Taxation in support of green transition: an overview and assessment of existing tax practices to reduce greenhouse gas emissions

Final Report

[Written by Ecorys and WIFO]
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Unit D4 — Economic analysis, evaluation and impact assessment

Contact: Ana Xavier

E-mail: TAXUD-UNIT-D4@ec.europa.eu

European Commission
B-1049 Brussels

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Abstract

The European Commission has set ambitious targets to make Europe the first carbon-neutral continent by 2050 and intends to reduce GHG emissions by 55% by 2030 compared to 1990 levels. Environmental tax measures help incentivise behavioural change and thus contribute to achieving these policy goals. The objective of this study is to define a set of concrete policy recommendations for national tax systems to enhance efforts to reduce GHG emissions in the EU effectively. The study conducts a literature review on tax measures targeting GHG emissions and builds an inventory of measures – consisting of taxes and tax incentives - across the EU-27, the UK, and five other countries. Subsequently, the benchmarking methodology assessing environmental effectiveness and political viability of tax measures is developed with an aim of identifying good practice examples. The results of the study illustrate that taxes and beneficial tax incentives are increasingly used tools to support green transition. However, there is still room to improve their design to render them more effective in reducing GHG emissions. Moreover, striking a successful balance between the effectiveness of tax measures and their wider political implications remains a challenge.

Résumé

La Commission européenne s'est fixé des objectifs ambitieux pour faire de l'Europe le premier continent neutre en carbone d'ici 2050 et a l'intention de réduire ses émissions de GES de 55% d'ici 2030 par rapport aux niveaux de 1990. Les mesures fiscales environnementales aident à encourager le changement de comportement et contribuent ainsi à atteindre ces objectifs politiques. L'objectif de cette étude est de définir un ensemble de recommandations politiques concrètes pour les systèmes fiscaux nationaux afin de renforcer les efforts visant à réduire efficacement les émissions de GES dans l'UE. L'étude mène une revue de la littérature sur les mesures fiscales ciblant les émissions de GES et dresse un inventaire des mesures - comprenant des taxes et des incitations fiscales - dans l'UE-27, au Royaume-Uni et dans cinq autres pays. La méthodologie de benchmarking développée par la suite évalue l'efficacité environnementale et la viabilité politique des mesures fiscales dans le but d'identifier des exemples de bonnes pratiques. Les résultats de l'étude montrent que les taxes et les incitations fiscales avantageuses sont de plus en plus utilisées pour soutenir la transition écologique. Cependant, il est encore possible d'améliorer leur conception afin de les rendre plus efficaces dans leur objectif de réduction des émissions de GES. En outre, trouver un bon équilibre entre l'efficacité des mesures fiscales et leurs implications politiques plus larges reste un défi.

Kurzfassung

Die Europäische Kommission hat sich ehrgeizige Ziele gesetzt, um Europa bis 2050 zum ersten klimaneutralen Kontinent zu machen. Sie beabsichtigt, Treibhausgasemissionen bis 2030 um 55% gegenüber 1990 zu senken. Umweltbezogene steuerliche Anreize können entsprechende Anreize setzen und tragen somit zur Erreichung dieser politischen Ziele bei. Ziel dieser Studie ist es, eine Reihe konkreter politischer Empfehlungen für die EU-Mitgliedsstaaten zu definieren, um die Bemühungen zur wirksamen Reduktion ovn Treibhausgasemissionen in der EU weiter voranzutreiben. Die Studie führt eine Literaturrecherche zu steuerlichen Instrumenten gegen Treibhausgasemissionen durch und erstellt eine Bestandsaufnahme vorhandener Instrumente – sowohl Steuern wie auch Steuervergünstigungen - in den Ländern der EU-27, im Vereinigten Königreich und in fünf weiteren Staaten. Anschließend wird eine Benchmarking Methode zur vergleichenden Analyse der Effektivität und der politischen Machbarkeit ausgewählter steuerlicher Instrumente entwickelt, um *Good Practice*- Beispiele zu identifizieren. Die Ergebnisse der Studie zeigen, dass Steuern und Steuervergünstigungen zunehmend zur Milderung des Klimawandels

eingesetzt werden. Es gibt jedoch noch Raum, ihre Ausgestaltung zu verbessern, um Treibhausgasemissionen noch effektiver zu reduzieren. Darüber hinaus sehen sich politische Entscheidungsträger nach wie vor der Herausforderung gegenübergestellt, erfolgreich ein Gleichgewicht zwischen dem Lenkungszweck (Reduktion von Treibhausgasemissionen) steuerlicher Instrumente und ihren weiteren ökonomischen und gesellschaftlichen Auswirkungen zu finden.

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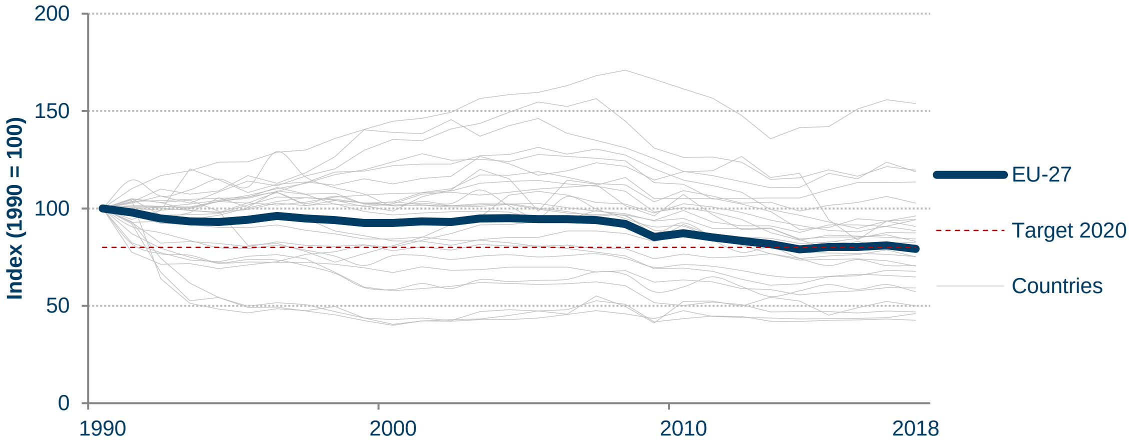
1 INTRODUCTION

Climate change is one of the defining challenges of our modern society. The manmade global warming has already and will increasingly affect the weather and climate across the world. Climate change endangers fragile ecosystems and the habitats of wildlife and plants. It also affects societies and our way of living. Rising sea levels, desertification, and more extreme weather phenomena are just three examples illustrating how climate change affects where we can live, how we can do business, and that we are vulnerable to global warming. As a global challenge, it requires action at local, regional, national, and international level.

The key driver of climate change, CO_2 emissions, needs to be reduced to achieve the internationally set goals to contain the adverse effects of climate change. At EU level, the European Green Deal and the latest Communication on Stepping up Europe's 2030 climate ambition put forward by the European Commission sets the ambition to make Europe the first carbon-neutral continent by 2050 and to reduce GHG emissions by 55% by 2030.[1] These targets are aligned with the global efforts to limit global warming to well below 2 °C, and to limit it ideally to 1.5 °C to reduce the costs and risks linked to greater warming.

To achieve these objectives, it is necessary to rethink our economies and societies and to mainstream the issue of climate change and GHG emission reduction across policies and instruments. Efforts have already been made. Data available until 2018 suggests that the EU is on track to achieve its goal to reduce GHG emissions by 20% by 2020 compared to the baseline year of 1990 (see figure below).

Figure 1 GHG emissions for the EU-27 and by country in relation to the target for 2020



Source: Ecorys based on Eurostat [sdg_13_10]

Mainstreaming efforts to limit climate change also includes first and foremost market-based instruments. The European Emission Trading System (ETS) is a key element of the efforts of the European Union to curb GHG emissions. The ETS creates a market for emission allowances companies need to buy and trade, incentivising them to lower emissions. According to the European Commission, the ETS has been effective in reducing emissions of installations covered by the system by about 35% between its set-up in 2005 and 2019.[2] Apart from the ETS, taxes are another market-based instrument to price emissions. In general, taxes are among the common measures to disincentivise environmentally harmful behaviour and to internalise external

[1] https://ec.europa.eu/clima/policies/eu-climate-action_en.
[2] https://ec.europa.eu/clima/policies/ets_en.

costs not born by the polluter. The role of environmental taxation, and especially of carbon taxes, as key market-based instruments to tackle climate change is also widely acknowledged in the literature (e.g. Kosonen and Nicodème 2009; Milne and Andersen 2014; Goulder et al. 2018). Note, however, that at EU level environmental taxation is not harmonised and is in competence of Member States. This leads to large variations across the Member States. Carbon taxes are of special relevance to reduce greenhouse gas emissions of the sectors not covered by the European Emission Trading System (ETS) or to complement the EU ETS.[3] The most important of these sectors is transport[4], where GHG emissions have been rising continuously in the past and are now making up for more than 20% of overall EU GHG emissions (Kettner-Marx and Kletzan-Slamanig 2018).

Various strategic documents issued at EU level stress the role of environmental taxes to make societies and economies more sustainable and environmentally friendly (e.g. European Commission 2017[5]). The polluter-pays principle, on which these taxes are based, is enshrined in Article 191/2) of the Treaty on the Functioning of the European Union. In a 2018 Communication[6], the European Commission recognised that environmental taxation, carbon pricing systems and revised subsidy structures should play an important role in steering the transition to Europe being the first climate-neutral continent by 2050. The proposed enabling framework for a climate-neutral society includes taxation as an important tool for ensuring an effective pricing of externalities and fair distribution of transition costs. The European Green Deal committed to creating the context for broad-based tax reforms at national level, removing subsidies for fossil fuels, including the maritime and aviation sectors in the ETS, shifting the tax burden from labour to pollution, and taking into account social considerations. The ability of tax systems to support economic recovery by contributing to inclusive and sustainable growth, including through shifting taxation from labour to environment, has been recognised in the 2020 European Semester.[7]

In 2018, EU governments collected around EUR 325 billion of tax revenues from environmentally-related taxes. Depending on the Member State, environmental taxes account for more than 5% of overall tax income (see Figure 2 below). The share is the highest in Latvia and Bulgaria with above or close to 10% of overall tax income and the lowest for Luxembourg and Germany just above 4%. In Iceland and Canada (included for comparison in this study), they are below 4%.[8] Across countries, energy taxes account for the largest share of environmental tax revenue.

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[3] See for example also the Communication from the Commission on Europe's 2030 climate ambition: "The Commission is aware that carbon pricing does not address all barriers to the deployment of low and zero emissions solutions. Other complementary policy actions are needed to ensure that the incentives align and to trigger further investments in clean energy technologies and infrastructure or to overcome financing difficulties for low-income households." COM(2020) 562 final.

[4] With the exception of intra-EU aviation.

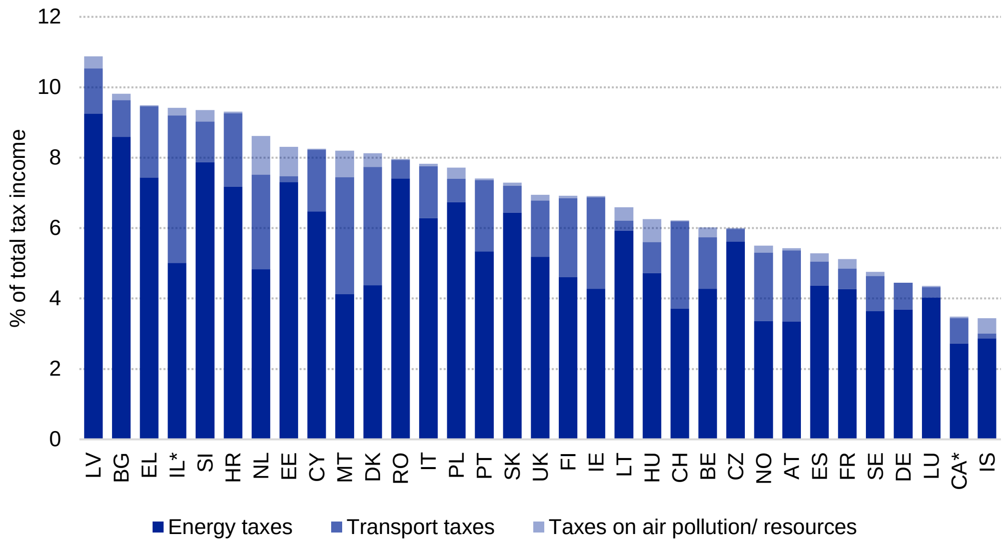
[5] European Commission (2017) Tax Policies in the European Union. 2017 Survey. Brussels: European Commission.

[6] COM (2018) 773 A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy

[7] https://ec.europa.eu/info/sites/info/files/2020-european-semester-csr-comm-recommendation-communication_en.pdf

[8] Note that the share of taxes stemming from environmental taxes does not necessarily allow a judgement of a country's efforts to reduce GHG emissions. For example, higher consumption of energy leads to greater tax revenue, yet also higher emission, and depending on the number and revenue from other taxes, the share of environmental taxes in government revenues differs as well.

Figure 2 Environmental tax income as share of overall tax income



**Data from 2018. Data for IL and CA from OECD (2014)*

Source: Ecorys based on Eurostat

More remains to be done. The adoption of carbon taxes varies among Member States and there is lot of heterogeneity in terms of scope and implementation of these policies.[9] Most commonly, these taxes target the transport sector and only some Member States have broadened the scope of fuel carbon taxes to other sectors than transport. Explicit or implicit carbon taxes are also relevant for other non-ETS sectors, in particular the housing sector.

In the realm of energy taxes, the recent evaluation of the Energy Taxation Directive (ETD)[10] concluded that the "*overall EU added value of the ETD has eroded significantly over time in particular due to the lack of indexation of the minimum rates and the extensive and highly divergent use of optional tax exemptions […]."* The evaluation found that the ETD was not coherent with policy efforts to reduce greenhouse and other pollutant emissions as well as energy diversification due to disregard of the energy content and CO_2 emissions of energy products and electricity, (too) low minimum levels of taxation and (too) many exemptions.[11] However, it is important to keep in mind that the ETD arguably was an important element to price polluting behaviour in times when the price for emission allowances under the ETS was still too low to be effective. Following the evaluation, the ETD is currently under review.[12]

The evaluation also found that "*the mandatory tax exemptions concerning international commercial aviation and maritime transport and optional exemptions and reductions for other modes of transport may distort the level playing field in the sector*" and that "*some of the preferential tax treatments may restrict the potential contribution of the transport sector to the EU's climate policies*". As transport CO_2 emissions have not decreased, but slightly increased between 2009 and 2018[13], the EU policy discussion focuses on how the transport sector may contribute to meet environmental and climate change goals and priorities. In this respect, one

[9] European Commission (2018): IN-DEPTH ANALYSIS IN SUPPORT OF THE COMMISSION COMMUNICATION COM(2018) 773
[10] https://ec.europa.eu/taxation_customs/sites/taxation/files/energy-tax-report-2019.pdf
[11] ibid
[12] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12227-EU-Green-Deal-Revision-of-the-Energy-Taxation-Directive.
[13] See Eurostat [ENV_AIR_GGE].

policy option is taxation: the aim of vehicle taxes is to switch purchase habits, increasing the tax burden on high-emissions vehicles while providing incentives for those with low or no emissions.[14]

Thus, if designed appropriately, tax measures can help leveraging efforts to reduce CO_2 emissions. In addition, countries also set positive incentives that reward emission reducing behaviour with tax breaks or even tax exemptions. Commonly known examples are tax exemptions for the purchase and use of electric vehicles, or income tax deductions for companies and individuals that resort to energy efficient technologies and products. At the same time, many countries also still have environmentally harmful tax incentives that incentivise higher GHG emission levels.

As the examples above illustrate, efforts to use taxes and tax incentives to tackle climate change differ across countries. Governments resort to different types of measures with a varying degree of success. A comprehensive mapping and comparison of the measures and the identification of good practice examples can therefore help to streamline efforts and enhance policy learning.

1.1 Objectives of the study

The objective of the study is to define a set of concrete policy recommendations to enhance efforts to reduce the emissions of GHG in the EU effectively. The study takes stock of the current state of research on tax measures targeting GHG emissions and maps tax measures that incentivise individuals and/or companies to change towards more sustainable or climate-neutral behaviours. The study makes use of these information and develops a solid benchmarking to identify a number of good practice examples among the tax measures. The output of the study is intended to support Member States to enhance their national strategies to ensure that taxes aiming at reducing GHG emissions are effective, efficient, fair and economically and politically viable.

1.2 Scope of the study

The study explores tax measures across the EU-27, the United Kingdom, and five other countries. These are Canada, Iceland, Israel, Norway, and Switzerland. Focusing research at the national level, the study limits itself to measures that are currently in place and disregards measures that are planned or have been phased out in the past.

The scope of this study entails taxes and beneficial tax incentives which incentivise a reduction of GHG emissions. To complement the work, this study also mapped and assessed some main types of harmful tax incentives. **The study does not explore the European Emission Trading System** (EU ETS). Given the current political debates about integrating the **maritime and aviation sector** in the EU ETS, taxes in these sectors **were also not considered** in the mapping and benchmarking.

In simple terms, we understand taxes as fiscal measures that increase the price for a certain product or behaviour, while tax incentives decrease this price. More specifically, this study uses the following definitions:

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[14] Note that this is not a recent discussion. Already in 2005, the European Commission published a proposal for a Council Directive to include CO_2 as tax base in annual circulation taxes, see COM(2005) 261 final.

- **Taxes** are defined as any compulsory, unrequited payment to a government. In contrast to revenues from fees, charges and certain other levies, which are often used to finance certain publicly provided goods and services, the revenues from environmental taxes (as, by definition, from taxes in general) are not earmarked. For this study, the focus lies on direct and indirect measures levied on tax bases deemed to be of environmental relevance, i.e. taxes that have a tax base with a proven, specific negative impact on the environment.

- **Beneficial tax incentives**, in this study simply referred to tax incentives, are defined as tax breaks, which are a deduction, exclusion, or exemption from a tax liability, offered as an enticement to engage in a specified activity for a certain period that induces a behaviour towards reducing GHG emissions.

- **Harmful tax incentives** are defined as those tax incentives (see above) that also fall within the definition of environmentally harmful subsidies by the OECD (1998)[15], according to which environmentally harmful subsidies are "…all kinds of financial supports and regulations that are put in place to enhance the competitiveness of certain products, processes or regions, and that, together with the prevailing taxation regime, (unintentionally) discriminate sound environmental practices."

Due to these definitions, levies, charges, and fees are generally excluded from the scope of this study.

1.3 Overall approach

The study builds on previous research that maps and assesses taxation in support of green transition. Research commenced with two work streams running in parallel:

The economic literature review screened relevant research in the field of environmental taxation, with a particular view to research that focuses on taxes and tax incentives targeting GHG emissions. The review provides an analysis of relevant theoretical and empirical literature concerning the effects of relevant environmental taxes. Main objectives of the literature review were to embed this study in the ongoing academic and policy debate. Further, the literature review provided the empirical evidence and insights on criteria that require attention in the benchmarking of measures and on design features of individual measures that influence their effects. The findings of the literature review are presented in Chapter 2.

The inventory of measures was created to gain a good overview of the tax measures countries already have in place. Building on existing work, this study took stock of taxes and tax incentives in place at national level across the 33 countries included in the research. Research builds on the PINE Database run by the OECD, and other relevant sources such as the World Bank's Carbon Pricing Dashboard, the inventory of excise duties on energy products provided by DG TAXUD,[16] and research by the EEA, . This preliminary compilation of measures was complemented by a country-by-country mapping of relevant tax measures, screening national sources and performing 60 interviews to gain a comprehensive overview of the measures in place. A horizontal discussion

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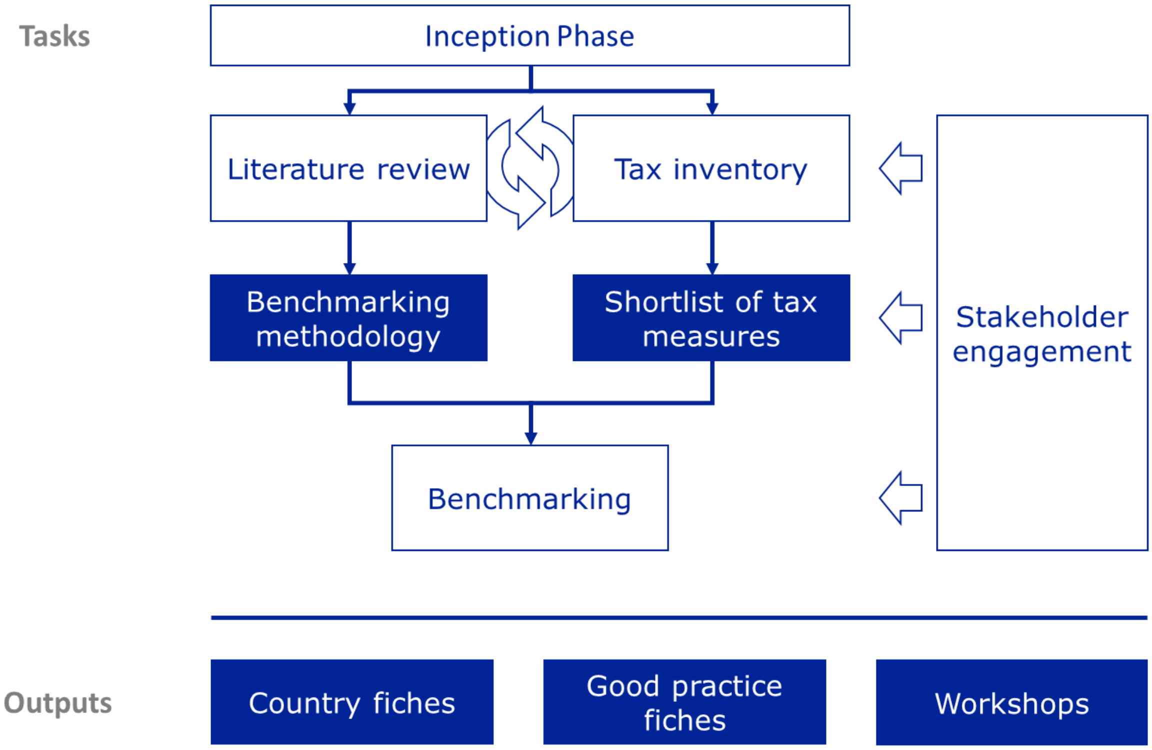
[15] OECD, Improving the Environment Through Reducing Subsidies. Part I: Summary and Policy Conclusions, Paris, 1998.
[16] https://ec.europa.eu/taxation_customs/sites/taxation/files/resources/documents/taxation/excise_duties/energy_products/rates/excise_duties-part_ii_energy_products_en.pdf

of the findings of the inventory is presented in Chapter 3. The 33 individual country fiches are included in Annex III.

Figure 3 Simplified overview of the overall approach



Source: Ecorys

The output of the two work streams yielded the input needed for the **identification of good practice examples**. On the one side, the economic literature review informed the development of the benchmarking methodology, which focuses on an assessment of the environmental effectiveness and political viability of tax measures. On the other side, the inventory of measures helped to identify a shortlist of measures that were included in the benchmarking exercise.

76 measures were included in the benchmarking and ranked according to their environmental effectiveness. As the intervention logic for taxes and tax incentives are quite distinct, two separate ratings and rankings were designed and implemented. Following this, the study analysed the political viability of the ten highest ranking taxes and tax incentives (i.e. 20 measures in total). Out of these, ten measures were selected as good practice examples, taking into account overall environmental effectiveness score, their political viability and reflecting on the diversity of existing measures. The results of the benchmarking and analysis are presented in Chapter 4. Good practice fiches for the ten selected measures are included in Annex IV.

Thus, a key element of the approach of this study was to repeatedly narrow down the number of measures assessed while widening the scope of the assessment. Mapping tax measures in 33 countries first, this funnelling process facilitated the identification of 10 diverse good practice examples, for which detailed assessments are provided.

The research progress was complemented by **two workshops** with representatives of the EU Member States. Representatives of national ministries of finance/ taxation and of national ministries of the environment were invited to discuss and validate the findings of the mapping and to provide feedback on the proposed methodology for benchmarking during the first workshop. During the second workshop, the finalised benchmarking methodology and preliminary results were presented. Member States also discussed what helps to enhance the political acceptance of measures, and how tax measures fit into the wider policy framework to ensure a green transition.

1.4 The study's challenges and limitations

The benchmarking methodology applied to assess environmental effectiveness of tax measures has various limitations. First, the number of variables or design features available for benchmarking variety of measures is limited and those design features may only partly contribute to effectiveness of the measure in reducing GHG emissions. In particular, the theoretical and empirical evidence for tax incentives remains limited in the literature, which restricted the number of aspects that could be assessed. Thus, benchmarking exercise should be viewed only with respect to the elements analysed.

Second, while aiming at the same objective – reduction in GHG emissions - environmental taxes and tax incentives are governed by distinct logics: taxes make environmentally undesirable behaviour more expensive, while tax incentives promote environmentally desirable behaviour with a subsidy. For that reason, the benchmarking exercise was done separately for taxes and tax incentives and therefore two separate rankings were developed, from which good practice examples were selected independently.

Third, the benchmarking assessment is based on design features, rather than actual environmental impacts of the evaluated measures given that empirical assessment exists for only a handful of measures. Thus, even though good practice principles (design features) are based on empirical evidence as well as theoretical considerations, future evidence (e.g. in a form of studies estimating actual impacts) might lead to different judgements.

The inventory of existing tax measures provided in the country fiches (Annex III) may not necessarily be exhaustive and provides a snapshot of the state of play at the time the research was undertaken.

1.5 How to read this report

This **Final Report** presents the results of the study for the European Commission on taxation in support to climate change mitigation. It presents an overview and an assessment of existing tax practices to reduce greenhouse gas emissions in the EU, the UK, and five additional countries. This report is structured as follow: Chapter 2 presents the literature review on the theoretical framework of environmental taxes and empirical evidence on their effects on GHG emissions. This chapter should help the reader to gain a comprehensive overview of the current state of play of the academic research in this field. Chapter 3 provides a horizontal assessment of the results of the mapping exercise. Chapter 4 presents the results of the benchmarking of tax measures and identifies good practice examples on the basis of this analysis. Chapter 5 concludes the study with key recommendations.

Several Annexes complement this report. A more detailed description of the methodology can be found in the methodological Annex (Annex I). Scoring tables and further results of the identification of good practice examples are presented in (Annex II). Country fiches and good practice examples are included in Annex III and Annex IV, respectively. An overview of the stakeholder engagement in the scope of this study is included in Annex V. The list of taxes and tax incentives identified in this study is presented in Annex VI.

2 ECONOMIC LITERATURE REVIEW

This chapter provides a comprehensive review[17] of the relevant theoretical and empirical literature addressing the effects of environmental taxes regarding several criteria commonly used in the literature and in the benchmarking undertaken in this study: effectiveness, cost efficiency, impacts on competitiveness and innovation, distributional implications, and political acceptance and administration of the environmental tax schemes. These criteria represent the focus areas on which we concentrate in the review of the theoretical and empirical literature. This focus on environmental taxes is complemented by an additional focus on beneficial tax incentives. The methodological approach comprised three steps.

In a first step, we **screened the existing theoretical and empirical literature** on the potential effects of taxes and tax-related measures aiming at the reduction of greenhouse gas emissions. Generally, the focus of the literature screening took a broad perspective regarding the theoretical aspects of environmental taxes and focused mainly on the 27 EU Member States, the United Kingdom and the additional selected countries concerning empirical results. However, the review was not limited to these countries in case that empirical studies and analyses were identified that are of interest with regard to the focus areas of the literature review. During the screening, we identified for which of the aspects of particular interest for this study each source is relevant. To perform the literature review in a systematic way, we established and then used key terms, words and phrases to identify reports or studies focusing on tax measures reducing greenhouse gas emissions.

In addition to key words identified above, we also added key words for the five focus areas, namely effectiveness, cost efficiency, impacts on competitiveness and innovation, distributional implications, and political acceptance and administrative costs.

In a second step, an **analysis of the literature by focus area** was provided. The theoretical part presents the most important theoretical propositions for each focus area. The review of the empirical analyses is structured along the focus areas as well. The presentation of the empirical evidence for each focus area is structured based on various criteria; in particular ex- ante versus ex- post evaluations and case studies versus cross-country analyses.

In a final step, a **comprehensive report** presenting the most important theoretical and empirical findings in the relevant literature was compiled. This report is the basis for an intervention logic serving as starting point for the benchmarking.

2.1 Overview of environmental policy instruments

Environmental taxes are one instrument in a toolbox of available environmental policy instruments. Figure gives a schematic overview over the range of environmental policy instruments.

Two basic categories can be distinguished: Market based (e.g. fiscal) instruments on the one hand and non-market-based instruments on the other hand. The latter group includes regulatory

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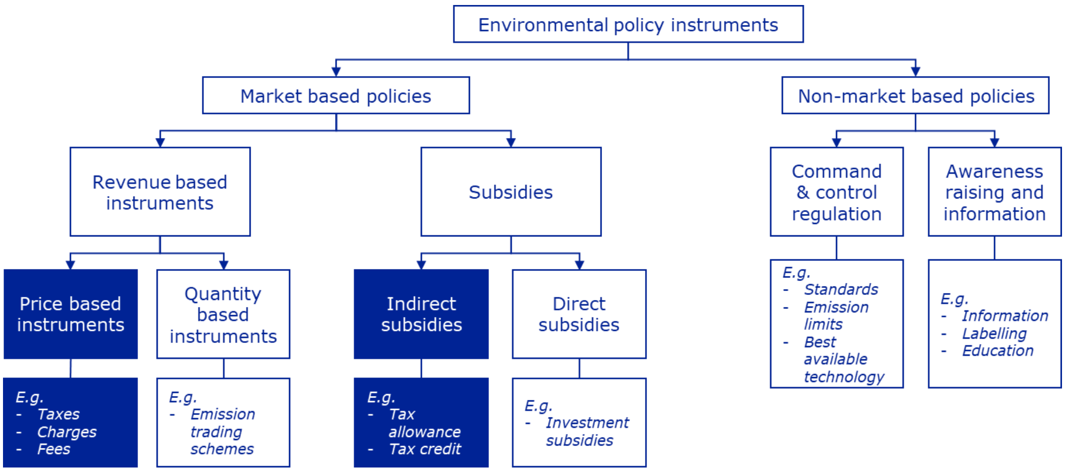
[17] The various draft versions of the literature review were discussed with DG TAXUD as well as country representatives in the two online workshops, whose feedback was incorporated in the final report.

instruments such as standards as well as awareness-raising measures or information. In line with the focus of this study, non-fiscal instruments will not be discussed further in the following.

Fiscal instruments, in turn, can be differentiated into incentives that make environmentally undesirable behaviour more expensive (taxes, emissions trading[18]) or that promote environmentally desirable behaviour (environmentally beneficial tax incentives, subsidies, grants). This study focuses on taxes among price-based instruments, and further looks at indirect subsidies via tax incentives. The corresponding sub-types of environmental policy instruments are highlighted in the figure below.

Figure 4 Overview of environmental policy instruments



Source: WIFO

A related issue are environmentally harmful subsidies because they can reduce the effectiveness of existing or newly introduced environmental policy instruments. Although their avoidance or elimination has positive environmental effects, they are not environmental policy instruments in a narrow sense and therefore are not systematically addressed in this literature survey.

In the following we focus on fiscal instruments and provide an overview over the current state of the theoretical and empirical literature on the topic of environmental taxes as the most important pricing instruments[19] and environmentally beneficial tax incentives.

2.2 The rationale for environmental taxes – theoretical framework

The literature review on the theoretical aspects of environmental taxes refers to both newer contributions like carbon taxes and to contributions that reflect the increasing importance of taxes in environmental economics starting already several decades ago.

2.2.1 The basic idea of pricing instruments and environmental tax reforms

Economists and environmental economists have been promoting environmental taxes already for several decades now as key instrument of environmental policy (Baumol and Oates 1971, Pearce and Turner, 1990, Pearce 1991, Goulder 1995, Köppl et al. 1996, Speck et al. 2006). The field is

[18] Emissions trading is in the case of grandfathering allowances not a fiscal instrument per se.
[19] Emissions trading as an alternative pricing instruments is discussed briefly.

the subject of broad and intensive research, both on theoretical issues as well as from an empirical perspective. Accordingly, there is a vast body of literature available on environmental taxes in general and, more recently, with a specific focus on carbon taxes (e.g. Kosonen and Nicodème 2009; Milne and Andersen 2014; Goulder et al. 2018). Thus, the design and the effects of environmental taxes are one of the best researched areas in environmental and climate economics, which stands in contrast to their actual relevance in existing tax systems so far.

Environmental taxes aiming at pricing individual environmentally harmful activities are emphasised as an effective and efficient instrument in environmental economics (e.g. Baumol and Oates 1988, Tietenberg 2009) to internalise negative impacts stemming from individual consumption behaviour and production activities. This goal is to be achieved by putting a price on negative externalities with the tax rate being set at the marginal social damage caused. The basic idea to use taxes to cope with negative externalities that are not included in market prices dates back to Pigou (1920), who, however, does not specifically focuses on the environment. Based on his seminal work so-called Pigouvian taxes have gained a place as key market-based instrument in the form of environmental taxes in general and of carbon taxes in the context of climate change in particular.

Environmental taxes are repeatedly integrated in the broader context of an environmental tax reform[20], i.e. the shift of the tax burden from labour to resource and environmental consumption. Such tax reforms have been a top research focus in environmental economics and have been on the agenda in the economic policy debate already for several decades (Pearce 1991, Goulder 1995, Ekins and Speck 2011). They are based on the double dividend hypothesis, arguing that such a tax shift, in addition to reducing environmental pollution, also brings about positive economic effects by using the revenues from environmental taxes to cut other more distortionary taxes[21].

In contrast to quantity-based instruments that have been gaining in importance worldwide in the aftermath of the Kyoto protocol and are applied in the EU in the form of the EU emission trading system, aiming at establishing a price for carbon emissions by regulating their quantity, environmental taxes set a price for environmentally harmful activities (e.g. the emission of greenhouse gases) to influence their quantity. The similarities and differences between price- and quantity-based economic instruments are also discussed in the context of carbon pricing as well as political economy arguments that support the acceptability of carbon taxes.

This chapter summarises the literature on environmental taxes in terms of effectiveness, efficiency, impacts on distribution as well as innovation and competitiveness and elaborates on some specificities of environmental taxes in the context of climate change. These aspects are complemented by a review on instrument choice.

2.2.2 How to determine the pricing of externalities

In an ideal world, the appropriate price of environmental externalities can be determined precisely, marginal damage and abatement costs are known, technologies for abatement investments are available, and the optimal abatement activity in response to the tax is chosen.

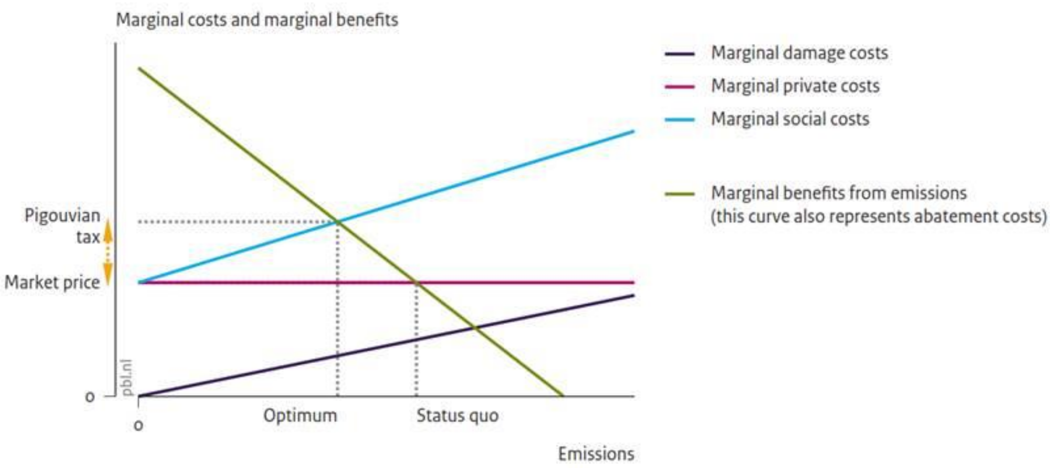
[20] The common view of environmental tax reform (ETR) is the use of the revenue from environmental taxes to reduce distortionary taxes, e.g. taxes on labour. The European Environmental Agency (EEA, 2005) e.g. defines an ETR as "… the term used for changes in the national tax system where the burden of taxes shifts from economic functions, sometimes called 'goods', such as labour (personal income tax), capital (corporate income tax) and consumption (VAT and other indirect taxes), to activities that lead to environmental pressures and natural resource use, sometimes called 'bads'."

[21] See, e.g., Bovenberg and de Mooij (1994, 1997), Parry (1995), Goulder (1995, 2000, 2013) and Fullerton and Metcalf (1997) on such an interaction of environmental taxes with the overall tax system.

In theory and in a perfect market situation taxes and allowance prices in a trading system are identical. The underlying assumption and pre-condition for the similarity of both regulatory systems are that the regulator and all market actors have equal information and uncertainty is negligible.

The following **Figure 5** exhibits the basic elements of this understanding both for consumption and for production of a commodity that generates besides private (marginal) costs also (marginal) damage costs. The optimal private choice both for a consumer or a producer is characterised by equating marginal benefits and marginal costs. However, the existence of social damage costs requires a tax that allocates the external costs to private actors, where the tax rate reflects the social damage costs. This shift from a private optimum to a social optimum can be induced by a Pigouvian tax.

Figure 5 The basic theory of environmental pricing



Source: Vollebergh (2012)

In the context of carbon emissions this tax rate on the market price would then be the optimal carbon price. In the case of a stock pollutant[22], as GHG emissions, however, and due to the complexities of the climate system, as well as the time separation of abatement costs and climate damage or benefits from emission mitigation, there is a broad range of estimates for the optimal carbon price, originating from differing model assumptions. Furthermore, as follows from Weitzman (2009, 2014) and his arguments on the climate tail risks (Wagner and Weitzman 2018) – i.e. the low probability of catastrophic climate change –, the determination of the optimal carbon prices is restricted by the underlying uncertainties. A similar argumentation can be found in Marron and Toder (2014) who stress that the estimated social costs of carbon[23] depend on controversial model assumptions. This argument does not dwarf the usefulness of carbon taxes and carbon prices but sheds more light on risks and uncertainties connected to climate change that are often not reflected in standard modelling exercises. Pindyck (2013a, 2013b) argues that because of high uncertainty and risk regarding the damage function of climate change,

[22] GHG emissions remain in the atmosphere for a long time and the yearly flows of GHG emissions add to GHG concentration in the atmosphere.

[23] For the transport sector, the European Commission takes a broad perspective on external costs of transport and relies on the concept of avoidance costs for climate costs. In the assessment not only climate costs are considered but also other external costs such as noise, congestion, accident costs, etc. (European Commission 2019).

technological change and thus on the social cost of climate change[24], these aspects taken together limit standard cost-benefit analysis. These constraints to standard cost-benefit analysis are, however, often not reflected in conventional economic models. This leads to a broad range of estimates on the social cost of carbon, which are differentiated further by the chosen rate of pure time preference and the discount rate of consumption[25] (e.g. Stern 2007, Mankiw 2009). Pindyck (2013b, 2019[26]) concludes that even if the true social costs of carbon are not known, a tax based on a rough estimate would signal that the costs of climate change need to be internalised in the prices. With increasing knowledge on the social costs of climate change the tax could be adjusted accordingly. Marron and Toder (2014) put forward as an alternative approach a carbon tax rate aligned to a political emission target. The resulting tax rate would not necessarily reflect the true social cost of carbon but would still ensure a cost-effective achievement of the policy target. Rezai and van der Ploeg (2019a) discuss in a simple framework how assumptions on the development of various drivers of climate policy, like the discount rate, technological progress, geophysical reactions as well as international climate policy impact outcomes. One of their conclusions is that the price for carbon is crucially driven by ethical considerations, that is on assumptions on the size and the development of the discount rate over time. Specifically, they illustrate how a hyperbolic discount rate impacts the carbon price.[27]

2.2.3 Effectiveness of environmental tax (dis)incentives

In principle, the introduction of environmental taxes or the implementation of an environmental tax reform should focus on the steering effect or environmental effectiveness of the instrument. The main motive is to set prices for negative external effects via fiscal interventions which increase the price of environmentally damaging inputs or activities. The tax base can be specified according to various criteria, depending on the type of externality to be regulated. This should change production and consumption activities towards more sustainable or environmentally friendly structures.

An environmental tax can be used to increase the price of a certain input or activity (e.g. a levy on fertilizers, pesticides or aircraft noise). If environmental pollution is caused by all economic sectors, a cross-sectoral, uniform environmental tax should be chosen, such as a tax on fossil fuels according to their specific climate impact in order to influence the current consumption by setting a price for external effects. Alternatively, instead of a tax on fossil fuels, i.e. an input tax, one could apply an emission tax, i.e. an output tax directly related to the pollution caused. In practice, inputs are often more easily accessible and are used as basis for calculating or estimating emissions. This is also the case in the context of climate change.

Taxing carbon emissions directly is not straightforward. Instead, in practice emission factors of the use of fossil fuels and their respective carbon content are used. However, such an indirect approach does not account for process emissions e.g. from steel or cement industries. Putting a

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[24] The social cost of carbon (SCC) corresponds to the monetarised marginal cost of carbon emissions and is used for the assessment of climate policy. An overview over different modelling approaches and estimates on the SCC can be found in Wang et al. (2019) and Tol (2018).

[25] Since climate change is a long-term issue the size of the discount rate is a decisive factor on cost estimates of climate change. The differentiation between the rate of pure time preference and the discount rate on consumption refers on the one hand to the value the current generation ascribes to welfare and wellbeing of future generations. On the other hand, the discount rate for consumption transfers the value of a unit of future consumption into the value of a unit of consumption today.

[26] In a recent paper Pindyck (2019) presents the estimation of an average social cost of carbon based on an expert survey. The expert opinions on average deliver higher costs of carbon than can typically be found in economic analyses. The higher SCC from the survey analysis are driven by experts' beliefs regarding a potential extreme damage with large GDP losses.

[27] For a thorough discussion on the appropriate carbon price, see also Rezai and van der Ploeg (2019b).

tax on non-carbon greenhouse gas emissions might be associated with high administrative costs compared to taxing fossil fuel-based emissions.[28] When deciding on the tax base, policy makers will thus be confronted with a trade-off between the scope of the GHG emissions covered on the one hand, and administrative costs on the other hand.[29]

Taxes can also be used to influence investment and purchase of durable consumer goods, since these decisions subsequently determine emissions over the whole service life of the capital stock and of products. Fiscal interventions to influence the investment phase are set, e.g., purchase tax for the transport sector, often with a specific environmental differentiation in tax rates as for ex…

Environmental taxes are characterised by a variety of design options with respect to tax base, tax rate and exemptions, and in the broader context of environmental tax reforms also regarding the redistribution of tax revenues. The price elasticity of demand or the tax incidence of environmental taxes influence the effectiveness of the tax. The extent to which the tax burden can be passed over e.g. to consumers when the production sector is taxed determines the distributional effects.

Summarising, the basic economic rationale underlying the effectiveness hypotheses is twofold: (1) there is a need for taxing certain side effects from economic activities, as the harm they are imposing on society (i.e. their negative external effects) is otherwise not considered in market transactions; and (2) the tax that attaches a price to these external effects alters individual choices and thus reduces environmental harmful effects . Pricing negative externalities has been one of the central pillars in environmental economics for long.

2.2.3.1 The double dividend hypothesis

The so-called double dividend hypothesis brings together the economic and the environmental dimensions of environmental taxes. The double dividend hypothesis claims that a double dividend may be expected if revenues arising from environmental taxation are used to decrease taxes on labour (Pearce 1991, Goulder 1995, 2000, 2013, Bovenberg and Goulder 1996), thus reducing existing distortions caused by labour taxation. Accordingly, increased or more effective use of environmental taxes might lead to both environmental and economic improvement, by shifting the tax burden away from more distortive taxes (OECD 2010). A revenue-neutral environmental tax reform can generate positive employment effects (second dividend) in addition to achieving a specific environmental goal (first dividend). Obviously, the redistribution of tax revenues is central to the realisation of this effect.

The strong double dividend hypothesis postulates that using environmental tax revenues to decrease distorting taxes leads to an overall welfare increase; while according to the weak double dividend hypothesis revenue recycling via a reduction of distorting taxes is more efficient than granting lump-sum transfers (Goulder 1995). An intermediate double dividend is the claim that whether an internalising environmental tax that replaces a distortionary tax will increase welfare depends on the specific properties of the distortionary tax (McCoy 1997, Andersen 2009).[30]

The findings in the theoretical literature on the double dividend hypothesis are ambiguous, however. A critical assessment has been put forward by Bovenberg and de Mooij (1994) who

[28] There exist clear emission factors for each fossil fuel that can be readily translated into CO_2 intensity (emissions per energy unit) which can be the basis for a respective carbon tax. Such a carbon tax translates into a specific price increase per fossil energy consumed. Non-CO_2 emissions vary greatly among sectors (e.g. livestock, fertilizer production) and regions. Data requirements and estimates on emission intensities thus could be more challenging than for CO_2-emissions.

[29] On a discussion on administrative costs of green taxes see e.g. Smulders and Vollebergh (1999).

[30] Jaeger (2012) discusses the evolution of the literature on the DD literature and points at remaining ambiguities in the debate stemming from specific conditions in the economy. See also Parry (1995) on the tax interdependency effect..

show in a simple general equilibrium model that pre-existing distortionary taxation can even be aggravated by environmental taxes. Fullerton and Metcalf (1997) state that a double dividend cannot be expected in all cases. They basically argue that it depends on the specific economic environment in which a restructuring of the tax system takes place. One of the authors' main conclusions is that the focus on the revenue raising effect of environmental taxes is misplaced by showing that different policies might have the same environmental and economic effects but differ in their revenue raising effect. They analyse three policy options that result in identical environmental benefits and economic outcomes: (1) one policy raises revenue from the environmental component to be used for a reduction of income taxes; (2) a command and control policy that shows identical economic effects compared to the former option; and (3) a subsidy financed by an increase in income taxes. The crucial point is that it is the specific design of policies that determines the economic outcome. Barrios, Pycroft and Saveyn (2013) argue that the main weakness of environmental taxes consists in their decreasing revenues due to their shrinking tax base if they are successful in containing the environmentally harmful activities they are taxing[31]. In his review article, Freire-Gonzalez (2018) summarises the theoretical aspects discussed above and provides an empirical meta-analysis on the validity of the double dividend hypothesis (see section 3.4.1.4.2). Although the theoretical literature on the double dividend hypothesis is extensive, there is no consensus concerning its validity, albeit the first dividend is not contested. Two aspects drive the specific results: (1) the complexity of the model and the economic structure that forms the starting point for the analysis; and (2) the assumptions that enter the model.

