveness of the carbon tax, but if the scope of the carbon tax is decreased at the same time, the effectiveness may not improve.

Also, while providing recommendations for the Netherlands based on the case studies abroad, the different contextual factors should be taken into account. The Netherlands has a relatively large heavy industry compared to most case studies analyzed, except for the United Kingdom and France. The United Kingdom and France have a clear CO_2 emission reduction during the period 1990-2017, while the Dutch emissions increased during that period. In addition, some countries, such as France and Sweden, have a lot of hydropower or use nuclear energy as significant source of energy production. These forms of energy result in relatively low GHG emissions. This is different for the Netherlands, which has the opportunity to exploit large amounts of natural gas from its territory. In order to take some of these contextual factors into account, Chapter 2 was added, describing background information about the Netherlands, and Appendix F, consisting of an overview of the energy production and consumption of the case studies.

Another limitation is the relatively small sample of interviewees. While aiming to present a nuanced picture by interviewing stakeholders with (expected) different perspectives, such as the viewpoints of industrial companies and environmental NGOs, it is not possible to consider all perspectives involved due to time constraints. Also, it should be noted that some industrial companies that are categorized in NVivo as a particular industry will have multiple labels in practice, since several former fossil fuel companies shift their focus towards more renewable energy sources or green technologies. For example, Shell was labeled as a petrochemical company solely, while it currently also invests in hydrogen.

According to Sumner, Bird and Dobos (2011), calculating the actual reduced GHG emissions as a result of a policy measure, as the implementation of a carbon tax, is challenging since several other contextual factors, including economic growth levels and other (energy- and climate-related) policies, influence the emissions as well. It is difficult to disentangle the effect of a carbon tax from the impact of other policies. This should be considered while using the analyses about the implications of the introduction of carbon taxes in the Netherlands and other cases. Furthermore, the emission of GHGs cannot be allocated to a specific region or country, which is another factor that makes it difficult to examine the effects of a carbon tax alone (Sumner, Bird & Dobos, 2011). For the same reasons, the emissions caused by land use, land use change, and forestry (LULUCF) are excluded in this research (Haites et al., 2018). This limitation shows that more research on the interaction between multiple policy instruments is necessary to gain more knowledge about the effectiveness of the particular policy instrument and to improve the design of the instrument.

Furthermore, more insights should be gained about adjusting the tax rate over time in relation to increased income and technological innovation. Haites et al. (2018) show that the adjustment of a carbon tax rate to other climate policies implemented is an important way to sustain or increase the emission reduction, but since there is insufficient knowledge about the relationship between these factors, more insight in this could increase the effectiveness of a carbon tax. Thus, the characteristics of a tax rate strategy leading to actual emission reductions ought to be subjected to future research.

Currently, several other countries besides the Netherlands, like Germany, are considering the implementation of a carbon tax. Also, some interviewees explained that some European countries, including the Netherlands, are in consultation about a harmonization of national carbon taxes or the implementation of a European carbon tax. This shows the urgency for future research to continue research on the most effective design, not only on a national scale, but also for a group of countries.

Another subject of future research would be the full and relative tax burden of various groups in society. Some interviewees stressed the difference between the tax burden of households versus industrial companies. For example, environmental organizations argued that households already pay a higher tax rate than the price of the externalities of the product amounts. Large industrial companies often pay a lower tax rate, which means that they do not pay for the externalities. Therefore, these interviewees argued that the implementation of a carbon tax for the industry solely would be better than the implementation of a carbon tax for the economy as a whole, i.e. including households. This perspective shows that additional research should be done the other way around: starting by investigating the tax burden for households versus industrial companies and looking at which groups should contribute more to pay the externalities.

As shown in this research, not all hypotheses could be confirmed or invalidated, because the design parameters did not always vary which makes it impossible to compare them in terms of effectiveness. For example, in order to test whether an increase of the carbon tax rate over time is beneficial for the effectiveness of a carbon tax, case studies with an increasing tax rate and case studies with a stable tax rate should be compared with each other. However, since all case studies in this research included the increase of the tax rate, additional case studies without increasing tax rate should be investigated.

Since there appears to be a considerable gap between the carbon tax designs as proposed by the stakeholders and the ultimately design of the carbon tax as recently presented by the government in the Netherlands, future research may focus on this gap. It can inquire which stakeholders and leverages has come to the government’s design.

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Appendix A: List of (opinion) articles from Dutch newspapers

Arranged by date

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* opinion article

Appendix B: List of debates of Dutch parliament

Date	Type of assembly	Topic	Participants
11-10-2018	Technical briefing	PBL and CPB – Analyses of 'Proposal Outlines of Climate Agreement'	• SP (S.M. Beckerman) • GroenLinks (T.M.T. van der Lee) • PVV (A. Kops) • D66 (J.M. van Eijs) • CDA (A.H. Mulder) • PvdD (L. van Raan) • VVD (D. Yesilgöz-Zegerius) • FvD (T.H.P. Baudet) • PBL Netherlands Environmental Assessment Agency (Pieter Boot and Michiel Hekkenberg) • CPB (Daniel van Vuuren and Patrick Koot) • CE Delft (Frans Rooijers)
31-10-2018	Plenary debate	Government Appreciation on Outline of Climate Agreement	• GroenLinks (J.F. Klaver) • D66 (R.A.A. Jetten) • SP (S.M. Beckerman) • PVV (A. Kops) • CDA (A.H. Mulder) • PvdD (L. van Raan) • SGP (C. Stoffer) • ChristenUnie (R.K. Dik-Faber) • VVD (D. Yesilgöz-Zegerius) • PvdA (W.J. Moorlag) • FvD (T.H.P. Baudet) • Minister of Economic Affairs and Climate Policy (E.D. Wiebes)
05-02-2019	Plenary debate	Climate Agreement	• D66 (R.A.A. Jetten) • GroenLinks (J.F. Klaver) • PVV (G. Wilders) • SP (L.M.C. Marijnissen) • 50PLUS (M.J. van Rooijen) • DENK (T. Kuzu) • PvdD (E. Ouwehand) • VVD (K.H.D.M. Dijkhoff) • ChristenUnie (G.J.M. Segers) • PvdA (L.F. Asscher) • CDA (S. van Haersma Buma) • SGP (C. Stoffer) • FvD (T.H.P. Baudet) • Prime Minister (M. Rutte) • Minister of Economic Affairs and Climate Policy (E.D. Wiebes)
14-03-2019	Plenary debate	Calculations on the Climate Agreement by PBL and CPB	• D66 (R.A.A. Jetten) • GroenLinks (J.F. Klaver) • PVV (G. Wilders) • SP (L.M.C. Marijnissen) • 50PLUS (M.J. van Rooijen) • DENK (T. Kuzu) • PvdD (M.L. Thieme) • VVD (K.H.D.M. Dijkhoff) • ChristenUnie (G.J.M. Segers) • PvdA (L.F. Asscher) • CDA (S. van Haersma Buma)