2.2.4 Cost efficiency of the tax measures

The main advantage of taxes and other market-based instruments compared with command and control instruments (standards, quotas, product bans) is their efficiency (Kosonen and Nicodème 2009). The efficiency of internalising environmental taxes vis-à-vis regulatory measures is explained with the flexibility polluters are provided with in how to respond when adjusting their operations. The cost efficiency of taxes and other price instruments may be reduced, however, when fiscal interactions, i.e. the effects of environmental taxation in factor markets (labour, in particular), are accounted for. The "tax interaction effect" as argued by Parry (1995) Parry and Oates (1998) describes a negative welfare effect resulting from the interaction of the newly introduced environmental tax with the already existing (distortionary) tax system. The environmental tax is reflected in higher consumer prices, which in turn means a reduction in real wages and leads to a decline in the supply of labour, unless revenues are recycled back into a lowering of other taxes. Parry (1995) suggests to offset environmental tax burdens by lowering income taxes and/or the social security contributions of employers and thus to mitigate the tax interaction effect.

Generally, taxes are favoured by economic theory as they are expected to encourage broad-based action to reduce environmental damage at least cost. Pricing instruments are seen as cost efficient in a static and a dynamic perspective: it is left to firms and individuals to find the least cost solutions and to search for new solutions that may reduce emissions further (Aldy and Stavins 2011). This of course implies that the regulator sets the optimal price and that economic actors know the social costs of carbon and have perfect information on abatement costs, which is not always the case in practice.

The empirical evidence on existing taxes shows, however, a large differentiation in effective tax rates when looking at the cost efficiency of carbon taxes (OECD 2018, 2019). In addition, doubts regarding the effectiveness of the tax, market barriers and stock-flow-interactions pose as

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behavioural constraints affecting the efficiency of taxes. GHG emissions are the result of the interaction between stocks and flows, e.g. the quality of the building stock and the related need for energy flows (Köppl and Schleicher 2018). Different barriers may arise as environmental taxes are typically levied on energy flows that do not directly influence infrastructure decisions. A tax on transport fuels may lead to the avoidance of redundant trips or may influence the model choice when purchasing a new car. However, fuel taxation has no direct influence on decisions on transport infrastructure investment (rail versus roads), which ultimately determines mobility options (e.g. Köppl, Schleicher and Schratzenstaller 2019). A well-known market failure related to the stock-flow interaction in housing is e.g. the tenant-owner problem. Typically, the tenant must bear the costs arising from an environmental tax on energy for housing but cannot decide on the energy efficiency of the building stock which determines the need for energy flows. Most of the standard literature and analyses on carbon taxes do not address these market failures explicitly.

2.2.5 Impacts on Competitiveness and innovation

From the perspective of economic sustainability, their incentive-enhancing effects towards green innovation are another benefit of environmental taxes. They provide incentives for further efficiency gains, green investment and innovation (OECD 2010). Van den Bergh (2013) highlights the importance "to get the prices right" in the context of environmental innovation. Acemoglu et al. (2012, 2013, 2014) and Popp, Newell and Jaffe (2010) conclude that environmental taxes coupled with state subsidies can effectively redirect innovation towards environmental-friendly technologies and energy efficient innovation. Borissov et al. (2019) argue that clean production tends to be skill intensive, carbon pricing may have a positive effect on human capital accumulation and therefore on economic growth: A carbon tax influences technology choice and thus provides incentives for human capital accumulation. Lillestam et al. (2020) refer to the theoretical argument of a dynamic effect of taxes on innovation. In theory environmental taxes incentivise continuous innovation of low-emission technologies in order to avoid paying the taxes. They point out, however, that besides costs, other relevant mechanisms influence the technological transition process[32].Since the beginning of the 1990s, and significantly influenced by Porter (1991) and Porter and van der Linde (1995), the hypothesis that environmental regulation can have a positive influence on growth and competitiveness has gained in importance. The proponents of this so-called Porter hypothesis assume that environmental policy can play an active role in improving and securing the competitive position of companies or entire industries. At the heart of the argument is the idea that environmental policy and regulation creates competitive advantages in a dynamic perspective because firms develop new innovative technologies and products as a result of environmental regulation that is efficient and flexible, e.g. by means of economic instruments.

In practice, however, concerns about competitiveness losses often lead to the introduction of exemptions from environmental taxes: a number of countries grant rebates on energy taxes for exposed industries or exempt these industries from environmental taxes if e.g. they are already regulated by emissions trading. This strategy is applied, for example, by Sweden, Norway and Denmark (Andersen 2004) and Switzerland (Diekmann and Bruderer Enzler 2019). Obviously, such exemptions reduce the environmental effectiveness of carbon taxes, while increasing the administrative burden. At the same time, accounting for competitiveness concerns of the industry in the design of environmental taxes supports their public acceptance.

[32] See also section 2.2.4.

Regarding the impact of carbon taxes on the competitiveness of companies affected by the tax, the argument is that in a highly globalised world, differences in the stringency of environmental policy could influence location decisions and shift polluting production capacities to countries or regions with less environmental regulations.

This discussion is led under the heading "carbon leakage"[33] (ZhongXiang 2012, Barker et al. 2007) and the "pollution haven hypothesis" (e.g. Koźluki and Timiliotis 2016, Ambec et al. 2013, Rubashkina 2015), when it comes to carbon pricing. Marron and Toder (2014) also point at potential competitive disadvantages caused by a national carbon tax and refer to the option of border tax adjustment, which, however, would be very complex when applied to intermediate and final products. The fear of relocation of emissions was one of the reasons why the EU emissions trading scheme stipulated free allocation of emission rights for production sectors that face international competition and in certain cases may not have emission avoiding alternatives (e.g. Aldy and Stavins 2011, Dechezleprêtre und Sato 2017, Aldy and Pizer 2015). However, policies aiming at avoiding losses in competitiveness are suboptimal from an environmental perspective as Klenert et al. (2017) point out. Their argument is that mitigation policies would allow low-emission industries to gain competitive advantages vis-à-vis more emission-intensive industries. Porter and van der Linde (1995) argue that innovation is induced and stimulated by environmental regulation. In this understanding, the function of politics as a prerequisite or support for the emergence of competitive advantages is brought to the fore. The first-mover-advantage argument is also emphasized by the EU as an essential advantage of medium-term energy and climate policy objectives. With regard to innovation effects according to the Porter hypothesis, the theoretical literature[34] generally points to a positive effect of environmental regulation on environmental innovations, but this does not offset the regulatory costs.

2.2.6 Distributional implications and public acceptability

Baranzini et al. (2017) address several issues related to the political economy of carbon pricing: the distributional consequences, lobbying, co-benefits, international policy coordination, motivational crowding in/out, and long-term commitment. While an in-depth discussion of all these political economy issues would exceed the scope of this study, distributional implications and public acceptability, as important political economy aspects associated with the implementation of carbon taxes, shall be briefly addressed in this section. The bulk of existing research on distributional effects of carbon taxes and the impact of various recycling options consists of empirical studies. This is also reflected in Section 2.3.6 on the review of empirical studies of distributional effects.

Distributional implications and acceptability are predominantly discussed from a household perspective in the literature, with only a minor share in analyses addressing distributional effects for the production sector. Typically, a pass-through of carbon taxes to consumers is assumed. Similar to other consumption taxes, carbon taxes would be regressive as lower income households spend a larger share of their income or a higher share of their consumption expenditure on energy intensive products (e.g. Marron and Toder, 2014). Similarly, Combet et al. (2010) show in a partial equilibrium setting that low income households are affected in two ways by carbon pricing: an income effect that shows in a lower purchasing power of their disposable income, and the basic need character of emission-intensive goods, resulting in a higher welfare loss for lower income households compared to high income households. This reasoning, however, assumes that the

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[33] See section 2.3.5 on the empirical evidence of carbon leakage.
[34] Enevoldsen et al. try to empirically assess the effects on the competitiveness of industries.

entire tax impact is passed on to consumers and no structural changes in the energy system will result from carbon pricing.

Distributional impacts not only apply to the household sector but may also affect production sectors differently. One relevant determinant of the distributional impacts in the production sector is the size of the price elasticity of demand, which determines the extent to which firms can pass on the tax to consumers and which may differ across sectors (Wang et al. 2016). Sectors with a high price elasticity, i.e. large demand reactions to price changes, would have to absorb the carbon tax from the direct use of fossil fuels as well as potential price increases from intermediates. Confronted with a price sensitive demand this could lead to profit losses in price elastic sectors. Sectors with an inelastic demand could shift the tax burden to downstream sectors and consumers. The sectoral impact of a tax may therefore vary considerably.

Sectors with high fossil fuel consumption and exposure to international competition are likely to be affected by a higher tax burden, at least in the short term. In the long run innovation and the switch to less emitting production technologies may alleviate this effect. (Temporary) preferential tax treatment, lower tax rates or tax exemptions could reduce sectoral distributional effects. An undesired effect of such policies, however, is that they may reduce the environmental effectiveness of environmental taxes. The substitution of emission-intensive technologies and products by less emission-intensive ones does not only play a role for production sectors, but is also an option for the household sector. Sectors and households that can switch to low emission technologies more easily will be less affected than others.

Concerning the household sector, the focus on distributional implications and acceptability of tax measures to reduce greenhouse gas emissions has gained attention recently, against the background of massive protests by citizens in several countries (e.g. France[35] or Iran) as a reaction to the introduction or the increase of taxes aiming at the reduction of greenhouse gas emissions. A rather broad consensus has emerged in the literature that motor fuel taxes are less regressive than other environmental taxes. This result is due to the fact that the share of household transport expenditure rises with income, whereas the share for household energy consumption for housing decreases with income. If there is a subsistence level of carbon intensive goods to satisfy basic needs of consumers, a carbon tax will have a regressive effect (Klenert and Mattauch 2016), meaning that the tax takes a larger percentage of income from low-income households compared to high-income households. In addition, distributional impacts of carbon taxes are also determined by socio-economic household characteristics like location, household type, demographics etc.

Similar to distributional aspects, political acceptance has drawn growing attention in research and in the political debate on emission-reducing tax measures. Baranzini and Carattini (2014) analyse ancillary benefits as one of the determining factors for public acceptance of carbon taxes. Case studies show that political and social acceptance crucially depends on the tax design (Klenert et al., 2018).

Both aspects, distributional impacts, and public acceptability, have increasingly drawn attention towards the use of tax revenues.[36] Wang et al. (2016) distinguish between ex-ante and ex-post measures to mitigate adverse distributional effects. Ex-ante measure reflect preferential tax rates

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[35] In France these protests occurred in the context of a wider tax reform, which had other re-distributional effects, that put a disadvantage at lower income groups.

[36] In a broader context additional policy measures also play an important role for acceptability. In the case of e.g. fuel taxes the available choices for mobility as public transport, secure bicycle lanes or rural planning that reduces mobility needs may support public acceptability.

or tax exemptions for most vulnerable groups. This, e.g., could ensure the subsistence level of emission intensive consumption or apply to sectors exposed to foreign competitors. Ex-post measures refer to revenue redistribution either through lowering other distortionary taxes (see also Section 2.3.4.2 on the double dividend hypothesis) or through an increase in transfer payments. In OECD (2002) compensation measures are referred to as basically ex-post, not affecting the tax rate or tax base of environmentally related taxes.. so they do not affect the tax base or rate structure of environmentally related taxes. Carattini et al. (2018) stress the role of communication strategies as an instrument to secure public acceptability, to reduce information asymmetry and to address the main concerns, like high personal costs, regressivity of the tax, negative impact on the wider economy and the lack of an incentive effect. Klenert at al. (2017) conclude that political trust together with the concrete tax design are decisive factors for acceptability of carbon taxes from a political science perspective.

If one summarises the discussed aspects of a carbon tax, three aspects are of particular relevance for the tax design: (1) a system perspective; (2) the specific tax design; and (3) strengthening public acceptance. The system perspective is of relevance in order to account for the stock-flow-interactions and possible persisting barriers as argued above. In addition, the existence of potential synergies and trade-offs vis-à-vis other important policy objectives suggests pursuing a system perspective.

2.2.7 Taxes versus emission trading

Economists agree on the recommendation to use pricing mechanisms as the core element of an effective environmental policy. However, this consensus is embedded in a broader debate on instruments in environmental policy, which reflects the controversy over price (taxes)or quantity (Emissions trading) regulation. A tax sets the price of emissions, while uncertainty remains on the resulting aggregate emissions level. Cap and trade systems define an aggregate emissions level, leaving the resulting price uncertain. In theory, in a world with perfect information both instruments, taxes and quantities, achieve the same result. In the real world, where uncertainty and asymmetric information prevail, the two instruments may deliver outcomes that are different from the theoretical optimal solution.

Whether taxes or quantity restrictions are the preferable instrument, is addressed in the seminal paper by Weitzman (1974), who shows that no clear conclusion can be drawn about which of the two approaches is to be preferred. He argues that only in the case of identical information on marginal costs and marginal damages would it be feasible to set the correct quantity or price signal. In a world with uncertainty and asymmetric information both instruments face efficiency losses. Weitzman's theoretical model shows that the preferred policy instrument depends on the steepness of the marginal abatement and marginal benefit (damage) functions. In his model a price instrument is preferred by a regulator when the marginal benefit function from reducing emissions is flat relative to the marginal cost of abatement. The opposite holds if the marginal benefit function is steeper.

Goulder and Schein (2013), Haites (2018) and Stavins (2019) provide a review of the differences and similarities of carbon taxes and trade systems. Carbon taxes are associated with lower administrative costs. Absence of price volatility is another advantage of taxes compared to trade systems. Floor or ceiling prices are tax elements introduced into trading systems to prevent price volatility. Floor or ceiling prices thus are exogenous price elements for trading systems and transform a pure cap and trade system into a so-called hybrid system with the aim to dampen price volatility. Metcalf (2009) in contrast discusses hybrid systems by introducing quantity elements in a tax system, i.e. to introduce a (automatic) change in the tax rate if a certain benchmark target regarding emission quantity is not reached. He argues that such an approach would have two advantages over a cap and trade hybrid system: It avoids the need for a new administrative structure to oversee this major new program as well as the creation of financial assets.

A price floor in an emissions trading system, defining a minimum price for allowances, is another form of hybrid system. It provides more certainty for firms that invest in abatement technologies and turns out to be especially important when abatement costs turn out to be lower than expected before implementation of the scheme. A price floor acts as an insurance for firms investing in low carbon technologies and abatement measures, guaranteeing a minimum return on investment and increasing planning security (Kettner et al. 2011). A price floor could be implemented easily (as design element of the auctioning or as part of the existing tax system) and without compromising the advantages of a cap-and-trade scheme. The introduction of a price floor could lead to an increase in transaction costs and might increase the administrative costs of the trading scheme. The Market Stability Reserve[37] in the EU ETS is another example of an instrument designed to increase the resilience of an emissions trading system to shocks by automatically adjusting the supply of allowances to be auctioned, according to pre-set rules.

One conclusion from the theoretical literature could be that policy choices depend on weighing different policy goals and that the concrete design of the policy instrument may play a more important role than general characteristics of the two instruments (taxes or emissions trading) applied in a pure manner.

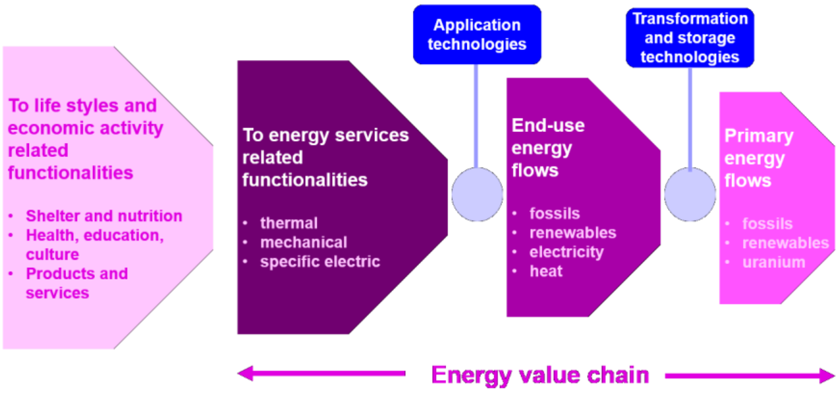
2.2.8 Additional aspects of carbon pricing

Attempts to green the tax system by shifting the tax base reflect an ongoing evolution of the underpinning theoretical concepts. The starting point was Pigou's seminal insight of the potential discrepancy between private and social costs of economic activities. The next step was the embedding of this discovery into the neoclassical paradigm, as exhibited e.g. in **Figure 5** above. It took some time, however, to acknowledge the limits of this reasoning: damage costs are difficult to monetise, all cost components are dependent on the time horizon considered and are not always independent of other decisions made. An important step was the emerging alternative, instead of taxing negative externalities to limit them within a cap-and-trade mechanism. The EU Emissions Trading System is the most far-reaching implementation of this approach so far, however, so far with limited success (Marcu et al. 2020).

Recently, the concept of using taxes for targeted energy and climate policies has experienced new momentum by widening the scope of the system addressed (Creutzig et al. 2018) Köppl and Schleicher 2018. Essential for this approach is an expansion of the full value chain, e.g. in the case of energy from supply of primary energy to the final thermal, mechanical and specific electric functionalities of energy services demanded, which in turn reflect life styles and the profile of economic activities along the entire energy value chain and pointing at the important role of application, transformation and storage technologies as depicted in **Error! Reference source not found.**.

[37] https://ec.europa.eu/clima/policies/ets/reform_en

Figure 6 Deepened structural concepts of resource use



Source: Köppl and Schleicher (2018)

This approach opens several other lines of reasoning: Köppl and Schleicher (2018) discuss the interaction of stocks and flows for providing the functionalities relevant for well-being, the need for differentiating incentives for investment and the use phase, the market failures from incomplete markets because of the separation of investors and users, the opportunities for harvesting synergies from this systemic approach. A basic message of this approach, which emphasises the details of resource use on this extended value chain, is the insight that a single instrument, such as a tax-based or a trade-based mechanism, will not be sufficient for correcting inefficiencies or externalities. Stiglitz (2019) therefore emphasises the importance of an instrument mix that is compatible with such a deepened structural view of our economies by considering the circumstances in which such differential policies may be best implemented through regulation or differential pricing.

Distributional concerns are another aspect of the discussion regarding carbon taxes in a broader context and generally of paying more attention to options for recycling tax revenues. In principle, revenue recycling options include lump-sum transfers to households, cutting existing taxes for households and/or firms, public spending for low-carbon infrastructure and/or subsidies for clean technologies, and support for developing countries. Each recycling option of the tax revenues has its pros and cons, as summarised by Stern (2019) in Table 1.

Summarising, a broad agreement among environmental economists (EAERE 2019) exists that taxes are an indispensable instrument for an effective decarbonisation strategy (World Bank Group 2019). The specificities of climate change, however, require expanding the perspective on carbon taxes as the exclusive solution for climate change (Rosenbloom et al. 2020). Several aspects have been addressed already above, like market failure due to stock-flow relations, or uncertainty on the likelihood of irreversible climate change. Carbon taxes thus need to be integrated in a broader policy package (e.g. High-Level Commission on Carbon Prices 2017). One important element in such a policy package would be the elimination of environmentally harmful subsidies as they reduce the price of emission intensive activities and act as adverse incentive for investment in clean energy technologies and in energy efficiency.

Table 1 Carbon Tax Revenue Use: Pros and Cons

All uses can be assessed relative to efficiency, equity, administrative burdens and environmental impact		
OPTION	PROS	CONS
General government budget	• Relatively simple to implement and manage. • Provide potential allocation to "best-use".	• Lack of transparency in allocation. • Potentially limits acceptability if low trust in politicians.
Revenue neutral-households	• Can be used to reduce distortions in other tax systems. • Ability to support lower-income/ vulnerable households.	• Potentially limited public awareness and understanding, unless direct "carbon transfers". • May divert revenue from better uses.
Revenue neutral-firms	• Simple and easy to manage. • Support can be offered to emission-intensive sectors and trade exposed firms. May overcome oppositions from industry.	• Less equitable than other revenue-recycling options. Might slow adjustment.
Allocation for 'green' purposes	• Demonstrates commitment to 'green' initiatives. • Additional support for investment in infrastructure/R&D programs with broad benefits.	• Limited flexibility due to need for long term allocation. • Possible mistrust of government 'schemes'.
Support for developing countries	• Demonstrate commitment to support objectives of Paris Agreement and SDGs. • Well established system for allocation and management.	• Potential public acceptability of use of revenues outside of the country.
All options should be coupled with clear communication and transparency of revenue-use. Important that uses are relevant for a broad range of constituencies. Must observe country specific regulations/laws e.g. ear-marking.		

Source: World Bank[38]

The arguments put forward about limits for carbon taxes mean that policy makers must carefully weigh up the different pros and cons when deciding on a coordinated climate policy package that is likely to achieve the envisaged long-term climate targets.

2.2.9 Conceptual aspects of beneficial tax incentives

While environmental taxes aim at making environmentally harmful behaviour more costly, the opposite is true for environmentally beneficial tax incentives. Tax incentives imply foregone public revenues to favour less polluting consumption and investment activities in order to achieve environmental policy goals. While there is a large body of theoretical literature on environmental taxes and emissions trading, the theoretical literature on beneficial tax incentives as well as direct subsidies is rather slim. Most of the existing literature in the field of beneficial tax incentives consists of empirical case studies on concrete tax incentives (see Section 2.4). This is also reflected in the current literature review.

Beneficial tax incentives are often discussed in the context of instrument choice for environmental policy (e.g. Goulder and Parry 2008). In many cases they are not discussed as an isolated instrument, but rather in the context of a combination of policy instruments in environmental policy. Kosonen and Nicodeme (2009) points out that under certain market imperfections, relying on a combination of instruments and applying e.g. also beneficial tax incentives may be less costly than relying on one pricing instrument alone.

The OECD has taken up the issue of environmental subsidies several times and has provided a comprehensive discussion of various conceptual aspects of beneficial tax incentives (e.g. Greene and Braathen 2014 or Duval 2008). An environmental tax relief or tax incentive is a government

[38] World Bank, 2019, The First International Research Conference on Carbon Pricing, cit. Stern, Nicholas. "Carbon tax design, the use of revenues and public acceptability;" LSE. Presented at CPLC Carbon Pricing Research Conference, New Delhi, India, February 2019.

measure that aims at steering expenditure of individuals and businesses away from environmental "bads" towards environmental "goods" by reducing the amount of tax that they have to pay (OECD 2011). Tax incentives thus imply that the government foregoes tax revenues to favour less polluting consumption and investment in order to achieve environmental policy goals and thus address positive externalities.[39] In other words, a tax incentive encourages behaviour that generates additional social benefits which would not have been created without the subsidy.

In its database documentation for the PINE[40] database the OECD defines environmentally motivated subsidies as follows:

> *"A subsidy is defined as environmentally motivated if it reduces directly or indirectly the use of something that has a proven, specific negative impact on the environment. … environmentally motivated subsidies consisting of payments from government to producers, or of preferential tax treatments with the objective of influencing the level of production, the price, or the remuneration of the factors of production. Environmentally motivated subsidies could take the form of a VAT exemption or another favourable tax treatment, such as the VAT exemption for electrical vehicles. …Other types of environmentally motivated subsidies would be grants or loans totally or partially financing projects or activities aimed at protecting or restoring the environment, nature preservation or conservation of environmental heritage. ….".*

This definition already gives an indication of the many ways in which environmentally relevant subsidies can be designed. However, it should be noted that the broader the policy objective and the more heterogeneous the sectors addressed, the more difficult it is to design a tax incentive suited for all.

Overall, there are several aspects that should be considered in the decision whether to implement tax incentives and how to design them. The following table is essentially based on Green and Braathen (2014) and summarises the aspects and arguments related to environmentally beneficial tax incentives discussed there.

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[39] The argument of positive externalities is also of relevance in connection with R&D spending, since the revenues from new technologies, despite patent protection, do not entirely flow to the original investor, R&D expenditures result in a level below the socially desirable level. For an overview see e.g. Hall and Van Reenen (2000).

[40] Policy Instruments for the Environment database. For the definition of environmentally motivated subsidies see http://www.oecd.org/environment/tools-evaluation/PINE_Metadata_Definitions_2016.pdf.

Table 2 Overview of findings on beneficial tax incentives

Tax incentives….	Explanation
do not internalise negative externalities into prices	Compared to environmental taxes that price negative externalities, tax incentives do not address the polluter pays principle.
can address true positive externalities	Tax incentives subsidise positive externalities. They encourage behaviour that generates additional social benefits which would not have been achieved without the subsidy. This applies in particular to R&D in general - not green technologies specifically - where positive innovation spill overs occur. Positive externalities can be relevant when the beneficial tax incentive contributes to reduce the risk for early adopters. Early adopters provide "learning by doing and use" information that can translate into lower costs for late adopters.
often attempt to "pick winners"	Since it is difficult to benefit all environmentally beneficial alternatives to the harmful activity, tax subsidies inevitably involve "picking winners", which may overrule other good alternatives. For example, a subsidy for low-emission vehicles does not provide any incentive for commuters to consider alternative forms of transportation such as public transport or cycling. The problem of "picking winners" can be mitigated if the tax exemption is linked to results or performance measures rather than inputs or specific technologies used. It can also lead to a rebound effect (see below under 'increased pollution').
are not well suited to address certain market failures	Preferential tax benefits are not appropriate for certain market failures, such as missing information on environmentally favourable alternatives, limited access to credit or a principal agent problem between landlords and tenants. Preferential tax incentives in such cases are likely to be costlier that other regulations, e.g. rental laws, information campaigns.
can lead to increased pollution	Tax reductions can lead to a rebound effect, as they make certain activities cheaper and thus possibly provide an incentive to increase the level of activity which then increases environmental harm. Support for more energy-efficient equipment can have a rebound effect if the new equipment is larger and thus offsets part of the efficiency gain.
require clear objective standards	The administrative costs of beneficial tax incentives depend on the implementation of clear and simple criteria on the eligibility for the preferential tax.
can cause windfall gains or "free riding"	Windfall profits are not specific to environmentally motivated beneficial tax treatment but apply to other government support as well. If beneficiaries would have undertaken the environmentally beneficial activity anyway costs are shifted from the private sector to the government sector. The more ambitious the standards and criteria for eligibility, the lower the probability of "free riders". Tightening the standards and eligibility over time can partly incentivise innovation.
require costly funding	Tax relief entails fiscal costs, as the lost tax revenue would have to be compensated by other sources of revenue. These costs should be made clear when designing tax relief schemes.

Tax incentives….	Explanation
are often less scrutinised than alternative policy instruments	Beneficial tax preferences, as tax preferences in general, are often perceived as permanent and often lack a regular evaluation. This calls for a close examination of whether this is the best policy instrument before being introduced.
may not be helpful to non-taxable entities	Only those will benefit from a beneficial tax preference who are liable to pay taxes. E.g. if the measure is aimed at reducing income tax, low incomes households that do not pay taxes may be excluded. In this case, the instrument lacks effectiveness.
may result in unwanted distributional effects	Especially picking winners as well as the exclusion of non-taxable entities can lead to non-desired distributional effects. Undesirable distributional impacts can also occur between higher-income and lower-income households if lower-income households do not have sufficient financial resources despite support. Also the design of a funding instrument has an impact on distribution. A tax allowance, for example, favours higher-income households more than lower-income ones
need to be coordinated with other domestic policies	Beneficial tax preferences are often seen as complementary measures and thus need to be embedded in an overall policy package.

Source: Green and Brathen (2014).

Compared to the discussion and theory on price incentives (taxes and emission rights), the literature on recommendations for the use of tax incentives, which can be derived from a theoretical perspective, is much less extensive.. Green and Brathen (2014) stand out with their paper and the clear discussion of the arguments. In contrast, beneficial tax incentives are often discussed as a complementary instrument in order to tackle specific environmental problems. Kosonen (2009) gives two examples: firstly, information costs that cannot be tackled by a tax alone or emissions that are difficult to measure or difficult to assign to individual emitters. Secondly, as already mentioned above, market barriers which are additional to external environmental effects. His argument is that a combination of instruments, such as a tax in combination with a tax relief, can achieve a policy objective at lower costs than a single tax.

In general, which policy instrument is ultimately chosen should be based on an analysis of different aspects, such as tax policy arguments, or how a specific policy objective can be achieved at the lowest cost and with the highest probability. Finally, aspects of political acceptance also play a role. In particular, a combination of a tax relief and an environmental tax can increase the acceptance of the latter.

2.3 Empirical evidence on the effects of GHG taxation

2.3.1 Methodological approaches

The number of studies analysing the effects of taxes directly or indirectly addressing carbon emissions on various outcome dimensions has been growing considerably during the last four decades. Meanwhile a large body of empirical studies has accumulated, which can be classified along various criteria.

First of all, very generally, as with most types of policy, also with regard to the effects of GHG taxation ex-ante and ex-post evaluations can be distinguished (Sachintha 2019). A "first generation" of empirical studies focusing on energy and emission taxes and starting in the beginning of the 1990s simulates the hypothetical effects of energy and/or emission taxes ex-ante prior to their implementation based on model simulations or other projection methods. A "second generation" of empirical analyses unfolding a decade later has been attempting to determine actual outcomes of energy and emission taxes ex-post, after their implementation, since the beginning of the 2000s. While the number of ex-post studies has been increasing recently, the vast majority of evaluations still consists of ex-ante analyses. As OECD (1997) states, ex-post analyses on the one hand have the advantage to yield more reliable results than ex-ante studies, as the latter generally need to rely on numerous assumptions when formulating specific simulation scenarios. On the other hand, as Andersen (2004) points out, the validity of results from ex-post analyses may differ as well, depending on the quality of data as well as the rigour and methodological approach they apply. Moreover, one important challenge ex-post studies are confronted with is to disentangle the effects of carbon taxes from other determinants (political measures as well as relevant economic developments) and thus to isolate the pure causal tax effect (Baranzini, Goldemberg and Speck, 2000).

Ex-ante analyses are based on model simulations conducted with a variety of models. The results of ex-ante simulations may differ due to differing model specifications, assumptions, data and simulated scenarios. In the context of attempts to determine macroeconomic effects of environmental taxes, including their potential impact on environmentally relevant variables as emissions and energy use, Freire-González (2018) distinguishes between macro-econometric models, input-output models, and applied computable general equilibrium (CGE) models, with the latter playing the most important role. In contrast, distributional analyses aiming at capturing the potential impact of environmental taxes on personal income distribution rest on micro-econometric simulation models or micro-economic projection schemes.

Existing ex-post evaluations of environmental taxes and tax reforms, respectively, are based on a variety of methodological approaches, ranging from qualitative methods (e.g. expert interviews) and descriptive statistics over case studies and simulation exercises to a variety of statistical and econometric approaches.[41] According to Andersen (2004), ex-post approaches may be separated in a first group requiring a baseline to be able to compare actual and projected developments (revealed behaviour) and a second group attempting at quantifying the impact itself (stated behaviour). Ex-post studies may also differ with regard to their scope: some aim at determining economy-wide effects, while others focus on specific branches (e.g. industrial firms) or sectors (households versus industry or firms). The results of ex-post evaluations may differ due to varying methodological approaches, data bases, and time periods studied. In addition, the effects of taxing GHG emissions may differ between countries due to different tax designs (regarding tax rates and base as well as exemptions), but also because of different general macroeconomic conditions (e.g. openness, productivity etc.) and specific framework conditions (e.g. energy mix, consumption and production patterns, transport infrastructure, energy policy etc.) (Andersen 2004).

Empirical analyses of GHG taxes may also be differentiated with respect to their geographical scope. Evaluation studies often cover a single country. Such case studies come in the form of ex-ante as well as ex-post evaluations. Besides, there are analyses for country groups, mostly EU Member States or the whole EU. These are almost always ex-ante analyses, while ex-post cross-country studies are very rare.

Finally, the theoretical effects of environmental taxes that are researched empirically differ between studies. Naturally, one central aspect studied empirically is the environmental effectiveness of environmental tax (dis)incentives, whereby their impact on GHG emissions is of particular interest. Also, further effects on the economy are evaluated, e.g. the impact of GHG taxation on GDP, output and employment. Another important question examined empirically is the distributional impact of GHG taxes. Furthermore, efficiency of environmental taxes is studied. Not the least important issue is social and political acceptability of tax measures to reduce GHG emissions. Many studies focus on one specific impact dimension associated with GHG taxation. Some studies analyse various effects jointly, particularly those examining whether GHG taxation may yield a double dividend (see Section 2.3.4.2). Thus, all theoretical aspects addressed in the section below have been examined empirically, with one exception, namely the administrative costs of GHG taxation, which is an under-researched area in the relevant empirical literature.

2.3.2 Environmental effectiveness of environmental tax (dis)incentives

Environmental taxes as instrument to reduce GHG emissions is a broadly studied area of research, both theoretical and empirical. A large part of the empirical literature reflects ex-ante studies, which are complemented by an increasing number of ex-post analyses, although their overall number is still small (Andersson 2019, Sachintha 2019). This lack of empirical ex-post evidence on the effectiveness of carbon taxes is problematic also because it restricts the diffusion of

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[41] See *Andersen* (2004) for a detailed discussion of various methodological approaches to conduct ex-post evaluations in the 1990s for the Nordic countries, which were the European forerunners regarding the introduction of carbon taxation.

experiences and knowledge gained on the effectiveness of climate policy instruments across countries (Carraro et al. 2015).

2.3.2.1 Elasticity of demand as crucial determinant of effectiveness of environmental taxes

The effectiveness of environmental taxes crucially depends on the price elasticity of demand, which reflects the relative change in the quantity demanded resulting from a change in prices. Empirical evidence on the size of price elasticities is still limited. Most of the existing evaluations focus on the price elasticity of demand for fuel or for energy. The results lie within a rather broad range, which can be explained by differing sample periods, types of publication, and estimation methods[42] (Labandeira, Labeaga and Lopez-Otero 2017).

Empirical estimations of the elasticity of motor fuel consumption suggest that the demand for fuel is highly inelastic particularly in the short run, while it is larger in the longer run and indeed leads to reduced fuel consumption (Sterner 2007). Dahl (2012) finds a price elasticity for gasoline consumption of -0.13 in the short and of -0.33 in the long run and for diesel consumption of -0.13 in the short and of -0.38 in the long run for 120 countries. Kettner-Marx and Kletzan-Slamanig (2018) estimate a price elasticity of -0.31% for gasoline and -0.16 for diesel for 22 EU Member States for the period 2004 to 2015. In their meta-study, Labandeira, Labeaga and Lopez-Otero (2017) stress that there are only few meta-studies summarising the results of existing research on fuel price elasticity and provide a brief overview over these meta-studies. The results of these studies for the short-run gasoline or car fuel price elasticity range between -0.09 and -0.76, for the long-run price elasticity between -0.31 and -1.16. In their own meta-analysis, the authors find a short-term price elasticity of -0.2 and a long-term price elasticity of -0.6 for diesel, while the average price elasticity for gasoline is about -0.2 in the short run and -0.7 in the long run. These results confirm those of earlier studies according to which the short-term price elasticity for fuel lies between -0.1 and -0.25, while the long-run price elasticity reaches about -0.7 on average (Graham and Glaister 2002, Goodwin et al. 2004). For the example of the carbon tax levied in British Columbia Rivers and Schaufele (2015) demonstrate a higher impact on fuel demand compared to equivalent market price changes, thereby confirming results derived by Li, Linn and Muehlegger (2014) for the US.

There are numerous papers estimating energy price elasticities, whereby studies for EU Member States are rather scarce and primarily exist for the front-runner carbon pricing Nordic countries (Kettner-Marx and Kletzan-Slamanig 2018). Enevoldsen et al. (2007) arrive at an energy price elasticity for the Swedish industry of -0.44 and of -0.38 for the Danish industry in the period 1991 to 2001. For Denmark, Bjorner and Jensen (2002) find an energy price elasticity for energy-intensive firms of -0.2 and of -0.7 for the remaining industry, yielding an average energy price elasticity of -0.44. The estimate provided by Enevoldsen et al. (2007) is of a similar magnitude, with an energy price elasticity of -0.38 for the Danish industry in the period 1991 to 2001. In their meta-analysis, Labandeira, Labeaga and Lopez-Otero (2017) find that on average estimations of the price elasticity of energy demand arrive at an elasticity of -0.22 in the short run and of -0.65 in the long run.

Finally, it should be noted that empirical evidence suggests that demand may react more sensitive to long-lasting carbon taxes than to short-term price fluctuations (Davis and Kilian 2011, Baranzini and Weber 2013, Li et al. 2014, Andersson 2015). Information on the permanent nature of carbon pricing mechanisms may thus strengthen their effectiveness by reducing uncertainty about future

[42] The authors provide a brief overview over the various estimation procedures applied in the literature to determine energy price elasticities.

prices for investors and households (Antweiler and Gulati 2015). Allcott and Rogers (2014) show, based on experimental studies, that the impact of carbon pricing could be reinforced by providing information to households and firms about emission reducing opportunities. Also complementary mechanisms to overcome information failures and bounded rationality can support an effective reaction of private actors to carbon pricing and tax incentives promoting low-carbon decisions and behaviour (Baranzini et al. 2017). There is also empirical evidence suggesting that carbon pricing does not lead to reduced climate-friendly behaviour, but on the contrary to "motivational crowding in".[43]

2.3.2.2 Impact of carbon taxes on emissions

The environmental effectiveness of carbon taxes, as measured by their impact on carbon emissions, has been studied based on ex-ante model simulations as well as by ex-post econometric evaluations. While the former still dominate the existing body of empirical studies, the growing number of countries that have introduced some form of GHG taxation has brought along an increasing number of ex-post analyses on the environmental effectiveness of GHG taxation.

Most ex-ante simulations focus on the Nordic countries and a few other countries that introduced carbon taxation or some other form of environmental taxes or tax reforms rather early. Such ex-ante simulations either attempt at quantifying the effects of governments' actual tax reform plans, as part of an ex-ante impact assessment, or of hypothetical tax proposals that in many cases have never been implemented, at least not in the proposed design.[44] These studies generally estimate rather sizeable effects of such taxes and tax reforms, respectively, and had a dominant role, compared to ex-post evaluations, in the 1990s. According to Speck et al. (2006), for example, the Danish Environmental Protection Agency estimated that the Danish carbon tax would reduce emissions by 24% in the period 1990 to 2011 vis-à-vis a business-as-usual scenario. Recently O Brion et al. (2019), utilising the residential sector's price elasticity of demand for energy estimate that had France, Germany, Italy, Spain and the UK introduced a carbon tax according to the example of Sweden in 1997, demand for fossil fuels would have been reduced at least by 10% to 20%, implying a yearly GHG decrease of a minimum of 60 Mt carbon equivalents.

Already in the 1990s a few ex-post evaluations were carried out, mostly for the Nordic forerunner countries Norway, Sweden and Denmark, which introduced carbon taxes as early as 1991 and 1992, respectively.[45] Andersen (2004) provides a brief summary of ex-post evaluation studies unanimously demonstrating that the carbon tax indeed reduced emissions in Sweden and that the carbon tax reduction for the industry implemented in 1993 resulted in a carbon emission increase. For Denmark, redistributing its carbon tax revenues to the industry to finance energy efficiency improving measures and conditioning reduced tax rates for energy-intensive processes on agreements with firms on energy savings, early ex-post studies show relatively sizeable emission-reducing effects in the industry (Andersen 2004). In the first five years, 20% of the revenues from Denmark's carbon-energy taxation were earmarked to support energy-efficiency measures and upgrade production technologies. According to an ex-post assessment by Bjorner and Togeby (1999), the energy savings achieved by firms participating in this energy savings programme were larger by 60% on average compared to the firms that paid the tax only. Larsen and Nesbakken (1997) show a decrease of household sector emissions in Norway by 3% to 4%

[43] See Baranzini et al. (2017) for a brief overview over relevant empirical analyses.
[44] See Köppl et al. (1996) for an early example for Austria.
[45] Actually, Finland was the first (Nordic) country to introduce a CO2 tax in 1990 already; however, probably due to the initially low level of the tax, there are no early ex-post evaluations (Andersen 2004).

between 1991 and 1993, while (because of numerous exemptions) the tax was much less effective in the industrial sector, where emissions were reduced by 0.5% only.

The bulk of ex-post studies, however, was conducted after the beginning of the new century. During the last 20 years, an increasing body of ex-post studies has emerged estimating the impact of environmental/carbon taxation on emissions, many of them focusing on EU countries. As mentioned above, for the EU, ex-post analyses concentrate on the Nordic countries as frontrunners in carbon taxation. Brännlund et al. (2014) study the environmental performance of the Swedish industry at the firm level, finding an improvement in all industry sectors examined, which suggests a decoupling of production growth and carbon emissions mainly driven by the Swedish carbon tax. Most recently, Andersson (2019) finds that the Swedish carbon tax and a value-added tax on transport fuel reduced carbon emissions in the transport sector by almost 11%; with the carbon tax alone accounting for a reduction of 6%. Using various econometric methods, Runst and Thonipara (2020) show that the augmentation of the Swedish carbon tax in the early 2000s, implying an increase of the carbon tax rate from around 40 € to 100 € per ton of carbon emitted between 2001 and 2004, significantly reduced carbon emissions also in the residential sector: from 200 kg per capita per year compared with other countries applying a carbon tax at a rate above 20 € to 800 kg compared with no-carbon-tax countries. One central finding of this analysis is that the effectiveness of the carbon tax crucially depends on its level.[46]

For Finland, Sairinen (2012) reports that a government working group on environmental taxation found that carbon and energy taxation decreased carbon emissions between 1990 and 1998 by over 7%.

According to the ex-post analysis provided by Enevoldsen et al. (2005), the energy productivity of the Danish industry was increased by 30% during the first decade of carbon-energy taxation – two to three times as much compared to comparable European countries without carbon-energy taxation. Moreover, carbon emissions were decreased by almost 10% compared to a business-as-usual-scenario. Without carbon taxes and energy investment subsidies, industrial CO2 emissions in Denmark would have been about 13% to 17% higher.

Bruvoll and Larsen (2004) find a rather modest decrease of CO2 emissions induced by the carbon tax in Norway, amounting to 2.3% in the period 1990-1999. According to the authors, the rather small emission-reducing effect of the Norwegian carbon tax identified in this study is due to the generous exemptions for fossil fuel-intensive industries.

Using a common methodological framework, the synthetical control method, for the four Nordic countries Denmark, Finland, Norway and Sweden, Sachintha (2019) finds that Norway has experienced the highest per capita emission reduction through its carbon taxes, followed by Sweden.[47] The emission reducing effects of the Finnish and Danish carbon taxes, however, are less clear according to this analysis. These findings somewhat differ from that of an earlier study by Lin and Li (2011, that based on the difference-in-difference-method shows that carbon taxation in Finland had a significant negative impact on the growth of CO2 emissions per capita, while the impact of the carbon tax in Denmark, Sweden and the Netherlands were also negative, but not significant. The authors explain this finding by generous exemptions for energy intensive industries.

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[46] This finding confirms the result of the earlier study by Aydin and Esen (2018) for 15 EU member states, according to which environmental taxes have to exceed certain thresholds to be environmentally effective.

[47] It should be noted that the study focuses on national emissions, not on the emissions in the sectors subjected to carbon taxation.

According to the ex-post assessment based on modelling with E3ME conducted by Barker et al. (2009a and 2009b), carbon-energy taxes implemented within environmental tax reform in Europe reduced greenhouse gases by 4% to 6% in the Nordic countries (Denmark, Finland, Sweden) and Germany between 1995 and 2004 compared to a business-as-usual-scenario, primarily resulting from a decrease in fuel demand. The greenhouse gas reductions achieved in the Netherlands and the UK amounted to about 2%, as these countries implemented their environmental tax reforms later and at less ambitious levels.

Outside the EU, the carbon tax implemented in British Columbia in 2008 has attracted some interest in empirical research on the effectiveness of carbon taxation. Murray and Rivers (2015) provide a review of empirical ex-post assessments suggesting that the carbon tax effectively reduced carbon emissions in British Columbia. The tax level had arrived at C$30/t CO_2 emissions and covered about three quarters of all GHG emissions in the Canadian province. According to empirical evaluations and model simulations, the carbon tax has decreased emissions in the range of 5% to 15% since its implementation. Rivers and Schaufele (2015) demonstrate that the carbon tax reduced fuel demand to a greater extent than equivalent market price changes. For Switzerland, Ecoplan (2017) estimates, based on a time series analysis, that between 2008 and 2015 the Swiss carbon tax resulted in a carbon emission reduction of 6.9 million tons (4.4% of combustion emissions).

To date, there are only a few cross-country empirical studies on the effectiveness of carbon pricing. One challenge when attempting to assess the effectiveness of carbon taxation in a cross-country comparison is the availability of data on effective tax rates which are comparable across countries, account for tax exemptions, and cover all sectors and energy sources. Sen and Vollebergh (2016) estimate the long-run effectiveness of a uniform carbon tax on energy consumption using a new and unique dataset containing effective tax rates of OECD countries related to carbon dioxide emissions across different energy user and resource categories and including all taxes directly or indirectly addressing carbon emissions. Their approach has several advantages. First, it allows to study the impact of taxes on energy consumption directly; in contrast to many previous studies using energy prices as a proxy for energy taxes. Second, in contrast to nominal tax rates, these effective tax rates account for tax exemptions. Third, the effective tax rates are comparable across countries, which allows to analyse their impact on energy consumption in a cross-country perspective. Finally, they are also comparable across energy use and resource categories, thus capturing the carbon content of the entire energy tax base. The authors find that taxing the carbon content of energy use in OECD countries effectively reduced carbon emissions. In a recent study, Best et al. (2020), based on various econometric modelling approaches, analyse the effectiveness of carbon pricing in decreasing national carbon emissions from fuel combustion for 142 countries over a period of 20 years. Of these 142 countries, 43 applied a carbon price by the end of the period analysed. The authors find that on average carbon pricing decreased the annual carbon emissions growth rate by about two percentage points compared to no-carbon-pricing countries. Increasing the carbon price by one euro per ton of carbon emissions reduces the subsequent annual emissions growth rate by around 0.3 percentage points. Also recently, Aydin and Esen (2018) show that energy and transport taxes in 15 EU countries were able to significantly reduce emissions in the period from 1995 to 2013 when they were above certain thresholds.[48] Of interest is also the analysis provided by Best and Burke (2018), which studies EU member states and a sample of additional countries to show that

[48] For energy taxes, including carbon taxes, the threshold level is 2.2%; at this threshold level the effect on carbon emissions changes from insignificantly positive to significantly negative.

carbon pricing changes the energy mix away from higher-emission energy sources towards lower-emission energy sources such as wind power.

Altogether, there is an increasing number of ex-post studies demonstrating that carbon taxes can effectively reduce carbon emissions or at least dampen their growth. The existing empirical results for individual countries differ somewhat due to differing methodological designs and approaches as well as databases used; and also the time period covered matters (Andersen 2004).[49] These factors also determine cross-country differences in the empirical results regarding the effectiveness of carbon taxes. In addition, the tax design as well as differing economic conditions (including the structure of the energy system and the availability of low carbon alternatives) influence the effectiveness of carbon taxes. Moreover, regardless of the rather broad range of estimates concerning the size of the emission-reducing effects, the existing empirical research suggests that the order of magnitude of the effects is insufficient to reach current medium- and long-term emission goals as stipulated in international and national agreements and plans, which may have to do with the fact that in most countries tax rates are rather moderate.

Finally, it is of interest whether carbon taxes or cap-and-trade systems are more effective to contain carbon emissions. Based on a review of recent empirical studies researching the effectiveness of carbon taxes and emission trading systems, respectively, Haites (2018) concludes that these do not allow to rank the two instruments with regard to their environmental effectiveness. They should rather be viewed as "… components of a portfolio of mitigation policies rather than as alternative 'first best' policies." (Haites, 2018: 963).

Box 1 Vehicle Taxes

In theory, under the assumption that consumers are far-sighted, the optimal instrument to decrease carbon emissions from transport is a fuel tax, as carbon emissions per litre of fuel are known (Anderson and Sallee 2016).[50] However, myopia from the side of consumers causing them to insufficiently consider future fuel savings from improved fuel efficiency may require additional tax instruments (Koch et al. 2019). Empirical evidence on the existence of myopia of consumers tending to undervalue fuel savings through low-emission cars does not yield clear-cut results. However, existing studies suggest that future fuel savings may at least be modestly undervalued.[51] Vehicle taxes complementing fuel taxes put a price on inefficient vehicles and provide incentives for more efficient ones.

A comprehensive set of vehicle taxes addressing carbon emissions rests on three pillars. Conventionally, the relevant literature identifies two pillars, namely fuel and vehicle taxes, as elements of a second-best taxation of vehicles (Bjernaes 2017), with vehicle taxes equalling the social costs of future emissions minus the part of social costs internalised by the fuel tax (Innes 1996).

Summarising recent empirical analyses for the effects of fuel taxes as the first pillar of vehicle taxation, Koch et al. (2019)[52] point out that higher fuel prices improve vehicle fuel efficiency by inducing consumers to buy more fuel efficient as well as smaller and lighter vehicles. Frequent drivers and diesel car drivers react particularly sensitively to fuel taxes, as well as the demand for trucks and SUVs. Fuel taxes may also incentivise consumers to scrap old inefficient vehicles and to keep newer and more efficient vehicles for a prolonged time period. Their effect on fuel economy is larger in the US compared to Western Europe. At the same time, fuel price elasticity of distance travelled is larger in Europe than in the US.

[49] See also section 3.2.1.
[50] See Bjertnaes (2017) for the theoretical foundations of vehicle taxation.
[51] See Yan and Eskeland (2018) and Koch et al. (2019) and the literature cited therein.
[52] See Koch et al. (2019) for references.

Vehicle taxes as second pillar of vehicle taxation comprise car purchase (registration) taxes and annual vehicle circulation taxes. Grigolon et al. (2018) find that regardless of consumer myopia, vehicle taxes have an impact on the structure of sales of new vehicles in Europe. Ryan et al. (2009) study vehicle taxes in EU15 countries for the period 1995 to 2004. The authors find that total new passenger car sales are strongly influenced by annual circulation taxes. The average CO_2 emissions intensity of car fleets is determined by the price of petrol fuel as well as the circulation tax for petrol and diesel cars, the latter reducing total new car sales and reducing the overall carbon intensity of new cars. In contrast, the car purchase tax does not have an important influence on the CO_2 emissions intensity of the new passenger car fleet. The authors' results also suggest that raising the diesel vehicle circulation tax can lead to an increase in the share of the (less fuel efficient) petrol vehicles and thus an increase in carbon emissions. According to Runkel et al. (2018), an annual circulation tax may again be undervalued by myopic consumers, as it may be reformed in the future and the car holding period is uncertain, while a car purchase tax represents upfront costs payable at the time of purchase and is therefore much more salient for buyers. Similarly, Yan and Eskeland (2018) show stronger effects of a car purchase tax compared to a circulation, when the former is based on CO_2 emissions. Nonetheless, many countries apply both a purchase tax and an annual circulation tax, as the latter provides regular revenues and is thus advantageous from a budgetary perspective.

In many European countries, vehicle taxes have been reformed since the beginning of the 2000s and are now often based on vehicles' carbon emission intensity. The studies by Gallagher and Muehlegger (2011), Haultfouille et al. (2014), Alberini and Bareit (2019), Gerlagh et al. (2018), Malina (2016) and Klier and Linn (2015) suggest that carbon-based registration taxes are more effective in reducing the carbon intensity of new vehicles than carbon-based annual circulation taxes.

The taxation of company cars can be regarded as third pillar of vehicle taxation. In principle, the private use of a company car is to be taxed as benefit in kind. However, in most European countries, the actual benefit accruing to users of company cars is considerably higher than the taxable benefit in kind (Runkel et al. 2018). Therefore, company car taxation often represents an environmentally harmful tax incentive, promoting the purchase and use of larger and more expensive cars (Harding 2014, Damert and Rudolph 2018) and benefiting higher incomes over-proportionally. Introducing environmental elements into company car taxation (emission intensity, distance travelled privately, fuel efficiency) would contribute to a vehicle taxation mix aiming at the reduction of carbon emissions.

COWI (2002) point out that effective vehicle taxation requires a combination of various specific taxes. To influence carbon emission intensity of new cars, vehicle taxes are more effective than fuel taxes. The latter are more effective to curb mileage driven and to promote efficient driving behaviour.

Obviously, transport causes other externalities besides carbon emissions. These range from greenhouse gas emissions other than carbon emissions over road congestion and local air pollution to accidents. The internalisation of these externalities calls for additional instruments including pricing mechanisms (e.g. road pricing or congestion charges) and regulatory instruments (Koch et al. 2019). In this context, Bjertnaes (2017) argues for a combination of a fuel tax and heavier taxes on fuel-efficient vehicles to decrease externalities from road traffic, as otherwise drivers avoid the road use element of the fuel tax by buying fuel-efficient vehicles.

Increases in fuel taxes are often associated with distributional concerns. However, recent empirical results suggest that generally fuel taxes have only weak regressive or even progressive distributional consequences (Kosonen and Nicodème 2012). Potential negative impacts could be overcome by redistributing revenues back to households via lump-sum transfers (Bento et al. 2009, Tovar Reanos and Sommerfeld 2016).

2.3.3 Cost efficiency of carbon taxation

Cost efficiency can be measured in terms of abatement costs, i.e. the costs accruing to economic actors when trying to avoid one tonne of carbon emissions. The 2013 OECD report on "Effective Carbon Prices" calculates abatement costs per tonne of carbon emissions associated with different environmental policy instruments for two sectors. For the electricity sector, emission trading and tax incentives cut carbon emissions at very low cost, while abatement costs are rather high for capital subsidies and feed-in tariffs. In the transport sector, fuel taxes are most cost effective, with fuel mandates and capital subsidies being associated with substantially greater abatement costs.

2.3.4 Macroeconomic effects of environmental taxes

The effect of environmental taxes on the economic performance has been a debated issue right from the beginning. Often fears concerning a negative impact of environmental taxes on key macroeconomic variables, as GDP or employment were voiced in the theoretical and political debate, making governments reluctant to implement environmental taxes. The theoretical reaction to such fears was the formulation of the double dividend hypothesis, stating that recycling carbon tax revenues via reducing other, more distortive taxes (e.g. labour taxes or social security contributions) might bring about simultaneous environmental and economic benefits. We first present some empirical research on the economic impact of environmental taxes, before summarising empirical evidence regarding the double dividend hypothesis.

2.3.4.1 Effects of environmental taxes on macroeconomic performance

The macroeconomic impact of environmental taxes is subject of numerous empirical studies. Generally, the isolation of the economic effects of carbon taxes from those of other policy instruments is challenging, particularly in those cases where – as in the Nordic countries – carbon taxes were introduced as element of more comprehensive environmental tax reforms (Kettner-Marx and Kletzan-Slamanig 2018). Generally, the separation of the effects of carbon taxes on the economy from those of other environmentally relevant measures (e.g. public investment programmes, subsidies, standards, etc.) also implemented in the time period analysed is methodologically difficult. This is a challenge also for empirical research on the double dividend hypothesis (see next section).

For the Danish environmental tax reform implemented in 1992, the Danish Ministry of Finance identifies a positive, but rather small effect on growth, at 0.3% of GDP for the period 1990 to 1995 (IEEP 2013). Andersen et al. (2007) find that the reform increased employment by 0.5% annually between 1994 and 2012. Infras and Ecologic (2007) identify only short-term positive employment effects, with (albeit negligible) negative medium-term effects. For Finland, Andersen et al. (2007) arrive at an average annual GDP enhancing effect of 0.5% between 1994 and 2002; for Sweden they find a long-term annual increase of GDP in the same order of magnitude accompanied by a growth in employment. According to a study by Martin et al. (2014), carbon pricing in the United Kingdom did not negatively affect manufacturing employment and revenue. For France, Dussaux (2020), using data for 8,000 firms representative for the French manufacturing sector for the period 2001 to 2016, shows that increasing energy prices and carbon taxation decreased energy use and carbon emissions without reducing net employment at the industry level. According to an ex-post evaluation based on the E3ME model of the environmental and economic effects of the environmental tax reforms implemented in seven EU member states (Denmark, Finland, Germany, the Netherlands, Slovenia, Sweden, and the UK) between 1990 and 2002, these reduced CO2 emissions in all member states with the exception of Slovenia, without harming GDP growth (Barker et al. 2009a). For the same group of countries, the results of the analysis by Enevoldsen et al. (2009) neither confirm the existence of a strong double dividend nor of negative economic effects. Murray and Rivers (2015) in their review of ex-post empirical studies find no significant impact on economic growth for the carbon tax levied in British Columbia. As the concrete design of carbon taxation in these countries varies (e.g. with regard to revenue use, exemptions for certain sectors, level and long-term trajectory of tax rates, etc.), it is difficult to identify the factors behind the overall positive or at least neutral effects on macroeconomic performance without further in-depth analysis. However, the results of the studies included in Andersen and Ekins (eds.) (2009) suggest that full revenue recycling via reducing social security contributions and the income tax is the or at least one key factor.

Another economic aspect is pointed out by Haites (2018), who compares existing carbon taxes and cap-and-trade-systems. He finds that while for the existing carbon taxes rates generally are specified only for a period of three to five years, so that a longer-term rate trajectory is missing, existing emission trading systems often specify annual reduction targets for a longer period in the future, thus providing a more stable and certain medium-term framework for tax subjects with regard to abatement investment. However, quantity-based pricing systems bear the risk of price volatility that can result in uncertainty on abatement investment. Carbon taxes based on a longer-term tax rate trajectory credibly implemented by the government may be advantageous compared to cap-and-trade-systems, as they provide planning security to businesses.

2.3.4.2 The double dividend hypothesis

The findings in the theoretical literature on the double dividend hypothesis are ambiguous, as an extensive survey provided by Freire-González (2018) shows: they range from the limited number of studies over the heterogeneity of empirical approaches, differing assumptions, data and scenarios to structural factors, as the existing tax structure and design of taxes, socio-economic conditions etc. (see section 2.2.3.1). The same is true for empirical research attempting at identifying double dividends of environmental tax reforms. Almost immediately after the double dividend hypothesis had been put forward by Pearce (1991) and Goulder (1995), economists set out to examine it with modelling studies. Early surveys provided by the IPCC (1995, 2001, 2007) deliver ambiguous results of ex-ante research of the double dividend hypothesis.

Ex-ante studies often use General Computable Equilibrium (CGE) models. An early example are the simulations by Felder and van Nieuwkoop (1996) which demonstrate that implementing a carbon tax and using the proceeds to reduce labour taxes in Switzerland would result in a significant simultaneous decrease of carbon emissions and an increase in employment and GDP. A recent study by Groothuis et al. (2016) for 27 EU Member States (EU27 without Croatia) simulates a tax shift from labour taxes towards taxes on natural resources and consumption using the macro-econometric E3ME model. A gradual shift within the period 2016 to 2020 would raise employment by 3% and GDP by 2%; water and energy use as well as carbon emissions would decline by more than 5%.

The ex-post analysis by Yamazaki (2017) suggests that the carbon tax recycling schemes applied in British Columbia had a positive impact on employment, thus supporting – similarly to the analysis by Murray and Rivers (2015) – the double dividend hypothesis.

In a recent review of 40 studies delivering altogether 69 different simulations of environmental tax reforms done with CGE models from 1993 to 2016, Freire-González (2018), using a statistical and a meta-regression analysis, finds that almost all environmental tax reforms simulated (about three fourth of which use carbon taxes, while one fourth apply energy taxes) are environmentally effective. However, a double dividend in terms of a simultaneous improvement of environmental and economic conditions is demonstrated by only 55% of the simulations (i.e. 38 simulations) included in the review. The review suggests that key to achieving a double dividend is the recycling instrument used in simulations. Accordingly, revenue recycling via reducing social security contributions is most effective (9 out of 10 simulations show a double dividend). Also, recycling via reducing taxes on labour income, capital taxes and other taxes mostly creates a double dividend, while lump-sum transfers generate a double dividend in only 10% of simulations. These empirical results corroborate Goulder's (1995) distinction between a strong, intermediate and a weak double dividend hypothesis (see section 2.2.3.1):

Maxim, Zander and Patuelli (2019) conduct a meta-regression analysis of simulation studies exploring the hypothesis of an employment double dividend, differentiating between European and non-European countries. A central finding of this meta-analysis is that both tax and recycling policies are important determinants of an employment double dividend, and that the optimal policy mix differs for European and non-European countries, requiring region-specific policy design.

Somewhat related to the double dividend hypothesis by (implicitly) building upon it is the "taxing for growth" debate that has been initiated by the OECD and gained momentum in the aftermath of the 2008 financial and economic crisis. This debate is based on empirical research demonstrating that a revenue-neutral tax shift away from labour towards other revenue sources may help to stimulate growth and to increase employment and investment (Arnold 2008, Arnold et al. 2011). It is generally considered that some types of tax bases are less detrimental to growth, in particular consumption taxes, recurrent housing taxes and environmental taxes. Possible employment gains by substituting distorting taxes on labour through revenues from environmental taxes have been labelled as "third dividend" in the literature (Freire-González 2018). However, some recent economic literature points to heterogeneity of responses, non-linear effects and differences in amplitude between the short-term and long-term effects. In their empirical analysis Baiardi et al. (2019) show that these results are only valid for the specific sample of countries and time period but are not robust to a different estimation set up. Analysing also short run effects they cannot find a growth-enhancing effect of a shift in the tax structure. These results, inter alia, underline the fact that the detailed design of a tax is at least as important as the type of tax and the tax base, respectively.

2.3.5 Impact on competitiveness and innovation

Potential impacts of carbon taxation on competitiveness and innovation are further economic aspects of interest. For carbon pricing in general, Ellis et al. (2019) conclude that ex-ante and ex-post analyses lead to contradicting results. Most model-based ex-ante simulations demonstrate that unilateral carbon pricing negatively impact competitiveness (Carbone and Rivers 2017). In contrast, most ex-post studies fail to identify statistically significant effects on various dimensions of competitiveness. Empirical ex-post evidence on the impact of carbon taxes on competitiveness is scarce. Salmons and Miltner (2009) cannot find evidence for a general loss of competitiveness for seven EU countries (Finland, Denmark, Sweden, Germany, the Netherlands, the UK and Slovenia) in the period 1990 to 2002 resulting from introducing environmental tax reforms. A review of the few existing empirical ex-post analyses provided by Arlinghaus (2015) finds that carbon taxes impair competitiveness to a small extent only, if at all.

The empirical evidence on the existence of carbon leakage is ambiguous, also because it is hard to be detected empirically. Again, ex-ante and ex-post studies on carbon leakage rates differ.[53] Moreover, there is only few empirical evidence specifically on carbon leakage related to carbon

[53] Zhang (2012) discusses the reasons for differences between ex-ante and ex -ost estimations of carbon leakage rates.

taxes. Various model simulations show that unilateral carbon pricing may cause international carbon leakage (e.g., Böhringer et al. 2012; Fowlie, Reguant, and Ryan 2016; Fischer and Fox (2012[54]). Some recent econometric analyses support these results. For example, Aichele and Felbermayr (2015) conclude that the Kyoto Protocol was indeed responsible for carbon leakage. For the US, Casey et al. (2020) show that state-level carbon pricing reduces employment, output and profits in the regulated state and increases them in nearby states. According to the meta-analysis by Branger and Quirion (2014) which covers 25 studies carbon leakage estimates range from 5% to 25% without policy; border carbon adjustment reduces leakage by 6 percentage points.

For the EU ETS, the few studies conducted up to now were not able to find empirical support for the theoretical expectation that it would cause carbon leakage. Naegele and Zaklan (2017), for example, do not find evidence for carbon leakage in European manufacturing induced by the EU ETS, thus corroborating the results of several earlier empirical ex-post analyses. Also, the brief overview by Joltreau and Sommerfeld (2019) over recent studies shows that up to now there is no convincing evidence for the existence of carbon leakage caused by the EU ETS. However, this finding could be explained by the low or zero emission costs the EU ETS imposed on firms during the first decade of its operation. As Lowe (2019) and Joltreau and Sommerfeld (2019) point out, more stringent emission-reducing policies in the EU, as planned for example within the European Green Deal, may well lead to carbon leakage in the future. The results of the ex-post assessment of environmental tax reforms in seven EU member states (Denmark, Finland, Germany, the Netherlands, Slovenia, Sweden, and the UK) performed by Barker et al. (2009a, 2009b) suggest that these tax reforms neither impaired the competitiveness of the respective countries vis-à-vis other member states, nor did they lead to carbon leakage.

The innovation effects of green policies in general have been researched by numerous empirical studies.[55] There is also some empirical evidence for positive innovation effects of carbon pricing schemes (see, e.g. Martin et al. 2013 and Calel and Dechezlepretre 2016 for the EU ETS). Popp (2006), using patent data, finds that energy prices have the most important inducement effect on innovation. According to Ley et al. (2016), a 10% increase in energy prices in OECD countries leads to an increase of the number of green innovations by 3.4% and of the ratio of green to non-green innovation by 4.8%. The ex-post assessment of environmental tax reforms in seven EU member states (Denmark, Finland, Germany, the Netherlands, Sweden, and the UK) conducted by Enevoldsen et al. (2009) provides indication of innovation effects in industry. According to the evaluation of the Swedish carbon tax for the period 1990 to 1995 by Bohlin (1998), the carbon tax combined with investment support policies resulted in a shift in the district heating sector from coal to bioenergy (forestry residue), while no effect in the transport and electricity sector can be found. Bruvoll and Larsen (2004) identify a fuel switch in heating, from fossil fuel to electricity, for the period 1990 to 1999 caused by the Norwegian carbon tax, which delivered a contribution of -1% to the (modest) overall CO2 emission reduction of 2.3%. Aghion et al. (2016), using firm-level panel data on auto industry innovation for 80 countries over several decades, find that higher tax-inclusive fuel prices encourage auto industry innovation towards clean (e.g. electric and hybrid) patents. Hereby, it should be noted that empirical research suggests (see, e.g., Popp 2002) that to induce innovation, the carbon price should be rather high, and there should be a credible future path for a high and stable carbon price (Laing et al. 2013).

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[54] See also the brief review of model-based ex-ante simulations in Condon and Ignaciuk (2013) and Naegele and Zaklan (2017) and the references cited therein.

[55] See Joltrau and Sommerfeld (2019) for a brief overview over empirical analyses.

Lilliestam, Patt and Bersalli (2020) review ex-post analyses for the EU, New Zealand, British Columbia, and the Nordic countries exploring the effectiveness of carbon pricing in promoting innovation and diffusion of the new technologies required for full decarbonisation. This review leads to the overall conclusion that so far there is no convincing empirical evidence suggesting a positive impact of carbon pricing on the necessary technological change. Hereby, however, it has to be noted that the review focuses on the innovation effects of emissions trading, while considering just a very small number of evaluations examining the effects of carbon taxes on technological change.[56] Moreover, the overall conclusion of the review is also the result of a very small number of studies explicitly studying the effect of carbon taxes on technological change and innovation.

2.3.6 Distributional implications

The distributional consequences of environmental / carbon taxes have been the subject of empirical studies for three decades now. Recently they have gained increased attention, against the background of massive protests by citizens in several countries (e.g. France or Iran) as a reaction to the introduction or increase of taxes aiming at the reduction of GHG emissions.

Generally, the existing empirical evidence suggests that the distributional impact of carbon taxes depends on the energy sources taxed and the indicators used to capture distributional effects (Kirchner et al. 2018). Two indicators are used in empirical research to identify the distributional effects of environmental / GHG related taxes: while income-based indicators reflect the distribution of the tax burden across income groups, expenditure-based indicators measure the tax burden relative to expenditure.

Kirchner et al. (2018) identify three groups of empirical approaches to study the distributional effects of carbon taxes, differing with regard to the indicators they use to determine the distributional impact as well as the analysed effects. A first group comprises empirical analyses making use of household consumption surveys or micro-simulation models, while a second group is based on static input-output models with household data or micro-simulation models. Both groups of approaches usually assess the tax burden relative to income or expenditure. A third group of studies simulate macroeconomic feedbacks, e.g. CGE or macroeconomic input-output models, measuring distributional consequences in terms of changes in equivalent variation or as changes in household expenditure and income.

The following review summarises the most important results from the rather extensive body of empirical analyses that has developed since the beginning of the 1990s.[57] Hereby we first present studies examining the distributional consequences of carbon taxes. In addition, analyses researching the distributional effects of compensation measures for households are summarised.

2.3.6.1 Distributional effects of carbon taxation

There are numerous empirical studies, based on different methodological approaches, showing that generally, carbon taxes pose an over-proportional burden on low income households compared to higher income groups.

Callan et al. (2009) survey earlier macroeconomic and micro-simulation studies conducted in the period 1991 and 2008, concentrating on high-income countries. Despite country-specific

[56] For example, the review ignores the analyses by Enevoldsen et al. (2009) and Aghion et al. (2016) reviewed in this section.
[57] This review is based on Kirchner et al. (2018), who provide a more detailed presentation of methodological approaches and issues as well as additional empirical literature.

differences, carbon taxes generally turn out to be regressive in most countries: they result in rising energy prices, which over-proportionately burdens poorer households who spend a higher share of their incomes on energy consumption. Callan et al.'s own model simulations for Ireland identify a regressive impact of carbon taxation.

Earlier studies for the US find regressive effects for taxes on transport fuel (e.g. Poterba 1991). Kosonen (2012), focusing on the Nordic countries, reviews the literature on the distributional implications of environmental taxes and concludes that these differ for different taxes. The author's survey shows that in contrast to taxes on transport fuels, taxes on heating and electricity are associated with a regressive impact, as the shares of expenditures for heating and electricity are decreasing with income, while the shares of expenditures for fuel are lower in the low income range and then are growing with income. These findings are supported by the study by Sterner (2012) who examines the distributional effects of energy taxes on transport fuels in 7 European countries (France, Germany, United Kingdom, Italy, Serbia, Spain and Sweden). A (very weak) regressive effect on an income basis can be identified for Sweden and Spain only, while for the other countries the tax burden is proportional across income groups. Based on lifetime incomes, even this very weak regressive effect disappears; and it does not occur at all in Serbia as the poorest country in the group analysed. In an extensive survey of empirical research for G20 countries McInnes (2017) also finds that generally transport fuel taxation is progressive in most countries, while taxes on heating fuels are mildly regressive and taxes on electricity are clearly regressive.

Flues and Thomas (2015) study the distributional effects of energy taxes in 21 EU countries. Their findings suggest that taxes on transport fuels on an expenditure basis generally are not regressive, which may be explained by the fact that car ownership is less widely spread in the lower expenditure deciles. Energy taxes affecting heating fuels generally tend to be mildly regressive, while taxing electricity has more marked regressive effects. The only EU country levying a substantial carbon tax that is included in the study is Finland. With respect to transport fuel, the Finnish carbon tax is found to be roughly proportional across income groups, while displaying an inverted U-shape impact across expenditure deciles, implying the largest burden for middle income households. In contrast, the carbon tax on heating fuels as well as on electricity has a clear regressive effect.

These findings corroborate the results of an earlier analysis by Wier et al. (2005) studying the distributional implications of carbon taxes on heating fuels and electricity in Denmark. The authors show that direct and indirect carbon tax payments (through tax-induced price increases for carbon-intensive goods and services due to the carbon tax levied on industry) imply a regressive distribution of the tax burden across households. Based on a similar approach, Kerkhof et al. (2008) show that similarly to the results for Denmark, direct and indirect carbon taxes are associated with regressive effects in the Netherlands.

A joint analysis of environmental and distributional effects of environmental taxes on transportation for Norway is conducted by Aasness and Roed Larsen (2003). The authors find that higher tax rates on air transportation and taxis, as rather pollution-intensive means of transportation, improve environmental quality and decrease inequality. The same is true for lower tax rates on rather environmentally friendly modes of transportation as buses, bikes and mopeds. Higher taxes on gasoline have beneficial environmental effects but are inequality increasing. That this last result of regressive effects of gasoline taxes contradicts the findings of most other empirical studies may have to do with specific Norwegian circumstances, with more low-income households depending on a car in the sparsely populated country.

Finally, a simulation study by Rausch et al. (2011) researching the distributional impact of a carbon tax for the US points at the importance of considering not only differing income groups in distributional analyses, but to also take into account differences between household types, regions, or race, as these influence spending patterns and thus the incidence of carbon taxes. This conclusion is supported by the findings by Cronin, Fullerton and Sexton (2017) for the US highlighting that besides vertical distribution, also horizontal distributional effects need to be accounted for. A recent meta-analysis by Ohlendorf et al. (2020) including 53 studies and 183 effects in 39 countries finds that about one third of the effects of market-based climate policies, inter alia carbon pricing, analysed in the study are progressive or proportional. One interesting finding of this meta-study is that the probability of identifying progressive effects is higher for lower income countries, and that it increases when lifetime incomes are used and when a broader range of economic aspects (e.g. indirect and demand-side effects) are considered.

2.3.6.2 Distributional consequences of compensation measures

An also much debated and topical issue is how to avoid or at least mitigate undesired distributional effects of carbon taxes. Empirical research illustrates that the distributional impacts of environmental taxes crucially depend on the use of tax revenues.[58] In an early study modelling ex-ante a carbon tax for Switzerland, Felder and van Nieuwkoop (1996) show that lump sum payments to compensate for the regressive effect of the carbon tax benefit lower incomes over-proportionately, while labour tax reductions benefit higher incomes more. Besides their progressive distributional impact, lump sum distribution is the easiest and administratively least complex and burdensome option to recycle carbon tax revenues (Baranzini et al. 2000, Padilla and Roca 2004). Similarly, in their analysis of the distributional impact of carbon taxation in Ireland, Callan et al. (2009) study the distributional impact of various compensation measures and find that labour tax cuts are well suited to provide relief for middle to high income groups, while lower incomes can be better compensated by increasing transfers. These results are confirmed by Rausch et al. (2011) in model simulations of the implementation of a carbon tax in the US. From their CCE model simulations of the introduction of a carbon tax in France, Combet et al. (2012) conclude: "A mix recycling scheme, which devotes the tax levied on firms to payroll tax rebates, and that levied on household to the financing of redistributive transfers, is proven to provide a compromise between the two polar options: it allows to achieve both an improvement of all macroeconomic indicators, and a control of the distributive impacts of the reform." Similarly, analysing various scenarios of carbon taxes on car fuels in France, Bureau (2011) finds that recycling carbon tax revenues via lump sum payments to households to mitigate the regressive effects of the tax makes poorest households better off. The study also shows that the regressive impact of the tax is reduced by accounting for the benefits from the reduction of congestion achieved by the tax. Flues and van Dender (2017) in a simulation for 20 OECD countries show that combining an energy tax increase with income-tested compensation financed by one third of tax revenues would make energy use affordable for the poorest population groups, leaving two third of tax revenues for other uses.

To sum up, the distributional impacts of carbon taxes as well as the results of empirical research attempting at measuring them are influenced by a number of factors: "… consumption and income patterns of households, the structure of the economy, macroeconomic feedbacks (e.g. factor incomes), price transmission of industries taxed, tax design (especially tax recycling), as well as the modelling approach and indicators used, and impacts will differ in the short- and long-term." (Kirchner et al. 2018: 8). Similarly, Pizer and Sexton (2017) highlight that the incidence of energy

[58] See, e.g., Pizer and Sexton (2017) and the literature cited therein.

taxes depends on the energy commodities taxed and on the physical, social and climatic conditions of the taxing jurisdictions.

Altogether, the great majority of empirical analyses for high-income countries find that without revenue recycling or compensation mechanisms a carbon tax tends to have a regressive effect, with lower income groups typically spending a higher proportion of their income on carbon intensive commodities (Wang et al. 2016). Hereby, a rather broad consensus has emerged in the empirical literature that fuel taxes are less regressive (or may even be progressive) than taxes on heating fuels and electricity. It should also be noted, however, that recent research calls for a more differentiated approach to and perspective on the distributional implications of carbon pricing. Cronin, Fullerton and Sexton (2017) point out that the measures used to capture distributive effects of carbon pricing play a crucial role. In particular, the authors underline that annual incomes, which are influenced by short-term fluctuations induced, e.g., by the employment and health status or family conditions, may be less suited than measures based on lifetime income or annual consumption. Moreover, they stress the necessity to also account for horizontal aspects, as focusing on the aggregate impact on household groups differing, e.g., with respect to their consumption expenditures, bears the danger of hiding differences within given household groups. The necessity of such a broader and more differentiated approach is supported by the recent meta-analysis by Ohlendorf et al. (2020). Related is the aspect of gender-differentiated distributional impacts of carbon taxes. Although the existence of such gender-differentiated effects appears plausible, as Chalifour (2010) argues, there is practically no relevant empirical research. This is true as well for intergenerational equity, another important distributional dimension (Baranzini et al. 2017).

It should also be noted that the overall distributional effects of carbon pricing are underestimated in empirical research, which generally neglects indirect effects in the form of tax-induced price increases of non-energy goods. On the other hand, distributional analysis confined to static effects may be misleading or at least may provide an incomplete picture: in the longer run, adjustment reactions by households may alleviate initial undesirable distributional effects, rendering them a transitory phenomenon (which would be supported by providing adequate alternatives to the taxed activities, for example affordable public transport). The analysis of distributional effects of carbon taxes in a dynamic perspective, however, is confronted with substantial methodological challenges. Not least, studies of the distributional impact of carbon taxation should be put into perspective by comparing them with the distributional effects of the resulting environmental improvements and of the cost of inaction.

Our literature review also allows some conclusions regarding the suitability of various compensation measures to mitigate undesired distributional effects of carbon taxation. Existing research suggests that lump sum payments are better suited to mitigate the regressive effects for lower incomes, while higher incomes benefit more from labour tax reductions. At the same time, there is a consensus that lump sum transfers are associated with an equity-efficiency trade-off whereas a decrease of labour taxes is more efficient economically (Kirchner et al. 2018). This conclusion is corroborated by the empirical research on the validity of the double dividend hypothesis summarized above showing that recycling schemes reducing labour taxes are far more likely to create a double dividend in terms of environmental and economic improvements than those compensating lower income households by lump sum transfers. As Cronin, Fullerton and Sexton (2017) highlight, also with regard to the design of compensation schemes, differences within various classes of households should be considered. Finally, it should also be mentioned here that the long-term potential of carbon taxes financing labour tax cuts within environmental tax reforms will decrease, as a successful significant reduction of GHG emissions, as envisaged in the existing international and national climate agreements and commitments, will significantly lower the potential tax base and thus the revenue raising potential of the tax (Speck 2017). This could be mitigated by maintaining energy taxes, subjecting all energy use to some level of taxation so as to contain overall demand for energy.

2.3.7 Political acceptance of carbon pricing schemes

Political aspects of carbon pricing have been attracting growing attention in academic research. Issues that have been researched empirically recently are the role the international climate policy framework, economic and fiscal crises, policy paradigms or country-specific economic conditions (e.g. income level, openness, emission intensity) play for countries' decisions whether to adopt carbon pricing policies.[59] Also the role of lobbying for or against carbon taxation has been studied empirically.[60]

Of particular importance in the context of this study is the issue of public acceptability of carbon taxes. As a consequence of an increasing number of failed attempts to introduce carbon-reducing measures,[61] awareness is rising among policymakers as well as within academia that the successful implementation of carbon taxes is not just a matter of setting the technical parameters, like tax rates and bases, right. As Jagers, Martinsson and Matti (2019) point out, there are two aspects related to the political feasibility of carbon taxes. First, there is the issue of the determinants of public support for or resistance against carbon taxes. The second question is how public resistance against carbon taxes can be avoided or mitigated. Moreover, with a perspective to the US, Feldman and Hart (2018) and Shwom et al. (2010) conclude that the motivation of policymakers to introduce climate policies crucially depends on public support.

Summarising the recent literature, Jagers, Martinsson and Matti (2019) identify numerous determinants of public attitudes towards environmental and climate policy, ranging from individual motivation over political ideology as well as institutional, political and interpersonal trust to contextual variables, as the degree of political polarisation, economic conditions and dependencies, political culture, and quality of government.[62]

Criqui et al. (2019) conduct a comparative country study (Sweden, France and Canada) to identify factors that support the introduction of carbon taxes. According to their analysis, trust in the government is a central factor (thus confirming an empirical analysis for 18 EU countries by Kollmann and Reichl (2015)) as well as the consideration of the wider perspective on the economy and energy system (e.g. availability of district heating). Awareness of potential lobbying interests and finally the use of the revenues contribute to the success of carbon taxes. The importance of national policy styles is stressed by Andersen (2019). Examining seven smaller European countries, the author finds that policy styles with neo-corporatist features make it easier to introduce carbon taxes despite larger pressures from international competition in smaller countries, as these provide coordination mechanisms allowing the introduction of complementary proactive macroeconomic policies.

In addition, Jagers, Martinsson and Matti (2019), in a large-scale randomised survey experiment conducted in Sweden, find that perceptions of fairness are important determinants of public support for carbon taxes. Their results support similar results by Johansson-Sternman and Konow (2010) and Kallbekken, Garcia and Korneliussen (2013). Also Savin et al. (2020), based on a computational linguistics analysis, show that different mindsets play an important role in shaping

[59] See Skovgaard, Sacks Ferrari and Knaggard (2019) for a brief overview over recent empirical studies on the factors influencing the adoption of carbon pricing policies by polities.
[60] See Baranzini et al. (2017) and Sterner et al. (2020) for a brief overview over relevant empirical studies.
[61] See Jagers, Martinsson and Matti (2019) and Drews and van den Bergh (2016) for examples.
[62] See Jagers, Martinsson and Matti (2019) for references.

public views on carbon taxation and its fairness and need to be taken into account when designing and communicating carbon taxes. While people accepting a carbon tax stress the necessity to solve environmental problems, people sceptical of a carbon tax emphasise fairness problems of the tax and the lack of low-carbon transport and renewable energies, and they exhibit less trust in politicians.

Altogether, most factors influencing public support that are identified in this research are, as Jagers, Martinsson and Matti (2019) point out, rather stable over time and can hardly be changed by external pressure. However, the authors stress that policy attitudes are also influenced by the design of policy measures itself and by the perceived consequences. Accordingly, public support may be increased, for example, by cushioning off undesired distributional consequences through compensatory measures.

Kirchner et al. (2018) report several examples where governments decided to forego the introduction of carbon taxes due to equity considerations.[63] Thus, their distributional effects are a crucial determinant of the political feasibility of carbon taxes (Baranzini et al. 2017). Bristow et al. (2010), Brannlund and Persson (2012), Gevrek and Uyduranoglu (2015) and Baranzini and Carattini (2016 find that public acceptability of climate policy in general and carbon taxes in particular can be substantially enhanced by a design that avoids burdening low-income households. To mitigate undesired distributional consequences of carbon taxes, existing carbon taxes often are embedded in recycling measures giving back carbon tax revenues to compensate households and firms. For example, the carbon tax recycling scheme in British Columbia uses a significant share of carbon tax revenues to compensate lower incomes (Murray and Rivers 2015) as well as rural households (Beck et al. 2016). Thus, compensation measures very generally help to increase public acceptance of carbon taxation, as concluded by Jagers, Martinsson and Matti (2019). Maestre-Andrés et al. (2019) study the role of individual preferences with regard to the design of revenue recycling schemes and their importance for the acceptability of carbon pricing schemes. Their review of empirical studies shows that generally there is a lack of trust in governments regarding the use of revenues from carbon pricing. Also, there is wide-spread concern that carbon taxation particularly hits lower incomes and thus is associated with regressive effects; and policy acceptability and support is improved if carbon pricing instruments are perceived as fair. Most interestingly, the bulk of empirical studies does not suggest that most people prefer to use carbon tax revenues to compensate particularly lower incomes. Rather, there is a significant share of people preferring to recycle carbon tax revenues via investment in "environmental projects". One recommendation the authors derive from these empirical results is that compensation measures for lower incomes should be combined with spending for "environmental projects", for example in renewable energy. Another one is that governments should provide sufficient information for citizens about the policy instruments used, as this also improves acceptance. This recommendation is supported by the work by Murray and Rivers (2015) and Carattini et al. (2016) which shows that the provision of evidence for the effectiveness of carbon taxes in decreasing emissions raises citizens' support for carbon taxation. That ideological preferences matter with regard to people's attitudes towards the necessity of compensatory matters is shown for Sweden by Jagers, Martinsson and Matti (2019). The authors find that right-leaning voters' support for carbon taxes is increased by offering compensatory measures, whereas left-wing people support a carbon tax combined with an income tax cut less.

[63] See also *Wang et al.* (2016) for more examples.

2.4 *Empirical evidence on the effects of tax incentives*

2.4.1 General aspects of environmentally beneficial tax incentives

Tax incentives to support environmentally friendly or to discourage environmentally harmful behaviour are much more diverse across countries than environmental taxes are. This regards the supported economic activity (consumption versus investment), the concrete environmentally relevant activity they try to influence (purchase and use of cars, use of public transport, use of biofuels and renewable energy, investment and research in energy efficiency and clean technologies), the economic actors they benefit (private households versus firms), the concrete tax they are built in (direct taxes, i.e. personal and corporate income tax, versus indirect taxes, i.e. consumption taxes), as well as their concrete design (direct taxes: tax allowances reducing taxable income versus tax credits reducing tax liability; indirect taxes: reduced tax rates, total or partial exemption of tax base). Tax incentives are but one – and probably the least important one – instrument to further environmentally beneficial behaviour and decisions. The existing theoretical and empirical literature suggests that fiscal incentives, in particular grants, direct subsidies, and preferential loans, are more prevalent than tax incentives.

Compared to the large body of empirical evidence on the effects of environmental taxes in general and taxes addressing greenhouse gas emissions in particular, the number of empirical analyses of environmentally beneficial tax incentives is rather limited. Many of these analyses evaluate individual measures in single countries (regarding the EU, these analyses with very few exceptions focus on "old" Member States), while cross-country comparative analyses are less common. A part of these studies analyse a given tax incentive isolatedly, i.e. without evaluating it against alternative policy instruments and thus without addressing the question what would have been the benefits of alternative policy measures to reduce emissions. However, there is a growing body of comparative evaluations of alternative policy interventions. The bulk of analyses consists of ex-post evaluations, there are only few ex-ante simulations of hypothetical scenarios.

Before presenting empirical evidence on specific tax incentives, we briefly provide an overview over some general, structural aspects concerning the effects of environmental tax incentives.

First, regarding the design of tax incentives to promote some specific desired environmentally beneficial behaviour, empirical evidence suggests that tax incentives must be salient to change behaviour (Chetty et al. 2009, Finkelstein 2009, Busse et al. 2013). Deshazo et al. (2017) show that tax rebates and exemptions granted at the time of sale are more effective than complex income tax incentives: as the latter have to be applied for by consumers and bring about financial relief with a delay only, which therefore may be undervalued due to consumer myopia (Allcott and Wozny 2012). For example, Gallagher and Muehlegger (2011) show for the US that exempting hybrid electric vehicles from the sales tax may lead to an increase of sales by 45%, while income tax credits of a similar magnitude increase sales by 3% to 5% only. Similarly, a study of government incentives policies in US states to support the adoption of hybrid-electric vehicles by Diamond (2009) suggests that incentives providing payments upfront are most effective. Accordingly, with specific regard to the design of vehicle taxes, there is growing empirical evidence that car purchase taxes as well as feebates (i. e. a combination of tax rebate for the purchase of a low-emission car and a fee for the purchase of a high-emission car), acting as upfront incentives, are more effective (Kok 2015, Brand et al. 2013).

Second, tax incentives are often viewed as problematic from a distributional point of view. Zachmann et al. (2019) generally assume that subsidies for low-carbon technology granted to private households (e.g. for vehicles, building insulation, or roof-top solar) can be rather regressive, as only higher income households can afford to invest in low-carbon durables. The scarce available empirical evidence suggests that the regressive effects of carbon pricing policies are less pronounced than those of subsidies. According to Borenstein and Davis (2016), the US clean energy tax credits have less favourable distributional effects than carbon pricing.

A third, related aspect is free-riding and the question of additionality, i.e. whether a tax incentive is granted for an activity that would have taken place anyway. The more prevalent free-riding is, the less cost-effective a given tax incentive is. Generally, tax incentives are often found to be little cost effective, which is why some authors (e.g. Metcalf 2008) argue that carbon pricing should be preferred to tax incentives. Tax incentives are generally perceived as being prone to free-rider aspects. Empirical evidence for free-riding is found particularly regarding tax incentives for the purchase of electric vehicles: e.g. by Chandra et al. (2010) for tax rebates granted in Canadian provinces for hybrid electric vehicles, by Huse and Lucinda (2014) for the Swedish "Green Car Rebate", or by Sun et al. (2018) for the sales tax reduction for electric vehicles. Low cost-effectiveness of tax rebates is also suggested by Yan (2018) who studies tax incentives for electric vehicles in 28 European countries from 2012 to 2014. For the case of California's tax rebate program for electric vehicles, Deshazo et al. (2017) demonstrate that a progressive design of tax rebates, which decreases the size of tax credits with income, may increase cost effectiveness per additional vehicle purchased, as free-riding decreases with decreasing income. Metcalf (2008) deems US energy-related tax incentives less cost effective compared to a carbon pricing scheme. Similarly, Markandya et al. (2009) compare tax incentives and subsidies against energy tax options to promote the production and consumption of energy-efficient appliances in different European countries (Denmark, Italy, France, and Poland) and find that generally the energy tax in most cases is more cost effective. According to Ruijs and Vollebergh (2013), an energy investment tax allowance granted to firms in the Netherlands was found to be associated with large free-rider effects.

Finally, there is some empirical evidence supporting the theoretical consideration that "package solutions" combining several climate policies in general and carbon pricing and tax incentives in particular (Baranzini et al. 2017) may be more effective than single measures. For example, Beresteanu und Li (2011) show that a combination of fuel tax increases and tax incentives stimulates the adoption of electric vehicles most effectively.

2.4.2 Specific tax incentives

The availability of empirical evidence on the effects of environmentally beneficial tax incentives varies greatly across the various kinds of tax incentives and the activities they intend to promote. While there is a growing body of empirical literature on the effects of tax incentives aiming at supporting the de-carbonisation of the transport sector, and here with a focus on the adoption of low-emission cars, there is practically no empirical research on the effects of tax incentives for "green" research and development and for the implementation of measures to further energy efficiency and the adoption of renewables. Obviously this reflects the fact that many countries have introduced rather similar (albeit differing with regard to the detailed designs) tax incentives to further the adoption of low-emission vehicles via the conventional tax measures applied with regard to individual transport: concretely, many EU Member States have introduced a carbon emission element in vehicle taxes (registration tax, annual circulation tax) as well as company car taxation; and there is some experience with feebate and car scrapping schemes as well as specific tax incentives to purchase (hybrid) electric vehicles. The group of Member States granting tax incentives for the use of public transport is considerably smaller, as is naturally the body of respective empirical evidence. The following review of empirical evidence on the impact of specific tax incentives to reduce GHG emissions therefore focuses on tax incentives in the transport sector and particularly on those attached to vehicle taxation aiming at supporting the decarbonisation of the car fleet.

2.4.2.1 Tax incentives in the transport sector

Incentives for the adoption of low-emission cars, in addition to fuel taxes, are generally justified by consumer shortsightedness regarding future fuel savings through low-emission cars. Such incentives can be built in into various vehicle-related taxes, and accordingly they are rather heterogeneous across countries. They range from sales tax reductions (granted e.g. by China during the financial and economic crisis one decade ago, Sun et al. 2018) and exemptions in VAT over reductions/exemptions from car purchase taxes and annual registration taxes to other vehicle-related tax incentives granted, for example, via company car taxation. Also, feebates combining a malus for high-emission and a bonus for low-emission cars have been gaining in popularity recently. The existing empirical evidence allows only limited conclusions which measures are particularly effective, as comparisons of the effects across individual measures are hardly possible. Moreover, most empirical analyses focus on one or at most two impact dimensions (with a particular focus on cost effectiveness, environmental effectiveness, and free-rider effects), so that trade-offs can be detected to a very limited degree only. In addition, certain impact dimensions, in particular distributional effects, are neglected in most evaluations. Most empirical studies focus on individual measures in individual countries, therefore based on existing empirical evidence neither cross-country comparisons nor comparing different designs of tax incentives aiming at the adoption of low-emission cars are possible. Finally, there is almost no empirical evidence for the "new" EU Member States having acceded the EU beginning with 2004.

2.4.2.1.1 Tax incentives for the purchase of low emission cars

Tax incentives for the purchase of low emission cars can take various forms. Specifically, two kinds of such tax incentives have gained in popularity in Europe as well as in other industrialised countries worldwide: tax incentives for the purchase of (hybrid) electric vehicles, and carbon-based car purchase taxes.

Experience from several countries shows that tax incentives can be an effective measure to incentivise sales of greener vehicles. Tax incentives immediately granted at the time of purchase and thus salient for consumer are found to be particularly effective. Responding to the recession during the crisis in 2008/09, China halved the sales tax on small engine size vehicles, which according to Sun et al. (2018) increased overall car sales, shifted demand from ineligible to eligible cars, and reduced carbon emissions. According to Gallagher and Muehlegger (2011), waiving sales taxes may lead to an increase of hybrid electric vehicle sales by 45% in the US and is thus far more effective than income tax credits of a similar size. For Canadian provinces, Chandra et al. (2010) show that tax rebates for hybrid electric vehicles support their adoption, and also in Sweden the market share of low-emission vehicles was increased by the Swedish "Green Car Rebate" (Huse and Lucinda 2014). Similarly, a survey by Ystmark Bjerkan and Norbech (2016) finds that exemptions from car purchase tax and VAT, resulting in upfront price reductions, are critical incentives for more than 80% of respondents. This survey is interesting also because it identifies different user groups (differentiated by gender, age, and education) responding to different incentive groups, whereby a substantial share of users rather responds to exemptions from operating costs (e.g. road tolling) than from upfront costs. Analysing the factors influencing electric vehicle sales on a regional and municipal level in Norway, Chaim Mersky et al. (2016) find no significant impact of toll exemptions, while access to battery electric vehicles charging infrastructure, proximity to major cities, and regional incomes are important determinants of electric vehicle adoption.