			• SGP (C.G. van der Staaij) • FvD (T.H.P. Baudet) • Prime Minister (M. Rutte) • Minister of Economic Affairs and Climate Policy (E.D. Wiebes)
27-03-2019	Roundtable discussion	Sector broad aspects of Climate Agreement	• SP (S.M. Beckerman) • D66 (M.F. Sienot) • GroenLinks (T.M.T. van der Lee) • CDA (A.H. Mulder) • PvdD (F.P. Wassenberg) • SGP (S. Geleijnse) • VVD (D. Yesilgöz-Zegerius) • PvdA (W.J. Moorlag) • Social and Economic Council (Ed Nijpels) • De Nederlandse Bank (Maarten Gelderman) • InvestNL (Wouter Bos) • Sustainable Finance Lab (Rens van Tilburg) • UvA/TNO (Annelies Huygen) • TU Delft (Fokko Mulder) • FME-CWM (Robert van Beek) • FNV (Kitty Jong) • CNV (Willem Jelle Berg) • Topsector Energie (Marsha Wagner) • HIER (Gijs Termeer) • Woonbond (Paulus Jansen) • Universiteit Utrecht (Sanne Akerboom)
27-03-2019	Technical briefing	Calculations Climate Agreement	• PvdA (W.J. Moorlag) • D66 (M.F. Sienot) • SGP (C. Stoffer) • CDA (A.H. Mulder) • GroenLinks (T.M.T. van der Lee) • 50PLUS (S. Geleijnse) • VVD (D. Yesilgöz-Zegerius and A. de Vries) • PvdD (L. van Raan) • PBL Netherlands Environmental Assessment Agency (Pieter Boot and Michiel Hekkenberg) • CPB Netherlands Bureau for Economic Policy Analysis (Patrick Koot, Ton Manders and Sander Hoogendoorn) • Utrecht University (Gert Jan Kramer)
11-04-2019	Roundtable discussion	Climate table 'Industry'	• SP (S.M. Beckerman) • SGP (C. Stoffer) • D66 (M.F. Sienot) • PvdD (L. van Raan) • VVD (D. Yesilgöz-Zegerius) • CDA (A.H. Mulder) • GroenLinks (T.M.T. van der Lee) • PvdA (W.J. Moorlag) • DIFFER/TU Eindhoven (Richard van de Sanden) • TNO (Peter Wolfs) • Utrecht University (Ernst Worrell) • Erasmus Universiteit (Dirk Schoenmaker) • VNPI (Erik Klooster) • VNCI (Colete Alma-Zeestraten) • CE Delft (Frans Rooijers) • Greenpeace (Joris Thijssen)

			• Milieudefensie (Donald Pols) • Yara Sluiskil BV (Gijsbrecht Gunter) • Natuur & Milieu (Marjolein Demmers) • Tata Steel (Ingrid de Caluwé)
25-06-2019	Technical briefing	SER, PBL, CPB, PwC – reports on climate policy for the industry	• PvdA (W.J. Moorlag) • PvdD (L. van Raan • CDA (A.H. Mulder) • GroenLinks (T.M.T. van der Lee) • 50PLUS (G.J.P. van Otterloo) • D66 (M.F. Sienot) SER (Mariette Hamer) • PwC (Dorine Helmer and Gülbahar Tezel) • CPB (Sander Hogendoorn and Ton Manders • PBL (Pieter Boot and Robert Koelemeijer)
03-07-2019	Plenary debate	Package of climate measures	• VVD (D. Yesilgöz-Zegerius) • SP (S.M. Beckerman) • PvdA (L.F. Asscher) • GroenLinks (J.F. Klaver) • PVV (A. Kops) • D66 (R.A.A. Jetten) • ChristenUnie (G.J.M. Segers) • CDA (P.E. Heerma) • PvdD (L. van Raan) • SGP (C. Stoffer) • 50PLUS (G.J.P. van Otterloo) • DENK (T. Kuzu) • FvD (T.H.P. Baudet) • Prime Minister (M. Rutte) • Minister of Economic Affairs and Climate Policy (E.D. Wiebes) • Minister of the Interior and Kingdom Relations (K.H. Ollongren) • Minister of Agriculture, Nature and Food Quality (C. Schouten) • State Secretary of Infrastructure and Water Management (S. van Veldhoven)

Appendix C: Topic list

Introduction: purpose of the research and ethical issues (recording of the interview, anonymity, informed consent form)

Background information:

- Description of profession and organization
- Opinion about climate change and CO_2 emissions
- Which actors are perceived as responsible for causing climate change or emitting CO_2
- Opinion about Polluter Pays Principle and the current Dutch climate policy (without carbon tax)

Design of carbon tax in the Netherlands:

- Opinion about carbon tax in general
- Opinion about the current idea of carbon tax, as in the Climate Agreement
- What would the ideal carbon tax for the Netherlands look like, concerning
  - The tax rate;
  - The redistribution of revenues;
  - The selection of the target group;
  - The point of enforcement;
  - The policy mix, including EU ETS, SDE+(+), ODE;
  - The MRV system.
- Which of abovementioned design parameters are most important?
- Potential collaboration with other organizations/companies during the consultations of the carbon tax; other organizations with a similar perspective

Carbon taxes implemented abroad:

- Degree of knowledge about other European carbon taxes
- Good examples of foreign carbon taxes for the case of the Netherlands
- To what extent are other carbon taxes considered during the decision making in the Netherlands?

Closing

Appendix D: List of interviewees

Name	Job	Organization	At location or telephone	Date
Martijn Broekhof	Head of Unit Climate and Energy	VNCI	Telephone	16-10-2019
Frans Rooijers	Director	CE Delft	At location	16-10-2019
Anonymous	Public & Government Affairs Advisor	Tata Steel	At location	17-10-2019
Guido Schotten	Economist	De Nederlandsche Bank	At location	23-10-2019
Corjan Brink	Researcher Environmental Economics	PBL Netherlands Environmental Assessment Agency	At location	24-10-2019
Faiza Oulahsen	Department Head Climate and Energy	Greenpeace	At location	25-10-2019
Dirk Schoenmaker	Professor of Banking and Finance	Erasmus University Rotterdam	At location	29-10-2019
Gert Jan Kramer	Professor of Sustainable Energy Supply Systems	Utrecht University	At location	29-10-2019
Willem Wiskerke	Senior Officer Climate Justice	Milieudefensie	Telephone	04-11-2019
Anonymous	Public Affairs Advisor	Multinational chemical company	Telephone	04-11-2019

Appendix E: Lists of cases and codes used in NVivo

Cases

Name	Files	References
Business	1	25
Chemical industry	2	25
Engineering	1	2
Installation and building companies	1	1
Metal industry	2	37
Petrochemical industry	2	26
Port of Rotterdam	1	3
SME	1	3
Utility	1	5
VNO-NCW	1	28
Consultancy	0	0
CE Delft	4	23
FTI-CL	1	1
Navigant	1	1
PwC	3	28
Dutch government	1	20
Minister of Economic Affairs and Climate Policy	5	40
Prime Minister	3	23
Environmental organizations	1	27
De Jonge Klimaatbeweging	1	1
Greenpeace	2	14
Milieudefensie	2	11
Natuur & Milieu	2	8
Natuur- en Milieufederaties	1	3
Other parties	0	0
Algemene Rekenkamer	1	2
CPB Netherlands Bureau for Economic Policy Analysis	4	17
De Nederlandsche Bank	3	31
Labor unions	2	16
PBL Netherlands Environmental Assessment Agency	4	36
Social and Economic Council (SER)	3	19
Statistics Netherlands (CBS)	1	2
Political parties	0	0
50PLUS	4	10
CDA	4	28
ChristenUnie	5	19
D66	5	36
DENK	3	3
FvD	3	7
GroenLinks	6	101
PvdA	6	52
PvdD	4	10
PVV	3	6
SGP	4	4
SP	5	32
VVD	6	47
Science	0	0
Economists	2	64
Instituut voor Milieuvraagstukken	1	1
Professor Climate (Policy)	3	10
Professor Climate Economy	1	10

Nodes

Name	Files	References
Proposals from the government	5	16
Proposal carbon tax of PvdA	1	15
Initiative law carbon tax of GroenLinks	2	20
In relation to other EU countries	15	40
Carbon taxes in other countries	13	24
Design of carbon pricing instrument	13	31
Selection of target group	15	45
Redistribution of revenues	19	100
Price level	22	119
Policy mix	22	88
Point of enforcement	9	20
Monitoring, reporting and vertification system	15	29
Contribution of the industry	17	63
Carbon tax	0	0
Potential positive implications	3	15
Stimulates (green) innovations	9	12
Reduces carbon emissions	2	4
Pollutor Pays principle	16	30
Offsets market failure	8	11
No loss of employment or more employment	4	12
Gives security for future investments	2	6
Frontrunner	2	2
Potential negative implications	3	13
Limits (green) investments	2	4
Higher market prices	8	16
Gaming	2	2
Disadvantages profit and competitive position	7	30
Loss of companies	7	24
Risk of carbon leakage	5	26
Disadvantages employment	4	34