Several studies research the effectiveness of tax incentives for the adoption of (hybrid) electric vehicles. Yan (2018) evaluates the effects of tax incentives for electric vehicles, which differ across vehicles, countries and over years, by analysing 10 pairs of battery electric vehicles and internal combustion engine vehicle counterparts across 28 European countries from 2012 to 2014. He finds that large battery electric vehicles benefit more from tax incentives compared to small ones. Moreover, the impact of tax incentives on hybrid electric vehicle sales is higher than for sales of battery electric vehicles. On average, a 10% increase of the total tax incentive raises the share of battery electric vehicles by around 3%. The author concludes that the cost effectiveness of tax incentives as instrument to decrease carbon emissions is rather low. Plötz et al. (2016) study the effectiveness of various instruments aiming at the increase of electric vehicle sales for selected European countries and US federal states and find that tax incentives can play a positive role. However, their results do not allow conclusions on the relative cost effectiveness of tax incentives compared to other policies as direct subsidies or charging infrastructure. A comparison of the effectiveness of financial incentives for hybrid electric vehicles granted in US states with gasoline prices undertaken by Diamond (2009) shows that financial incentives promote hybrid adoption, but to a much lower degree than gasoline prices.

Bjernaes (2017) mentions some additional aspects that should be considered in the discussion about subsidising electric vehicles. First, financial incentives neglect the fact that also electric cars are associated with certain externalities that should be internalised by a tax; from this perspective, substantial tax incentives are counterproductive. Second, in small car-importing countries that do not have a domestic car industry tax incentives for electric vehicles can hardly be justified by the aim to encourage the domestic development of green technologies.

2.4.2.1.2 CO_2 differentiated vehicle taxes

Vehicle taxes can be based either on the purchase of new cars (car purchase or registration tax), or they can be levied annually in the form of circulation taxes. These taxes have been reformed in many countries since the beginning of the 2000s as to consider vehicles' carbon emission intensity. As these reforms lead to preferential tax treatment of low emission cars, vehicle taxes with tax rates differentiated according to emission intensity are viewed as environmentally beneficial tax incentives in the context of this study. Several empirical evaluations can be found in the literature for either of these models; some of these evaluations offer a comparison of the effectiveness of carbon-based purchase and annual registration taxes. Most of the existing empirical evidence focuses on individual countries. It includes ex-ante as well as ex-post analyses, some studies combine ex-post and ex-ante analyses. In addition, there is some empirical evidence on further vehicle-tax related specific tax incentives, in particular in the area of company car taxation. There is a small, but growing body of studies examining the effects of various designs of vehicle-related taxes in comparison.

For the UK vehicle excise duty (an annual circulation tax based on carbon emissions rates), Cerruti et al. (2019) find that it promoted the adoption of low-emission cars and decreased sales of high-emission vehicles. Aggregate emissions decreased, albeit to a rather limited extent. Comparing the UK annual circulation tax with hypothetical alternative tax measures, the authors show that a tax proportional to carbon emissions per kilometre is twice as effective in reducing total emissions of new cars, because it leads to adjustments in miles driven. A carbon tax, in contrast, is half as effective. In a model-based simulation study for the UK, Brand et al. (2013) demonstrate that car purchase taxes and feebate schemes are the most effective policies to promote low carbon technology uptake, with the further advantage of revenue neutrality. Also, an annual circulation tax is an effective, however potentially politically contested instrument. Car scrapping schemes turn out to be least favourable, as they are little effective in carbon reduction and may even increase emissions.

Klier and Linn (2015) study the CO_2 differentiated annual circulation taxes in Germany and Sweden that are linear in emission rates and find that they are less effective in reducing emission rates compared to the French car purchase tax which rests on a progressive feebate design. The authors offer two possible explanations (besides potentially differing consumer preferences). First, consumers may be more responsive to purchase taxes as they expect that annual circulation taxes may be changed in the future. Second, the progressive design of the French car purchase tax might make it more salient compared to the Swedish and German circulation tax.

Adamou et al. (2012) simulate the effects of a revenue-neutral partial replacement of the existing car registration tax in Greece, which increases considerably with engine size, with a CO_2 emissions-based tax, and find that such a tax reform may lead to higher average carbon emissions of new cars. In contrast, a feebate scheme for the car purchase tax could decrease carbon emissions of new cars without negative economic consequences (e.g. in the form of large tax revenue losses).

According to Zimmermannova (2012), the introduction of an emissions-based car registration fee in the Czech Republic in 2009 caused significant environmental improvements: it increased the share of alternative fuel cars and decreased emissions from private car transport.

Replacing the engine-based registration and annual circulation tax in Ireland by an emissions-based system reduced average specific emissions of new cars by 13% in the first year; resulting not from a reduction in engine size but through a shift to diesel cars (Rogan et al. 2011). The reform also caused a considerable decrease of tax revenues by about one third. The ex-post assessment by Ryan and et al. (2019) finds that the reform improved the fuel economy of new cars, however at the same time supported the adoption of diesel vehicles. Giblin and McNabola (2009) provide an ex-ante simulation of the effects of the introduction of the Irish CO_2 based purchase tax. Their model predicts that the reform will reduce CO_2 emissions intensity from new vehicle purchases by 3.6% to 3.8%.

Using data from 15 EU countries for the period 2001 to 2010, Gerlagh et al. (2018) find that the increased consideration of carbon emission intensity in the design of registration taxes has decreased the carbon emission intensity of new cars only slightly, by 1.3% for the average new car; whereby a part of this decrease resulted from a higher share of diesel-fuelled cars.

In an ex-post evaluation of emission-based reforms of vehicle taxation in the Netherlands since 2007, Kok (2015) shows that the introduction of a carbon emission element in company car taxation has contributed most to lowering the emission intensity of the car fleet; followed by the reformed vehicle registration tax also differentiated according to emission intensity.

One specific feature of introducing carbon emission components in vehicle taxation that has gained some attention in tax policy rather recently is considering carbon intensity of vehicles in company car taxation. There are several country examples demonstrating that differentiating company car taxation according to carbon intensity has contributed to the reduction of carbon emissions: e.g. in the UK or the Netherlands (Kok 2015).

2.4.2.1.3 Feebates

More recently, feebates, combining a tax rebate for the purchase of low-emission cars and fees for the purchase of high-emission vehicles have been implemented in several countries. While the advantage of these bonus/malus schemes is that their introduction does not require additional public funds and that their revenue neutrality may increase political acceptance (Brand et al. 2013, Adamou et al. 2014), the existing empirical evaluations of this instrument yields mixed results. According to Haultfouille et al. (2016) the French "bonus/malus" feebate introduced in

2008, together with an energy label requirement introduced some years before, shifted consumer preferences towards low-emission cars beyond price effects. For the Norwegian car registration tax applied to the purchase of new cars and based on a feebate scheme, Yan and Eskeland (2016) show that it explains the majority of the significant decrease in CO_2 intensity of new cars. The authors also find that sales of large high-emission cars are much more responsive than those of lighter low-emission vehicles. Haultfouille et al. (2014) show that consumers respond asymmetrically to the French feebate scheme in that they are more responsive to tax rebates compared to fees: resulting, in addition to the incentive to buy low-emission vehicles, in growing overall sales and therefore eventually carbon emissions. In the same vein, an ex-ante simulation of hypothetical feebates for Germany done by Adamou et al. (2014) suggests that fees must be higher than rebates to achieve welfare gains, while revenue-neutral feebate schemes are welfare decreasing. Similar asymmetric reactions by consumers are found for a long-standing feebate scheme applied in the Canadian province of Ontario by Rivers and Schaufele (2017). For Swiss cantons, Alberini and Bareit (2019) identify an only small effect of even a high malus for high-emission vehicles in annual car registration taxes regarding a shift of car sales towards low-emission vehicles. The authors show that the bonus may eventually increase net emissions by resulting in new car sales. Specifically regarding the impact of bonus/malus schemes on the retirement of old high-emission cars, Alberini et al. (2018) show for Swiss cantons that a retrospective malus applied to all high-emission cars (as in the canton Obwalden) accelerates the retirement of old inefficient cars, while a prospective malus on new cars only (as in the canton Geneva) induces car owners to postpone the retirement of their old high-emission cars.

2.4.2.1.4 Car scrapping schemes

Another tax incentive model which is rather well researched are car scrapping schemes, incentivizing the replacement of old by new cars. The existing evaluations yield rather mixed evidence on the economic and environmental performance of these schemes. Altogether, empirical analyses suggest that car scrapping schemes provide only a short-run economic stimulus, have modest environmental effects only, and are not cost effective as they are associated with substantial free-rider effects.

An early study by Adda and Cooper (2000) analyzing tax credits granted to individuals scrapping their old cars and buying new ones in France 1994 to 1996 finds evidence for a short-run positive economic stimulus effect, but no long-run effect. Also, government revenues are increased in the short-run but lower in the long-run compared to the baseline scenario. Similarly, Mian and Sufi (2012), Kopeland and Kahn (2013), Li et al. (2013), Gayer and Parker (2013), and Hoekstra et al. (2017), studying the "Cash-for-Clunkers" car scrapping scheme of $ 3 billion in the US adopted to support the auto industry in the financial and economic crisis find only short-run increases of car sales which were offset in the medium run. Analysing scrapping subsidies in 8 European countries also introduced in the 2008/09 crisis, Grigolon et al. (2015) find that these considerably stabilised total car sales in the short run; long-run effects are not analysed. Studying car scrapping schemes in EU member states as stimulus measures after the 2008/09 measures in EU member states, Pollin (2011) identifies high returns in terms of short-term economic impact per unit of spending as they combine public and private financing.

Environmental effects are researched by Li et al. (2013) as well as Gayer and Parker (2013) for the US "Cash-for-Clunkers" program and by Grigolon et al. (2015) for scrapping subsidies granted during the economic and financial crises in 8 European countries. These are found to be modest for the US and slightly positive in the case of targeted European car scrapping schemes but missing for non-targeted ones. Similarly, Pollin (2011) in his study of EU Member States' car scrapping schemes identifies short-lived environmental benefits only, as a considerable share of the old vehicles would have been substituted soon anyway. Also, the simulation study by Brand et al. (2013) for the UK finds only limited emission reducing effects of a car scrapping scheme.

Li et al. (2013) and Hoekstra et al. (2017) identify substantial free-rider effects, making the evaluated car scrapping schemes little cost effective. Analysing three national car scrapping schemes (France, Germany, and the US), OECD (2011) finds that on the one hand these indeed reduced carbon emissions and air pollution and contributed to road safety. On the other hand, the gains were overcompensated by the lost value of the scrapped cars. Gayer and Parker (2013) find that the implied cost per job created by the US "Cash-for-Clunkers" program exceeded that of alternative fiscal stimulus policies considerably. While the scheme's cost effectiveness is found to be little cost effective in terms of cost per ton of carbon dioxide reduction it caused, it was still more cost effective compared to other environmental policies, in particular the tax subsidy for the purchase of electric vehicles and the tax credit for ethanol. The authors also note that the value of the destruction of used vehicles should be balanced against the (short-lived) economic gains.

There is almost no evidence on the distributional impact of car scrapping programs. Gayer and Parker (2013) find that participants in the US "Cash-for-Clunkers" program had a higher income compared to consumers who purchased a new or used vehicle, but that their income was lower than that of consumers buying a new car outside the scrapping scheme during the same time period.

2.4.2.1.5 Tax incentives for public transport

Tax incentives for public transport are another option to promote the de-carbonisation of transport, by furthering a shift from individual emission intensive transport modes (specifically car use) to public transport. In the literature, several arguments are put forward in favour of such tax incentives to further public transport. Basso and Silva (2014) argue that subsidizing public transport should benefit lower incomes, who use public transport more often, over-proportionally. In addition, tax exemptions often are administratively less complex than setting up a subsidy scheme. On the other hand, such tax incentives may be associated with free-rider effects, as (high income) households would have bought tickets for public transport anyway; thus, compared to targeted incentives, these tax incentives bear the danger of being relatively costly (Kosonen and Nicodème 2009). Not least, reduced VAT rates on public transport may encourage public transport use by a switch from even more climate-friendly modes of transportation, particularly cycling and walking.

Most common is to offer reduced VAT rates for public transport tickets; other exemptions (e.g. exempting the electricity used in public transport from electricity tax or tickets provided by the employer from employees' personal income tax on in-kind benefits) are used in a few cases only. Generally, there is hardly any empirical evidence on such tax exemptions in the area of public transport.

One crucial aspect regarding the effectiveness of tax relief for the providers of public transport (reduced VAT rates, exemption from input taxes) is whether they are passed on to consumers in the form of reduced prices. Copenhagen Economics (2007) report empirical evidence showing that VAT rate reductions will be passed through to consumers in the long run by lowering final prices. Benedek et al. (2015) qualify this finding: based on data for 17 Eurozone countries for the period 1999 to 2013, the authors show that a decrease in the regular VAT rate eventually is passed on fully to consumers, while only 30% of reductions of reduced VAT rates are passed on. For the example of a large VAT reduction for French restaurants, Benzarti and Carloni (2019) find that consumers benefited least from the reform, compared to other groups involved (suppliers, restaurant owners, etc.). Not least, Benzarti et al. (2018), using all VAT changes in the EU from

1996 to 2015, show that VAT rate reforms have asymmetric effects insofar as rate increases are passed on to consumers via price changes to a larger extent than rate reductions.

Even if tax rate reductions are passed through to consumer, there is the question how price sensitive consumers are regarding price signals in public transport. According to a study by CASE/IHS/TML (2014), generally reduced VAT rates and exemptions have a limited impact, due to low elasticities of demand for passenger transport services and pass-through rates that vary between 7% and 50%. For the UK, Paulley et al. (2006) find that fare elasticities are higher in the long-run than in the short-run. The authors caution, however, that the demand for public transport is dependent on numerous factors besides fares (ranging from service quality over walk and wait time as well as wait environment, information provision and awareness campaigns to personal security), and that there is substantial uncertainty considering their relative importance.

2.4.2.1.6 Conclusions

Overall, tax incentives to promote the adoption of low-emission vehicles may have mixed effects. While they appear to be effective in promoting purchases and increasing the market share of low-emission vehicles, empirical evidence also suggests various drawbacks. As mentioned above (Section 2.4), free-riding effects are considerable, thus dampening cost effectiveness. Moreover, these tax incentives may result in a rebound effect, by increasing total car sales and thus overall carbon emissions.

2.4.2.2 Tax incentives to encourage green R&D

Generally, most countries offer tax incentives for R&D, however, not specifically for "green" R&D (OECD 2020). Belgium and Spain belong to the few exceptions. Baveye and Valenduc (2011) find the Belgian tax incentives granted to individuals and firms to encourage green R&D to be efficient. The Spanish employment and environmental investment tax credit according to an ex-post evaluation by Martinez-Ros and Kunapatarawong (2019) increased employment in SMEs and – even more markedly – for micro firms.

2.4.2.3 Tax incentives to encourage energy efficiency

Generally, empirical evidence is scarce, reflecting that policies to support energy efficiency of consumers and firms are dominated by other instruments, while tax incentives play a rather marginal role only. A study by The Institute of Environmental Studies (2008) focusing on reduced VAT rates as tax incentive to promote energy efficiency offers several case studies, which will, together with additional empirical analyses, be briefly reviewed in the following sections. For Belgium, Baveye and Valenduc (2011) show that the efficiency of the tax credit granted for an energy saving scheme is rather limited.

2.4.2.3.1 Climate friendly energy sources

According to The Institute of Environmental Studies (2008), the reduced VAT for photovoltaic and renewable energy instalments in Portugal was not very effective. The same is true for the reduced VAT rate applied in the UK since 2000 for the installation of specific energy-saving materials. One possible reason may be that this reduction is not salient from the perspective of end consumers, as the installer and not the end consumer buys the product.

Reduced taxes for "green" electricity are another option to encourage the use of climate friendly energy sources. A temporary exemption for green electricity from energy tax in the Netherlands between July 2001 and December 2003 markedly raised the market share of green electricity. After removal of the tax exemption, the market share of green electricity remained stable.

Alberini and Bigano (2015) find that an Italian tax credit program aiming at encouraging heating system replacement to increase energy efficiency is generally not cost effective. These results contradict an earlier analysis by Markandya et al. (2009) according to which tax credits for boilers appear to be a cost-effective option for Italy and for Denmark.

2.4.2.3.2 Energy efficient white goods

Tax incentives for energy efficient white goods have been rather effective, as several case studies show (The Institute of Environmental Studies 2008). For example, (temporary) VAT rate cuts for the most energy efficient household appliances were very effective in the UK in substantially increasing sales of these appliances, while sales of products not included in the tax reduction fell considerably. An income tax credit granted in Italy since 2006 to consumers buying certain energy efficient appliances raised their market shares markedly.

2.4.2.3.3 Thermal insulation

Reduced VAT rates for thermal insulation material are used in various EU Member States. According to The Institute of Environmental Studies (2008), it is questionable whether these are effective, as the material is purchased by installers and not by end consumers. Moreover, the effectiveness of VAT rate reductions may decrease in the long run, as buyers get used to the lower tax rates which were reduced in a one-off move. In a survey by the European Commission provided with regard to the experimental application of reduced VAT rates for labour intensive services (European Commission 2003), renovation and repair of private dwellings were found to be the only sector in which service providers pass through the tax advantage, probably due to the comparatively large level of expenditures involved. The survey also showed, however, that even if in a given sector, e.g. the repair of dwellings in the case of France, the reduced VAT rate was passed on to consumers immediately after the tax cut, consumer prices tend to be increased again after some time.

2.4.2.3.4 Energy efficient equipment in industry

Ryan, Jessula and Rozite (2012) review the evidence of tax relief programs for the Netherlands, the United Kingdom, and Ireland concerning their effectiveness and efficiency. While the programs appear to be rather cost effective, they are also associated with considerable free-riding. Moreover, the efficiency of these tax advantages is reduced by overlaps with other policies.

2.5 Evidence on the (scale of) negative effects of harmful tax incentives

Literature shows that harmful tax incentives can have negative impacts on health, environment as they notably increase CO2 emissions and other air pollutants as well as negative economic and financial impacts (Withana et al., 2012). Their impact varies across the type and design of the incentives.

In the road transport sector, which contributed to 21% of EU's total CO2 emissions in 2017 (European Commission), special tax treatments encourage behaviours that have a negative impact in terms of GHG emissions. These behaviours depend mainly on the type of the tax incentive that is being implemented and the scale of the negative effects on the environment will depend on multiple factors.

Under-taxation of the capital component (for e.g. reduced VAT on company car acquisition) may affect the number of cars in a country as it reduces the cost of car ownership. This might encourage the employer to provide income to its employees through the supply of company cars and make them more likely to keep the company car as an additional vehicle to the ones they already privately own (Harding 2014).

Tax incentives aiming at reducing or exempting the distance component benefits to employees from the tax system (for e.g. deduction of company cars' private use from the personal income tax, deduction of commuting costs) can reduce the marginal cost of driving (for the driver) to zero and encourage employees to increase the use of the company's vehicle at the expense of other transport mode. This may also result in increasing the distance travelled (Harding 2014). Several studies (Le Vine and Jones 2012, Graus and Worrell 2008) identified that company car users drive more than private car users. Moreover, employees that do not pay the full costs of transports may be encouraged to buy larger vehicles than they would normally do (Roy, 2014).

In terms of environmental impacts, Roy (2014) provides a first indicative estimation of the negative effects of company cars subsidies. According to the study, subsidies to company cars cost €3.9 billion every year in all OECD countries for the CO2 emissions they generate and €32.8 billion for the local air pollution they contribute to.

Energy prices are considered as key elements for environmental policies. The evaluation report of the Energy Taxation Directive (ETD) conducted by the European Commission in 2019, recognises that the "ETD has been less supportive to the objectives of the reduction of greenhouse and other pollutant emissions […] as it includes many exemptions" and reductions. The "diesel bias" is one of the harmful tax incentives resulting from the ETD. According to Transport & Environment (2017), the minimum rate specified in the directive for diesel is lower by 9% than for petrol and many provisions exist for diesel used for commercial purposes. This under-taxation of diesel represented a €24 billion loss of revenues in the EU in 2019 according to Transport & Environment's interactive tool.

2.6 Concluding remarks on environmental taxes in a wider policy context

A broader perspective of environmental taxes in the context of climate change needs to take into account the fact that the transition towards climate neutrality requires deep structural change that cannot be achieved by incremental (policy) steps. Such a deep structural change rather implies huge investment needs. In this context the focus on a broader policy mix that integrates a broad range of instruments like pricing instruments, subsidies, standards and public infrastructure investment will be needed, not to forget the greening of finance. Environmental taxes thus need to be integrated in a broader system perspective. Given the urgency of GHG emission reductions the transformative signal of policy instruments towards long-run decarbonisation is of utmost importance.

Several conclusions can be drawn from the review of the theoretical literature on the effects and importance of environmental taxes in general and carbon taxes in particular.

First of all, as Hepburn et al. (2020) emphasise recently, **environmental taxes are one important instrument in a toolbox** of available environmental policy instruments, but are not enough for various reasons. Still, pricing negative externalities has been one of the central pillars in environmental economics for long. Hereby, "optimal" pricing in the context of climate change is faced with uncertainties related to the complexities of the climate system. The specificities of climate change require a broadening of the perspective on carbon taxes due to the importance of stock flow relationships or market barriers such as the principal agent problem between homeowners and tenants. Crucial for carbon pricing is the concrete policy design, in particular regarding the distributional impacts, which considerably influences public acceptability and distributional aspects play an important role. Although there is broad agreement on the usefulness of carbon taxes, there is also a consensus that they have to be embedded in a broader policy mix. **A complementary instrument to pricing external effects are environmentally beneficial tax incentives**. Tax incentives imply foregone public revenues to favour less polluting consumption and investment activities in order to achieve environmental policy goals. Beneficial tax incentives, however, should be reviewed prior to their introduction in view of their expected effects. Altogether, the policy instrument ultimately chosen should be based on an analysis of different aspects, such as tax policy arguments, or how a specific policy objective can be achieved at the lowest cost and with the highest probability.

The review of empirical studies further yields several conclusions regarding the various impact dimensions considered. An increasing number of ex-post studies – case studies as well as cross-country analyses – demonstrate that carbon taxes can effectively reduce carbon emissions or at least dampen their growth without harming economic growth and employment. Hereby, the level of the carbon tax rate is a crucial factor determining its effectiveness: Only a sizeable tax rate is able to effectively reduce carbon emissions. Key to achieving a double dividend consisting of environmental effectiveness and the improvement of economic welfare is the use of revenues: Revenue recycling via reducing social security contributions and reducing taxes on labour income mostly creates a double dividend, in contrast to lump-sum transfers. Moreover, carbon taxes impair firms' competitiveness to a small extent only, if at all. Up to now, there is no convincing empirical evidence that carbon pricing, e. g. via carbon taxes, can bring about the technological change required to achieve full decarbonisation of the economy and the society. There is also an empirical consensus that environmental taxes have differentiated distributional effects: Generally, fuel taxation is progressive in many countries, while taxes on heating fuels are mildly regressive and taxes on electricity are clearly regressive. Lump sum transfers are better suited to mitigate the regressive effects for lower incomes, while higher incomes benefit more from labour tax reductions. Finally, public acceptability of carbon taxes is dependent on a number of factors and can be increased by public information, avoiding negative distributional consequences and earmarking part of revenues for "environmental projects".

With respect to tax incentives, one key finding is that they must be salient to change behaviour. However, they are often viewed as problematic from a distributional point of view. Moreover, tax incentives are often found to be little cost effective, and they are generally perceived as being prone to free-rider aspects. "Package solutions" combining several climate policies in general and carbon pricing and tax incentives in particular may be more effective than stand-alone measures.

Apart from the broad theoretical and empirical consensus on the usefulness of environmental taxes, any concrete policy reform needs to consider the system boundaries as well as the specific policy context and general socio-economic conditions and policy styles in the given country. Moreover, the relevant literature suggests that international or at least EU-wide policy coordination yields additional economic and environmental benefits.[64]

[64] See, e.g., Parry (2020).

3 INVENTORY OF TAX MEASURES

The inventory of tax measures provides an overview of measures (taxes and tax incentives) inducing a change in behaviours towards reducing GHG emissions across the 33 countries included in the scope of this study. The inventory further provides an overview of some of the most important harmful tax incentives that increase GHG emissions.

As briefly described in the overall approach, the mapping of tax measures was implemented in a two-stepped approach:

As a first step, a mapping was developed on the basis of existing research, including the OECD PINE database, and other relevant sources such as the World Bank's Carbon Pricing Dashboard, the inventory of excise duties on energy products provided by DG TAXUD,[65] and research by the EEA. Yet, while the information provided in this database was useful, it was not possible to solely rely on this source. Reporting for this database is voluntary, and the information in the database was sometimes incomplete and not always up to date.

In the second step, country researchers complemented and extended the mapping. Drawing on national sources and interviews with key stakeholders from ministries of finance and environment, researchers checked their list of measures for completeness and identified additional measures where necessary. Based on their research, country experts also identified up to three measures each for the benchmarking and provided a detailed description of these measures. This analysis provides information on the design of the individual measure as well as available evidence on their respective environmental effectiveness, economic and distributional impacts, political viability, and transferability.

The inventory also includes information on some relevant environmental harmful tax incentives. These harmful tax incentives were partly identified by country researchers, and information collected by them were complemented by additional desk research. A more detailed description of the approach and scope of the mapping of measures is presented in Annex I.

The key output of this activity are 33 country fiches with an overview of existing measures per country. These are presented in Annex III. A detailed list of taxes and tax incentives identified in this study is presented in Annex VI. The following sections of this chapter provide an overview and synthesis of the findings.

3.1 Typology

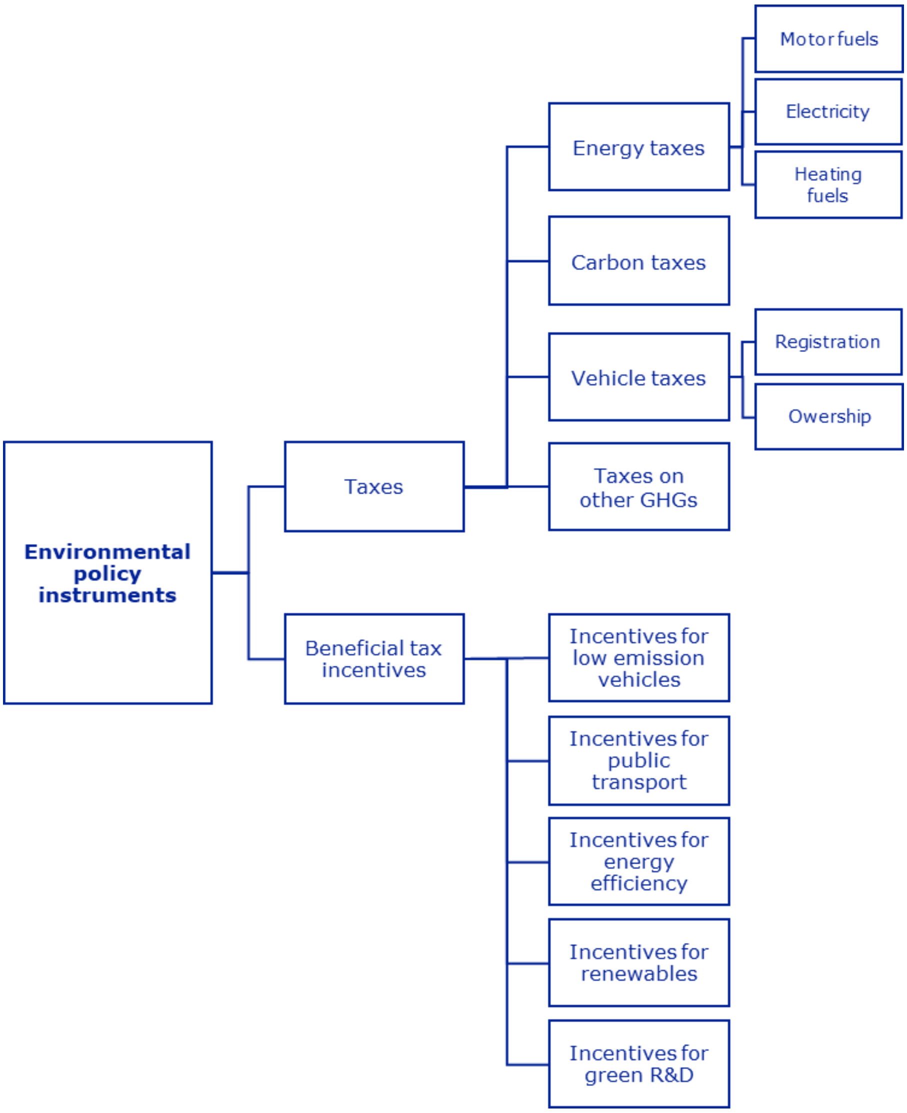
The inventory covers environmental tax measures – taxes and tax incentives - which aim at inducing behavioural change of producers and consumers to reduce GHG emissions. These are sub-types of environmental policy instruments, for which an overview has been included in **Figure 4** in the introduction to the literature review above. Therefore, the visualisation below extends the previous figure and provides more detail:

- Taxes are divided into four main types of measures – energy taxes, carbon taxes targeting explicitly CO2 emissions, vehicle taxes and taxes on non-carbon GHG emissions.

[65] https://ec.europa.eu/taxation_customs/sites/taxation/files/resources/documents/taxation/excise_duties/energy_products/rates/excise_duties-part_ii_energy_products_en.pdf

- Tax incentives can be divided into five broad categories: incentives for electric/hybrid vehicles, incentives for energy efficiency, incentives promoting the use of public transport, incentives encouraging investments in renewable energy sources and incentives for green R&D.

Figure 7 Typology of environmental tax measures targeting GHG emissions



Source: Ecorys

3.2 Taxes

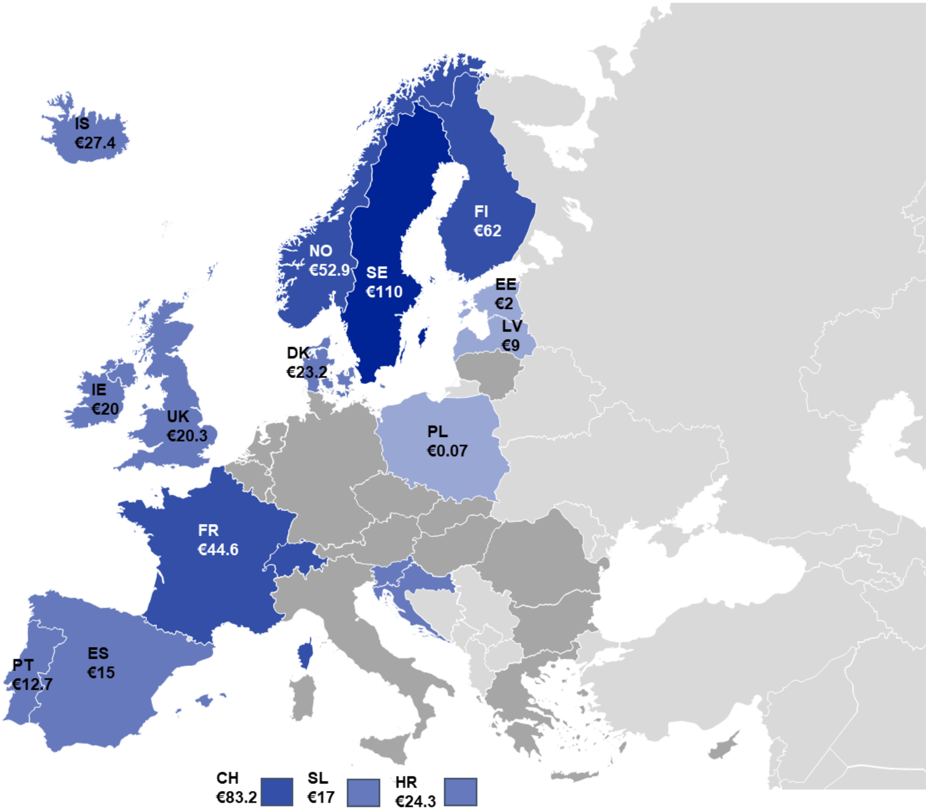
The country research identified 142 taxes that target GHG emissions across the 33 countries covered by this study. This excludes taxes under the Energy Tax Directive (ETD) which are present in all EU Member States. While the number of taxes differs across countries, there is not a single country included in our sample which does not employ at least one tax to reduce GHG emissions. Overall, identified taxes belong to three main categories: carbon taxes, vehicle taxes and energy taxes. Some countries also apply taxes targeting non-carbon GHG emissions.

During the research, it has been noted that the taxes countries employ show great similarities. While the specific design of measures varies with regards to tax rates, exemptions, and tax base, the activities targeted are almost always the same across countries. In the following we shed more light on three most common types of taxes employed across a larger number of countries.

3.2.1 Carbon Taxes

In our country sample, 16 out of 33 have adopted a form of carbon tax[66]. The tax rates applied range from less than €1 per ton of carbon emissions in Poland to €110 in Sweden. While in some countries carbon taxes have been in place for almost 30 years (Finland, Sweden, Denmark, Norway, Poland), others have introduced this measure relatively recently (Portugal, France, Spain) or are only considering to introduce it in the future (the Netherlands and Austria). The figure below provides an overview of the carbon taxes across Europe and the respective tax rates. Countries in grey do not have a carbon tax in place.

Figure 8 Carbon taxes in Europe



Source: Ecorys (2020), based on World Bank Carbon Pricing data[67]

In addition to very divergent tax rates, the scope or tax base of each country's carbon tax also differs, which results in varying shares of GHG emissions covered by the tax (from 3% in Spain[68] and Estonia to 62% in Norway)[69]. Operators covered by the EU ETS are often exempt or partially exempt from paying carbon taxes. The tax base of carbon taxes is rarely carbon content or CO_2

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[66] Denmark, Estonia, Finland, France, Iceland, Ireland, Latvia, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, Canada (British Columbia)

[67] https://carbonpricingdashboard.worldbank.org/map_data

[68] The Spanish carbon tax applies to fluorinated GHG emissions (HFCs, PFCs, and SF6), not CO_2.

[69] World Bank Carbon Pricing Dashboard https://carbonpricingdashboard.worldbank.org/map_data

emissions. Most countries (see table below) administer carbon taxes in the same way as fuel excise taxes and calculate the corresponding rate in common commercial units based on the official EU emission factors of the various fuels. For instance by reference to kilograms for solid fuels, litres for liquid fuels, and cubic metres for gaseous fuels.[70] It has been shown that administrative and compliance costs of such an approach are generally low.[71] There are however a few countries which apply carbon tax directly on emissions: Poland, Latvia and Estonia. Under this approach, administrative and compliance costs tend to be somewhat higher than with fuel-based approaches and carbon taxes are only applied to emitters above a certain emissions threshold or to installations that fulfil certain technological criteria. This can perhaps explain why countries that apply such an approach are characterised by the lowest share of GHGs covered.

Table 3 Overview of Carbon Taxes

Country	Tax Rate (per ton of CO_2) in EUR	GHG emissions covered (in %)	Year of implement-tation	Use of tax revenues for env or climate related measures[72]	CO_2-based	Fuel-based
Denmark	23.21	40	1992	X		X
Estonia	2	3	2000	X	X	
Finland	62	36	1990			X
France	44.6	35	2014	X		X
Ireland	20	49	2010			X
Latvia	9	15	2004	X	X	
Poland	0.07	4	1990	X	X	
Portugal	12.74	29	2015			X
Slovenia	17	24	1996			X
Spain	15	3	2014		X[73]	
Sweden	110	40	1991			X
UK	20.34	32	2013			X
Iceland	27.38	29	2010			X
Norway	52.9	62	1991			X
Switzerland	83.17	33	2011	X		X
Canada (BC)	25.9	70	2008	X		X

Source: World Bank Carbon Pricing, OECD PINE database, own research

[70] OECD (2019) Taxing Energy Use 2019: Using Taxes for Climate Action https://www.oecd-ilibrary.org/sites/058ca239-en/1/2/3/index.html?itemId=/content/publication/058ca239-en&_csp_=733ba7b0813af580090c8c6aac25027b&itemIGO=oecd&itemContentType=book

[71] ibid

[72] X if at least part of the revenues is earmarked for environmental protection, increased energy efficiency, support to green transition or climate-related mitigation measures.

[73] In Spain the tax is levied on fluorinated gases

As highlighted in the empirical literature review, carbon taxes often have important distributional effects which in turn impact their political viability. To mitigate undesired distributional consequences, existing carbon taxes are often embedded in revenue recycling measures giving back carbon tax revenues to compensate households and firms. Carbon taxes can also be designed to be revenue-neutral, meaning introduction of or increase in carbon taxation within environmental tax reforms will result in reductions in other taxes[74].

Analysis of the carbon tax policies in 16 jurisdictions (see Table 3) that apply such taxes has shown that revenues from carbon taxes are either allocated to general government revenue or are fully or partly earmarked to be used for defined purposes. Out of 16 jurisdictions that apply carbon tax, 44% earmark at least part of the revenues for environmental or green transition purposes. Examples of such earmarking include: provision of credits and subsidies to support business transition from fossil fuels (British Columbia), green spending and reduction of energy use in the building sector (Switzerland), or for regeneration of natural resources, preservation of the state of the environment and reparation of the environmental damage (Estonia). Such a use of carbon tax revenues for "green projects" should, according to existing empirical research, increase public acceptability (see Section 2.3.7).

3.2.2 Vehicle taxes

Taxes on car ownership are a widely used measure. Almost all countries included in our research tax vehicles in one form or another. The individual tax regimes differ with regards to many elements, including for example types of vehicles covered. Apart from the tax rate, there are two key components on which a typology of vehicle taxes can be based: the frequency of taxation and the tax base applied.

There are three options for the **frequency of taxing vehicles**:
- A country can decide to tax the purchase and registration of a vehicle (**registration tax**). In this case, a tax has to be paid once when the vehicle is registered;
- A second option is to tax the car on a recurrent, yearly basis (**circulation tax**);
- Finally, some countries apply taxes both at registration and on a recurring basis.

As presented in the table below, there are two EU countries which tax the registration of vehicles only, and eight which solely apply an circulation tax. Two EU Member States (Estonia and Lithuania)do not apply either of them. The majority of 17 countries has both taxes in place. Three countries do not have any tax regime for vehicles.

Table 4 Overview of types of vehicle taxes employed across countries (passenger cars)

Country	Registration tax	Circulation tax	Country	Registration tax	Circulation tax
Austria	+	+	Luxembourg		+
Belgium	+	+	Malta	+	+
Bulgaria		+	Netherlands	+	+

[74] Jurisdictions where carbon taxes are designed to be revenue neutral include among others British Columbia (Canada), Denmark and France. https://openknowledge.worldbank.org/bitstream/handle/10986/26300/Carbon%20Tax%20Guide%20-%20Appendix%20web%20FINAL.pdf?sequence=7&isAllowed=y

Country	Registration tax	Circulation tax	Country	Registration tax	Circulation tax
Croatia	+	+	Poland	+	
Cyprus	+	+	Portugal	+	+
Czechia		(+)**	Romania		+
Denmark	+	+	Slovak Republic	+	(+)**
Estonia			Slovenia	+	+
Finland	+	+	Spain	+	+
France	+	+	Sweden		+
Germany		+	United Kingdom	(+)*	+
Greece	+	+	Canada		
Hungary	+	+	Iceland	+	+
Ireland	+	+	Israel	+	
Italy	+	+	Norway	+	
Latvia		+	Switzerland		+
Lithuania					

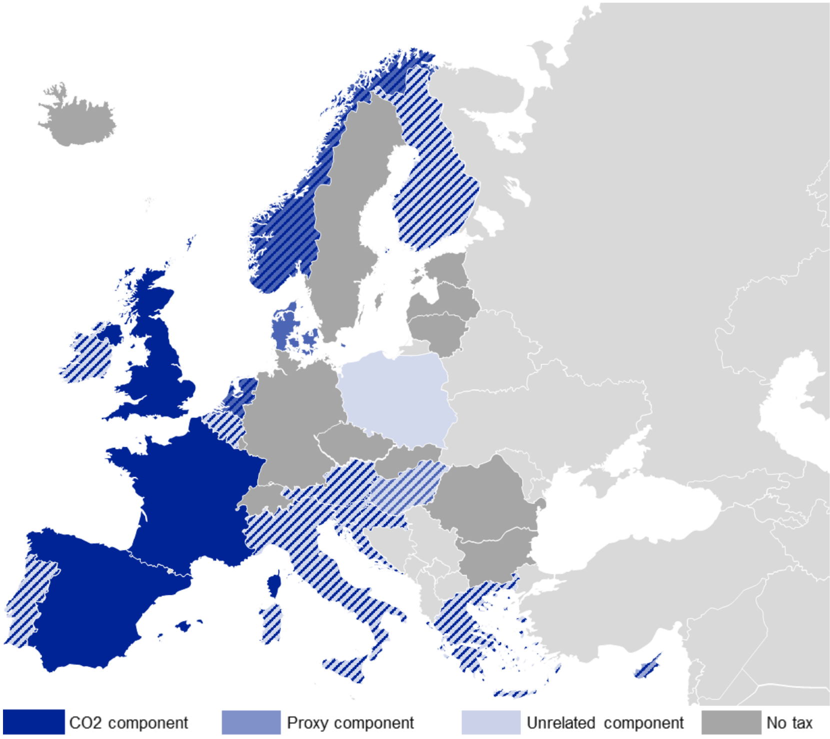
**In the UK, a CO_2-based 'first year rate' applies. **In Czechia and the Slovak Republic, the circulation tax applies to company cars only.*

Source: DIW[75], Eionet[76], and own research

Countries use different **tax bases** to calculate the rates. Increasingly, taxes are based on emissions of vehicles, or features of cars which correlate with GHG emissions as proxy indicators. Some countries use indeed CO_2 emissions as the tax base, or combine CO_2 emissions with other features. Correlated, or proxy features used are fuel consumption, fuel efficiency, and the EURO norm. Features that are used to calculate tax rates but are unrelated to GHG emissions include e.g. the fuel type of the vehicle, its weight, size, number of seats, price, and engine power. The cylinder capacity is a less clear-cut feature. Some studies consider cylinder capacity as a proxy for GHG emissions, while others do not. While cylinder capacity is somewhat correlated with fuel consumption, the relation is not very clear cut. We therefore follow a stricter interpretation of proxies and do not include cylinder capacity as an emission related tax base. The following figures provide an overview of which registration and circulation taxes have a component directly or indirectly linked to GHG emissions.

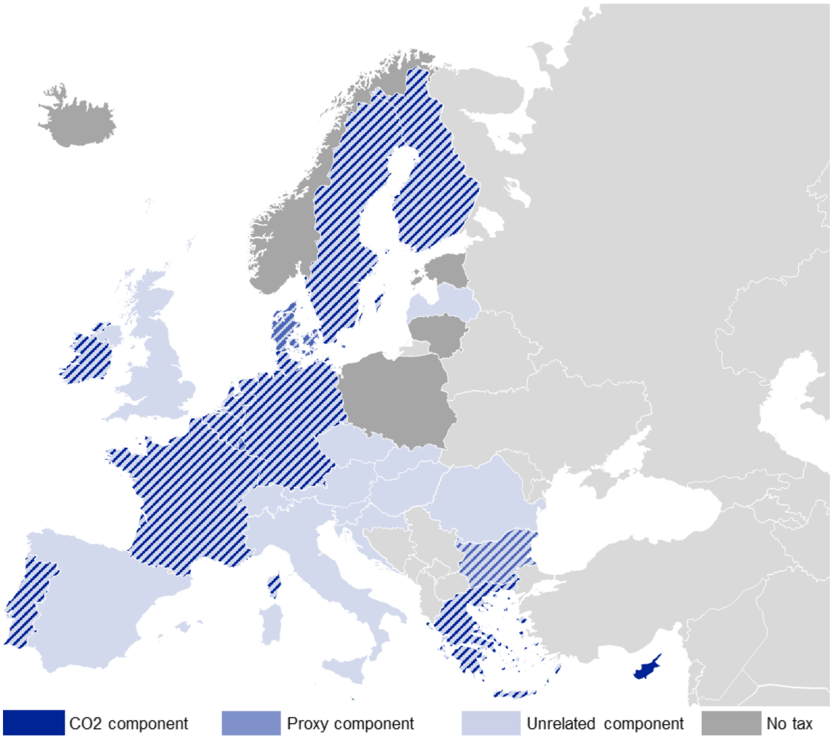
[75] https://www.diw.de/documents/publikationen/73/diw_01.c.595772.de/18-32-1.pdf.
[76] https://www.eionet.europa.eu/etcs/etc-atni/products/etc-atni-reports/eionet_rep_etcacm_2018_1_vehicle_taxes.

Figure 9 Tax base of registration taxes across Europe (passenger cars)



Source: Ecorys

Figure 10 Tax base of circulation taxes across Europe (passenger cars)

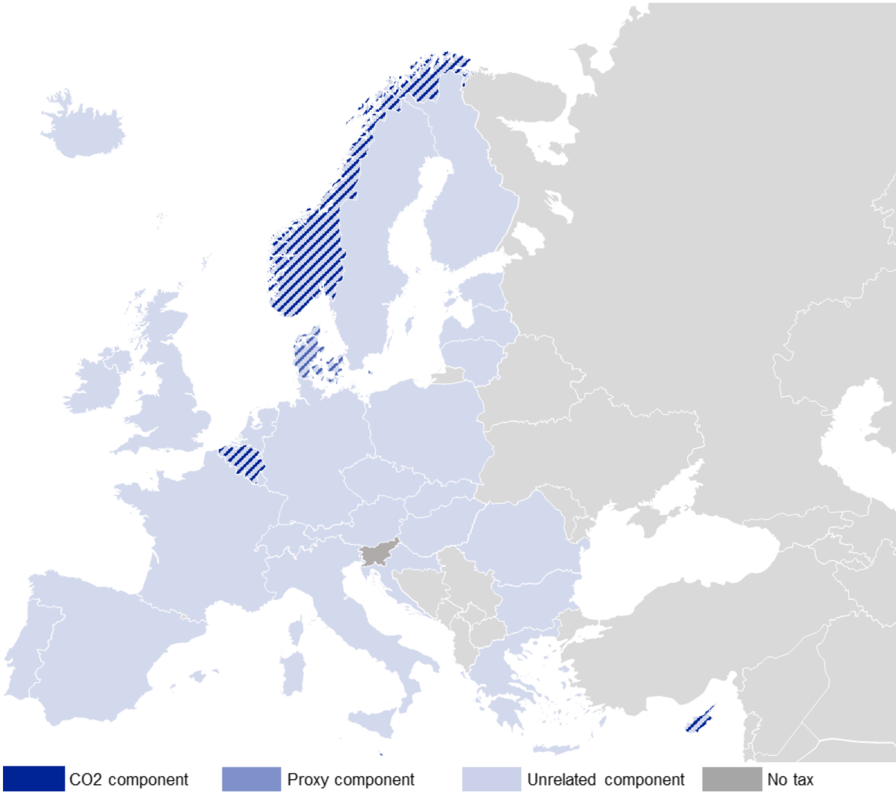


Source: Ecorys

As the two figures illustrate, countries opt for different tax bases, and tend to combine different criteria for the calculation of vehicle tax rates. Circulation taxes appear to rely more often solely on criteria which are not linked to GHG emissions. In particular, many Member States towards the South and East of the EU base circulation vehicle taxes on such criteria. Only few countries base vehicle taxes solely on CO_2 emissions: three for registration taxes (Spain, UK and France), and only one for circulation tax (Cyprus). A plurality of countries opts for a mix of a CO_2 component with emission unrelated components, such as age of the vehicle, fuel type, and cylinder capacity. Indirectly linked components, such as fuel consumption, are used less frequently. Countries solely using proxy components or combining these with other components are Norway, Denmark, and the Netherlands. Larger countries not including CO_2 at all are Spain and Italy.