Appendix F: Energy resources and consumption of case studies

Case study 1: Denmark

Overview of the country's energy resources and consumption

Denmark has large amounts of resources of gas and oil in the North Sea and is therefore the second-largest producer of oil in the EU. However, since 2005, the export of oil and gas is decreased, due to the transition towards the production of energy from renewables (OECD, 2019b). The Danish industry was in 2016 responsible for 52% of the total domestic CO_2 emissions (EEA, 2018b). Table F2 below shows what industry sectors are responsible for which emissions. In 2017, the Danish GHG emissions, including CO_2 emissions, were 8.26 tCO_2e per capita (EEA, 2019b).

Energy resource	**Total primary energy supply in 2017**[22]
Coal	9%
Natural gas	17%
Oil	36%
Biofuels and waste	30%
Geothermal, solar and wind	8%

Table F1. Total primary energy supply in 2017 (OECD, 2019b).

Industry sector	**Share of the total domestic CO_2 emissions**
Non-metallic minerals	7%
Food and drink	3%
Energy supply	38%
Chemicals	1%
Other	3%
Total	*52%*

Table F2. The Danish industry and its share of the total domestic CO_2 emissions in 2016 (EEA, 2018b).

Case study 2: The United Kingdom

Overview of the country's energy resources and consumption

From the 1980s onwards, the UK has been a large player in the production of oil and natural gas (OECD, 2019b). This is illustrated in Table F3 below, since natural gas and oil together were responsible for more than 70% of the primary energy supply in 2017.

Energy resource	**Total primary energy supply in 2017**[23]
Coal	6%
Natural gas	39%
Oil	35%
Biofuels and waste	7%
Geothermal, solar and wind	3%
Nuclear	10%

Table F3. Total primary energy supply in 2017 (OECD, 2019b).

UK's industry was in 2016 responsible for 45% of the total domestic CO_2 emissions (EEA, 2018c) and is the second largest emitter of GHG in the EU (Reuters, 2019). Table F4 presents the shares of the total domestic CO2 emissions from the industry in more detail. France has relatively low per capita GHG emissions, compared to other European countries, namely 6.95 tCO_2e per capita in 2017 (EEA, 2019b).

Industry sector	**Share of the total domestic CO2 emissions**
Pulp, paper and wood	1%
Non-metallic minerals	2%

[22] Excluding net electricity import

[23] Excluding net electricity import

Iron and steel	3%
Food and drink	1%
Energy supply	29%
Chemicals	2%
Other	7%
Total	*45%*

Table F4. UK's industry and its share of the total domestic CO2 emissions in 2016 (EEA, 2018c).

Case study 3: Sweden

Overview of the country's energy resources and consumption

Sweden has a relatively high share of renewable and nuclear energy, as is visible in Table X below. The primary energy supply of Sweden consisted in 2017 of 21% oil, 4% coal and 1% natural gas, thus in sum approximately 26% of the total national energy supply is based on fossil fuels. In addition, low carbon energy sources as nuclear, hydro, biofuels and waste, and geothermal, solar and wind together contribute to 73% of the primary energy supply (OECD, 2019b). Partly as a result of this, Sweden has the lowest emission intensity and the second lowest GHG emissions per capita in the European Union (Ecofys, 2018).

Energy resource	**Total primary energy supply in 2017**[24]
Coal	4%
Natural gas	1%
Oil	21%
Biofuels and waste	25%
Geothermal, solar and wind	3%
Nuclear	34%
Hydro	11%

Table F5. Total primary energy supply in 2017 (OECD, 2019b).