We also explored whether different tax bases are adopted to (heavy) commercial vehicles with our country research. The results are presented in the following figure.

Figure 11 Tax base of circulation taxes across Europe (commercial vehicles)



Source: Ecorys

Circulation taxes for (heavy) commercial vehicles are usually based on different components than passenger cars. In most of the countries covered by the study, circulation taxes are levied based on vehicles' weight and other proxies not related to GHG emissions, such as the number of axles and suspension type. In only few countries, Belgium, Cyprus, Malta, and Norway, the circulation tax is based on CO2 emission, while in Denmark, it is levied on an indirect proxy, the fuel consumption.

3.2.3 Energy Taxes

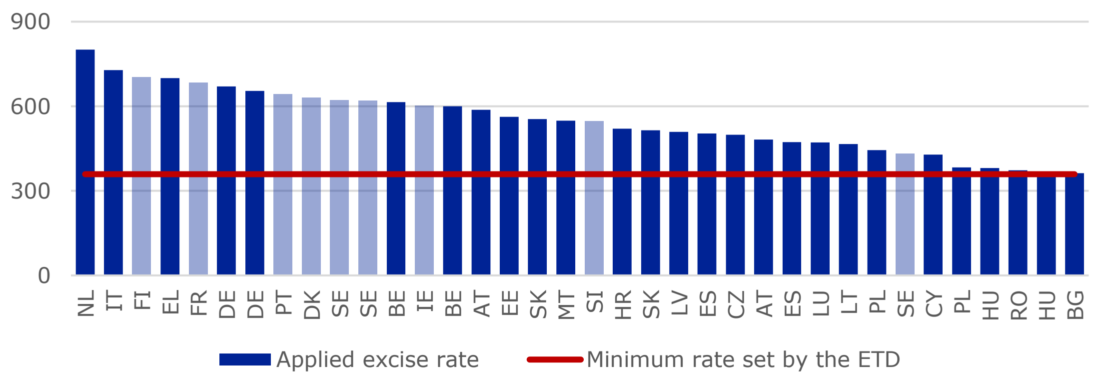
Directive 2003/96/EC (hereafter the Energy Taxation Directive or ETD)[77] establishes the minimum excise duty rates that Member States must apply to energy products for motor fuels, heating fuels and electricity. In principle, the Member States are free to apply excise duty rates above these minimum levels of taxation, according to their own national needs and environmental ambitions.

[77] Note that the ETD is currently under revision after an evaluation found that its EU added value with regards to environmental protection and reduction of GHG emissions is very limited.

The ETD also lays down the conditions for applying tax exemptions and reduction for the above-mentioned energy products, which are however not systematically based on the potential of energy savings or emission reductions (see below harmful tax incentives). Indeed, energy taxes do not directly focus on the reduction of GHG emissions, however they can have an indirect impact on the emissions firstly by improving energy efficiency (using less fuel per unit of output and less fuel at the margin) and secondly by increasing effectiveness if fuel with a lower carbon content is used (tax on fossil fuels increases attractiveness of alternative fuels).

In the area of energy, taxes and charges are applied on energy products used for transport, mainly petrol and diesel, (Figure 12 and Figure 13) and for stationary purposes including fuel oils, natural gas (Figure 15 and Figure 16), coal and electricity (Table 5). The ETD sets minimum excise rates for kerosene (Figure 14), however all EU Member States apply exemptions for aviation. The rate of taxation applied varies significantly across different energy products, sectors and countries. Most EU Member States apply rates that are well above the minimum for most of the motor fuels (see figures below, the minimum rate is identified by a red line). In particular, those countries, which in addition to excise tax apply also a carbon or CO_2 tax to fuels, are characterised by an above average total excise tax rate paid on motor fuels (Finland, Denmark, Sweden, Ireland, Slovenia and Portugal). On the other hand, several countries make use of Article 15(1) of ETD[78] which allows Member States to apply a reduction or completely exempt natural gas and LPG when they are used as propellants.

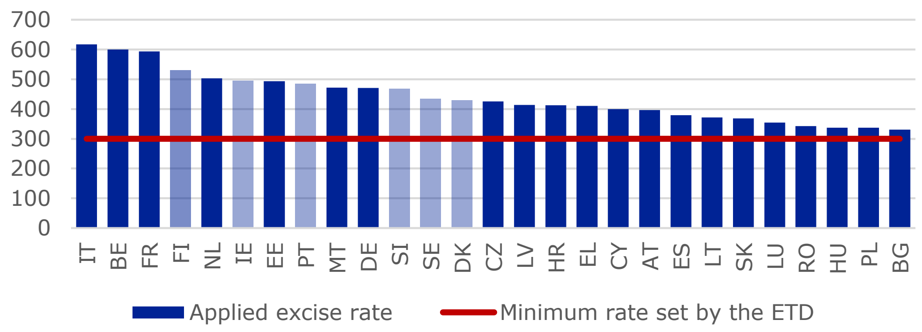
Figure 12 Unleaded petrol excise rate, EU 27, values in EUR at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax. Several countries apply different rate to unleaded petrol depending on level of sulphur (BE), environmental class (SE), level of market price of crude oil (HU) or biofuel content (AT).

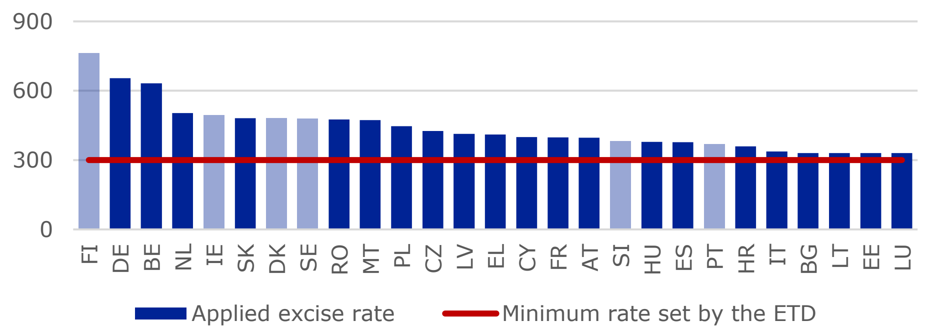
[78] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02003L0096-20180915&qid=1555408487782&from=EN

Figure 13 Gas oil (used as propellent) excise rate, EU 27, values in EUR at 01/01/2020



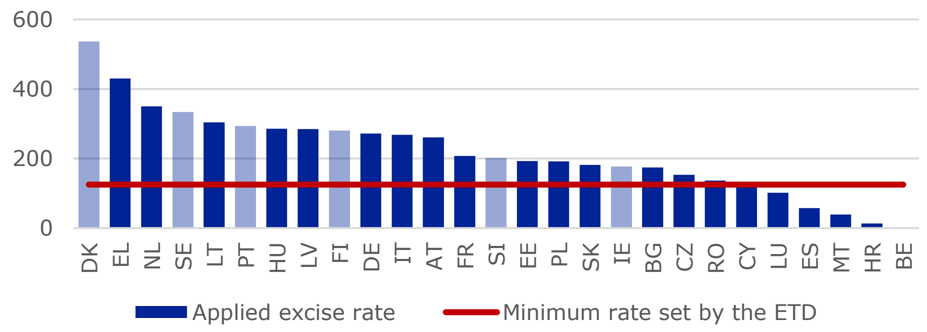
Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax.

Figure 14 Kerosene (used as propellent) excise rate, EU 27, values in EUR at 01/01/2020



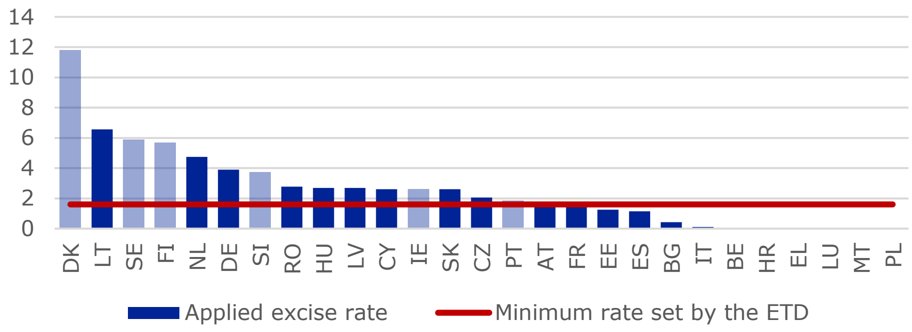
Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax.

Figure 15 LPG (used as propellent) excise rate, EU 27, values in EUR at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax.

Figure 16 Natural gas (used as propellent) excise tax, EU 27, values in EUR at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax

With regard to use of fuels for heating purposes, similarly to taxes on fuels used as propellants, most EU Member States apply rates that are well above the minimum reduced rates, which are however much lower than the minimum rates on fuel used as propellant[79]. Minimum rates for business and non-business use are equal for gas oil, heavy fuel oil, kerosene and LPG (see **Table 5**) and Member States apply the same tax rate for those four fuels used in heating regardless of their purpose, with an exception of Italy (for LPG and heavy oil), Germany (for LPG, gas oil, and kerosene), Sweden (for kerosene, heavy oil and gas oil) where somewhat higher rates are applied for non-business purposes. The figures below present the rates applied. As in the case of motor fuels, countries, which in addition to excise tax also apply a CO2 tax, are characterised by an above average total excise tax rate for heating fuels (Finland, Denmark, Sweden, Ireland, Slovenia and Portugal).

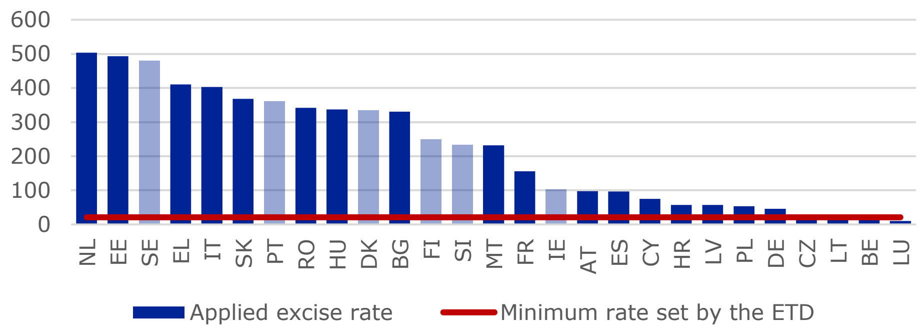
Table 5 Minimum rates for heating and electricity as required by the ETD

Fuel	Rate expressed per	Rate for business use	Rate for non-business use
Gas Oil	Euro per 1000 litres	21	21
Heavy fuel oil	Euro per 1000 kilos	15	15
Kerosene	Euro per 1000 litres	0	0
LPG	Euro per 1000 kilograms	0	0
Natural Gas	Euro per gigajoule	0.15	0.3
Coal and Coke	Euro per gigajoule	0.15	0.3

Source: Directive 2003/96/EC

[79] Article 11 of ETD allows Member States to apply differentiated rates for heating fuels and electricity for business use vs. non-business use (Article 11)

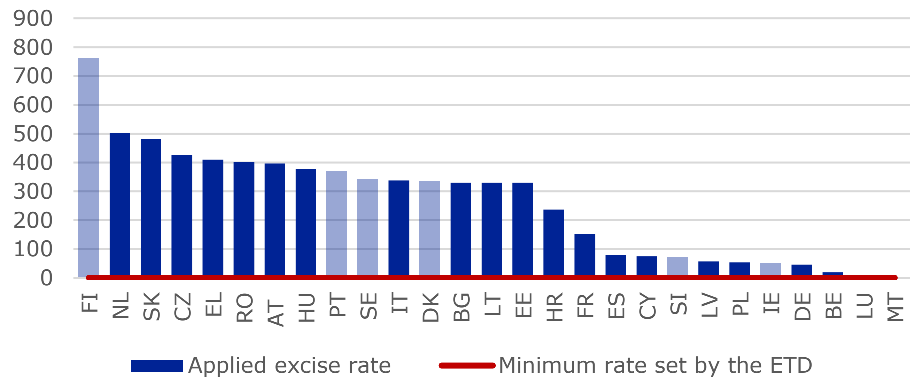
Figure 17 Gas oil (heating business use) excise rate, EU 27, values in EUR at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html

Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax

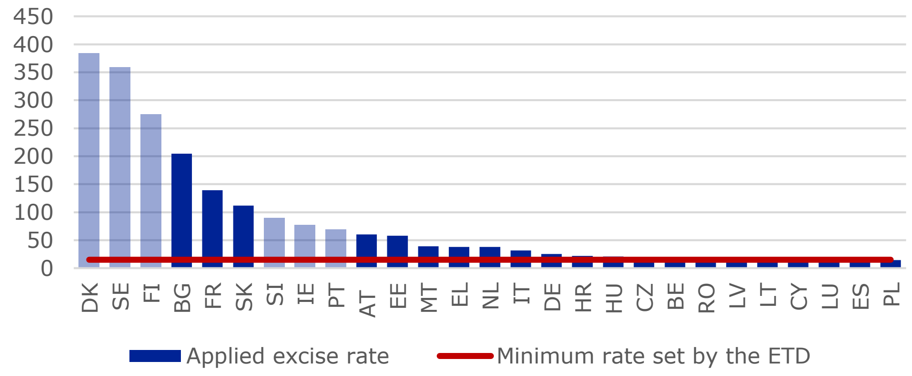
Figure 18 Kerosene (heating business use) excise rate, EU 27, values in EUR at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html

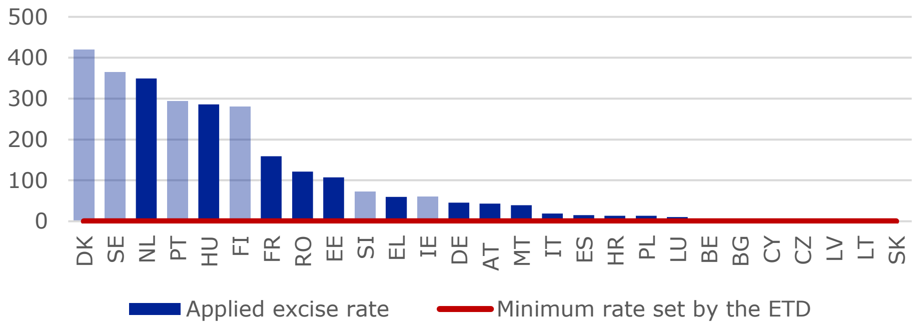
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax

Figure 19 Heavy fuel oil (heating business use) excise rate, EU 27, values in EUR at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax

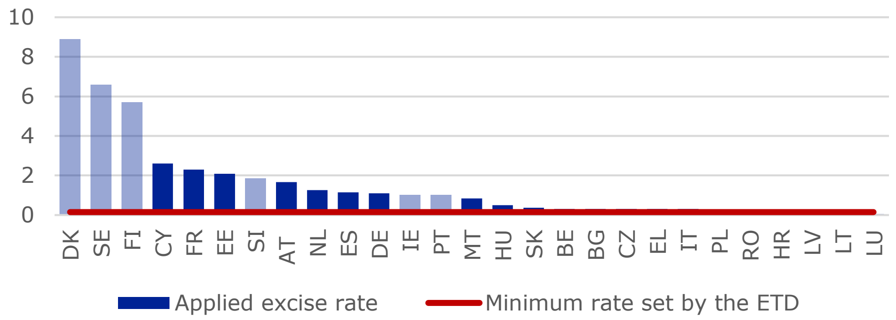
Figure 20 LPG (heating business use) excise rate, EU 27, values in EUR at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html

Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax

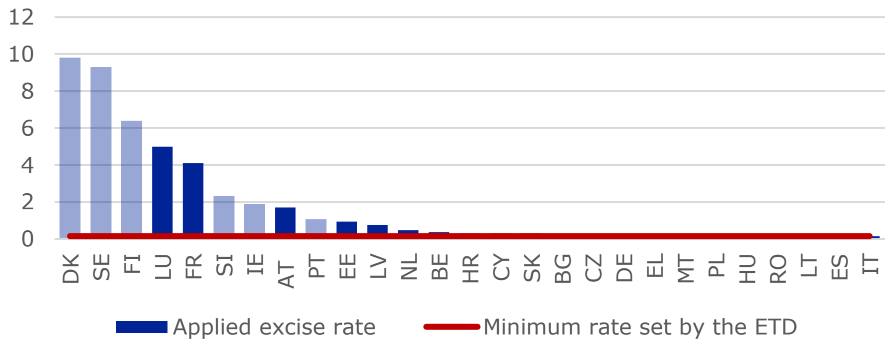
Figure 21 Natural gas (heating business use) excise rate, EU 27, values in EUR at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html

Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax

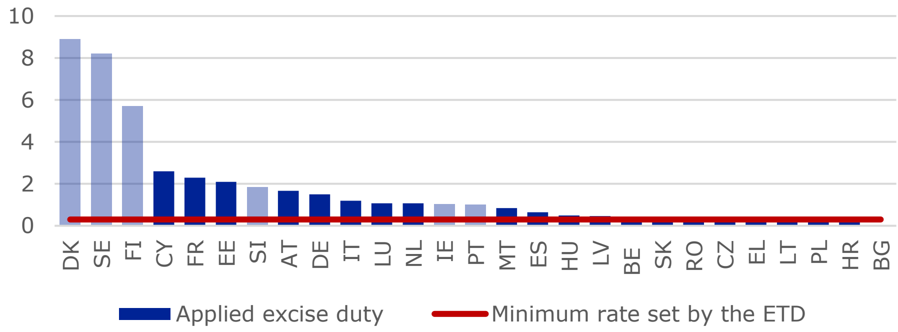
Figure 22 Coke and coal (heating business use) excise rate, EU 27, values in EUR at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax.
Several countries apply different rates to certain heating fuels depending on level of sulphur (AT, BE, DE, IT), level of market price of crude oil (HU), consumption level (NL, EL) or whether the fuel is used for heating purposes in the manufacturing process in industry where No CO2 tax is applied in the manufacturing process in industry within the Emission Trading Scheme (SE).

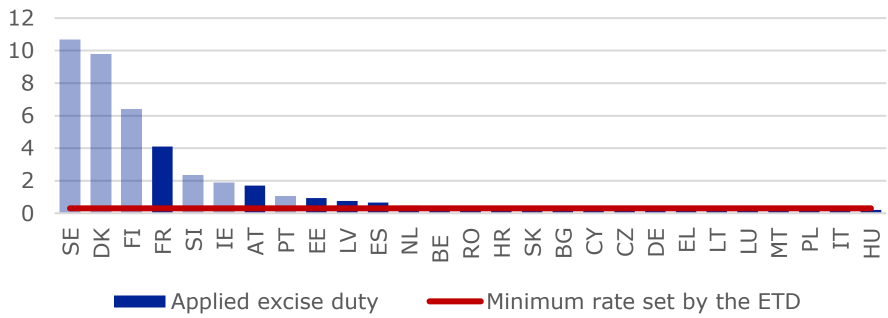
Minimum taxation rates for natural gas and coke and coal used as heating fuels for non-business use are higher than the minimum rates for business use (0.3 Euro per gigajoule as opposed to 0.15 Euro per gigajoule in business use). The actual rates applied also vary in most Member States depending on the purpose. Figure 23 and Figure 24 show that 22% of Member States apply the minimum rate for natural gas for non-business use and 52% apply the minimum rate (or a rate which is less than 10% higher than the minimum) for coke and coal for non-business use. In the absence of an increase in minimum rates for more than a decade at EU level[80] and low actual rates applied, the tax-induced price signal that could encourage investment in energy-efficient and greener technology and behaviour was and is still absent in Member States that apply minimum rates. In case of coke and coal which has relatively high carbon content compared to other fuels[81] and is often used as heating fuel in certain Member States (e.g. Poland, Czechia), the price signals from taxation in those countries that apply minimum rates are likely to have weak impact on consumption and thus do not contribute to lowering of GHG emissions.

Figure 23 Natural gas (heating non-business use) excise rate, EU 27, values in EUR per gigajoule at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax

Figure 24 Coke and coal (heating non-business use) excise rate, EU 27, values in EUR per gigajoule at 01/01/2020



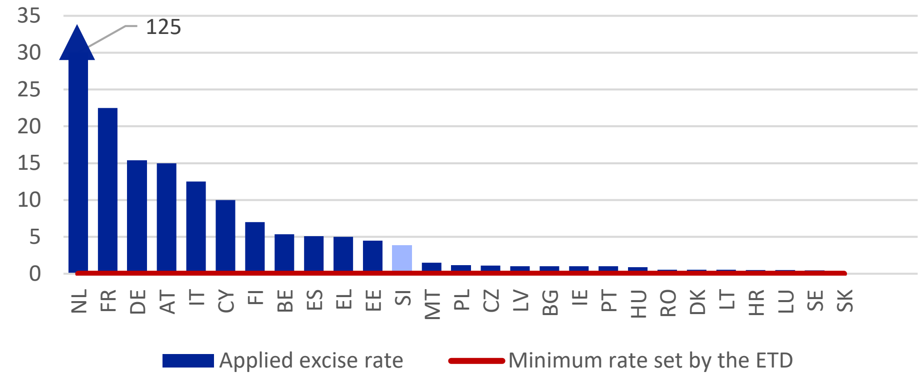
Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax

In terms of electricity, several Member States apply nominal rates above the minima set by the ETD (1 EUR/MWh for non-business and 0.5 EUR/MWH for business use) as shown in Figure 25 and Figure 26. The highest rate applied to electricity in 2020 was 125 EUR/MWh in the Netherlands[82]. At the same time, nine Member States applied the minimum rate to either business or non-business electricity use and in one Member State households remained exempted in 2020. However, the environmental case for electricity taxation is weaker than for taxation of motor or heating fuels. Firstly, most electricity taxes are not differentiated by energy source, and hence make all energy sources more expensive irrespective of the carbon content.[83] Secondly, they can

[80] https://ec.europa.eu/taxation_customs/sites/taxation/files/energy-tax-report-2019.pdf p. 17
[81] The carbon content of coal and coke is around 26 kg/Gj (kilogrammes / gigajoule) compared to 17 kg/Gj in LPG and 15 kg/Gj in natural gas. Source: http://wds.iea.org/wds/pdf/WorldCo2_Documentation.pdf.
[82] The Dutch electricity tax is financing RES and is thus akin to parafiscal charges financing feed-in-tariffs in other countries.
[83] https://www.oecd-ilibrary.org/sites/499f15c2-en/index.html?itemId=/content/component/499f15c2-en

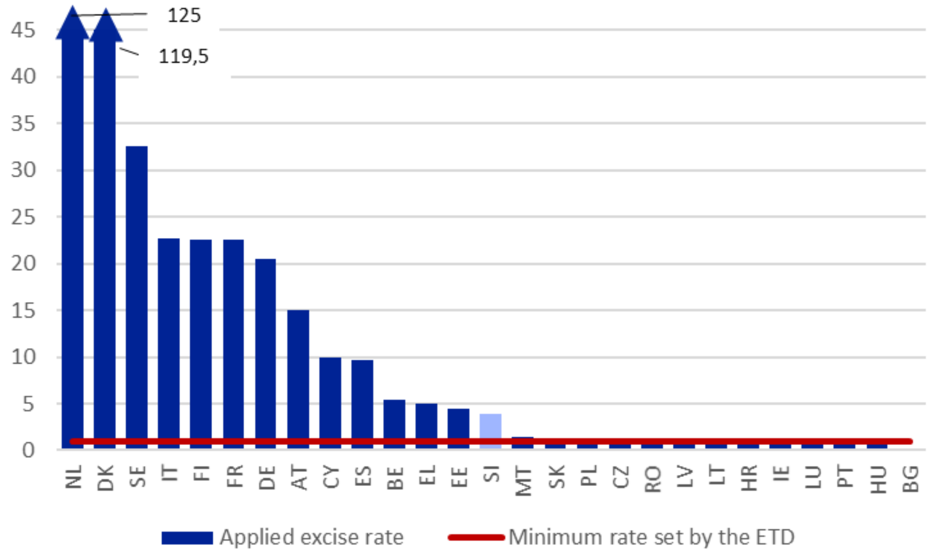
discourage electrification and decarbonisation of sectors such as road transport making switching to electricity (and in case of transport to electric or hybrid cars) less profitable for end users, everything else being equal.[84]

Figure 25 Electricity (business use) excise rate, EU 27, values in EUR per MWh at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: Tax rate in countries marked in light blue includes carbon tax in addition to excise tax

Figure 26 Electricity (non-business use) excise rate, EU 27, values in EUR per MWh at 01/01/2020



Source: Taxes in Europe Database https://ec.europa.eu/taxation_customs/tedb/taxSearch.html
Note: In certain Member States differentiated rate is applied depending on consumption; for business-use (the Netherlands and Italy) and non-business use (the Netherlands and Slovenia). The rates presented above apply for the consumption of first 10,000 MWh; for higher consumption, lower rates are applied.

3.3 Beneficial tax incentives

The country research yielded a variety of beneficial tax incentives. In addition, while a relatively concise number of emission related taxes is employed in almost all countries (though characteristics of the individual tax measure differ from country to country), uptake of specific tax incentives is far less consistent across countries. Therefore, tax incentives could provide ideal opportunities to foster policy learning across borders.

[84] ibid

In total, we identified around 129 beneficial tax incentives. The table below provides an overview of the tax incentives that have been identified per country covered in this study. All 33 countries covered employ tax incentives to reduce GHG emissions.

Table 6 Overview of the number tax incentives per country covered

Country	Tax incentives identified	Number of tax incentives identified	Country	Tax incentives identified	Number of tax incentives identified
Austria	✓	5	Malta	✓	3
Belgium	✓	8	Netherlands	✓	2
Bulgaria	✓	5	Poland	✓	4
Croatia	✓	2	Portugal	✓	3
Cyprus	✓	1	Romania	✓	2
Czechia	✓	9	Slovak Republic	✓	2
Denmark	✓	1	Slovenia	✓	3
Estonia	✓	2	Spain	✓	2
Finland	✓	10	Sweden	✓	4
France	✓	7	United Kingdom	✓	3
Germany	✓	4	Canada	✓	6
Greece	✓	2	Iceland	✓	2
Hungary	✓	6	Israel	✓	6
Ireland	✓	2	Norway	✓	1
Italy	✓	8	Switzerland	✓	2
Latvia	✓	2			
Lithuania	✓	5			
Luxembourg	✓	2			

Source: Ecorys

Overall, the universe of tax incentives appears to be more diverse than that of taxes employed by Member States. This renders the categorisation of measures a bit more challenging. At the same time, this diversity also provides more opportunities to assess a wider portfolio of measures and their respective effectiveness. The fact that any given tax incentive is also less frequently employed also provides more opportunities for policy learning.

The following table reports on some of the more common tax incentives. Three types of incentives have been identified that are used in a larger number of countries: tax incentives to enhance the uptake of electric vehicles, incentives to enhance energy efficiency (and related R&D), as well as measures to enhance the use of public transport. The table below identifies which of the three incentives has been identified in each country.

Table 7 Overview of common types of tax incentives in countries covered

Country	EV	EEI	PT	Country	EV	EEI	PT
Austria	✓		✓	Malta	✓	✓	
Belgium	✓	✓	✓	Netherlands	✓	✓	✓
Bulgaria	✓	✓		Poland	✓	✓	✓
Croatia			✓	Portugal	✓		
Cyprus	✓			Romania	✓		
Czech Republic	✓	✓		Slovak Republic	✓		
Denmark		✓		Slovenia	✓		
Estonia	✓			Spain			✓
Finland	✓		✓	Sweden	✓		✓
France		✓		United Kingdom	✓	✓	
Germany	✓		✓	Canada	✓	✓	✓
Greece			✓	Iceland	✓		
Hungary	✓	✓		Israel	✓	✓	
Ireland	✓	✓		Norway	✓		
Italy	✓	✓	✓	Switzerland		✓	
Latvia							
Lithuania		✓					
Luxembourg	✓						

EV: electric vehicles; EEI: energy efficiency & related innovation; PT: public transport

Source: Ecorys

3.3.1.1 Tax incentives to foster the uptake of electric vehicles (EVs)

Tax incentives for electric vehicles are very common in the countries covered in this study. A total of 25 countries have EV related tax incentives in place. The tax incentive itself can take various forms. Many countries opt for exempting EVs from vehicle taxes. Depending on the specific vehicle tax regime in the respective country, this means that EVs are exempt from registration taxes, circulation taxes, or both. A full exemption from vehicle taxes appears to be more common, while some countries (including e.g. Finland and Ireland) apply the lowest tax rate possible to EVs. In few countries, including e.g. Germany, exemptions are temporary (10 years full exemption, and 50% of usual rate afterwards in Germany). Some countries (e.g. Austria) exempt EVs also from other taxes, such as VAT for company cars. The table below provides an overview of the tax to which a tax break is applied to incentivise individuals and companies to buy electric vehicles.

Table 8 Overview of number of EV related tax breaks and related taxes per country

Country	Number of EV tax incentives	Vehicle tax	VAT	PIT/ CIT	Energy	Other
Austria	4	✓	✓	✓		
Belgium	3	✓		X		
Bulgaria	1	✓				
Cyprus	1	✓				
Czech Republic	3	✓	✓	✓		
Denmark	3	✓		✓		
Estonia	1			✓	✓	
Finland	2	✓				

Country	Number of EV tax incentives	Vehicle tax	VAT	PIT/ CIT	Energy	Other
Germany	2	✓				
Hungary	3	✓				
Ireland	1		✓	✓		
Italy	2	✓				
Luxembourg	2			✓		✓
Malta	2	✓				
Netherlands	1	✓				
Poland	1				✓	
Portugal	3	✓	✓			
Romania	2	✓				
Slovak Republic	2	✓				✓
Slovenia	2	✓				
Sweden	2	✓				✓
United Kingdom	1			✓		
Canada	1					✓
Iceland	1		✓			
Israel	1	✓				
Norway	1	✓				

Source: Ecorys

The availability of charging factors is a key determining factor of the uptake of EVs.[85] If the density of charging stations is too low, buyers are reluctant to purchase an electric vehicle. However, while purchase incentives are widespread, this is less the case for incentives to set up charging stations. The table below provides an overview of the countries where infrastructure incentives exist. In most instances, these take the form of payments, i.e. subsidies, which are not considered further in this report. Only two countries (France and Italy) appear to have tax breaks in place to incentivise the installation of charging stations.

Table 9 Overview of tax incentives and subsidies for the installation of EV charging stations

Country	Tax incentive	Subsidy
Austria		✓
Denmark		✓*
Finland		✓
France	✓	✓*
Germany		✓**
Greece		✓
Ireland		✓
Italy	✓	
Lithuania		✓
Malta		✓
Romania		✓
Spain		✓
Sweden		✓

[85] See https://www.iea.org/reports/global-ev-outlook-2019.

Country	Tax incentive	Subsidy
United Kingdom		✓
Canada		✓
Iceland		✓
Israel		✓
Norway		✓

**Unclear whether subsidies are still in place; **At least partially at Länder level*

Source: European Alternative Fuels Observatory[86]

3.3.1.2 Tax incentives to enhance energy efficiency and related innovation

Another relatively common tax incentive are tax breaks to increase energy efficiency. The individual design of the measure can take various forms. Quite common are tax breaks on income or corporate tax when individuals or companies decide to renovate their buildings in line with stricter energy efficiency rules. Business specific are tax breaks that reward installing environmentally friendly or energy efficient equipment and machines (for example, the Netherlands apply such incentives). Finally, there are a few instances where countries incentivise R&D in energy or resource efficiency via tax breaks. Almost all tax breaks targeting energy efficiency and related innovation are applied to the personal or corporate income tax. A few tax incentives are related to reduced VAT. Depending on the individual design of the tax incentives, companies or individuals, or both are eligible. The table below provides an overview of the number of relevant tax incentives per country, and which tax the tax breaks are applied to.

Table 10 Overview of number of EEI related tax breaks and related taxes per country

Country	Number of EEI tax incentives	VAT	Personal income/ corporate tax	Other
Belgium	3		✓	✓
Bulgaria	1		✓	
Canada	3		✓	✓
Czech Republic	4		✓	✓
Denmark	1		✓	
France	3	✓	✓	✓
Hungary	1		✓	
Ireland	1		✓	
Israel	2		✓	
Italy	3		✓	✓
Lithuania	5	✓	✓	
Malta	1		✓	
Netherlands	3		✓	
Poland	2	✓	✓	
Switzerland	1		✓	
United Kingdom	2	✓	✓	

EEI: Energy efficiency & related innovation

Source: Ecorys

[86] https://www.eafo.eu/.

3.3.1.3 Tax incentives to strengthen public transport

Several countries use tax incentives to support public transport. In total, we have identified 11 countries which employ such measures. We identified 16 tax incentives that support the use of buses, trains, and other means of public transport. Overall, we have identified three channels through which tax breaks can support public transport. First, commuters themselves can benefit from tax incentives targeting public transport. Most often, this is achieved via VAT reductions (such as in Germany and Austria), lowering the price of tickets, or via tax breaks applied to the income tax for (annual) subscriptions. A second channels support public transport via employers who can deduct support for subscriptions for employees from their taxes. Finally, there are countries (e.g. Finland and Germany) where public transport companies benefit from tax breaks, e.g. for the use of energy as allowed under the ETD. The table below summarises the measures in use across the countries covered in this study.

Table 11 Overview of number of public transport related tax breaks and related taxes per country

Country	Number of incentives	Vehicle tax	VAT	PIT/ CIT	Energy
Austria	1		✓		
Belgium	1			✓	
Canada	1			✓	
Croatia	1				✓
Finland	5	✓	✓	✓	✓
Germany	2		✓		✓
Greece	1			✓	
Italy	1			✓	
Netherlands	1			✓	
Poland	1		✓		
Spain	1			✓	

PT: public transport

3.4 Environmentally harmful tax incentives

3.4.1 Definition

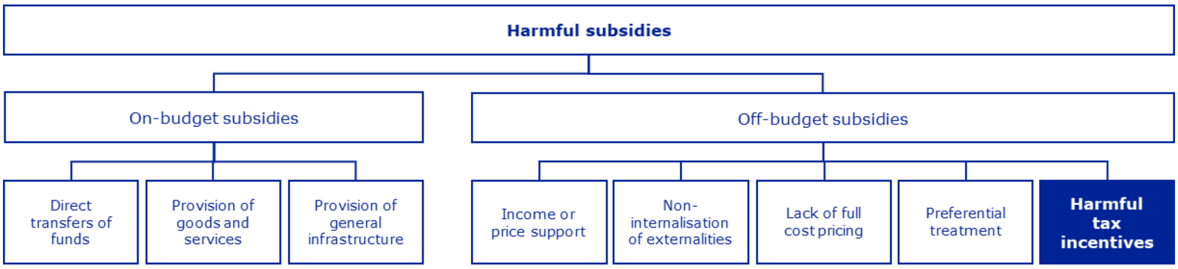
There is no universally accepted definition of a subsidy or an environmentally harmful subsidy, but there are rather several different definitions (WIFO, 2016). In general, subsidies are the result of a government action providing advantages for consumers or producers, by increasing their income or reducing their production costs. In 1998, the OECD defines environmentally harmful subsidies as "…all kinds of financial supports and regulations that are put in place to enhance the competitiveness of certain products, processes or regions, and that, together with the prevailing taxation regime, (unintentionally) discriminate sound environmental practices."

The Environmental Environment Agency distinguishes on-budget subsidies, that appear as government expenditures on national budgets and off-budget subsidies that do not appear as government expenditures on national accounts (EEA, 2004).

As the objective of the study is to define a set of concrete policy recommendations to enhance efforts to reduce the emissions of greenhouse gases, it is also important to consider harmful tax subsidies within the scope of tax schemes given that their removal can lead to a reduction in polluting behaviours.

Therefore, this study encompasses harmful tax incentives, a specific sub-type of environmentally harmful subsidies. Tax incentives are considered harmful when the provisions they provide in the tax system favour polluting behaviours (for e.g. through the use of technology, consumption etc.). They usually lead to negative environmental impacts such as increase in GHG emissions and support emission-intensive behaviours (e.g. favourable tax treatment for company cars).

Figure 27 Different economic types of harmful subsidies



Source: Ecorys based on IEEP (2012)

3.4.2 Typology of harmful tax incentives

In the course of the study, we identified several types of harmful tax incentives which are in place within the European Union, linked to the transport and the energy sectors:

- commuter allowances ;
- company car benefits ;
- favourable tax treatments for specific business sectors ;
- rebated excise duties for fuels, electricity, and the like (exemptions under the ETD) for specific sectors (aviation, maritime, energy intensive business,…);
- CO2 tax exemption for GHG-intensive companies ;

The scope of the present study does not encompass aviation and maritime transports. Other types of harmful tax incentives exist within these sectors: the Directive 2006/112/EC currently contains several exemptions for the passenger transport sector. International flights and maritime passenger transport are de facto not subject to VAT. With its action plan for fair and simple taxation[87] published in July 2020, the European Commission will consider reviewing these exemptions to ensure their coherence with the objectives of the European Green Deal.

Table 12 Main types of harmful tax incentives

Type of harmful tax incentive	Economic type(s)	Sector	Description
Commuter allowance	Corporate/ Personal income tax deduction	Transport	Commuter allowances create incentives to use private cars to commute to work. It usually benefits the employee, who can deduct a set rate per kilometre for their commute to work, as for example in Germany. In Austria, the

[87] Communication from the Commission to the European Parliament and the Council on an Action plan for fair and simple taxation supporting the recovery strategy, 15 July 2020.

Type of harmful tax incentive	Economic type(s)	Sector	Description
			allowance is based on the distance to work and whether the use of public transport is possible or not.
Company car benefits	Corporate/ Personal income tax deduction VAT deduction/exemption	Transport	Company car benefits create incentives to use company cars for private use. They set incentives for employers (as well as employees) when the vehicle tax burden on company cars is smaller than for privately held cars.
Favourable tax treatments for specific business sectors	VAT deduction/exemption Tax exemption	Transport	Favourable tax treatments often apply for vehicles used in specific business sectors for which activities rely on the use of road vehicles, such as taxis, rental companies, security or courier. The tax incentive is often applied as a deduction or sometimes exemption of the VAT. Favourable tax treatments also apply for the use of agricultural vehicles. They set incentives for owners of agricultural vehicles who benefit from reduced road taxes or complete exemptions.
Rebated energy taxes	Reduced rates and tax exemptions	Energy	The wide range of reduced rates and exemptions from energy taxation are one of the most important harmful tax subsidies. These concern important sectors, such as aviation and maritime transport that are currently fully exempt from energy taxation, but also other sectors such as (energy intensive) business and manufacturing sectors or agriculture whereby the tax rates are reduced or part of the tax payment is refunded. Often such reductions are justified with the aim of safeguarding important sectors' competitiveness and public acceptability. Member States are currently allowed to apply a wide range of exemptions under the ETD. In the context of the revision of the ETD, the European Commission will look at current tax exemptions and assess how to close any loopholes and end fossil-fuel subsidies to reach the objectives of the European Green Deal.
Carbon tax exemption for GHG-intensive companies	Tax exemption	Energy	This exemption allows GHG intensive installations of small and medium-sized enterprises (in specific industries) to be exempted from paying the carbon tax on the use of fossil fuels. It applies to solid, liquid and gaseous fossil fuels when used for heating purposes and to fuel stationary motors. It is usually justified on grounds of

Type of harmful tax incentive	Economic type(s)	Sector	Description
			international competitiveness of the enterprises in these industries. Their competitiveness would be at risk due to their high CO_2 tax burden in relation to their value.

3.4.3 Overview of harmful tax expenditures across the EU

Our research suggests that harmful tax incentives are the most widespread within the road transport and energy sectors. Therefore, we provide a more detailed overview of harmful tax incentives for those two specific sectors given their prevalence and their contribution to GHG emissions.

3.4.3.1 Mapping of harmful tax incentives in the road transport sector in the EU

We identified three main types of harmful tax incentives in the road transport sector: company cars incentives, commuter allowances and preferential tax treatment for vehicles used in specific business sectors. Some measures, such as commuter allowances, are more concentrated in some countries than others, which are more widely spread (for e.g. preferential tax treatment for specific business sectors).

In 2012, between 42% and 56% of the taxable benefit from the use of a company car was not taxed according to an OECD Working Paper (Harding, 2014). These company car incentives usually take the form of income tax deductions, personal income tax deductions and/or VAT deductions applied on acquisition and functioning costs of a company car. In several countries (Belgium, Estonia, Hungary, Latvia..) company cars can benefit to a VAT deduction up to 50% while in other countries (Ireland), the level of the deduction depends on the level of the car's CO2 emissions.

Commuter allowances often take the form of personal income tax deduction based on a fixed amount per kilometre travelled. This amount varies between countries and can be subject to specific modalities: in Denmark, the amount is fixed based on the distance between the residence and the workplace when in Austria, the incentive is only available if the use of public transportation is possible. An employee in Germany can deduct 0.30 EUR per kilometre from his personal income tax with a maximum of 4,500 EUR per year while an employee in Luxembourg cannot deduct more than 2,574 EUR per year.

Preferential tax treatment is often used for specific business activities such as taxis and rental companies where the use of a vehicle is intensive. These preferential treatment are also widely spread in the agricultural sector where vehicles can benefit from tax reductions and exemptions: for example, agricultural vehicles can benefit up to 25% of reduction from the road tax in Czech Republic and are exempted from the special road tax in Spain.

Some countries, including Belgium and Austria, combine several harmful tax incentives in the road transport sector, which is likely to have a further negative effect on GHG emissions (see Table 13).

Table 13 Overview of harmful tax incentives in the road transport sector

Company cars incentives	Commuter allowances	Preferential tax treatment for vehicles used in specific business sectors
Corporate/Personal income tax deduction		
Austria, Belgium, Bulgaria, Czech Republic, Latvia, Luxembourg, Romania	Austria, Belgium, Denmark, Finland, Germany, Luxembourg, Slovenia, Sweden	
VAT deduction		
Belgium, Czech Republic, Estonia, Germany, Hungary, Ireland, Netherlands, Slovakia, Spain, Sweden		Austria, Belgium, Bulgaria, Czech Republic, Denmark, France, Finland, Greece, Italy, Latvia, Portugal, Romania, Slovenia, Spain
VAT/Tax exemption		
		Estonia, France, Netherlands, Portugal, Luxembourg, Poland, Slovakia, Spain, Sweden

Source: Ecorys based on PWC 2019 Global Automotive Tax Guide

3.4.3.2 Mapping of harmful tax incentives in the energy sector

Harmful tax incentives are also widely spread in the energy sector. The Energy Taxation Directive allows for a range of exemption and reduction rates on several types of energy sources.

Primarily designed to avoid competitive distortions within the energy market, the ETD established common rules at the EU level for the taxation of energy products. It covers specific sectors that are not encompassed by the EU ETS (e.g. vehicles) and provided a minimum price on carbon for energy uses when the EU allowance prices under the EU ETS were low. However, using the directive as an instrument to contribute to climate change policies was left at the discretion of the Member States.

The current exemptions and reductions allowed under the directive represent forms of fossil fuel subsidies that are not in line with the objectives of the European Green Deal. The ETD remained unchanged since its implementation while technologies, energy markets and the EU framework evolved, which results in a significant misalignment with other policy instruments (European Commission, 2019). Therefore, the tax incentives of the ETD can be considered as harmful tax incentives to reach the EU's climate targets.

The table below maps the tax incentives provided by Member States under the ETD (described in section 3.2.3). It shows which countries apply which exemptions or reduced rates for different energy products and electricity. Most Member States apply a reduced excise tax rate for gas oil when used for agricultural, horticultural or piscicultural works, and in forestry (74% of Member

States) and when used as a heating fuel (74% of Member States). Most countries also make use of the provision to apply a reduced rate for LPG and natural gas when they are used for heating fuel (81% and 52% respectively). Reduced rates are also often applied when motor fuels are used for commercial and industrial use. 15 Member States apply reduced rates on gas oil, 7 apply reduced rates on kerosene (aviation excluded), 8 apply reduced rates on LPG, 4 apply a reduced rate on natural gas and 4 apply no excise tax on natural gas when it is used for commercial and industrial purposes.

Table 14 Reduced rates and exemptions applied in Member States for energy products and electricity

Sector or use	Article in ETD	Number of countries	Reduced rate	Zero rate
Gas oil				
Agricultural, horticultural or piscicultural works, and in forestry	Article 8(2)(a); Article 15(3)	20	CY, CZ, DK, EE, FI, FR, DE, HU, IE, IT, LV, LT, PT, RO, SL, ES, SE	BE, HR, LU,
Industrial/commercial use	Article 8(2)(b); Article 8(2)(c); Article 8(2)(d);	15[88]	AT, BE, CY, FI, FR, DE, EL, HU, IE, IT, LU, PT, SL, ES, SE	
Heating fuel	Article 5	20	AT, BE, HR, CY, CZ, DK, FI, FR, DE, IE, IT, LV, LT, LU, MT, PL, PT, SL, ES, SE	
Commercial use as propellant	Article 7(2)	6	BE, HR, FR, HU, IT, SL	
Kerosene (aviation excluded)				
Agricultural, horticultural or piscicultural works, and in forestry	Article 8(2)(a); Article 15(3)	9	BE, CY, CZ, DK, IE, LU, PT, SL, SE	
Industrial/commercial use	Article 8(2)(b); Article 8(2)(c); Article 8(2)(d);	7[89]	BE, CY, DE, IE, LU, SL, SE	
Heating fuel	Article 5	13	BE, HR, CY, DK, FR, DE, IE, LV, LU, RO, SL, ES, SE	
Heavy fuel oil				
Agricultural, horticultural or	Article 15(3)	4[90]	DK, IE, SE	BE

[88] In Austria, Cyprus, Hungary and Portugal the reduced rate applies only to stationary motors ((Article 8(2)(b)).
[89] In Cyprus and Germany the reduced rate applies only to stationary motors ((Article 8(2)(b)).
[90] Reduced rate compared to the rate applied to heavy fuel oil used for heating fuel for business use.

Sector or use	Article in ETD	Number of countries	Reduced rate	Zero rate
piscicultural works, and in forestry				
LPG				
LPG used as propellant	Article 15(1)(i)	5[91]	HR, LU, MT, ES	BE
Agricultural, horticultural or piscicultural works, and in forestry	Article 8(2)(a); Article 15(3)	8[92]	DK, FR, DE, IE, LU, MT, ES	BE
Industrial/commercial use	Article 8(2)(b); Article 8(2)(c); Article 8(2)(d);	8	CZ, FR, DE, EL[93], HU[94], IE, IT, LU	
Heating fuel	Article 5	22[95]	AT, BE, DK, EE, FR, DE, EL, IE, IT, LU, PL, RO, SL, ES	BG, CY, CZ, LV, LT, SK
Natural gas				
LPG used as propellant	Article 15(1)(i)	14[96]	AT, BG, CZ, EE, FR, IT, PT, ES	BE, HR, EL, LU, MT, PL,
Agricultural, horticultural or piscicultural works, and in forestry	Article 8(2)(a); Article 15(3)	10[97]	DK, FR, DE, IE	BE, HR, EL, LU, MT, PL
Industrial/commercial use	Article 8(2)(b); Article 8(2)(c); Article 8(2)(d);	8	CZ, DE, HU, IE	BE, HR, MT, PL
Heating fuel	Article 5	14[98]	BG, CZ, DK, DE, HU, IE, LT, NL, PT, RO, SK, SL, ES	
Coke and coal				
Agricultural, horticultural or	Article 15(3)	2	DK	BE

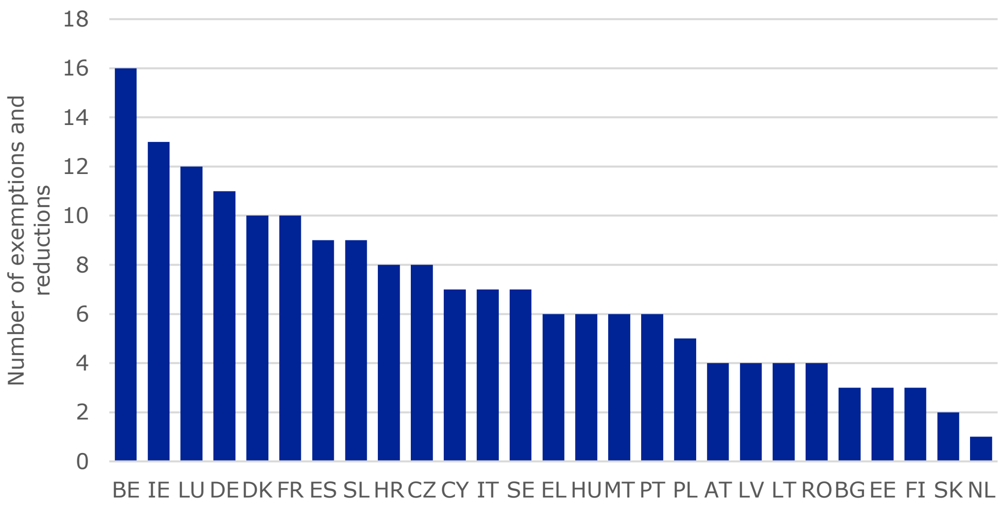
[91] Number of countries that applies total or partial exemption or reduction compared to the minimum set at €125.
[92] Number of countries that applies a reduced rate compared to the rate used for taxing LPG as propellent
[93] In Greece the reduced rate applies only to stationary motors ((Article 8(2)(b)).
[94] In Hungary the reduced rate applies only to vehicles intended for use off the public roadway or which have not been granted authorisation for use mainly on the public roadway ((Article 8(2)(d)).
[95] Number of countries that applies total or partial exemption or reduction compared to the rate used for taxing LPG as propellent
[96] Number of countries that applies total or partial exemption or reduction compared to the minimum set at €2.6
[97] Number of countries that applies total or partial exemption or reduction compared to the rate used for taxing natural gas as propellent
[98] Number of countries that applies total or partial exemption or reduction compared to the rate used for taxing natural gas as propellent. Only applies for heating for business use in BG and ES.

Sector or use	Article in ETD	Number of countries	Reduced rate	Zero rate
piscicultural works, and in forestry				
Electricity				
Agricultural, horticultural or piscicultural works, and in forestry	Article 15(3)	2		BE, EL

Source: Ecorys based on Taxes in Europe Database

There are significant differences when it comes to the total number of exemptions or reductions applied among Member States. Belgium applies 16 exemptions, while the Netherlands only one (for natural gas used as a heating fuel). The average number of exemptions applied is eight per Member State.

Figure 28 Reductions and exemptions for energy products and electricity by Member State



Source: Ecorys

4 BENCHMARKING OF MEASURES

The literature review in Chapter 2 provided the theoretical and empirical foundation to understand the reasoning behind environmental taxes and tax incentives targeting GHG emissions. Taxes help to put a price on the negative economic and societal externalities of GHG emissions, while beneficial tax incentives signal rewards for more sustainable and less polluting behaviour. This makes all forms of tax measures a popular policy instrument to curb GHG emissions.

The literature review however also indicates the challenge of finding an ideal price to apply to emissions to reduce them effectively, as the effectiveness of each policy measure is interdependent with a variety of contextual factors. The review further highlighted that conflicting interests, including e.g. revenue generation for general budget and making biggest polluters pay vs gaining public support (through reduced rates for impacted stakeholders), can influence the implementation of new taxes and tax incentives, creating reduced or – in the case of environmentally harmful incentives – even adverse effects on GHG emissions. Another key finding of the empirical literature review is that the design features of taxes and tax incentives determine their effectiveness and effects to a large degree. The tax base, the tax rate, the generosity of the tax incentive and scope of taxes and tax incentives determine the effect and success these measures have.

Indeed, the mapping of measures in Chapter 3 has shown that while similar types of measures such as energy or transport taxes, incentives for EVs and energy efficiency are employed across Europe, there is a large degree of variation in the design features of these measures. Our research has mapped a variety of tax rates and scopes of the carbon taxes employed in the country sample, showing that the generosity of energy efficiency incentives, as well as the types of technologies eligible vary starkly. The inventory confirms that there is a large body of environmental taxes and tax incentives employed across the EU and beyond, and it provides a snapshot of the variation among these measures.

Drawing on these observations, the question arises whether there are measures among the ones mapped, that are more suitable than others to reduce GHG emissions effectively, and if there are measures that are better than others in mitigating potential conflicts with other policy objectives. Thus, is it possible to identify examples of good practices that illustrate how environmental taxes and tax incentives can be designed to maximise their environmental effect while keeping adverse externalities minimal? Synthesising the results of the literature and the mapping of measures, this Chapter reports on the results of the analysis of this question. Building on the insights from the literature review on the effects and trade-offs of design features of taxes and tax incentives, a benchmarking methodology was developed to help identify a set of diverse good practice examples among the sample identified during the mapping of measures.

Starting point and guiding the development of the methodology is a working definition of what constitutes a good practice within the scope of this study. The definition captures the key elements – environmental effectiveness, political viability, and transferability – around which the assessment of measures was based. After the definition was refined during the implementation of the study to take the result of our research into account, the final definition is provided below:

> *"A good practice is a tax measure that incentivises an individual or company to change their behaviour to reduce their production of GHG emissions. A good practice tax measure does not necessarily need to be but benefits from being politically viable. This means that such a measure should at least not cause substantial negative economic effects for competitiveness and innovation, or even generate positive economic effects. It targets key producers of GHG and remains reflective on distributional effects, in*

particular when targeting individuals. It is embedded in a supportive political and regulatory context and does not create unnecessary burden for administrations and target groups. It can be applied easily across different regulatory settings."

The approach for the identification of good practice examples built on this definition. The methodology developed reflects on the key elements of the definition and is split into three steps:

1. An **assessment of the environmental effectiveness** of measures constitutes the first step. As the objective of the study is to identify measures that have an impact on GHG emissions, their environmental effectiveness constitutes a key element of concern. Since it was not possible to identify detailed empirical evidence on the environmental impacts of the individual measures, we benchmarked selected measures on the basis of their design features, building on the findings from the literature on the effects of these design features on a given measures' effectiveness. Two distinct sets of criteria were used – one for taxes, and one for tax incentives – as the intervention logics for these two types of measures differ. For each design feature, which includes for example tax rates and scope, scores were assigned depending on the design feature specifications. Per criterion, design feature specifications with the greatest beneficial environmental effect received the highest score. The set of scores were applied to the individual measures, yielding an individual overall score for each of them. Subsequently, measures were ranked based on the individual scores, with the highest scoring measures (representing the measures with the most effective design features) at the top of the ranking. This yielded two lists of scores, one for taxes, and the other one for tax measures. From both lists, the ten highest ranking measures (20 measures in total) were selected to assess their political viability.

2. During the second step, the **political viability of the shortlisted measures** was assessed. The qualitative assessment explored the simplicity (and costs) of measures, as well as their economic and distributional externalities. While this study looks at individual measures, the context in which they are implemented matters. Therefore, the analysis of the political viability also included an assessment of the contextual factors that supported or hindered the implementation of the individual measure. Based on the scores for the environmental effectiveness and the results of the assessment of political viability, good practice examples were identified. As a general rule, and to ensure that diverse measures are presented, the highest-ranking measures of a particular type of measure that are politically viable are considered to be good practices.

3. The **discussion of transferability** is the third and last step. There, we reflected on the elements that need to be considered when assessing if a given measure can be implemented in another country and thus different policy context. A simplified decision tree was developed to support the thought process.

A detailed account of the methodology can be found in Annex I. In the following, we report on the results of the benchmarking and identification of good practice examples.

4.1 Assessment of the environmental effectiveness of taxes

Environmental taxes directly address the failure of markets to take environmental impacts into account by incorporating these impacts into prices (OECD, 2011). However, effective implementation of environmental taxes requires careful consideration of a number of factors as inadequately designed taxes can lead to a reduced environmental effectiveness.

One of the key design features is the **scope of tax measure**. Energy industries, fuel combustion by energy users and transport sectors are responsible for the majority of GHG emissions in the EU. Energy industries and fuel combustion by energy users excluding transport are responsible for 54.5% of GHG emissions while road transport is responsible for 16.7% (almost 72% of all transport sector GHG emissions (23.8%) are attributed to road transport).[99] It can be considered that if a tax is applied to both sectors (energy and transport), it has a potential to be most effective, as the scope of taxed activities is the largest. To be environmentally effective, the tax base should target to the pollutant or polluting behaviour, with few (if any) exceptions (OECD, 2011). However, to the detriment to the effectiveness of environmental taxes, preferential tax treatment, lower tax rates or **tax exemptions** are sometimes applied to reduce sectoral distributional effects and lower the risk of carbon leakage. Certain countries grant tax exemptions that at the same time induce firms to change behaviour towards being more sustainable, in which case, environmental effectiveness is not compromised. Setting the appropriate **level of tax rate** is another key design feature of environmental taxation. The rate of carbon tax is one of the most important element of carbon tax design Coupled with the decision on the coverage of the tax, it will ultimately determine the amount of emissions abatement achieved.[100] Carbon prices need to be significant to have an impact on decision making, and not lead simply to paying the tax and/or buying carbon offsets. In case of vehicle taxation, the tax rate applied should increase progressively in line with the vehicle's CO2 intensity. Research suggests that countries with high and highly differentiated (with regards to CO2 emissions) tax rates, have been the most successful in reducing average CO2 emissions. In order to measure the level of taxation, tax curves can be drawn to show how the CO2-based tax component changes with every g/km. The tax curves visualise the structure of the tax system with respect to CO2 emission values. Finally, it is considered that in order to impact consumption decisions excise duties levied on energy products (motor fuels, heating fuels and electricity) should be higher than the minimal rates currently required by the Energy Tax Directive[101]. In fact, many Member States apply rates which are considerably higher than the required minima. Defining the **tax base** is another important design feature. Research suggests that an environmental tax should generally be levied as directly as possible on the pollutant or action causing the environmental damage (OECD, 2011). Therefore, taxes that have as its base carbon content or other greenhouse gas, can be considered most effective. The second-best approach is to levy a tax on a close proxy. Research suggests and stakeholders that took part in the workshop agreed that not all design features are equally relevant for environmental effectiveness. In particular, the scope of a measure appears to be the most important, followed, by the tax rate and the tax base.

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[99] https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-4a.html
https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-12

[100] World Bank (2017) : CARBON TAX GUIDE A Handbook for Policy Makers http://documents1.worldbank.org/curated/en/728421535605566659/pdf/129668-V1-WP-PUBLIC-Carbon-Tax-Guide-Main-Report.pdf

[101] In the recent evaluation of the Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity, the study had found that : "*ETD provides no financial incentives for final consumers to participate in demand response, neither in the form of energy savings, nor in the form of demand flexibility. The current ETD sends wrong price signals, discouraging users from choosing greener and more efficient energy sources".* https://ec.europa.eu/info/sites/info/files/swd_2019_0329_en.pdf. Other research further suggests that energy taxes should be uniform (per unit of Gigajoule) and aligned with other policy efforts, as for example Andersen (2015) suggests.

Based on these considerations, criteria were defined and scores assigned to individual design feature specifications. Per criterion, the specification with the greatest positive impact on environmental effectiveness received the highest score, meaning it is considered a good practice. We scored and ranked the shortlisted taxes. The assessment included 46 measures from 27 countries, which are presented in the table below.

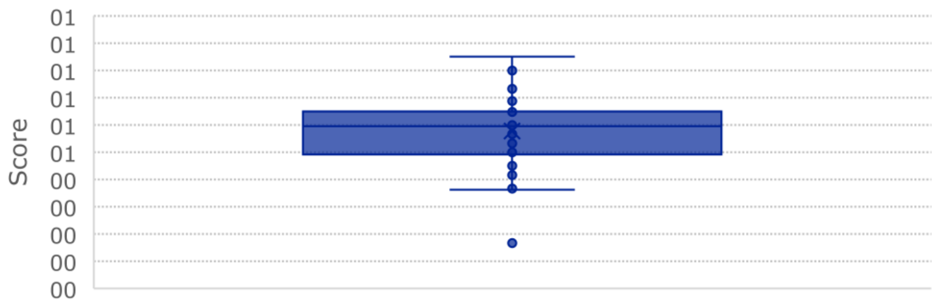
Table 15 Overview of taxes included in the benchmarking

Country	Name of the measure	Type of measure
AT	Duty on vehicle purchase based on fuel consumption	Vehicle Tax
CA	British Columbia Carbon Tax	Carbon tax
CA	Excise Tax on Fuel-Inefficient Vehicles	Vehicle Tax
CH	CO2 Tax (Carbon tax)	Carbon Tax
CY	Vehicle annual circulation tax	Vehicle Tax
DE	Vehicle Tax for passenger cars (annual circulation tax)	Vehicle Tax
DK	Carbon Tax	Carbon Tax
DK	Electricity (non-business use)	Energy taxes - electricity
DK	Tax on Nitrous Oxides (NOx)	Tax on other pollutant
EE	Carbon Tax	Carbon Tax (emission charge)
EL	Vehicle registration tax	Vehicle Tax
EL	Electricity (non-business use)	Energy taxes - electricity
ES	Taxation on first registration)	Vehicle Tax
ES	Tax on fluorinated greenhouse gases	Tax on other pollutant
ES	Gas oil excise duty	Energy taxes - motor fuel
FI	Motor vehicle registration tax	Vehicle Tax
FI	Carbon Tax	Carbon Tax
FR	Malus scheme for car purchases	Vehicle Tax
FR	Climate energy contribution (Carbon tax	Carbon Tax
HR	CO2 emission tax on non-ETS stationary sources	Carbon Tax
HR	Special tax on motor vehicles (Registration tax)	Vehicle Tax
HR	Gas oil excise duty	Energy taxes - motor fuel
IE	Vehicle registration tax	Vehicle Tax
IE	Carbon Tax	Carbon tax
IL	Green tax on the purchase of cars	Vehicle Tax
IS	Carbon Tax	Carbon tax
IT	Motor vehicle circulation tax	Vehicle Tax
LT	Environmental pollution tax	Tax on other pollutant
LU	Road tax (ownership vehicle tax)	Vehicle Tax
LV	Law on Vehicle Operation Tax and Company Car Tax (Vehicle Operation Tax/circulation tax)	Vehicle Tax
LV	Natural Resources Tax Law (Natural Resources Tax on CO2 Emissions)	Carbon Tax
MT	Vehicle registration tax	Vehicle Tax
NO	Environmental tax on greenhouse gases – hydrofluorocarbons (HFC) and perfluorocarbons (PFC)	Tax on other pollutant
NO	CO2 Tax (on Mineral Products)	Carbon Tax
PL	Carbon Tax	Carbon tax
PT	Motor vehicle registration tax	Vehicle Tax
PT	Carbon Tax	Carbon Tax

Country	Name of the measure	Type of measure
RO	Taxes on pollutant emissions into the atmosphere	Tax on other pollutant
RO	Coke and coal excise duty (heating, non-business use)	Energy taxes - heating fuel
SE	Carbon Tax	Carbon Tax
SE	Coke and coal excise duty (heating, non-business use)	Energy taxes - heating fuel
SE	Differentiated Vehicle Tax (circulation tax)	Vehicle Tax
SL	Carbon Tax	Carbon Tax
SL	Car taxation based on CO2 emissions (registration tax)	Vehicle Tax
UK	First Year Rates of the Vehicle Excise Duty (VED) (circulation tax)	Vehicle Tax
UK	Carbon price support (CPS) rates of the Climate Change Levy	Carbon Tax

The analysis included 16 carbon taxes, 6 energy taxes, 19 vehicle taxes and 5 taxes on other greenhouse gases. The figure below visualises the distribution of scores. On a scale from 0 to 1, taxes scored between values of 0.17 and 0.85. The average score is 0.58. In general, carbon taxes show the highest average scores (0.63), with individual measures scoring between 0.45 and 0.85. Due to national differences in scope, tax base, and tax rates, scores for transport (or vehicle) taxes differ much more and take values between 0.17 and 0.73 for individual measures. The spread of scores is smaller for pollution and energy taxes, which can partially be explained by the fact that smaller numbers of these measures have been included in the assessment.

Figure 29 Box-plot of the distribution of scores for the 46 taxes included in the assessment



Source: Ecorys

Table 16 Summary of scores for the taxes included overall and broken down by type of tax

Taxes	# of measures	Min score	Max score	Average
Number of measures	**46**	**0.17**	**0.85**	**0.58**
Carbon tax	16	0.45	0.85	0.63
Pollution tax	5	0.42	0.7	0.56
Energy tax	6	0.36	0.6	0.45
Transport tax	19	0.17	0.73	0.58

Below we report on the highest-ranking taxes with regards to environmental effectiveness. A full overview of the scores of tax measures and their ranking is provided in Annex II.

Table 17 Highest ranking taxes

Country	Measure	Score	Rank #
Switzerland	CO2 Levy (Carbon tax)	0.85	1
Sweden	Carbon Tax	0.80	2
Denmark	Carbon Tax	0.75	3
France	Malus scheme for car purchases	0.73	4
Finland	Motor vehicle registration tax	0.73	
Israel	Green tax on the purchase of cars	0.73	
Norway	Environmental tax on greenhouse gases – hydrofluorocarbons (HFC) and perfluorocarbons (PFC)	0.70	7
Finland	Carbon Tax	0.69	8
Portugal	Motor vehicle registration tax	0.67	9
France	Climate energy contribution (Carbon tax)	0.66	10

Carbon taxes are the most prevalent among the highest ranked tax measures (5 out of 10 measures). This is driven primarily by the fact that carbon taxes apply to both energy and transport sectors – the two sectors responsible for the majority of GHG emissions in the EU (unlike vehicle taxes that can only impact the GHG emission level in the transport sector) and that they target explicitly the carbon content of the fuels (unlike energy taxes whereby the tax rate is not always linked to the polluting potential of the taxed fuel). The ranking also contains 4 vehicle taxes, which reflects the fact that in a number of countries vehicle registration and circulation taxes are designed to promote the purchase of low carbon vehicles. The highest scoring vehicle taxes are those whose tax base solely includes CO2 emissions of the purchased car and whose rate is high and highly differentiated (by CO2) as such characteristics have been found to be most conducive in successfully reducing car fleet average CO2 emissions.

4.2 *Assessment of the environmental effectiveness of tax incentives*

The intervention logic for beneficial tax incentives follows the opposite direction of the one for environmental taxes: instead of increasing the price for undesirable behaviour, beneficial tax incentives are tax breaks that reduce the price for behaviour more desirable from an environmental perspective. Therefore, the design features and characteristics relevant to assess impacts are sometimes different for beneficial tax incentives.

The **generosity of the tax break** is one of the key variables in assessing the effectiveness of a tax incentive, as it indicates the amount of money beneficiaries are saving due to the tax incentive. As the literature review pointed out, a key challenge for policy makers is to identify the optimal generosity of a tax break, i.e. maximising its cost-effectiveness. Ideally, the tax break is large enough to incentivise a change in behaviour of the beneficiary, but as small as possible to minimise costs. Tax incentives require financing which means that the resources used to finance incentives cannot be used for other purposes The literature review (see Section 2.4.1) suggests that tax incentives are prone to free-rider effects, and empirical research finds evidence for free riding e.g. for tax incentives for EVs and public transport incentives. Note, however, that the ideal tax break is highly contingent on the individual measure and the contextual (national) circumstances. As a result, the optimal tax break cannot be adequately reflected in a horizontal assessment such as this analysis. Therefore, our analysis cannot capture the cost-effectiveness of tax incentives properly. Instead, we consider the generosity of a tax break as a measure of its effectiveness, in the sense of the ability of a tax incentive to have an effect. Thus, we assume that generally the larger a tax break, the greater the effect of the tax incentive can be expected. We are aware that this assumption is a simplification, as a tax break that is too large is inefficient and might reduce resources available for the implementation of other green incentives. Thus, this should be kept in mind when interpreting the results of the benchmarking. To soften the effect of this assumption, we have adjusted the weight assigned to the generosity of the tax break when calculating the overall score.[102] Another important element is the **scope of the tax incentive** to assess the environmental effectiveness. In this regard, a crucial aspect is the behaviour or externality the tax break aims at incentivising. As Greene and Braathen (2014) suggests, a tax incentive is the most effective if it is used to incentivise behaviour creating positive externalities, i.e. when it triggers research and innovation, rather than purely incentivising the avoidance of negative externalities by making less polluting options cheaper. Expressed differently, the change in behaviour should go beyond the regulatory baseline of the polluter-pays principle. Linked to the previous consideration is the question how a given tax break aims to avoid negative externalities. Greene and Braathen (2014) further suggest that tax incentives that aim at reducing emissions should directly target the emissions reduction, similarly to taxes on emissions. The incentive should reward the actual emission reduction, rather than the choice of a habit or product by the beneficiary. Yet, many tax incentives are designed in a way to "pick a winner". They champion a certain habit or product (e.g. electric vehicle) instead of incentivising the emission reduction directly (incentivising the use of an emission avoiding vehicle, remaining neutral on the choice of the actual propellant chosen). Finally, research suggests that the **tax the incentive is built into** also matters for the effectiveness of a tax incentive (see Section 2.4.1). Findings suggest that tax rebates and exemptions granted at the time of sale are more effective than complex income tax incentives, as the cost savings are more imminent and clearer to the consumer/ buyer. Evidence for VAT reductions are less clear cut: while applied when a product is sold, VAT reductions are not always passed onwards to the consumers.

Based on these considerations, criteria were defined, and scores assigned to individual design feature specifications. Per criterion, the specification with the greatest positive impact on environmental effectiveness received the highest score, meaning it is considered a good practice. We scored and ranked the shortlisted taxes. The assessment included 30 tax incentives from 23 countries. The table below provides an overview of these tax incentives.

Table 18 Overview of taxes included in the benchmarking

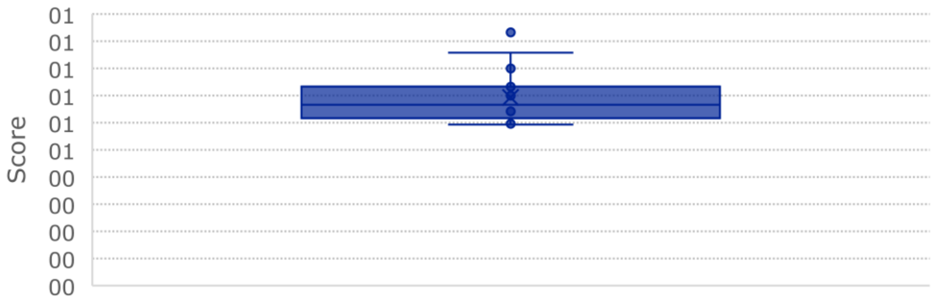
Country	Name of the measure	Type of incentive
AT	Reduced VAT rate for passenger transport	Tax incentives for public transport
BE	Regional Income tax reduction for roof insulation	Tax incentives for energy efficiency
BG	Tax exemption for buildings with energy certification	Tax incentives for energy efficiency
BG	Tax exemption for electric vehicles	Tax incentive for vehicles (alternative propellant)

[102] For more information on the weighting, please also refer to the Methodological Annex.

Country	Name of the measure	Type of incentive
BG	Tax relief for vehicles with high European emissions standard	Tax incentive for vehicles (alternative propellant)
CA	Canadian Renewable and Conservation Expense (CRCE)	Tax incentive for renewable energy and energy efficiency
CZ	Registration tax exemption for electric vehicles (company cars)	Tax incentive for vehicles (alternative propellant)
FI	Tax relief for employer-subsidised public transport tickets	Tax incentives for public transport
FR	Energy Transition Tax Credit	Tax incentives for energy efficiency
HR	Exemption of excise duties on electrical energy used in railway and public transport	Tax incentives for public transport
HU	Tax credits on energy efficiency investments	Tax incentives for energy efficiency
HU	Tax Exemptions for electric, hybrid and zero emission vehicles from vehicle registration tax	Tax incentive for vehicles (alternative propellant)
IE	Accelerated capital allowance for energy efficient equipment	Tax incentives for energy efficiency
IL	Accelerated depreciation for R&D in the field of renewable energy	Tax incentive for R&D
IL	Purchase tax on cars reduction for electric and hybrid vehicles	Tax incentive for vehicles (alternative propellant)
IS	Tax incentives for electric and hydrogen cars	Tax incentive for vehicles (alternative propellant)
IS	Tax incentives on bikes and electric bikes	Tax incentive for vehicles (alternative propellant)
IT	Tax credit for costs incurred in R&D, innovation and design activities	Tax incentives for R&D
LU	Investment tax credit for zero emission cars	Tax incentive for vehicles (alternative propellant)
MT	Tax incentives for businesses to implement energy-efficient practices	Tax incentives for energy efficiency
NL	Energy investment allowance	Tax incentives for renewable energies
NL	Tax relief for investments in environmentally friendly technology	Tax incentives for energy efficiency
NO	Tax exemption for EV	Tax incentive for vehicles (alternative propellant)
PL	Income tax break for thermo-modernisation of single-family residential buildings	Tax incentives for energy efficiency
PT	Tax exemption for electric vehicles	Tax incentive for vehicles (alternative propellant)
RO	Exemption of means of transportation tax for electric vehicles	Tax incentive for vehicles (alternative propellant)
SI	Excise duty exemption for biofuels	Tax incentive for vehicles (alternative propellant)
SK	Tax Incentive under the Motor Vehicle Tax (EVs & alternative propellants)	Tax incentive for vehicles (alternative propellant)
SK	Favourable depreciation of electric vehicles	Tax incentive for vehicles (alternative propellant)
UK	Enhanced capital allowances for energy-saving technologies	Tax incentives for energy efficiency

The analysis included 14 incentives for (electric) vehicles, 11 incentives for energy efficiency and the production of renewable energy, 2 incentives targeting R&D and 3 incentives to foster public transport. The figure below visualises the spread of scores. Please note that the criteria applied to incentives are distinct from the criteria applied to taxes. Therefore, the scores for taxes and tax incentives are not comparable.

Figure 30 Box-plot of the distribution of scores for the 30 tax incentives included in the assessment



Source: Ecorys

On a scale from 0 to 1, scores for individual tax incentives range between 0.59 and 0.93. The average score across the 30 incentives included in the assessment is 0.69. R&D incentives score highest, while there are also several vehicle and energy efficiency incentives that show scores above 0.7. On average, vehicle incentives appear to score slightly higher than scores for energy efficiency and renewable incentives (0.69 compared to 0.67).

Table 19 Summary of scores for the taxes included overall and broken down by type of tax

Taxes	# of measures	Min score	Max score	Average
Number of measures	**30**	**0.59**	**0.93**	**0.69**
R&D incentives	2	0.86	0.93	0.9
Vehicle incentives	14	0.61	0.73	0.69
Energy efficiency and renewables incentives	11	0.59	0.8	0.67
Public transport incentives	3	0.65	0.67	0.66

Below we report on the highest-ranking tax incentives with regards to environmental effectiveness. A full overview of the scores of measures and their ranking is provided in Annex IV.

Table 20 Highest ranking tax incentives

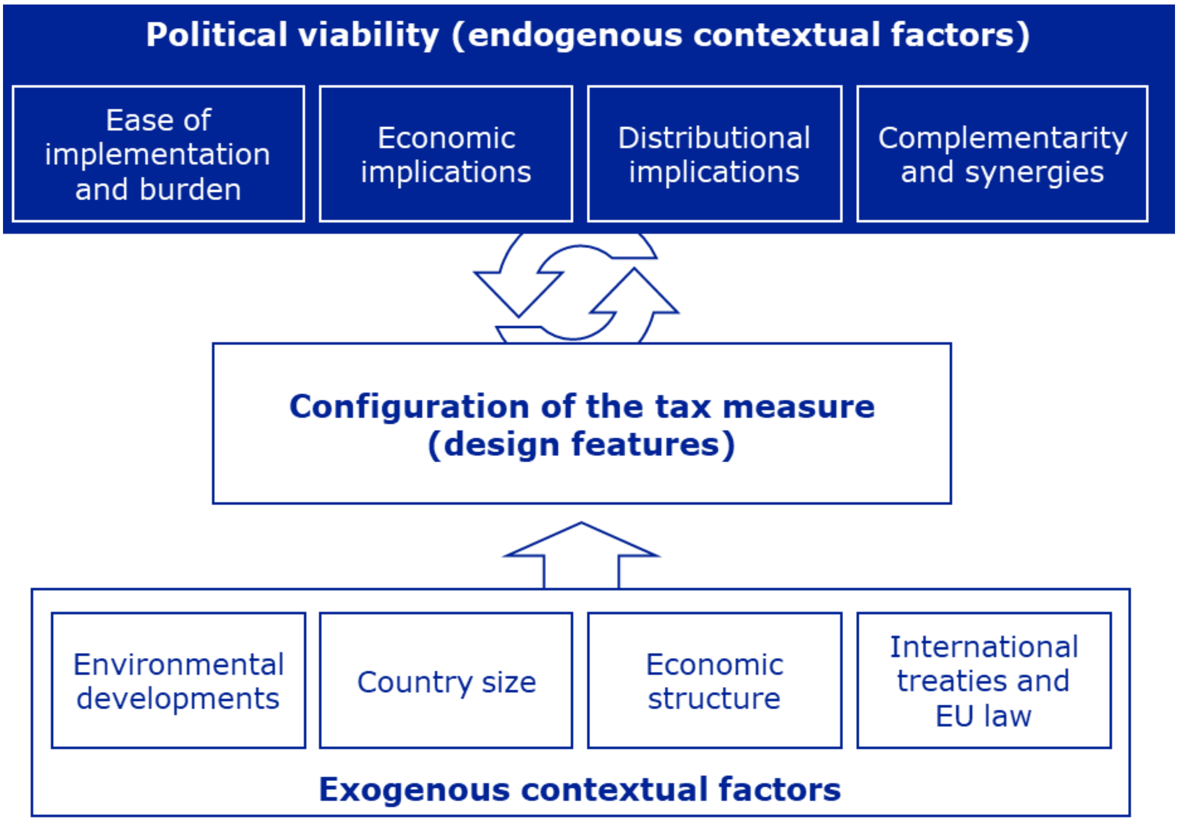
Country	Measure	Score	Rank #
Israel	Accelerated depreciation for R&D in the field of renewable energy	0.93	1
Italy	Tax credit for costs incurred in R&D, innovation and design activities	0.86	2
Bulgaria	Tax exemption for buildings with energy certification	0.80	3
Hungary	Tax credits on energy efficiency investments	0.76	4
Netherlands	Energy investment allowance	0.75	5
Malta	Tax incentives for businesses to implement energy-efficient practices	0.75	
Norway	Tax exemption for EV	0.73	7
Bulgaria	Tax exemption for electric vehicles	0.73	
Czechia	Registration tax exemption for electric vehicles	0.73	
Portugal	Tax exemption for electric vehicles	0.73	

A diverse set of beneficial tax incentives is among the highest-ranking ones. Given that they aim at incentivising green and sustainable innovation, it is not surprising that the two R&D measures included in the sample are at the top of the ranking. Further, there are several tax incentives that target energy efficiency. These are usually incentives that are not prescriptive with regards to the equipment or technologies chosen to enhance energy efficiency, but rather incentives that depend on the actual energy efficiency achieved. In total, there are four tax exemptions for electric and alternative propellants that rank among the top ten. The scores are identical for all of them, which can be explained by the fact that many vehicle taxes and tax exemptions for electric vehicles are very similar in their set-up, scope and design.

4.3 Assessment of political viability

Political viability of tax measures is a crucial dimension to be considered when selecting good practices. Our research has identified several relevant elements that need to be considered when designing a new or changing the design of an existing tax measure. Tax measures are not implemented in isolation, but always interact with the political, economic, and societal setting they are based in. Therefore, **contextual factors** influence the design of measures, as well as their effects. Hence, it is important to reflect on these contextual factors here as well. The figure below provides a simplified illustration of the interdependence of tax measures and contextual factors.

Figure 31 Schematic overview of relations between tax measures and contextual factors



Source: Ecorys

Generally, contextual factors can be divided into two groups: political viability (or endogenous) factors and exogenous factors. **Exogenous contextual factors** are those which first and foremost affect the design of tax measures, but are themselves not affected by the tax measure implemented.[103] This includes, but is not necessarily limited to, the size of a country, its economic structure, the overall environmental developments, but also the international and European legal framework. There is a second set of contextual factors that are rather **endogenous**. These factors affect the design of a given tax measure, but they are also influenced by the measure's design. The economic literature review identified the economic and distributional externalities of a given measure, the ease of implementation or costs linked to a given measure, as well as its

[103] At least in the short to medium term.

complementarity with other policies as relevant endogenous factors. As these factors are affected by the design of a given tax measure, they determine a given measure's **political viability**.

The more the measure is designed in light of the endogenous factors, the greater is its political viability. The literature review (see Section 2.3.7) highlighted that policymakers need to balance different and often conflicting interests. A tax measure that is particularly effective in reducing GHG emissions, for example because it puts a high price on carbon emissions, will raise concerns among and resistance from different societal groups. Depending on political majorities and the pressure protesting societal groups can create, policymakers will therefore aim at softening the effects of a tax measure, even if this comes at the cost of reducing its environmental effectiveness. This will increase the acceptance of and compliance with the measure within society. Similarly, policymakers need to ensure that the tax measure fits within a wider set of policy initiatives and is not contradicting them to gain support. A measure that complements an existing policy initiative or builds on it is easier to implement and can even yield greater effectiveness as synergies are realised. Conflicting policy initiatives, e.g. a harmful tax incentive, can undermine the effectiveness of the tax measure. At the same time, it might be necessary to keep the harmful tax incentive in place to cushion negative economic or social effects. The **choice of the type of measure** (tax or tax incentive) has an imminent impact on the political viability. A tax creates additional burden for the addressee (negative economic externalities), while it creates a new revenue stream for administrations (cost of measure). The opposite applies to tax incentives. The choices of **design features** affect the political viability in the following ways:

Firstly, the design of a tax measure affects its **ease of implementation and the costs of the measure** (for tax authorities). In addition, the **simplicity and certainty of the scheme** (for tax incentives beneficiaries) plays a role. We assume that tax measures that are easy to implement are also more politically viable.. The lower the costs or the higher the revenues for administrations are, the higher will also be its political viability.

Secondly and thirdly, we specify in our working definition[104] of a good practice that a tax measure should minimise any negative or bring about positive economic and distributional implications. The greater the positive externalities of a measure, the higher is its political viability. Thus, design features that **leverage on positive or mitigate negative indirect effects** are relevant.

- For taxes, this includes e.g. taking into account effects on economic interests. By having an upward effect on prices, a rise of environmental taxes is likely to raise production costs and adversely affect cost competitiveness. Companies might be inclined to move production to other countries to reduce costs (carbon leakage). However, according to the literature review, most empirical studies find no statistically significant effects of carbon pricing or energy prices on different dimensions of competitiveness, and evidence on carbon leakage is inconclusive (see Sections 2.2.5 and 2.3.5). Instead, there is evidence that carbon pricing drives innovation in clean technologies. The scope of the tax measure and exemptions can have a major impact on economic competitiveness and innovation. Research suggests that sectors with high fossil fuel consumption and exposure to international competition are likely to be affected by a higher tax burden, at least in the short term. In the long run innovation and the switch to less emitting production technologies may alleviate this effect. Instruments like the Carbon Border Adjustment Mechanism[105] under the ETS can further help to alleviate negative effects on competitiveness. Academic research on the economic implications of tax breaks

[104] See above.
[105] https://ec.europa.eu/clima/policies/ets/allowances/leakage_en.

incentivising a reduction of GHG emissions is very limited. Yet, a tax break incentivising innovation and research does not only enhance the measure's environmental impact, but also creates positive economic externalities. Further, for incentives targeting energy efficiency, the beneficiary of a tax incentive matters, too. Energy efficiency measures that benefit businesses arguably reduce (production) costs for these beneficiaries in the medium to long run. As a result, these businesses will enhance their competitiveness in comparison to other companies. Moreover, it is important to clarify whether there are negative or unpopular impacts on income distribution and to assess how these could be alleviated (e.g. through earmarking). Empirical evidence suggests that particularly imposing taxes on heating and electricity would impose heavier burdens on low-income than on high-income households, since the former spend a larger share of their income on these goods. Often contrasting public perceptions (e.g. gilets jaunes), literature does not find a clear cut regressive effect for taxes on transport fuels.[106] The literature suggests that regressive effects of energy/carbon taxes can be alleviated, however, through revenue recycling whereby (parts of) tax revenues are used for direct transfers and for reduction in labour income tax. The use of revenues clearly contributes to the success of carbon taxes (perceptions of fairness are important determinants of public support). Interestingly, research suggests that the public prefers to recycle carbon tax revenues via investment in "environmental projects". For tax incentives, the distributional effect depends on the tax the incentive is built into. Research shows that for some tax incentives (such as tax breaks for electric vehicles, solar panel installations or insulation investment), high-income households benefit disproportionally more. This suggests that many low-carbon tax incentives are regressive because they reduce the price of goods that are primarily bought by higher-income households (Zachmann et al, 2019, Borenstein and Davis, 2016). Yet, evidence suggests that there is one notable exemption. Tax incentives that reduce costs for public transport can have positive distributional effects.[107]

Fourthly, the external dimension of the measure in terms of its **complementarity with other policies** plays a role. For taxes these can be e.g. being **part of a wider green reform** or energy transition efforts (e.g. in Sweden fossil fuel heating was gradually replaced by district heating and aid schemes for conversion to renewable heating were offered etc.) or the provision of alternatives (biofuels, district heating, public transport, housing insulation etc). For tax measure and tax incentives, examples include the existence of parallel measures incentivising the same behaviour (**double-targeting**) and thus creating synergies (e.g. in Norway in addition to registration tax exemption for EV, EV are exempt from VAT). In case of tax incentives, existence/implementation of infrastructure reinforcing the uptake of a measure (**interdependencies**) is also sometimes relevant (e.g. existence of EV charging stations is key for the uptake of electric vehicles).

Based on these considerations, we assessed the political viability of the ten taxes and tax incentives which each ranked highest in the environmental effectiveness scoring. An overview of the results of this assessment is provided in the table below. A detailed assessment for each measure is presented in Annex II.

[106] Taxes on transport fuels do not appear to be generally regressive as shares of expenditures for fuel are lower in the low-income households and are growing with income. Lacking negative distributional effects of transport fuel taxes may also be explained by the fact that car ownership is less widely spread in the lower expenditure deciles.

[107] While also better-off individuals benefit from reduced costs, public transport is mostly used by less well-off individuals, thus benefitting them disproportionally.

Table 21 Political viability assessment scores

			Economic implications		Distributional implications	
Name of measure	Ease of implementation	Complementarity & synergies	Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional implications	Leveraging on positive distributional effects
Swiss CO2 levy	Yes	Yes	Yes	N/A	Yes	N/A
Green tax on the purchase of cars (IL)	Uncertain	Yes	Yes	N/A	N/A	Yes
Environmental tax on greenhouse gases – hydrofluorocarbons (HFC) and perfluorocarbons (PFC) (NO)	Uncertain	Yes	No	N/A	N/A	N/A
Motor vehicle registration tax (PT)	Yes	Yes	N/A	N/A	N/A	N/A
Finland Carbon Tax	Yes	Yes	Yes	N/A	Uncertain	N/A
Sweden Carbon Tax	Yes	Yes	Yes	N/A	Uncertain	N/A
Denmark Carbon tax	Yes	Yes	Yes	N/A	Yes	N/A
Malus scheme for car purchases (FR)	Uncertain	Yes	Yes	N/A	N/A	N/A
Motor vehicle registration tax (FI)	Yes	Yes	N/A	N/A	N/A	Yes
Climate energy contribution (Carbon tax) (FR)	Yes	Yes	Yes	N/A	No	N/A
Registration tax exemption for EV (NO)	Yes	Yes	N/A	No	No	N/A
Tax exemption for EV (PT)	Uncertain	Yes	N/A	Uncertain	No	N/A
Accelerated depreciation for R&D in the field of renewable energy (IL)	Yes	No	N/A	Yes	N/A	N/A
Tax credit for costs incurred in R&D, innovation and design activities (IT)	Uncertain	Yes	Uncertain	Yes	N/A	N/A

			Economic implications		Distributional implications	
Name of measure	**Ease of implementation**	**Complementarity & synergies**	**Mitigation of negative economic externalities**	**Leveraging on positive economic effects**	**Mitigation of negative distributional implications**	**Leveraging on positive distributional effects**
Tax exemption for buildings with energy certification (BG)	Yes	Yes	N/A	Yes	N/A	Yes
Bulgaria Tax exemption for electric vehicles	Uncertain	Uncertain	N/A	Uncertain	No	N/A
Czech Republic Registration tax exemption for electric vehicles	Uncertain	Uncertain	N/A	Uncertain	No	N/A
Tax credits on energy efficiency investments (HU)	Uncertain	Yes	N/A	Uncertain	N/A	N/A
Energy investment allowance (NL)	Yes	Yes	N/A	Yes	N/A	N/A
Tax incentives for businesses to implement energy-efficient practices (MT)	Yes	Yes	N/A	Yes	N/A	N/A

Note: N/A means not applicable. Uncertain means that there is not enough evidence to make a judgement

The tax measures that rank the highest are characterised by an overall ease of implementation. For certain measures, especially tax incentives, there is however not enough information to make a judgement with regard to this dimension. All assessed tax measures and majority of tax incentives seem to form part of wider green policy initiative aiming at reduction of GHG emissions. Moreover, they are often complementary to other measures in place aiming to achieve the same effect (double targeting) which has a potential to make them more effective. With regard to indirect effects that the measures targeting reduction in GHG emissions can have on the economy and income distribution, most tax measures (in particular carbon taxes) are designed to mitigate potential negative economic externalities, however only few tax measures in their design take into considerations mitigating negative distributional consequences. Such negative impacts can be however offset by the use of policy tools and measures that are independent of the assessed measure. In case of evaluated tax incentives, half of them seem to leveraging on positive economic externalities as they target positive externalities (tax incentives for R&D) and can be considered to potentially boost firms' competitiveness by subsidising energy efficiency investments.

4.4 Selection of good practice examples

Based on the assessment of their environmental effectiveness and political viability, 10 measures were selected as good practice examples. As their intervention logic is very different and it is therefore not possible to directly compare taxes and tax incentives, the selection was done independently for these two types of measures. We have identified seven good practice examples among taxes, and three among tax incentives. Different numbers of taxes and tax incentives were selected due to the weaker empirical evidence base this study has highlighted for tax incentives. A higher number of good practice examples among taxes is also reflective of the general agreement in literature that taxes appear to be more effective than tax incentives. In addition to the aforementioned criteria, we also reflected on the diversity of measures in our selection to show different types of measures that can be available for policymakers aiming at reducing GHG emissions.

An overview of good practice examples is presented in the table below. Good practice fiches providing a detailed overview for each of the ten measures identified below is included in Annex IV.

Table 22 Good practices examples

Taxes		Tax incentives	
Switzerland	CO2 levy	**Italy**	Tax credit for costs incurred in R&D, innovation and design activities
Sweden	Carbon Tax	**Netherlands**	Energy investment allowance
Israel	Green tax on the purchase of cars	**Norway**	Tax exemption for EV
France	Malus scheme for car purchases		
Norway	Environmental tax on GHG – hydrofluorocarbons (HFC) and perfluorocarbons (PFC)		
Denmark	Carbon Tax		
Portugal	Vehicle registration tax		

The selected good practice examples provide a good impression of the diversity of measures that are used across the EU and beyond. The taxes selected cover different types of emission creating behaviour (energy, transport) and also different types of GHG. Similarly, the tax incentives selected present the wider set of measures employed, including incentives for transport (tax exemption for EVs), energy efficiency and innovation.

As the name suggests, the measures selected should be seen as examples of good practices – in terms of their design. They all received high scores with regards to environmental effectiveness and are generally viable. However, selection or not-selection should not be seen as a judgement on the quality of the measures listed. Rather, the measures selected provide valuable insights into several elements that are relevant when designing taxes and tax incentives targeting GHG emissions. As can be seen from the good practice fiches, the measures selected also have limitations, which further underpins the notion that they have been selected as examples among a larger set of good measures.

In the following, we provide a brief description for each of the good practice examples. Noteworthy commonalities among them include the use (and earmarking) of tax revenues to soften equity issues or to support green transition. Similarly, the taxes and tax incentives were usually introduced as part of wider policy initiatives to address GHG emissions more comprehensively. Note that the methodology for the analysis is geared towards an assessment of design features, rather than their actual effectiveness and effects.

The CO2 levy (Switzerland) is a carbon tax that covers heating and process fuels. With a current rate of approx. EUR 83 per ton of CO2, the tax rate is the second highest among the carbon taxes explored, after the Swedish carbon tax. As part of a comprehensive policy package, the CO2 levy is one instrument among several that jointly aim at reducing GHG emissions until 2020 by 20% compared to the base year in 1990. Research suggests that indeed after introduction of the measure CO2 emissions decreased, and that between 2005 and 2015 the levy accounted for a reduction of CO2 emissions between 4.1 and 8.6 million tons. One third of the revenue from the CO2 levy is earmarked for a buildings program subsidising refurbishment and fuel switching to renewable energy. The remaining two thirds of the revenue is returned to the population on a per capita basis and to the business community based on wages paid to employees. The levy is collected by the Federal Customs Administration on top of the mineral oil tax from importers at border crossing (there are no fossil fuels produced in Switzerland).[108] It is applied to upstream suppliers of fossil fuels which minimises administrative costs.