The study of Shmelev and Speck (2018) shows that the oil price as well as the innovations regarding hydro energy and nuclear energy in Sweden are to a great extent responsible for the patterns of energy use, resulting in a reduction of CO_2 emissions. The energy intensity (energy consumed/unit of GDP) is relatively high in Sweden, due to the cold climate, the scattered population and a relative large energy-intensive industry sector. The Swedish per capita GHG emissions were 5.24 tCO_2e in 2017, which is the lowest of all case studies considered in this research (EEA, 2019b). Regarding the energy consumption and related emissions, the Swedish industry was in 2016 responsible for approximately 54% of the total domestic CO_2 emissions and 34,7% of the energy consumed (EEA, 2018d). Table F6 below shows the proportion of emissions from each industry sector. During the period 1991-2014, the total emissions caused by the industry (except iron and steel sector) were reduced with 24%, while the emissions as a result of steel and iron industry increased by about 10%. However, since 2001, there is pattern of absolute reduction of emissions, which is consistent with stronger reductions in less-emission intensive industries, which have a higher carbon price level compared to the heavy industry (Ecofys, 2018).

Industry sector	**Share of the total domestic CO_2 emissions**
Pulp, paper and wood	2%
Non-metallic minerals	8%
Non-ferrous metal	1%
Iron and steel	9%
Food and drink	1%
Energy supply	23%
Chemicals	3%
Other	7%
Total	*Approximately 54%*

[24] Excluding net electricity import

Table F6. Swedish industry and its share of the total domestic CO2 emissions in 2016 (EEA, 2018d).

Case study 4: Norway

Overview of the country's energy resources and consumption

Norway is the third-biggest oil and natural gas exporter globally and the state owns one-third of the reserves of oil and gas (OECD, 2019b). This is visible in Table F7 below, where 31% of the Norwegian primary energy supply in 2017 came from oil and 14% from natural gas. Nevertheless, hydro energy is responsible for the biggest share of the energy supply, namely 43%. However, the proportion of hydro power depends on the precipitation and water inflows in the country's water reservoirs.

Energy resource	**Total primary energy supply in 2017[25]**
Coal	3%
Natural gas	14%
Oil	31%
Biofuels and waste	7%
Geothermal, solar and wind	1%
Hydro	43%

Table F7. Total primary energy supply in 2017 (OECD, 2019b).

Norway's industry was in 2016 responsible for approximately 64% of the total domestic CO_2 emissions and 29.4% of the energy consumed (EEA, 2018e). Norway emitted 9.99 tCO_2e per capita GHG emissions in 2017 (EEA, 2019b). Table F8 below shows the proportion of emissions from each industry sector. Due to the oil and natural gas export, Norway has relatively high CO_2 emissions from petroleum industry and natural gas extraction (Lin & Li, 2011).

Industry sector	**Share of the total domestic CO2 emissions**
Non-metallic minerals	4%
Non-ferrous metal	5%
Iron and steel	6%
Food and drink	1%
Energy supply	40%
Chemicals	5%
Other	3%
Total	*Approximately 64%*

Table F8. Norway's industry and its share of the total domestic CO_2 emissions in 2016 (EEA, 2018e).

Case study 5: Finland

Overview of the country's energy resources and consumption

Due to its cold climate and large heavy industry, Finland has a relatively high energy intensity as well as energy consumption per capita. Most of its primary energy supply in 2017 consisted of biofuels and waste and oil, but around 71% of its energy needs are met through imports (OECD, 2019b).

Energy resource	**Total primary energy supply in 2017[26]**
Coal	13%
Natural gas	6%
Oil	28%
Biofuels and waste	30%
Geothermal, solar and wind	1%
Nuclear	18%
Hydro	4%

Table F9 Total primary energy supply in 2017 (OECD, 2019b).

[25] Excluding net electricity import

[26] Excluding net electricity import

Finland's industry was in 2016 responsible for approximately 64% of the total domestic CO_2 emissions and 42.2% of the energy consumed (EEA, 2018f). Table F10 below shows the proportion of emissions from each industry sector. The country emitted 10.05 tCO_2e per capita GHG emissions, including CO_2 emissions, in 2017 (EEA, 2019b).

Industry sector	**Share of the total domestic CO2 emissions**
Pulp, paper and wood	6%
Non-metallic minerals	4%
Iron and steel	6%
Energy supply	40%
Chemicals	4%
Other	4%
Total	*Approximately 64%*

Table F10. The Finnish industry and its share of the total domestic CO2 emissions in 2016 (EEA, 2018f).