The carbon tax (Sweden) constitutes a corner stone in Swedish climate policy and targets a broad range of sectors. Sweden levies the highest carbon tax rate in Europe, €110 per ton of carbon emissions (2020). It is levied in addition to excise tax on energy products, including motor fuels and for fuel for heating purposes and is levied on most products causing CO2 emissions when combusted, such as petrol, oil and coal, thus the tax applies to fossil fuels combusted to generate energy[109], but not electricity. The carbon tax in Sweden was part of a major initiative *grön skatteväxling*, aiming on increasing environmental taxes while reducing other taxes. Tax revenues are not earmarked, therefore the tax revenues from the Carbon tax goes into the treasury. Since 1994, the carbon tax is adjusted to changes in the consumer price index, taking into account inflation. Swedish GHG emissions decreased by 26% since introduction of the tax. It is difficult to determine the exact extent to which the carbon tax reduced the GHG emissions; yet, as the carbon tax has been the primary instrument to reduce fossil fuel consumption and CO2 emissions, a large part of the reduction can be attributed to the tax. The gradual increase of the carbon tax over time increased the financial burden for households. To mitigate the distributional effects of the carbon tax, increases in the carbon tax have been combined with general tax reliefs.

The green tax on the purchase of cars (Israel) was introduced in 2009 as part of a broader policy package, the Israeli Green reform. It aims to increase purchase prices of highly polluting vehicles and lower prices of less polluting vehicles, especially electric and hybrid cars. This should incentivise individuals to buy fewer polluting vehicles. The Israeli purchase tax is considered an

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[108] http://documents1.worldbank.org/curated/en/799761535605686418/pdf/129668-V2-WP-PUBLIC-Carbon-Tax-Guide-Appendix.pdf

[109] Swedish Tax Agency, https://www.skatteverket.se/foretagochorganisationer/skatter/punktskatter/energiskatter/energiskatterpabranslen.4.15532c7b1442f256bae5e56.html?q=Koldioxidskatt

innovative measure as different tax rates are applied according to 15 polluting grades calculated on the basis of several pollutants, including CO_2, HC, CO, NO_x, PM_{10}. Its purpose is to avoid that individual switch from purchasing petrol vehicles to diesel ones. Evidence suggests that the measure had a strong impact on the composition of car fleet according to their pollution level. From 2009 vehicles with a pollution grade between 10 and 15 decreased from 23.5% to 7.4%. The share of vehicles with a pollution grade 1-5 reached 70%, in 2013, compared to 19% in 2009. In 2019, the 20% of vehicles were hybrid and CO2 emissions per car were reduced by 21%.

The Ecological Malus (France) was introduced in 2008 as part of a comprehensive new tax system favouring least polluting vehicles. The malus is part of a two-side system to encourage the acquisition of low-polluting vehicles: the ecological bonus, associated with a conversion premium, and the ecological malus, a penalty striking the most polluting models. The malus, which is levied at the time of registration, applies both to new and used vehicles and aims to limit greenhouse gas emissions caused by motor vehicles. Currently, the rate of the Ecological Malus varies between EUR 50 and EUR 20 000 depending on the CO_2 emissions of the car. Large families benefit from a deduction of emissions per child. The Ecological Malus (combined with the Bonus part) has had a positive environmental impact in its first years of implementation reducing emissions between 2008 and 2012 by 14.6 $MtCO_2$[110]. Even though there has been a rebound effect in following years via the bonus scheme, leading to increased registrations of cars, the overall impact remains positive. The mechanism remains overall beneficial for the French State. Even though public expenditure linked to the bonus for the acquisition of low CO_2 emission cars and to the "conversion premium" reached record levels, the revenue from the malus remained higher than the expenditure. The finance bill 2021 will amend the rules relating to the Ecological malus on certain particularly polluting vehicles and introduce a new tax of EUR 10/kg for vehicles weighting more than 1,800kg.[111]

The tax on hydrofluorocarbons (HFC) and perfluorocarbons (PFC) (Norway) targets f-gases. While their share in total GHG emissions is low, f-gases have an effect up to 23 000 times greater than the effect of CO2. The tax rates are calculated according to the actual content of HFC or PFC. The tax is imposed on the import and production of the gases in pure state and the import of all mixtures of HFC and PFCs, including mixtures with other substances. In addition, imports and production of goods in which the gases are included as an ingredient, such as air conditioning and refrigeration systems, vehicle air conditioning, sealant foam and propellant gas in spray boxes, are also subject to the tax. In 2004, a refund scheme was added: if products are returned to an approved recycling facility for HFCs and PFCs, the taxes paid are fully refunded. The tax and reimbursement schemes have resulted in better maintenance and improved routines for discarding old equipment. It also provides a strong incentive for choosing HFCs with the lowest GWP possible and has resulted in the increased use of natural refrigerants and alternative processes.

The carbon tax (Denmark) is part of a broader ecological tax reform developed by the government during the 1990s with the implementation of a Green Tax Package in 1994 and of the Green Energy Package in 1996. The carbon tax explicitly targets CO_2 emissions across sectors and contributed to the decrease of CO_2 emissions in Denmark. When the tax was introduced, companies were exempt to maintain the competitiveness of Danish businesses. To avoid a decrease in the environmental effectiveness of the carbon tax, the Danish government conditioned the exemptions to commitments from businesses to reduce their energy use. The carbon tax generated around EUR 437 million of revenues in 2019, of which 60%

[110] http://temis.documentation.developpement-durable.gouv.fr/docs/Temis/0078/Temis-0078465/20744.pdf
[111] https://www.actu-environnement.com/media/pdf/news-36500-amendement-malus-poids.pdf

are used to reduce taxes on labour (e.g. reduced social insurance, pension contributions, etc.) and 40% for environmental purposes.

The vehicle registration tax (Portugal) was introduced in 1998, forming part of a broader package called "Fiscalidad Verde," aiming at promoting the transition towards a carbon-neutral economy. Since 2006, the tax is calculated based on two components: the cylinder capacity of vehicles and CO_2 emissions of vehicles. The measure also includes an exemption for electric vehicles. Evidence shows that the measure strongly contributed over time to reduction in the CO2 emissions in Portugal by supporting the purchase of less CO2 intensive and electric vehicles. The registration tax is accompanied by the vehicle circulation tax also partly based on CO_2 emissions, and implemented to decrease the use of polluting vehicles, and increase the share of low and zero-emissions cars. Subsidies schemes are also in place for the purchase of electric vehicles. Such complementary measures reinforce each other, rendering the different tax measures more effective.

The tax credit for costs incurred in R&D (Italy) is a tax credit for enterprises, applicable to costs incurred in the context of R&D and innovation activities. The goal of the measure is to strengthen enterprises' capacity to innovate and become competitive by contributing to the country's sustainable growth. In the energy sector, the objective is to promote new and renewable energy sources, encourage energy diversification and efficient use of energy resources[112]. This incentive consists of company income tax reduction of 50% or 25% of the expenses associated with the implementation of R&D activities. Enterprises have R&D expenditure in their annual tax declaration and the Italian tax authority checks if the required conditions are met.

The Energy Investment Allowance (Netherlands) is a tax scheme that the government uses to support companies and entrepreneurs in investing in energy-saving assets and renewable energy. When companies use the EIA they have a double advantage: their energy costs go down and they pay less tax. [113] They can deduct 45% of the investment costs of energy-saving assets from the taxable profit, in addition to the usual depreciation. Assets that qualify for EIA meet energy performance requirements and promote efficient use of energy. The measure was originally part of a broader energy tax policy package that was initiated in the Netherlands following the failure to implement a European-wide carbon tax in the early 1990s. The EIA defines eligibility criteria for products and technologies companies need to comply with if they want to benefit from the incentive. Research suggested that over a time period of 4.5 years, the EIA helped to save approx. 2 million tons of CO2 emissions.

The registration tax exemption for electric vehicles (Norway) is part of a substantial package of incentives developed to promote zero-emission vehicles into the market. Introduced in 1990 by the Norwegian government, it has contributed to develop the demand and the use of electric vehicles in the country. The impact of these tax incentives towards EV resulted in a sharp increase of electrical vehicles in the country since its implementation. The estimated benefit in terms of CO2 savings from incentives for electrical vehicles are expected to amount to 1.1Mt in 2020. The evidence suggests that it was the combination of different measures that helped to reduce emissions effectively. The incentives complements other Norwegian electrical vehicles measures (for example new rules allow local authorities to limit the access to only include EVs that carry one or more passengers).

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[112] Nicoolai, M. (2010) Guida agli incentivi per ricerca e innovazione tecnologica (R&IT) in Italia e in Lombardia. Maggioli Editore9

[113] https://www.rvo.nl/subsidie-en-financieringswijzer/energie-investeringsaftrek-eia

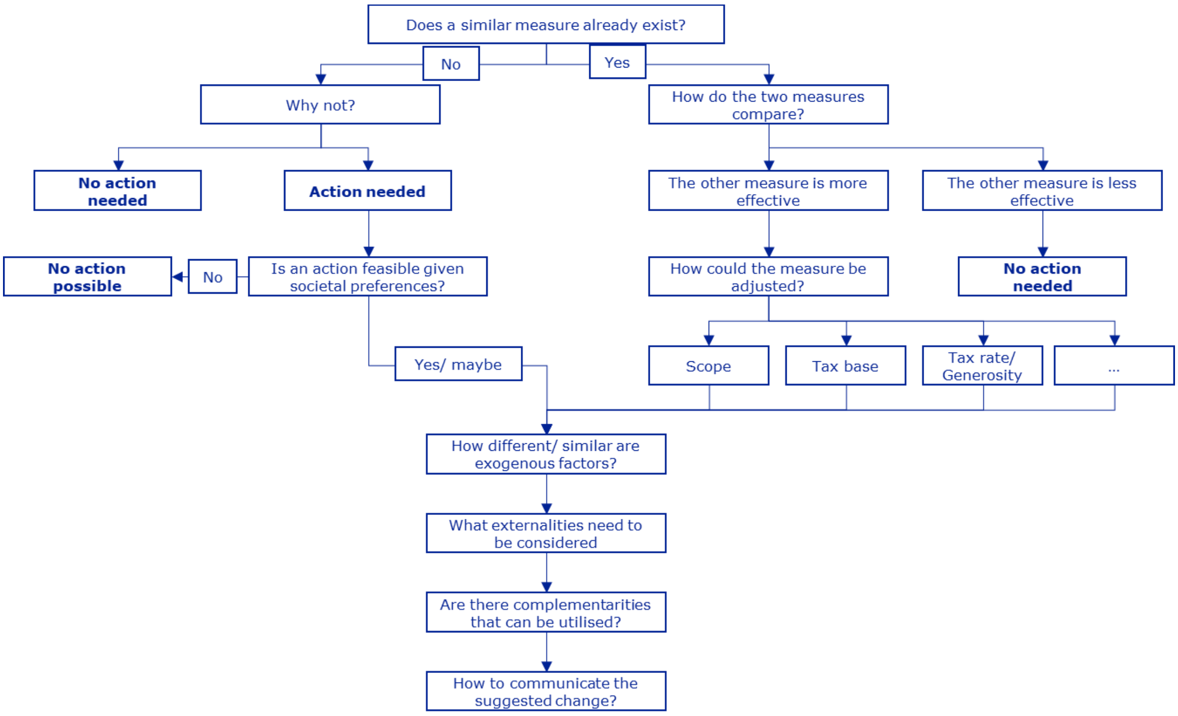
4.5 Discussion of transferability

Finally, the transferability is an important factor to consider. Transferability refers to the potential to implement a tax measure identified in one of the countries in another one. The research for the inventory has highlighted that the diversity of measures identified is limited. This is in particular the case for taxes, while less applicable for tax incentives. Many of the taxes and tax incentives identified are already implemented across a large set of countries. This implies that differences between countries can rather be found in the design of individual measures, than in the set of measures themselves. For example, vehicle taxes are implemented in almost all the countries included in the sample. Yet, the individual specifications of these measures differ.

This finding also affects our reflections on transferability, as it implies that in many cases no new measure has to be introduced, but rather that it needs to be reflected whether a change to an existing measure could enhance its environmental effectiveness, and only then if this change is feasible. Equally, the finding suggests that in many cases the exogenous factors identified above play a lesser role for the question whether or not a specific measure can be introduced, given that similar measures can already be found in a diverse set of countries. Again, here the question rather becomes if certain design features are dependent on the specific external circumstances in a given country, and how these influence the design of the measure in detail.

Generally speaking, the same factors identified for the assessment of the political viability are also relevant to assess transferability. Greater attention has to be paid however to exogenous factors as well. Based on these considerations, the figure below provides a simplified decision tree to check the transferability of a given measure.

Figure 32 Simplified decision tree supporting the thought process to assess transferability of measures



Source: Ecorys

Having decided on the internal design factors within the given context, it is important to decide on the **communication and awareness campaign** which can influence the political viability of the measure. Communication addresses the awareness for and perception of a tax measure. Arguably, awareness is more important for the successful implementation of a tax incentive, while perception matters more for taxes.

As the literature has highlighted, salience is an important element for the success of tax incentives, meaning that citizens need to be aware of tax breaks to make use of them. As discussed previously, taxes meet scepticism and resistance from societal groups that fear higher costs. Therefore, communication and awareness is key to explain to citizens taxes and accompanying instruments to improve the perception of such measures and consequently their acceptance. Thus, a communication and awareness campaign needs to reflect on how the measure is communicated to taxpayers, including concessions (to increase its acceptance) or beneficiaries of tax incentives (to increase its uptake). Questions to be answered are whether there is a clear environmental goal stated as the reason behind introduction of the measure and how this can be outlined to the public. Clear communication is critical to public acceptance of environmental taxation. Research also points to the role of communication strategies as an instrument to achieve public acceptability, to reduce information asymmetry and to address the main concerns, like high personal costs, regressive impact of the tax or negative impact on the wider economy. Provision of sufficient information for citizens about the policy instruments used (e.g. provision of evidence for the effectiveness of carbon taxes in decreasing emissions raises citizens' support for carbon taxation) also improves acceptance.

5 CONCLUSIONS AND RECOMMENDATIONS

Our research illustrates that environmental taxes and beneficial tax incentives are an increasingly used tool among countries to support the green transition towards lower GHG emissions. This study has identified more than 260 taxes and tax incentives that fall within the scope of the research approach. A growing body of research is available to countries helping them to make informed policy choices to strike a successful balance between designing tax measures that are effective in reducing GHG emissions yet remain reflective of the wider political (including economic and distributional) implications. The study identified ten good practice examples that are representative of a wider set of measures developed with care to ensure that the taxes and incentives are successful.

Yet, the research also flagged that there is still room to improve and learn from each other. Although there is a growing body of evidence that could help to design their taxes more effectively, in many instances countries still resort to second-best or less effective schemes for their taxes and tax incentives. Further, there are still important gaps in the research agenda, especially with regard to tax incentives. This raises doubts to which extent policy makers can resort to solid empirical evidence when designing specific measures. The work on the inventory of tax measures further highlighted that the availability of ex-post evaluations of taxes and particularly of tax incentives is limited. Yet, this information is crucial to support administrations that consider greening their tax schemes. Countries further need to reflect if there is further room to enhance their efforts to curb GHG emissions via taxation. In some instances, the design of measures might rather serve other purposes, including revenue generation or meeting political demands, rather than focusing on a reduction of emissions. Striking the right balance between various and often conflicting interests will remain a key challenge for future policy making.

There is already some guidance available to policy makers to enhance the effectiveness and designs of taxes and tax incentives to make them fit for purpose. This study provides further insights and adds on this research, providing a thorough mapping and comparison of measures across countries. While neither the mapping nor the benchmarking encompasses all existing relevant measures, the inventory of measures and country fiches accompanying this study provide a wealth of evidence and sources authorities can build on. The benchmarking and good practice fiches provide further insights in examples of successful policymaking. Therefore, this study should be understood as a reference source for countries to learn about approaches that other countries have taken, while at the same time it compiles a good overview of the current state of academic research.

Based on our findings and conclusions, we derive a number of recommendations for **individual Member States:**

1. **Before considering the design of a specific tax measure, tax authorities are recommended to look beyond their home country for inspiration. Particularly, we recommend…**
    a. **Do not reinvent the wheel** – most likely other countries already have similar measures in place. Countries should compare their measures with similar measures in other countries and critically reflect if their or other countries' measures are more effective in curbing GHG emissions, and why this is so. The assessment in this report, the inventory and good practice fiches provide information countries can use to benchmark their measures.
    b. Based on the **inventory and typology of measures**, countries should map any

gaps in their offer, assess why these gaps exist, and reform existing measures or implement new ones where deemed appropriate. The good practice examples provide for examples how certain taxes and tax incentives could be designed, what their strengths but also weaknesses or limitations are. To find successfully implemented tax measures, Member States should also look beyond countries in their direct neighbourhood.

2. **Tax authorities, designing tax measures, are recommended to make sure to consider existing good practice. Particularly, we recommend…**
    a. Where possible, aim at **taxing GHG directly**. Proxies appear to have an effect as well, yet the anticipated effect can be expected to be smaller. This applies to taxes, but also to tax incentives.
    b. In general terms, **give priority to taxes over tax incentives**. There is more clear-cut evidence for the effectiveness of taxes over tax incentives. In addition, given the larger scope of taxes, it is arguably possible to achieve greater GHG emission reductions via taxes than tax incentives. Among taxes, carbon taxes appear to have the greatest potential to reduce emissions effectively.
    c. **Reduce environmentally harmful subsidies and tax incentives**, for instance towards specific transport modes, heating, or industrial purposes. Such a reduction would need to take into account the social and competitiveness impacts and consider complementary policies to tackle them.

Based on our findings and conclusions, we recommend **Member States collectively and the EU level:**

3. **To increase the effective uptake of proven solutions, exchange, evaluation, and collaborative learning should be enhanced. Particularly, we recommend…**
    a. **To foster exchange** among countries to step up common efforts to reduce GHG emissions and to enhance policy learning. Coordination among Member States, at EU level and beyond can help to realise synergies and avoid adverse side-effects (such as, e.g., carbon leakage).
    b. **More research** is needed to fully understand the effectiveness of tax measures in general, and tax incentives in particular. There are still significant gaps in the assessment of the effectiveness of existing measures. Critically reflect on existing policy measures and strengthen efforts to perform ex-post assessments more consistently, especially for tax incentives. These insights – including those on political viability - should then be used to strengthen the evidence base for future measures – to help ensure they are fit for purpose.

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ANNEX I: METHODOLOGICAL ANNEX

The following Annex provides a detailed overview of the methodology employed. It follows the structure of the main report.

Scope of the study

The study explores tax measures across the EU-27, the UK, and five other countries, namely Canada, Iceland, Israel, Norway and Switzerland. It looks at taxes, as well as beneficial tax incentives that incentivise GHG emission reductions. To complement the research, this study also maps and assesses some main types of harmful tax incentives. Only tax measures currently in place and which specifically address GHG emissions are considered in the study. The following considerations influenced the definition of the scope of the study:

- Tax measures and tax incentives which do not specifically address GHG emissions;
- Vehicle taxes (registration, acquisition, circulation tax) which are only based on criteria not related to GHG emissions, including the weight of vehicles or the engine capacity were excluded. We only included vehicles taxes based on CO_2 emissions or proxies;
- Air pollution taxes not targeting greenhouse gases were excluded;
- Tax measures and tax incentives implemented at sub-national level[114] were excluded;
- Other environmental taxes without a link to GHG emissions were excluded;
- The focus of the study have been taxes and tax incentives. Fees, charges, and subsidies have been mostly excluded from the research. Yet, some important levies and other forms of fiscal instruments have been included in the mapping where they were deemed relevant;
- Aviation and maritime taxes were excluded.

Economic Literature review

The literature review provides a comprehensive and systematic overview[115] of the relevant theoretical and empirical literature addressing the effects of environmental taxes regarding several criteria commonly used in the literature and in the benchmarking undertaken in this study: effectiveness, cost efficiency, impacts on competitiveness and innovation, distributional implications, and political acceptance and administration of the environmental tax schemes. The methodological approach comprised three steps.

In a first step, we **screened the existing theoretical and empirical literature** on the potential effects of taxes and tax-related measures aiming at the reduction of greenhouse gas emissions. Generally, the focus of the literature screening took a broad perspective regarding the theoretical aspects of environmental taxes and focused mainly on the 27 EU Member States, the United Kingdom and the additional selected countries concerning empirical results. However, the review was not limited to these countries in case that empirical studies and analyses were identified that are of interest with regard to the focus areas of the literature review. During the screening, we

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[114] We made an exemption for the British Columbia Carbon tax (CA) that was included in the inventory as considered a best practice (see the following section).

[115] The various draft versions of the literature review were discussed with DG TAXUD as well as country representatives in the two online workshops, whose feedback was incorporated in the final report.

identified for which of the aspects of particular interest for this study each source is relevant. To perform the literature review in a systematic way, we established and then used key terms, words and phrases to identify reports or studies focusing on tax measures reducing greenhouse gas emissions.

In addition to key words identified above, we also added key words for the five focus areas, namely effectiveness, cost efficiency, impacts on competitiveness and innovation, distributional implications, and political acceptance and administrative costs.

In a second step, an **analysis of the literature by focus area** was provided. The theoretical part presents the most important theoretical propositions for each focus area. The review of the empirical analyses is structured along the focus areas as well. The presentation of the empirical evidence for each focus area is structured based on various criteria; in particular ex- ante versus ex- post evaluations and case studies versus; cross-country analyses; or case studies.

In a final step, a **comprehensive report** presenting the most important theoretical and empirical findings in the relevant literature was compiled.

Mapping of tax measures

The inventory of tax measures aimed at gaining an overview of measures (taxes and tax incentives) across the 33 countries included in the scope of this study. The inventory further provides an overview of some of the most important harmful tax incentives that increase GHG emissions. The mapping of tax measures was implemented in a two-stepped approach.

Step 1: Preliminary mapping based on existing databases

As a first step, a mapping was developed on the basis of existing research. A key data source has been the OECD PINE database.[116] Filtering for the *Environmental Domain* 'Climate Change', data on existing measures was retrieved for the 33 countries included in the sample. Measures not falling within the scope of the study were removed from the database. As countries report information to the OECD on a voluntary basis, information in the database is incomplete and not always up to date. Therefore, additional desk research was performed to complement the list of measures. Sources of information used were the World Bank's Carbon Pricing Dashboard[117] and other publications from the OECD and EEA. Based on this desk research, a preliminary mapping emerged with a number of measures identified per country.

Step 2: Additional mapping and in-depth description by country researchers

In the second step, country researchers complemented and extended the mapping. The objective for country researcher was to complement the list of pre-identified measures to get a final list that is as comprehensive as possible. Extensive guidance was provided to country researchers to align the understanding of the task among researchers and provide further information. Two workshops were organised during which the country researchers had the opportunity to ask for clarifications. Country researchers received a package of helpful documents, including guidance note, providing background information on the study and its objectives, as well as a step-by-step

[116] https://pinedatabase.oecd.org/.
[117] https://carbonpricingdashboard.worldbank.org.

guide, an extract from the preliminary database for their country, an inventory template that built the basis for the country fiches, and interview guidelines.

The data collection strategy for country researchers was twofold:

- They were asked to screen relevant (national) sources for information on additional measures. As most of the country researchers were native in the national languages, it was possible to cover a wide array of studies, reports, academic literature, grey literature, and other sources.

- To complement and validate the mapping, country researchers were asked to perform three interviews, one each with the national ministry of finance/taxation, the national ministry of the environment, and a national NGO.

In addition to the mapping, country researchers were further asked to provide an in-depth description for up to three selected measures per country. Country researchers were asked to make the selection of measures for the in-depth description on the basis of their effectiveness and the availability of data. The researchers were tasked to screen national sources for information on the selected measures for their environmental effectiveness, economic and distributional implications, as well as their political viability. During the interviews, country researchers were asked to complement the information on the measures selected and to validate their selection of measures. All of these information were reported in an inventory template which was quality checked by the core team for the study and transformed into a country fiche.

Efforts were made to schedule interviews with as many relevant interviewees as possible. However, the country research coincided with the outbreak of COVID-19 in Europe. As a result, it was not possible to arrange interviews with all three stakeholders per country.

The results of the mapping were presented to Member State representatives prior to the first workshop. Member State representatives had the opportunity to comment on the identified list of measures and to suggest corrections. Following the second workshop, Member State representatives had the opportunity to receive the full country fiches and provide further comments and suggestions. 6 Member States made use of this opportunity.

Identification of good practice examples

The approach for the identification of good practices examples was split into an assessment of the environmental effectiveness of measures and an assessment of their political viability.

Starting point and guiding the work was a working definition of what constitutes a good practice within the scope of this study. A first draft was presented in the proposal for this study. The definition was then refined at several stages during the implementation of the project implementation and presented and discussed with Member State representatives during the first workshop.

> *"A good practice is a tax measure that incentivises an individual or company to change their behaviour to reduce the individual production of GHG. A good practice tax measure does not necessarily need to be but benefits from being politically viable. This means that such a measure should at least not cause substantial negative economic effects for competitiveness and innovation, or even generate positive economic effects. It targets*

key producers of GHG and remains reflective on distributional effects, in particular when targeting individuals. It is embedded in a supportive political and regulatory context and does not create unnecessary burden for administrations and target groups. It can be applied easily across different regulatory settings."

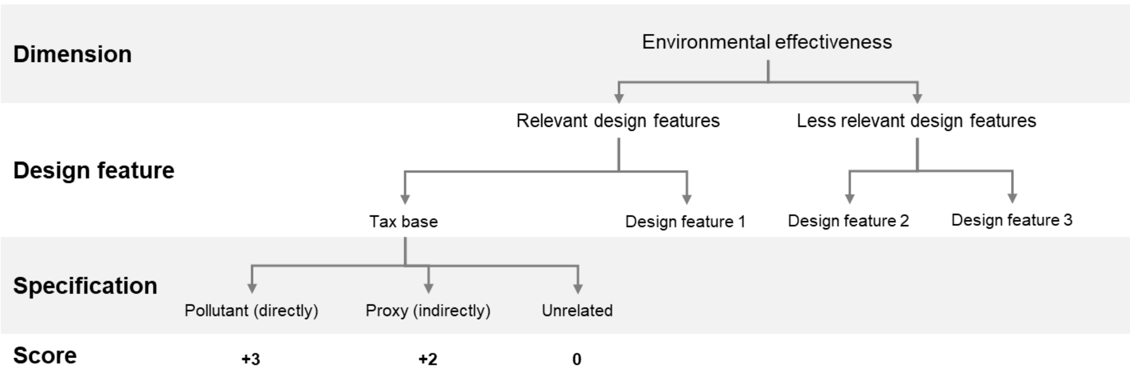
Assessment of the environmental effectiveness of measures

The benchmarking builds on the insights of the literature review. The benchmarking identifies relevant design features of tax measures that bring about positive (or negative) effects with regards to environmental effectiveness. For each of the design features, it defines the best specification applicable to maximise positive effects. Jointly, these defined best design feature specifications form the criteria for good practices. The following two questions have been guiding the development of the benchmarking methodology:

1) **What design features have an effect?** Not all design features are equally relevant for environmental effectiveness. Building on the input from participants to the 1st workshop and the literature review, we selected a number of design features to focus on. The key determining factor was indeed whether or not there is scientific research on potential effects of given design features. This, however, suggests that there might be gaps in the methodology where research is not yet sufficiently advanced.
2) **What design feature specification can be considered as good practice?** Each design feature can take on different specifications, which determine the effect of the design feature on the dimension in question. To identify the good practice specification, we rely on the outcomes of the economic literature review.

The following decision tree exemplifies the thought process for the identification and definition of the individual criteria, using the example of the good practice for the tax base to maximise the environmental effectiveness for a given tax.

Figure 33 Example of a decision tree visualising the thought process for the development of criteria



Source: Ecorys

Scores assigned to individual design feature specifications reflect their respective effect. We employ a scale which goes from -1 to +3. Per criterion, the best specification (i.e. the specification bringing about the largest positive effect) is scored highest (+3). Other specifications, that bring about a smaller yet still desirable effect, are scored lower, yet still positively. If a certain specification has no effect or the effect is not clear from the evidence collected via the literature review, it receives the score 0. Where there is evidence that a certain design feature specification has an adverse effect, the score is negative. The scores and the types of specification are provided in the table below.

Table 23 Overview of possible scores for design feature specifications

Type of specification	Score	Guidance
Best specification	+3	Used for design feature specification which based on literature can be considered the best option to achieve desirable effects under the dimension explored
Second-best specification	+2	Used for design feature specification which are not ideal, but which still bring about desirable effects under the dimension explored, according to literature
Third-best	+1	
Neutral	0	Design feature specification which do not appear to have an effect under the dimension explored
Adverse	-1	Design feature specification with an adverse effect under the dimension explored

Where needed, qualifications have been made for specific types of tax measures. For example, the ideal tax rate differs by type of tax, meaning that there is not one ideal tax rate for vehicle, energy, and carbon taxes. Where this is the case, a tax measure specific rating has been defined. Yet, to ensure comparability, the same system of scores has been employed. **The benchmarking criteria for taxes and tax incentives are presented further below.**

The tables on the following pages provide an overview of the criteria and scores developed for taxes and tax incentives.

Taxes

Criterion	Design feature specification	Score	Explanation
Scope of the tax	*Energy and transport sector*	+3	Energy industries, fuel combustion by energy users and transport sectors are responsible for the majority of GHG emissions in the EU, respectively 54.5% and 16.7%. It can be considered that if a tax is applied to both sectors, it has a potential to be most effective as the scope of taxed activities is the largest.
	Energy sector	+2	
	Transport sector	+1	
Scope of tax measure (existence of exemptions)	*Lack of environmentally harmful exemptions*	+3	To be environmentally effective, taxes should target the pollutant or polluting behaviour, with few (if any) exceptions (best-case scenario +3). Certain countries grant exemptions that at the same time induce firms to change behaviour towards more sustainable, in this case, environmental effectiveness is not compromised, at least not in the medium run (second best case +2).
	Exemptions /reduced rates are contingent on commitment to reduce their emissions or energy use	+2	
	Environmentally harmful exemptions granted without incentive to change behaviour	-1	
The level tax rate (carbon tax)	$Score = \frac{tax\ rate\ applied\ x\ (\frac{1}{PPS} coefficient)}{(highest\ tax\ rate\ applied\ x\ (\frac{1}{PPS} coefficient)} x3$	0 +3	The rate of carbon tax is one of the most important element of carbon tax design. Coupled with the decision on the coverage of the tax, it will ultimately determine the amount of emissions abatement achieved. The larger the tax, the greater the effect can be assumed to be. Thus, the score is calculated by dividing the carbon tax rate applied in a given country by the highest rate applied among all countries which apply carbon tax (currently, Sweden – 110 EUR/t CO2). The result is multiplied by three to align the score with the overall logic. To account for income disparities, purchasing power standards coefficients are used.
The level tax rate (vehicle tax)	*Steep tax curve (progressive)*	+3	To be most effective, the tax rate applied should increase progressively in line with the vehicle's CO2 intensity. Countries with high and highly differentiated (by CO2) taxes, have been the most successful in reducing average CO2 emissions.
	Moderately steep tax curve	+2	
	Rather flat tax curve	+1	
The level tax rate (energy tax)	$Score = \frac{tax\ rate\ applied\ x\ (\frac{1}{PPS} coefficient)}{(highest\ tax\ rate\ applied\ x\ (\frac{1}{PPS} coefficient)} x\ 3$	0 +3	To be effective and impact consumption decisions, excise duties on energy products (motor fuels, heating fuels and electricity) need be significantly higher than the minimal rates currently required by the Energy Tax Directive. The larger the tax, the greater the effect can be assumed to be. Thus, the score is calculated by dividing the tax rate applied for a given fuel in a given country by the highest rate applied for the same fuel among all EU countries. The result is multiplied by three to align the score with the overall logic. To account for income disparities, purchasing power standards coefficients are used.

Criterion	Design feature specification	Score	Explanation
Tax base	*Explicit carbon/CO2 component// other greenhouse gases (NOx, HFC, PFC)*	+3	Research suggests that an environmental tax should generally be levied as directly as possible on the pollutant or action causing the environmental damage (+3). The second-best approach is to levy a tax on a proxy (+2).
	Proxy/implicit carbon content	+2	
	Not related	0	

Tax incentives

Criterion	Design feature specification	Score	Explanation
Generosity of the tax break	$Score = \frac{Reduction\ (\%)}{100\%}\ x\ 3$	0 to +3	The larger the tax break, the greater the effect can be assumed to be. Thus, the score is calculated by dividing the incentive specific reduction by the maximum possible (100%). The result is multiplied by three to align the score with the overall logic.[118]
Scope of the tax break (I)	*Tax break incentivises positive externalities*	+3	Two scores can be assigned: +3 for incentivising positive externalities, and +2 (second-best) for tax breaks incentivising the avoidance of negative externalities.
	Tax break incentivises avoidance of negative externalities.	+2	
Scope of the tax break (II)	*Tax incentive is output oriented (i.e. targets emission reduction directly)*	+3	Following research, incentives targeting the emission reduction directly (so called output oriented incentives) can be considered best practice and are therefore scored +3, while other incentives (so called input oriented incentives) are scored +2.
	Tax incentive is input oriented (i.e. "picks a winner")	+2	
Tax the incentive is built into	*Tax incentive built into one-off tax (sales related tax, excise taxes, etc.)*	+3	The scores assigned reflect the findings of research. A break built into a one-off tax at the time of purchase receives the highest score (+3), while a tax built into a reoccurring tax (paid at a later stage) is less effective (+1). Since evidence on VAT is mixed, it is considered a second-best (+2).
	Tax incentive built into VAT	+2	
	Tax incentive built into reoccurring tax (e.g. income tax, annual vehicle tax, real estate tax…)	+1	

[118] This assumes that any beneficial tax incentive built into a tax will have at least some minor positive effect on the environmental effectiveness.

The measures included in the benchmarking were selected among the measures described in detail by country researchers. The selection was further based on the availability of empirical and theoretical literature that allowed to create criteria against which the measures will be evaluated. For certain measures, e.g. taxes on packaging materials, there is not enough evidence to judge the effect of individual design features. In addition, certain measures included in the inventory – such as renewable energy levy – are excluded from benchmarking because they are not considered a tax (they are a charge) and thus cannot be compared to tax measures.

As a result of the selection, the following types of tax measures presented in the table below will be considered in the benchmarking exercise.

Table 24 Overview of types of tax measures reflected in the benchmarking

Taxes	Beneficial tax incentives
• Energy taxes (excise duties on motor fuels, heating fuels and electricity) • Explicit carbon taxes • Taxes on other greenhouse gases (NOx, HFC, PFC • Vehicle taxes	• Incentives for electric/hybrid vehicles • Incentives for energy efficiency • Incentives for public transport • Incentives for renewables • Incentives for green R&D

For each selected measure, a **score per relevant criterion** developed in Step 1 was assigned. In almost all cases, criteria allowed for a clear-cut decision on what score to assign. Where this was not the case, decisions were made jointly among the researchers and a comment added to the score.

Once all scores were assigned, the **overall score per measure** was calculated. Values were then normalised:

$$N_m = \frac{S_m}{S_{max}},$$

where N is the normalised score for a given measure *m*, and S_{max} denotes the maximum score possible. The normalised score can take a value between 0 and 1.

Weights were applied to reflect differences in the importance of the individual design features. The following weights were applied:

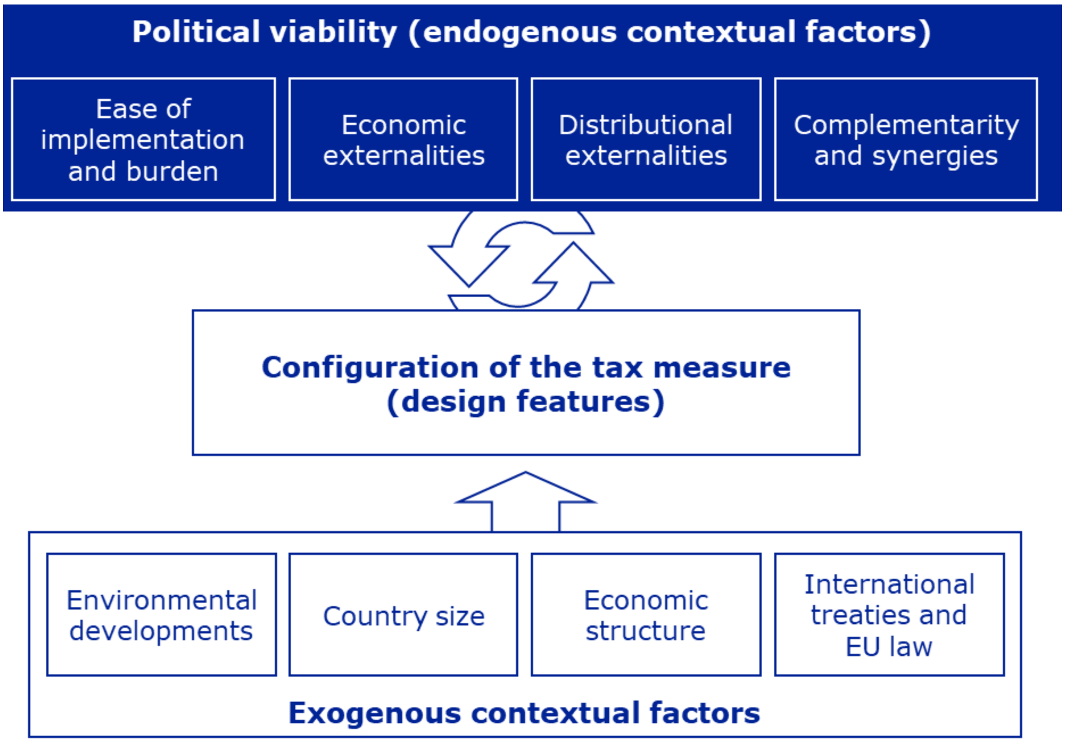
Table 25 Weights applied to the individual criteria scores

Taxes		Tax incentives	
Scope of the tax	40%	Generosity of the tax break	10%
Existence of exemptions	15%	Scope of the tax break (I)	40%
Level of the tax rate	25%	Scope of the tax break (II)	40%
Tax base	20%	Tax the incentive is built into	10%

Following this, the measures were ranked based on their values. Measures were ranked from the highest to lowest score. The ten highest ranking taxes and the ten highest ranking tax incentives were selected to be included in the assessment of political viability.

Assessment of political viability

The assessment of political viability takes **contextual factors** into account. The figure below provides a simplified overview of the interdependence of tax measures and contextual factors.



Generally, contextual factors can be divided into two groups: political viability (or endogenous) factors and exogenous factors. **Exogenous contextual factors** are those which first and foremost affect the design of tax measures, but are themselves not affected by the tax measure implemented.[119] This includes, but is not necessarily limited to, the size of a country, its economic structure, the overall environmental developments, but also the international and European legal framework. There is a second set of contextual factors that are rather **endogenous**. These factors affect the design of a given tax measure, but they are also influenced by the measure's design. The economic literature review identified the economic and distributional externalities of a given measure, the ease of implementation or costs linked to a given measure, as well as its complementarity with other policies as relevant endogenous factors. As these factors are affected by the design of a given tax measure, they determine a given measure's **political viability**.

The more the measure is designed in light of the endogenous factors, the greater is its political viability. The literature review (see Section 2.3.7) highlighted that policymakers need to balance different and oftentimes conflicting interests. A tax measure that is particularly effective in reducing GHG emissions, for example because it puts a high price on carbon emissions, will raise concerns among and resistance from different societal groups. Depending on political majorities and the pressure protesting societal groups can create, policymakers will therefore aim at softening the effects of a tax measure, even if this comes at the cost of reducing its environmental effectiveness. This will increase the acceptance of and compliance with the measure within society. Similarly, policymakers need to ensure that the tax measure fits within a wider set of

[119] At least in the short to medium term.

policy initiatives and is not contradicting them to gain support. A measure that complements an existing policy initiative or builds on it is easier to implement and can even yield greater effectiveness as synergies are realised. Conflicting policy initiatives, e.g. a harmful tax incentive, can undermine the effectiveness of the tax measure. At the same time, it might be necessary to keep the harmful tax incentive in place to cushion negative economic or social effects. The **choice of the type of measure** (tax or tax incentive) has an imminent impact on the political viability. A tax creates additional burden for the addressee (negative economic externalities), while it creates a new revenue stream for administrations (cost of measure). The opposite applies to tax incentives. The choices of **design features** affect the political viability in the following ways:

Firstly, the design of a tax measure affects its **ease of implementation and the costs of the measure** (for tax authorities). In addition, the **simplicity and certainty of the scheme** (for tax incentives beneficiaries) plays a role. We assume that tax measures that are easy to implement are also more politically viable.. The lower the costs or the higher the revenues for administrations are, the higher will also be its political viability.

Secondly, the external dimension of the measure in terms of its **complementarity with other policies** plays a role. For taxes these can be e.g. being **part of a wider green reform** or energy transition efforts (e.g. in Sweden fossil fuel heating was gradually replaced by district heating and aid schemes for conversion to renewable heating were offered etc.) or the provision of alternatives (biofuels, district heating, public transport, housing insulation etc). For tax measure and tax incentives, examples include the existence of parallel measures incentivising the same behaviour (**double-targeting**) and thus creating synergies (e.g. in Norway in addition to registration tax exemption for EV, EV are exempt from VAT). In case of tax incentives, existence/implementation of infrastructure reinforcing the uptake of a measure (**interdependencies**) is also sometimes relevant (e.g. existence of EV charging stations is key for the uptake of electric vehicles).

Thirdly, we specify in our working definition[120] of a good practice that a tax measure should minimise any negative or bring about positive economic and distributional externalities. The greater the positive externalities of a measure, the higher is its political viability. Thus, design features that **leverage on positive or mitigate negative indirect effects** are relevant.

- For taxes, this includes e.g. taking into account effects on economic interests. By having an upward effect on prices, a rise of environmental taxes is likely to raise production costs and adversely affect cost competitiveness. Companies might be inclined to move production to other countries to reduce costs (carbon leakage). However, according to the literature review, most empirical studies find no statistically significant effects of carbon pricing or energy prices on different dimensions of competitiveness, and evidence on carbon leakage is inconclusive (see Sections 2.2.5 and 2.3.5). Instead, there is evidence that carbon pricing drives innovation in clean technologies. The scope of the tax measure and exemptions can have a major impact on economic competitiveness and innovation. Research suggests that sectors with high fossil fuel consumption and exposure to international competition are likely to be affected by a higher tax burden, at least in the short term. In the long run innovation and the switch to less emitting production technologies may alleviate this effect. Instruments like the Carbon Border Adjustment Mechanism[121] under the ETS can further help to alleviate negative effects on competitiveness. Academic research on the economic implications of tax breaks incentivising a reduction of GHG emissions is very limited. Yet, a tax break incentivising

[120] See above.
[121] https://ec.europa.eu/clima/policies/ets/allowances/leakage_en.

innovation and research does not only enhance the measure's environmental impact, but also creates positive economic externalities. Further, for incentives targeting energy efficiency, the beneficiary of a tax incentive matters, too. Energy efficiency measures that benefit businesses arguably reduce (production) costs for these beneficiaries in the medium to long run. As a result, these businesses will enhance their competitiveness in comparison to other companies.

- Moreover, it is important to clarify whether there are negative or unpopular impacts on income distribution and to assess how these could be alleviated (e.g. through earmarking). Empirical evidence suggests that particularly imposing taxes on heating and electricity would impose heavier burdens on low-income than on high-income households, since the former spend a larger share of their income on these goods. Often contrasting public perceptions (e.g. gilets jaunes), literature does not find a clear cut regressive effect for taxes on transport fuels.[122] The literature suggests that regressive effects of energy/carbon taxes can be alleviated, however, through revenue recycling whereby (parts of) tax revenues are used for direct transfers and for reduction in labour income tax. The use of revenues clearly contributes to the success of carbon taxes (perceptions of fairness are important determinants of public support). Interestingly, research suggests that the public prefers to recycle carbon tax revenues via investment in "environmental projects". For tax incentives, the distributional effect depends on the tax the incentive is built into. Research shows that for some tax incentives (such as tax breaks for electric vehicles, solar panel installations or insulation investment), high-income households benefit disproportionally more. This suggests that many low-carbon tax incentives are regressive because they reduce the price of goods that are primarily bought by higher-income households (Zachmann et al, 2019, Borenstein and Davis, 2016). Yet, evidence suggests that there is one notable exemption. Tax incentives that reduce costs for public transport can have positive distributional effects.[123]

Based on these considerations, the following table was used to assess the political viability of the ten pre-selected taxes and tax incentives:

Dimension	Indicators	Questions to be addressed in our assessment	Judgement options
Ease of implement-tation/ adminis-trative burden	Administrative burden for tax authorities	Are the indicators used to calculate the tax base/ or identify eligible tax incentive beneficiaries easily collectable/ accessible to the authority?	Yes/ no/ uncertain/ N/A
	Simplicity and certainty of the scheme for tax incentive beneficiaries	Does the implementation of the measure demand tax incentive beneficiaries to spend a significant amount of time to collect and provide data in order to benefit from the measures?	Yes/ no/ uncertain/ N/A
Complementarity with other policies	Being part of a wider agenda	Is the measure being introduced as part of a wider greening agenda?	Yes/ no/ uncertain/ N/A

[122] Taxes on transport fuels do not appear to be generally regressive as shares of expenditures for fuel are lower in the low-income households and are growing with income. Lacking negative distributional effects of transport fuel taxes may also be explained by the fact that car ownership is less widely spread in the lower expenditure deciles.

[123] While also better-off individuals benefit from reduced costs, public transport is mostly used by less well-off individuals, thus benefitting them disproportionally.

Dimension	Indicators	Questions to be addressed in our assessment	Judgement options
	Enhancing effect through double-targeting	Are there other measures in place aiming to achieve the same effect?	Yes/ no/ uncertain/ N/A
	Inter-dependencies	Are there measures in place that provide a pre-condition for this measure to work? (e.g. infrastructural investments/incentives to allow for the use of electric cars)	Yes/ no/ uncertain/ N/A
Indirect effects	Economic effects	Is the measure designed to mitigate potential negative economic externalities?	Yes/ no/ uncertain/ N/A
		Is the measure designed to leverage on potential positive economic externalities?	Yes/ no/ uncertain/ N/A
	Distributional effects	Is the measure designed to mitigate potential negative distributional externalities?	Yes/ no/ uncertain/ N/A
		Is the measure designed to leverage on potential positive distributional externalities?	Yes/ no/ uncertain/ N/A

ANNEX II: DETAILED RESULTS ANNEX

Tables 25 and 26 provide additional information of the tax base of individual vehicle taxes across the 33 countries covered in this study. Partly building on previous research, the tables have been updated and complemented by findings from our own country research.