Case study 6: France

Overview of the country's energy resources and consumption

France has few fossil-energy resources compared to other European countries. Therefore, the government adopted policies that support the nuclear energy industry, in order to reduce its dependence on imports. Besides the importance of nuclear energy, oil was responsible for another big share of the primary energy supply in 2017 (see Table F11), but has dropped from 37% in 1990 (OECD, 2019b). Most of France's electricity is generated by nuclear energy, another part is hydroelectric, which makes its electricity generation primarily carbon free (Sumner, Bird & Dobos, 2011). This explains why the share of the total domestic CO_2 emissions caused by energy supply is relatively small compared to other countries. The country's GHG emissions was 6.95 tCO_2e per capita in 2017 (EEA, 2019b).

Energy resource	**Total primary energy supply in 2017**[27]
Coal	4%
Natural gas	15%
Oil	29%
Biofuels and waste	7%
Geothermal, solar and wind	1%
Nuclear	42%
Hydro	2%

Table F11. Total primary energy supply in 2017 (OECD, 2019b).

The French industry was in 2016 responsible for approximately 34% of the domestic CO_2 emissions and 18.9% of the energy consumed (EEA, 2018g). Table F12 shows the emission share from each industry sector.

Industry sector	**Share of the total domestic CO2 emissions**
Pulp, paper and wood	1%
Non-metallic minerals	5%
Iron and steel	4%
Food and drink	2%
Energy supply	14%
Chemicals	5%
Other	3%
Total	*Approximately 34%*

Table F12. The French industry and its share of the total domestic CO2 emissions in 2016 (EEA, 2018g).

[27] Excluding net electricity import

Case study 7: Ireland

Overview of the country's energy resources and consumption

Ireland has few fossil fuels resources on its territory and imports most of its fuels (OECD, 2019b).

Energy resource	**Total primary energy supply in 2017**
Coal	13%
Natural gas	31%
Oil	45%
Biofuels and waste	5%
Geothermal, solar and wind	5%

Table F13. Total primary energy supply in 2017 (OECD, 2019b).

Ireland's industry was in 2016 responsible for approximately 48% of the total domestic CO_2 emissions and 21% of the energy consumed (EEA, 2018h). Table F14 shows the proportion of emissions from each industry sector. Ireland emitted 12.64 tCO_2e GHG per capita in 2017 (EEA, 2019b).

Industry sector	**Share of the total domestic CO2 emissions**
Non-metallic minerals	8%
Non-ferrous metal	4%
Food and drink	2%
Energy supply	31%
Chemicals	1%
Other	2%
Total	*48%*

Table F14. Ireland's industry and its share of the total domestic CO2 emissions in 2016 (EEA, 2018h).

Case study 8: Iceland

Overview of the country's energy resources and consumption

Compared to other European countries, Iceland obtained 89% of its primary energy supply (see Table F15) from renewables.

Energy resource	**Total primary energy supply in 2017**
Coal	2%
Oil	10%
Geothermal, solar and wind	67%
Hydro	21%

Table F15. Total primary energy supply in 2017 (OECD, 2019b).

Iceland has the highest per capita electricity consumption in the world, and more than 85% of this electricity is consumed by the industry (OECD, 2019b). However, since most of the electricity is produced from renewables, the emissions are relatively low. Iceland's industry was in 2016 responsible for approximately 59% of the total domestic CO_2 emissions and 50.5% of the energy consumed (EEA, 2018i). Table F16 shows the proportion of emissions from each industry sector. The country has GHG emissions of 13.85 tCO_2e per capita in 2017, which is the highest of all case studies analyzed (EEA, 2019b).

Industry sector	**Share of the total domestic CO2 emissions**
Non-ferrous metal	37%
Iron and steel	12%
Food and drink	1%
Energy supply	4%
Other	5%
Total	*Approximately 59%*

Table F16. Iceland's industry and its share of the total domestic CO_2 emissions in 2016 (EEA, 2018i).