Table 27 and 28 below provide detailed results of environmental effectiveness benchmarking exercise for taxes and tax incentives. They contain the name of the measure, the country where it is in place, the type of the measure, the scores per design feature and the justification for the provided score.

Table 29 presents the results of detailed political viability assessment that was conducted on 20 measures (10 taxes and 10 tax incentives). It contains the name of the measure, the country where it is in place, the assessment of different aspects of political viability, such as ease of implementation, complementarity with other policy measures and economic and distributional externalities.

Detailed overview of tax base of vehicle taxes

Table 26 Detailed overview of tax base of vehicle taxes (registration) across countries covered in this study (passenger and commercial vehicles)

Components:	CO_2	Fuel consumption	Fuel efficiency	EURO Norm	Engine power	Fuel type	Age	Cylinder capacity	Other
Emission targeting:	*Direct*	*Indirect (proxy)*			*Unrelated*				
Austria	+					+			
Belgium	+						+	+	+
Bulgaria									
Croatia	+					+			
Cyprus	+							+	
Czechia									
Denmark		+							+
Estonia									
Finland	+								+
France	+								
Germany									
Greece	+								+
Hungary				+				+	

Components:	CO_2	Fuel consumption	Fuel efficiency	EURO Norm	Engine power	Fuel type	Age	Cylinder capacity	Other
Ireland	+								+
Italy	+								+
Latvia									
Lithuania									
Luxembourg									
Malta	+								+
Netherlands	+		+						
Poland								+	
Portugal	+							+	
Romania									
Slovak Republic									
Slovenia	+								+
Spain	+								
Sweden									
United Kingdom	(+)*								
Canada									
Iceland									
Israel	+								+
Norway	+					+			+
Switzerland									

Source: European Commission (2019) Transport taxes and charges in Europe[124] and ACEA tax guide (2020)[125] and own research

**In the UK, a CO_2-based 'first year rate' applies.*

[124] European Commission (2019) Transport taxes and charges in Europe https://ec.europa.eu/transport/sites/transport/files/studies/transport-taxes-and-charges-in-europe-isbn-978-92-79-99561-3.pdf

[125] ACEA tax guide (2020) https://acea.be/uploads/news_documents/ACEA_Tax_Guide_2020.pdf .

Table 27 Detailed overview of tax base of vehicle taxes (circulation) across countries covered in this study (passenger cars)

Components:	CO_2	Fuel consumption	Fuel efficiency	EURO Norm	Engine power	Fuel type	Age	Cylinder capacity	Other
Emission targeting:	*Direct*	*Indirect (proxy)*			*Unrelated*				
Austria					+				
Belgium	+							+	
Bulgaria				+	+				
Croatia					+		+		
Cyprus	+								
Czechia*					+				
Denmark		+							+
Estonia									
Finland	+								+
France	+								+
Germany	+							+	
Greece	+							+	
Hungary					+		+		
Ireland	+							+	
Italy					+				
Latvia					+			+	+
Lithuania									
Luxembourg	+							+	
Malta	+						+		
Netherlands	+					+			+
Poland									
Portugal	+							+	
Romania								+	
Slovak Republic*							+	+	
Slovenia								+	
Spain									+
Sweden	+								+
United Kingdom						+			

Components:	CO_2	Fuel consumption	Fuel efficiency	EURO Norm	Engine power	Fuel type	Age	Cylinder capacity	Other
Canada									
Iceland	+								
Israel									
Norway									
Switzerland					+	+		+	+

**In Czechia and Slovakia, the circulation tax applies to company cars only.*

European Commission (2019) Transport taxes and charges in Europe[126] and ACEA tax guide (2020)[127] and own research

Table 28 Detailed overview of tax base of vehicle taxes (circulation) across countries covered in this study (commercial vehicles)

Components:	CO_2	Fuel consumption	Fuel efficiency	EURO Norm	Engine power	Fuel type	Age	Cylinder capacity	Weight	Other
Emission targeting:	*Direct*	*Indirect (proxy)*			*Unrelated*					
Austria									+	
Belgium	+								+	+
Bulgaria									+	
Croatia					+		+			
Cyprus	+									
Czechia									+	+
Denmark		+							+	+
Estonia									+	+
Finland									+	+
France									+	+
Germany									+	+
Greece									+	
Hungary									+	

126 European Commission (2019) Transport taxes and charges in Europe https://ec.europa.eu/transport/sites/transport/files/studies/transport-taxes-and-charges-in-europe-isbn-978-92-79-99561-3.pdf

127 ACEA tax guide (2020) https://acea.be/uploads/news_documents/ACEA_Tax_Guide_2020.pdf

Components:	CO_2	Fuel consumption	Fuel efficiency	EURO Norm	Engine power	Fuel type	Age	Cylinder capacity	Weight	Other
Ireland									+	
Italy									+	+
Latvia									+	+
Lithuania									+	+
Luxembourg									+	+
Malta	+						+			
Netherlands									+	+
Poland									+	+
Portugal									+	+
Romania									+	+
Slovak Republic									+	+
Slovenia										
Spain										+
Sweden									+	+
United Kingdom									+	+
Canada										
Iceland									+	+
Israel										
Norway	+								+	
Switzerland								+	+	+

Source: European Commission (2019) Transport taxes and charges in Europe[128] and ACEA tax guide (2020)[129] and own research

[128] European Commission (2019) Transport taxes and charges in Europe https://ec.europa.eu/transport/sites/transport/files/studies/transport-taxes-and-charges-in-europe-isbn-978-92-79-99561-3.pdf

[129] ACEA tax guide (2020) https://acea.be/uploads/news_documents/ACEA_Tax_Guide_2020.pdf .

Environmental effectiveness benchmarking results

Table 29 Environmental effectiveness benchmarking results - taxes

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
CH	CO_2 Tax (Carbon tax)	Carbon Tax	Energy and Transport	3	Operators of greenhouse gas-intensive installations can be exempted from the CO_2 levy if they are in an internationally highly competitive industry and they commit to reduce their greenhouse gas emissions; large greenhouse gas-intensive installations participating in the ETS are exempted.	2	83 EUR/t CO_2	1.81	CO_2 component	3	0.85
SE	Carbon Tax	Carbon Tax	Energy and Transport	3	Various exemptions. Due to numerous exemptions, Sweden's carbon tax covers only about 40 percent of all greenhouse gases emitted nationally. While some of the exempted industries are subject to the EU ETS, others are not subject to any type of carbon pricing.	-1	110 EUR/t CO_2	3	CO_2 component	3	0.80
DK	Carbon Tax	Carbon Tax	Energy and Transport	3	Tax rebates for companies that participate in the voluntary industrial energy efficiency agreements. There are ceilings on tax rates on certain industrial GHGs and some tax reductions are given to light and heavy industrial processes.	2	23 EUR/tonne CO_2	0.58	CO_2 component	3	0.75

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
IL	Green tax on the purchase of cars	Vehicle Tax	Transport	1	Lack of environmentally harmful exemptions.	3	Higher rates are applied for higher GHG emissions	3	CO2 component, and other pollutants	3	0.73
FI	Motor vehicle registration tax	Vehicle Tax	Transport	1	Lack of environmentally harmful exemptions.	3	Higher rates are applied for higher CO2 emissions (Steep)	3	Only CO2 component	3	0.73
FR	Malus scheme for car purchases	Vehicle Tax	Transport	1	Reduction of CO2 penalty for vehicles equipped to run on E85 fuel as well as half-fares.	3	Higher rates are applied for higher CO2 emissions (Steep)	3	CO2 component and fiscal power, but malus scheme heavily influences the total registration tax	3	0.73
NO	Environmental tax on greenhouse gases – hydrofluorocarbons (HFC) and perfluorocarbons (PFC)	Tax on other pollutant	Industry	2	Lack of environmentally harmful exemptions. Exemptions apply for NATO and multilateral organisations. In addition, exemptions are also made in the case of temporary use within the country.	3	Imports of HFC increased sharply until 2002. When a tax duty was imposed on the gas in 2003, imports	1	other GHG component	3	0.70

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
							fell consequently				
FI	Carbon Tax	Carbon Tax	Energy and Transport	3	Certain industries and fuel uses are (partially) exempt from the carbon tax, such as fuel use in refineries and CHPs or use of coal and natural gas as raw materials in industrial processes.	-1	62 EUR/tonne CO2	1.65	CO2 component	3	0.69
PT	Motor vehicle registration tax	Vehicle Tax	Transport	1	Lack of environmentally harmful exemptions. Exemptions apply to: • Non-motorised vehicles • Vehicles exclusively powered with electricity or a renewable energy • Public services (i.e. Ambulances, transport of school children, armed forces, transport of disabled people, etc.) • Large families	3	Higher rates are applied for higher CO2 emissions (Steep)	3	CO2 component and cylinder capacity	2	0.67

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
FR	Climate energy contribution (Carbon tax	Carbon Tax	Energy and Transport	3	Operators covered by the EU ETS are exempt from the tax. Also certain industrial processes (non-combustion usage), power production, shipping, aviation, public transport and freight transport are (partly) exempt from the carbon tax.	-1	44 EUR/tonne CO2	1.35	CO2 component	3	0.66
CY	Vehicle annual circulation tax	Vehicle Tax	Transport	1	Lack of environmentally harmful exemptions.	3	Higher rates are applied for higher CO2 emissions (moderately steep, step-like)	2	Only CO2 component	3	0.65
IE	Vehicle registration tax	Vehicle Tax	Transport	1	Lack of environmentally harmful exemptions. Exemptions apply to: • Disabled drivers or disabled passengers • Vehicles used for public services • Temporary new residents • Diplomats	3	Higher rates are applied for higher CO2 emissions (moderately steep)	2	Only CO2 component	3	0.65

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
LU	Road tax (ownership vehicle tax)	Vehicle Tax	Transport	1	Lack of environmentally harmful exemptions. Exemptions apply to: • vehicles used exclusively by the State, the communes or public or public interest institutions; • vehicles used for agricultural, forestry and wine-growing activities; • self-propelled machinery; • passenger cars used as personal transport by disabled individuals.	3	Higher rates are applied for higher CO2 emissions (moderately steep)	2	Only CO2 component, higher rates applied for diesel	3	0.65
AT	Duty on vehicle purchase based on fuel consumption	Vehicle Tax	Transport	1	Few exemptions	3	Higher rates are applied for higher CO2 emissions (moderately steep)	2	Only CO2 component	3	0.65
UK	First Year Rates of the Vehicle Excise Duty (VED) (circulation tax)	Vehicle Tax	Transport	1	Yes, but not environmentally related.	3	moderately steep	2	Existing cars based on engine size and new cars based on CO2 emission ratings	3	0.65

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
NO	CO2 Tax (on Mineral Products)	Carbon Tax	Energy and Transport	3	Exemptions apply to: 1) aircraft in international service and 2) shipping in international service. Biodiesel is exempt from CO2, sulphur and basic tax. There are also reduced rates for some types of industries, e.g. agriculture and fishery sectors have temporarily been excluded.	-1	53 EUR/tonne CO2	1.18	CO2 component	3	0.65
PT	Carbon Tax	Carbon Tax	Energy and Transport	3	Fuel for maritime and air transport is exempt. Certain industrial processes (notably non-combustion usage) and modes of transport and vulnerable consumers are (partly) exempt from the carbon tax.	-1	€23.6 per tonne of CO2	0.94	CO2 component	3	0.63
RO	Taxes on pollutant emissions into the atmosphere	Tax on other pollutant	Industry	2	None	3	No evidence if the tax had an impact on polluting behaviour, as other factors come into play: use of less pollutant fuel, improved combustion technology	0	other GHG component	3	0.62

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
							and equipment, and use of other techniques to lower the levels of the mentioned pollutants.				
IE	Carbon Tax	Carbon tax	Energy and Transport	3	Operators in the EU ETS are partially exempted from the carbon tax up to the minimum level allowed by the EU Energy Taxation Directive. Certain industrial processes, export of the fuels covered, power production, shipping and aviation are (partly) exempt from the carbon tax.	-1	26 EUR/tonne CO_2	0.74	CO_2 component	3	0.61
CA	British Columbia Carbon Tax	carbon tax	Energy and Transport	3	Various exemptions and rebates including exported fuels, fuel consumption by aviation and shipping travelling outside British Columbia, and coloured gasoline and coloured diesel purchased by farmers.	-1	25 EUR/tonne CO_2	0.7	CO_2 component	3	0.61

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
SL	Carbon Tax	Carbon Tax	Energy and Transport	3	Operators covered by the EU ETS that are deemed exposed to carbon leakage and/or energy-intensive entities are exempt from the carbon tax. Also, certain exemptions for fuel used to generate electricity, fuel used for purposes other than transport or heating fuel, fuel used in aviation and maritime transport and for propulsion of fishing vessels, except in the case of private or private aircraft, and fuel used in the production of non-metallic mineral products.	-1	17 EUR/tonne CO2	0.67	CO2 component	3	0.61
SE	Coke and coal excise duty (heating, non-business use)	Energy taxes - heating fuel	Energy	2	Reduced rates applied for business use.	-1	10.7 EUR (including carbon tax)	3	Energy taxes do not directly target GHG emissions (implicit)	2	0.60
HR	CO2 emission tax on non-ETS stationary sources	Carbon Tax	Energy	2	For tax payers that invest in energy efficiency, renewables and other measures to reduce CO2 and other greenhouse gas emissions are charged a lower fee.	2	5.3 EUR	0.3	CO2 component	3	0.59

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
MT	Vehicle registration tax	Vehicle Tax	Transport	1	Electric, plug-in and hybrid vehicles are exempted.	3	Higher rates are applied for higher CO2 emissions (Moderately steep)	2	CO2 component and length of the car	2	0.58
EL	Vehicle registration tax	Vehicle Tax	Transport	1	Yes, but not environmentally related. Exemptions only for electric cars.	3	Higher rates are applied for higher CO2 emissions (moderately steep)	2	CO2 component and emission standards component	2	0.58
SL	Car taxation based on CO2 emissions (registration tax)	Vehicle Tax	Transport	1	Exemptions to this tax include vehicles owned by the Slovenian government, state administration bodies, health institutions, fire brigades, diplomatic and consular offices, vehicles used for taxi services and vehicles adapted for transporting people with disabilities.	3	Higher rates are applied for higher CO2 emissions (moderately steep)	2	CO2 component, cylinder capacity, eurostandard	2	0.58
IS	Carbon Tax	Carbon tax	Energy & transport	3	Exemptions for Emissions-Intensive and Trade-Exposed (EITE) sectors, aviation fuel and coal are exempt.	-1	25 EUR/tonne CO2	0.34	CO2 component	3	0.58

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
EE	Carbon Tax	Carbon Tax (emission charge)	Energy	2	Operators covered by the EU ETS are exempt from the carbon tax. The Environmental Charges Act gives the opportunity to replace the emission charge (including CO2 emission charge) with the environmental investments of the companies.	2	2 EUR/tonne CO2	0.08	CO2 component	3	0.57
LT	Environmental pollution tax	Tax on other pollutant	Industry	2	Most of the tax reliefs are in place if: • natural or legal persons are implementing environmental measures aimed at reducing the emission of pollutants into the atmosphere, • vehicles have installed and functioning exhaust gas neutralisation systems, use biofuel.	2	The pollution tax has been too low for the industries to consider implementing different environmental measures to receive tax reliefs.	0	other GHG component	3	0.57
ES	Taxation on first registration)	Vehicle Tax	Transport	1	Yes, but not environmentally related.	3	Rather flat, step-wise (large brackets), it was found not to be effective	1	Only CO2 component	3	0.57

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
LV	Law on Vehicle Operation Tax and Company Car Tax (Vehicle Operation Tax/circulation tax)	Vehicle Tax	Transport	1	Yes, exemption for cars older than from 2008. Tax not based on CO2 emissions applies to those.	-1	Higher rates are applied for higher CO2 emissions (Steep)	3	Only CO2 component, but only for cars registered after 2008	3	0.53
ES	Tax on fluorinated greenhouse gases	Tax on other pollutant	Industry	2	Exemptions apply to the first sale and delivery of fluorinated gases: • by economic agents devoted to resale only (not using fluorinated gases in their productive processes), • devoted to exports, • devoted to chemical transformations where its composition is altered, • to be incorporated for the first time into new equipment or devices, • devoted to the production of medical aerosols for inhalation, • imported or acquired in new equipment or devices, or • imported or acquired in medical aerosols for inhalation	-1	The reduction of fluorinated GHG emissions since the introduction of this tax has been notable. In 2013, a year before the tax came into effect, emissions in Spain reached 16.180 million tonnes of fluorinated GHG. Four years later, in 2017, this figure lowered to 7.513 million tonnes	1	other GHG component	3	0.50

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
DE	Vehicle Tax for passenger cars (annual circulation tax)	Vehicle Tax	Transport	1	Yes, but not environmentally related. Exemptions only for electric cars.	3	Flat rate (2 EUR per CO2/km)	1	CO2 component and cylinder capacity	2	0.50
HR	Special tax on motor vehicles (Registration tax)	Vehicle Tax	Transport	1	The following exemptions apply: • for vans and campers the tax is reduced by 85% • motor vehicles older than 30 years the tax is paid in a lump sum of 2,000.00 HRK (EUR 262).	-1	Higher rates are applied for higher CO2 emissions (Steep)	3	CO2 emissions and the type of fuel used	2	0.47
UK	Carbon price support (CPS) rates of the Climate Change Levy	Carbon Tax	Energy	2	Small power generators, stand-by generators and power production in Northern Ireland are exempt from the tax rates of the UK carbon price floor. Consumption of electricity generated from efficient on-site combined heat and power (CHP) plants is also exempted and from inefficient CHPs partially exempted.	-1	20 EUR/tonne CO2	0.58	CO2 component	3	0.47
HR	Gas oil excise duty	Energy taxes - motor fuel	Energy and Transport	1	Few harmful exemptions (e.g Agricultural, horticultural or piscicultural works, and in forestry).	-1	412.9	2.93	Implicit	2	0.46
DK	electricity (non-business use)	Energy taxes - electricity	Energy	2	Reduced rates applied for business use.	-1	119.5	2.85	unrelated	0	0.45

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
LV	Natural Resources Tax Law (Natural Resources Tax on CO2 Emissions)	Carbon Tax	Energy	2	Operators covered by the EU ETS are exempt from the carbon tax. The carbon tax also does not apply to the use of peat in industrial activities.	-1	9 EUR/tonne CO2	0.41	CO2 component	3	0.45
EL	electricity (non-business use)	Energy taxes - electricity	Energy	2	No exemptions, no reduced rates.	3	5 EUR	0.22	Unrelated	0	0.44
PL	Carbon Tax	Carbon tax	Energy	2	Exemption of entities covered by the EU ETS. Entities are also exempt if the annual tax amount due is less than 800 złoty.	-1	0.07 EUR/tonne CO2	0	CO2 component	3	0.42
DK	Tax on Nitrous Oxides (NOx)	Tax on other pollutant	Industry	2	yes	-1	It was found not very effective	0	other GHG component	3	0.42
ES	Gas oil excise duty	Energy taxes - motor fuel	Transport	1	Few harmful exemptions (e.g Agricultural, horticultural or piscicultural works, and in forestry).	-1	379 EUR	1.92	Energy taxes do not directly target GHG emissions (implicit)	2	0.38
SE	Differentiated Vehicle Tax (circulation tax)	Vehicle Tax	Transport	1	Yes, exemption for cars older than from 2006. Tax not based on CO2 emissions applies to those.	-1	Rather flat tax rate curve	1	Explicit CO2 component for cars registered after 2006	3	0.37

Country	Name of the measure	Type of measure	Scope of the tax	Score	Scope (existence of exemptions)	Score	The level of tax rate	Score	Tax base	Score	Total
RO	Coke and coal excise duty (heating, non-business use)	Energy taxes - heating fuel	Energy	2	Reduced rates applied for business use.	-1	0.32 EUR	0.16	Energy taxes do not directly target GHG emissions (implicit)	2	0.36
CA	Excise Tax on Fuel-Inefficient Vehicles	Vehicle Tax	Transport	1	The following exemptions apply: • Pickup trucks, • vans equipped to accommodate 10 or more passengers, • ambulances and hearses	-1	Three values depending on fuel efficiency, low effectiveness, few cars covered	1	Proxy (based on fuel efficiency)	2	0.30
IT	Motor vehicle circulation tax	Vehicle Tax	Transport	1	30-year-old cars are exempt. Tax exemptions apply also to LPG vehicles: this exemption, however, is not regulated at national level but by single regions.	-1	Rather flat tax rate curve	1	Unrelated (based on engine power and to lesser extent EURO standard)	0	0.17

Table 30 Environmental effectiveness benchmarking results – tax incentives

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
IL	Accelerated depreciation for R&D in the field of renewable energy	Tax incentive for R&D	Companies may use accelerated depreciation: • up to 200% of the standard/ordinary rates for machinery or equipment • up to 400% of the standard/ordinary rate for buildings. R&D labour costs and other R&D expenses can be deductible at up to 100%.	3	The measure incentivises the investment in R&D in the field of renewables	3	Output oriented	3	CIT	1	0.93
IT	Tax credit for costs incurred in R&D, innovation and design activities	Tax incentives for R&D	50% until 2018, 25% until 2020	0.75	The measure consists of a tax credit for investments in R&D activities	3	Output oriented	3	Company Income Tax	1	0.86
BG	Tax exemption for buildings with energy certification	Tax incentives for energy efficiency	100%	3	The measure targets energy efficiency in the residential sector	2	Output oriented	3	Recurring/real estate	1	0.80
HU	Tax credits on energy efficiency investments	Tax incentives for energy efficiency	45%-65% of eligible costs	1.65	The incentive on investment projects that enhance	2	Output oriented	3	CIT	1	0.76

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
					energy efficiency for corporations						
NL	Energy investment allowance	Tax incentives for renewable energies	45% of the investment cost	1.35	This incentive aims at increasing the investments in renewable energy	2	Output oriented	3	Company Income Tax	1	0.75
MT	Tax incentives for businesses to implement energy-efficient practices	Tax incentives for energy efficiency	The tax credit amounts at maximum 45% of eligible expenses (65% in the area of Gozo).	1.35	The incentive on investment projects that enhance energy efficiency for corporations	2	Output oriented	3	CIT	1	0.75
NO	Tax exemption for EV	Tax incentive for electric/ hybrid vehicles	Exemption from registration tax, which is otherwise calculated based on the vehicle's emission levels (CO2 and NOx), levy category, size etc.	3	This measure disincentivise the use of polluting cars.	2	Input oriented, it directly targets the purchase of EVs	2	This is built into registration tax	3	0.73
BG	Tax exemption for electric vehicles	Tax incentive for electric/ hybrid vehicles	100% exemption as compared to standard circulation tax	3	This measure disincentivise the use of polluting cars.	2	Input oriented	2	Registration tax (one-off)	3	0.73

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
CZ	Registration tax exemption for electric vehicles	Tax incentive for electric/ hybrid vehicles	100%	3	This measure disincentivise the use of polluting cars.	2	Input oriented	2	Registration tax (one-off)	3	0.73
HU	Tax Exemptions for electric, hybrid and zero emission vehicles from vehicle registration tax	Tax incentive for electric/ hybrid vehicles	100%	3	This measure disincentivise the use of polluting cars.	2	Input oriented	2	Registration tax (one-off)	3	0.73
PT	Tax exemption for electric vehicles	Tax incentive for electric/ hybrid vehicles	100% exemption	3	The measure incentivises the use of less polluting vehicles	2	The measure identifies the type of vehicle benefitting from an exemption/ reduction and is therefore output oriented	2	Registration tax (one-off)	3	0.73

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
IL	Purchase tax on cars reduction for electric and hybrid vehicles	Tax incentive for electric/ hybrid vehicles	The tax rate applied to electric and hybrid vehicles is 10% and 30% respectively.	2.4	The measure incentivises the use of less polluting vehicles	2	The measure identifies the type of vehicle benefitting from an exemption/ reduction and is therefore output oriented	2	Purchase tax	3	0.71
IS	Tax incentives for electric and hydrogen cars	Tax incentive for electric/ hydrogen vehicles	The purchase of electric, hydrogen and plug-in hybrids is exempt from VAT	3	The measure incentivises the use of less polluting vehicles	2	The measure identifies the type of vehicle benefitting from an exemption/ reduction and is therefore output oriented	2	VAT	2	0.70

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
IS	Tax incentives on bikes and electric bikes	Tax incentive for (electric) motorbikes	Exemption of VAT for new hydrogen and electric motorcycles and bicycles in this category.	3	The measure incentivises the use of less polluting vehicles	2	The measure identifies the type of vehicle benefitting from an exemption/ reduction and is therefore output oriented	2	VAT	2	0.70
HR	Exemption of excise duties on electrical energy used in railway and public transport	Public transport (exemption of payment on electrical energy used for the purposes of commercial transport of goods and persons in railway and public transport)	100%	3	Incetivises use of greener modes of transport	2	Input oriented	2	Energy tax	1	0.67

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
IE	Accelerated capital allowance for energy efficient equipment	Tax incentives for energy efficiency	The ACA allows companies to write off 100% of the purchase value of qualifying energy efficient equipment against their profit in the year of purchase	3	The incentive on investment projects that enhance energy efficiency for corporations	2	Input oriented	2	CIT	1	0.67
FI	Tax relief for employer-subsidised public transport tickets	Tax incentives for public transport	100% (income tax free)	3	Incentivises use of greener modes of transport	2	Input oriented	2	PIT	1	0.67
SK	Tax Incentive under the Motor Vehicle Tax (EVs & alternative propellants)	Tax incentive for electric/ hybrid vehicles	Motor Vehicle Tax is reduced by 100% for electric vehicles The tax is reduced by 50% for other alternative propellants (only the former is taken into account)	3	The measure incentivises the use of less polluting vehicles	2	The measure identifies the type of vehicle benefitting from an exemption/ reduction and is therefore output oriented	2	Annual circulation tax	1	0.67

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
RO	Exemption of means of transportation tax for electric vehicles	Tax incentive for electric/ hybrid vehicles	100% exemption from the vehicle tax	3	The measure incentivises the use of less polluting vehicles	2	The measure identifies the type of vehicle benefitting from an exemption/ reduction and is therefore output oriented	2	Annual circulation tax	1	0.67
SI	Excise duty exemption for biofuels	Tax exemption for alternative propellant	Excise duty exemption for biofuels applies 0 EUR excise duty for biofuels and reduction of excise duties up to 5% for fuels with biofuel component.	3	The measure incentivises the use of less polluting fuel	2	The measure identifies the type of fuel exempted and is therefore output oriented	2	Energy tax	1	0.67

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
AT	Reduced VAT rate for passenger transport	Tax incentives for public transport	10% reduction of VAT	1.5	The reduced VAT rate on passenger public transport, it may reduce the costs of public transport and thus disincentivise the use of individual transports	2	Input oriented as the measure's aim is to incentivise the use of public transport	2	VAT	2	0.65
FR	Energy Transition Tax Credit	Tax incentives for energy efficiency	Maximum 75% of the expense	2.25	The measure targets energy efficiency in the residential sector	2	Input oriented	2	PIT	1	0.64

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
LU	Investment tax credit for zero emission cars	Tax incentive for electric/ hybrid vehicles	• 'Overall investment' - Businesses investing in a zero-emission car can benefit from an overall investment tax credit of 8 % on the first EUR 50 000 of the purchase price per vehicle, 8 % on the first EUR 150 000 of the total investment and 2 % on the amount exceeding that amount. • 'Complementary investment' - an additional investment tax credit of 13 % can be granted on an investment in this type of car. The limit of EUR 50 000 does not apply	1.5	This measure disincentivise the use of polluting cars.	2	Input oriented	2	CIT	1	0.62
UK	Enhanced capital allowances for energy-saving technologies	Tax incentives for energy efficiency	Claim values' vary according to the different product categories (depending on how energy efficient they are)	1.5	The measure aims at reducing GHG emissions by incentivising the use of energy efficient equipment	2	input oriented	2	CIT	1	0.62

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
CA	Canadian Renewable and Conservation Expense (CRCE)	Tax incentive for renewable energy and energy efficiency	CRCE may be • deducted from income in the year incurred, • carried forward indefinitely and deducted in future years, or • renounced to investors under a flow-through share agreement	1.5	The measure aims at reducing GHG emissions by incentivising the use of energy efficient equipment	2	Input oriented	2	CIT	1	0.62
SK	Favourable depreciation of electric vehicles	Tax incentive for electric/ hybrid vehicles	Depreciation period for BEV and PHEV is 2 years compared to 4 years for motor vehicles powered with other fuel or energy (including HEV).	1.5	The measure incentivises the use of less polluting vehicles	2	The measure identifies the type of vehicle benefitting from an exemption/ reduction and is therefore output oriented	2	CIT	1	0.62

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
PL	Income tax break for thermo-modernisation of single-family residential buildings	Tax incentives for energy efficiency	The maximum amount that can be deducted is capped at 53,000 zl (€ 12,270).	1.5	The measure aims at reducing GHG emissions by incentivising the use of energy efficient equipment	2	The measure defines which investments are eligible for exemption/ reduction, it is therefore output oriented	2	PIT	1	0.62
BG	Tax relief for vehicles with high European emissions standard	Tax relief from vehicle circulation tax, depending on the environmental categorisation of the vehicle	Depending on the emissions standard of the vehicles (see below) the tax relief ranges from 20% to 60% of the standard circulation tax	1.2	This measure disincentivise the use of polluting cars.	2	Input oriented	2	Annual circulation tax	1	0.61
BE	Regional Income tax reduction for roof insulation	Tax incentives for energy efficiency	30% reduction of the total cost incurred	0.9	The measure targets roof insulation which improves the energy performance of buildings	2	Input oriented	2	Personal Income Tax	1	0.60

Country	Name of the measure	Type of incentive	Generosity of the tax break	Score	Scope (targeting positive or negative externalities)	Score	Scope (input or output oriented)	Score	The tax the incentive is built into	Score	Total
NL	Tax relief for investments in environmentally friendly technology	Tax incentives for energy efficiency	Entrepreneurs and companies benefit from an investment allowance that can amount to 36% of the investment amount. The deduction is in addition to the usual investment deduction and the three percentages are 13.5%, 27% and 36%.	0.81	The measure aims at reducing GHG emissions by incentivising the use of energy efficient equipment and practices	2	The measure defines which investments are eligible for exemptions, it is therefore output oriented	2	CIT	1	0.59

Table 31 Political viability assessment

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
Swiss CO2 levy	**Yes** The CO2 levy is collected by the Federal Customs Administration on top of the mineral oil tax from importers at border crossing (there are no fossil fuels produced in Switzerland). It is applied to upstream suppliers of fossil fuels which minimises administrative costs of the tax measure by making use of existing institutions	**Yes** Carbon tax serves as a complementary policy measure to the Switzerland ETS. Firms too small to be covered by ETS, have to pay the carbon tax. Switzerland introduced a CO2 levy in 2008 as part of a comprehensive climate policy package to decrease the use of fossil fuels. In addition, the CO2 levy is part of the Swiss CO2 Act, which also includes provisions for energy efficiency improvements in buildings, emissions standards for passenger vehicles, the national ETS, standards for and the carbon levy on heating and process fuels, and an obligation for motor fuel importers and thermal power plants to offset CO2 emissions.	**Yes** Entities whose competitive position is at risk due to the CO2 levy can seek exemption from the tax if they enter into a legally binding commitment to lower their CO2 emissions.	**N/A**	**Yes** The 2/3 of the revenues raised through carbon tax is returned to the population on a per capita basis and to the business community based on wages paid to employees.	**N/A**
Green tax on the purchase of cars (IL)	**Uncertain**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	The tax rates is based on all GHG emissions (not only CO2) estimated for each vehicle prototype and there are 15 different grades that apply based on the polluting potential of the vehicle. The rates are also updated regularly according to changes in GDP per capita and population growth. It became compulsory to mark the green grade at every point of sale and this information was also published on the Ministry of Transport's website. After a year of preparations for the implementation of the new system, with major efforts directed at creating an extensive database of the emission levels of all the imported cars	It was introduced in 2009 as part of the Israeli Green Tax Reform.	The tax has been designed taking into account that Israel is a vehicles import based country so this tax doesn't have a negative impact on Israeli car manufacturers.		Vehicle taxes do not have negative distributional externalities	Green tax made Israeli cars more affordable (effective tax rate for the cleaner vehicles became much lower than before and thus more affordable).
Environmental tax on greenhouse gases – hydrofluorocarbons (HFC) and perfluorocarbons (PFC) (NO)	**Uncertain**	**Yes**	**No**	**N/A**	**N/A**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	**Leveraging on positive economic effects**	**Mitigation of negative distributional externalities**	**Leveraging on positive distributional effects**
	The tax is calculated by the number of kilos of gas. In some cases, however, the content of gas is only stated in volume, and need to be recalculated in kilograms. There are no standard recalculation factors or rules for the temperature to be used in the recalculation.	The climate Change Act adopted in 2017 includes instruments that provide strong incentives to reduce GHG emissions (including HFC and PFC). These includes direct regulation under the Pollution Control Act and voluntary agreements. The tax is included in the Excise duty Act but there is no evidence that it forms part of a broader initiative/policy package.	Industries are significantly impacted by the tax. Exemptions only apply for NATO and multilateral organisations. In addition, exemptions are also made in the case of temporary use within the country.			
Motor vehicle registration tax (PT)	**Yes** The tax is calculated based on New European Driving Cycle and the Worldwide Harmonized Light Vehicle Test Procedure. They are tests to assess the emissions level of vehicles and data are easily accessible.	**Yes** The tax is part of a tax reform that intends to promote the transition towards a carbon-neutral economy, known as fiscalidade verde. The tax is implemented in combination of the circulation tax. This tax also includes an additional component addressing highly polluting vehicles which aims at decreasing the use of polluting vehicles. In addition, subsidies are provided for the purchase of EVs.	**N/A**	**N/A**	**N/A** Vehicle taxes do not have negative distributional externalities	**N/A**
Finland Carbon Tax	**Yes**	**Yes**	**Yes**	**N/A**	**Uncertain**	**N/A**

	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
Name of measure			**Mitigation of negative economic externalities**	**Leveraging on positive economic effects**	**Mitigation of negative distributional externalities**	**Leveraging on positive distributional effects**
	The carbon tax is added on the energy tax and security of supply tax	Introduced in 1990, the Finnish Carbon tax was reviewed several times. In 1997, the carbon tax was added with a tax on electricity consumption. In 2011, a combination of carbon- and energy tax was applied where the tax rates were adjusted according to the amount of carbon and energy components. Tax serves as complimentary to EU ETS, so that sectors or activities not covered by the ETS are subject to the carbon tax.	Finland implemented a number of exemptions right from the beginning to minimize the tax's potential negative effects on certain industries. This includes peat and natural gas having a favourable deduction scheme for the sales tax to partially offset the carbon tax, as well as Finland's export-oriented wood industry being exempted from the carbon tax; fuels used in industrial production as raw material or manufacturing input have also been exempted		Some mitigation of negative income effects through carbon tax. Part of carbon tax revenues was used to cut income tax.	
Sweden Carbon Tax	**Yes**	**Yes**	**Yes**	**N/A**	**Uncertain**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	Carbon tax is paid by the companies that make the fuels available in the Swedish market, with the added costs of the carbon tax being passed on to the consumer through fuel pricing; the CO2 tax rates are in the tax law expressed in weight or volume units for the different fuels. The CO2 tax is collected in the same way as the energy tax, which gives low administrative costs for the tax authorities as well as for the operators	The introduction of the Carbon tax in Sweden was part of a major tax reform, which also implied lowering income taxes on capital and labour. The tax reform aimed at "green tax switch", including the increase of environmental taxes, while other taxes were reduced. Tax serves complimentary to EU ETS, companies taking part in EU ETS are exempt from carbon tax, sectors and companies not being subject to ETS should be addressed through carbon tax.	The carbon tax rate per kg is since 1992 differentiated for industry and households and service providers , meaning that smaller companies and households have paid higher effective carbon tax than industry since. When the general level of the CO2 tax was raised during following years, adjustments were also made of the lower level based on competitiveness assessments and other factors.		Typically increases in the CO2 tax have been combined with general tax relief in other areas to avoid increases in overall level of taxation. While not earmarking CO2 tax revenues for specific purposes, significant parts of the national budget have still over the years been allocated to various projects, such as better public transport, an increased use of bio-fuelled district heating and housing isolation	
Denmark Carbon tax	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	Carbon tax is paid by suppliers of the different goods (fuel, etc) but is shifted to consumers; • VAT registered firms obtain a partial refund of the carbon tax for energy used in production processes conditional of the energy intensity of the process • The carbon tax fully burdens all non-VAT registered sectors, i.e. households, the financial sector etc.	Part of the Energy 2000 plan, which called for a 20% reduction in CO2 emissions until 2005 relative to 1988 levels. Similar to other EU countries, the CO2 tax is complementary to the EU ETS system and ETS industries are generally exempt from the CO2 tax on fuel use for industrial processes and electricity production. However, District Heating Plants and waste incineration plants covered by the ETS are required to pay the Carbon tax as well. In addition, the Green Energy Package was adopted a few years after the general CO2 tax—including an extra CO2 tax for businesses, in addition to a new SO2 tax and energy taxes on space heating—was introduced in 1996.	The CO2 tax was accompanied by reductions in the energy tax and labour/employment taxes. Energy-intensive companies that participated in the Danish Energy Agency's Long-Term Energy Efficiency Agreements voluntary program could receive a partial refund on their CO2 tax payments CO2 taxes have only seen a modest increase in recent years. When the tax was introduced, companies were exempt from paying the tax in order to maintain the competitiveness of Danish business.		Revenue from the carbon tax has been used to reduce taxes on labor, subsidize energy efficiency investments, and subsidize the associated administrative costs of small companies. Approximately 40% of the tax revenue is used for environmental incentives, while the remaining 60% is returned to industry through reduced social insurance, reduced pension contributions, and compensation of administrative expenses for small businesses with limited payrolls	
Motor vehicle registration tax (FI)	**Yes**	**Yes**	**N/A**	**N/A**	**N/A**	**Yes**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	The registration tax is based on the CO2 emissions and the common retail value of the car which should be easily accessible by the authority	In 2008, the tax base of the vehicle registration tax is modified to include environmental criteria (i.e. CO2 emissions). The same year, Finland published its Climate and Energy Strategy and the EU biofuels directive (2003/30/EC) came into force in the country. Like in several countries, Finland also has a motor vehicle circulation tax which is also based on the CO2 emissions of the vehicle. Both tax aim at decreasing emissions generated by vehicles, prompting individuals to buy cleaner vehicles.			Vehicle taxes do not have negative distributional externalities According to Finnish Ministry of Finance as the tax is partly based on the value of the vehicle, this tax does not lead to negative distributional effect since high income households prefer more expensive cars than lower income households. The households in lowest income classes typically have no car at all.	
Malus scheme for car purchases (FR)	**Uncertain**	**Yes**	**Yes**	**N/A**	**N/A**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	The nine taxes on motor vehicles will be recast (2020-21) with the aim, in particular, of strengthening their environmental coherence and simplifying the fiscal framework. So lower lower administrative burden can be expected in the future	The malus scheme for car purchase was created within the framework of the Grenelle de l'environnement (2007) and strengthened by the Automobile Plan of July 2012. The malus scheme for car purchases is combined with a bonus scheme for individuals who buy a low emission car. Moreover, an additional annual tax (annual malus) applies to the most polluting vehicles that are emitting more CO2 than a certain threshold, which should strengthen the incentive to switch to cleaner cars provided by the malus scheme.	The malus does not apply to commercial vehicles	No effects on firms competitiveness or innovation could be linked to the scheme. The bonus-malus mechanism remains overall beneficial for the French State (revenues from the malus part being higher than expenditures of the bonus side). One can however argue that if efficient in the long run (i.e. it discourages people to buy polluting cars), the positive economic effect may disappear.	Vehicle taxes do not have negative distributional externalities. In addition, large families can benefit from malus reduction. The reduction applies to families with at least three dependent children on the purchase of a vehicle with at least five seats and is limited to one vehicle per household. The CO2 emission rate is reduced by 20g/km per child starting from the third child.	
Climate energy contribution (Carbon tax) (FR)	**Yes**	**Yes**	**Yes**	**N/A**	**No**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	**Leveraging on positive economic effects**	**Mitigation of negative distributional externalities**	**Leveraging on positive distributional effects**
	The climate-energy contribution is integrated into taxes on polluting products. It is found in the Internal Consumption Tax on Energy Products (TICPE), the Internal Consumption Tax on Natural Gas (TICGN) and the Internal Consumption Tax on Coal (TICC) which lowers the administrative costs.	This measure result from the Grenelle de l'environnement, a multi party debate aiming at defining public policies on ecological and sustainable development issues. At the end of the Grenelle Environment Forum and to support national targets for the reduction of emissions, a "carbon tax" was voted for in the Parliament in the finance bill (PLF) for 2010 but was censored by the Constitutional Council. It was finally adopted in 2013 in the form of a "climate energy contribution". It was introduced to include the impact of energy products on climate change and serves as a complementary policy measure to the EU ETS.	Operators covered by the EU ETS are exempt from the tax. Also certain industrial processes (non-combustion usage), power production, shipping, aviation, public transport and freight transport are (partly) exempt from the carbon tax.		The increase of the tax rate until 2018 particularly affected: •precarious households (higher effort rate due to lower income) •households with fossil heating equipment (higher energy expenses) •households living far from work (higher fuel expenses) Although an energy voucher has been created for the poorest households (reducing their energy renovation and housing energy expenses partly compensating for negative distributive effects), the carbon tax has been the ground for the "yellow vests" protest, representing initially the households which are most vulnerable to the rise in the price of fossil fuels. A report from the ADEME pointed in 2018 the importance of implementing additional redistributional measures for the most impacted households.	
Registration tax exemption for EV (NO)	**Yes**	**Yes**	**N/A**	**No**	**No**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	The exemption from registration tax was introduced in early 2000s and has not been revoked, which implies certainty. A clear, stable policy framework and political commitment has been crucial to create a long-term reliable EV market conditions	The Norwegian Parliament has decided on a goal that all new cars sold in 2025 should be zero or low emission. Besides, a White Paper from the Environmental Protection Agency from 2012 declared, that in 2020 the average emissions from new private vehicles will not exceed an average of 85g of CO2/km. To achieve this goal, the report described different measures and incentives that should be included ,i.e. "Continue to use vehicle taxes to contribute to the shift to a greener and a more climate friendly vehicle fleet." The Norwegian Parliament has issued several additional incentives to encourage people to buy more electric cars. The incentives are both tax-related and behaviour-related (or structural related). The complementary incentives include: No purchase/import taxes, Exemption from 25% VAT on purchase, Low annual road tax, No charges on toll roads or ferries , Free municipal parking Access to bus lanes 50% reduced company car tax, National investment in charging stations - the Norwegian government has also		Given the lack of a Norwegian automobile industry, the co-benefits of the policies in terms of direct manufacturing jobs are negligible.	The measure could benefit higher income individuals/households as EVs are more typically more affordable for this group. No specific elements to mitigate this negative effect of low-income individuals/ household have been introduced. In addition, one of several unintended consequences of the incentives would be if people favours EVs in contexts where it would make sense to use public transport options, particularly in urban areas with high density. In Norway, traffic lanes reserved for buses, taxis and EVs have experiences congestion as a result of the increasing presence of EVs.	

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications: Mitigation of negative economic externalities	Economic implications: Leveraging on positive economic effects	Distributional implications: Mitigation of negative distributional externalities	Distributional implications: Leveraging on positive distributional effects
		introduced a support scheme for a rapid charging network along the main highways and the development of a big network of more than 2,000 charging stations to make the system highly operational				
Tax exemption for EV (PT)	**Uncertain** The exemption applies to certified EVs	**Yes** The tax is part of a tax reform that intends to promote the transition towards a carbon-neutral economy, known as fiscalidade verde. In addition to vehicle registration tax exemptions, EV are exempt also from the annual circulation tax (IUC), and buyers receive a subsidy of up to €1,000 upon acquisition of an electric vehicle, depending on the type. EUR 1.5 million are available to provide grants to the build charging points for electric vehicles	**N/A**	**Uncertain** One of the biggest barriers to market breakthrough of electric vehicles is that they are currently not cost-competitive with internal combustion engine (ICE) vehicles. This incentive is among a set of fiscal incentives and subsidies provided by the Portuguese government to stimulate sales of EVs.	**No** The measure could benefit higher income individuals/households as EVs are more typically more affordable for this group. No specific elements to mitigate this negative effect of low-income individuals/ household have been introduced.	**N/A**
Accelerated depreciation for R&D in the field of renewable energy (IL)	**Yes**	**No**	**N/A**	**Yes**	**N/A**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	In terms of implementation the Israeli system is relatively efficient, offering a short turnover time on applications of only two months. A one-stop shop is available, which is also facilitated by the application procedure online.	There are several policy measures (e.g. subsidized) in place in Israel to support R&D investments. However, they are not included in a broader policy initiative There are several other instruments available in Israel to support investments in R&D, such as subsidies, programmes, other fiscal measures, etc. They also address R&D in RE.		Overall, the scheme is expected to have a positive effect on innovation and competitiveness of enterprises. Moreover, this tax incentive is output oriented		
Tax credit for costs incurred in R&D, innovation and design activities (IT)	**Uncertain**	**Yes**	**Uncertain**	**Yes**	**N/A**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	The incentive covers the 50% of eligible costs incurred for the operationalisation of R&D activities aimed at promoting energy efficiency. Eligible costs are clearly defined in official documents Enterprises that want to benefit from this incentive have to declare it in the annual fiscal declaration and attach all relevant documentations that is check by the Italian tax Authority. Documentation submitted should be certified by a statutory audit company. This applied to all companies, including those not subjected to mandatory statutory audit. The latter can thus incur in additional costs. This can potentially represent an additional burden to small enterprises	The measure was first established in 2013 for the policy plan Destination Italia and further rewritten and modified in 2015 as part of the Piano Nazionale Industria 4.0. The Piano Nazionale Industria 4.0 includes many subsidies and fiscal incentives for R&D. As this incentives all those measure cover also investment in RE and EE but are not limited to them.	The measure aims at increasing and improving the use of RE. For this, standard energy producers and providers are negatively affected by the measure.	This tax incentive is output oriented. The measure has a positive impact on the economy, as economic gains would be generated by the sale of energy efficiency facilities for renewable and energy efficiency producers. Moreover, costs incurred for the production and consumption of energy would be decreased.	The measure does not seem to have particular negative distributional externalities	
Tax exemption for buildings with energy certification (BG)	**Yes**	**Yes**	**N/A**	**Yes**	**N/A**	**Yes**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	The measure is easy to implement and enforce. It is set in the Law on local taxes and fees and it is easy to design, i.e. its regulatory replicability is high. The exemption applies to building with energy certification according to their energy class. Getting an energy certificate in EU is quite easy, it can be done only in the EPC platform	This measure is part of the Building Renovation Strategy. Several subsidies, funding instruments and other fiscal measures addressing energy efficiency in buildings are in place in Bulgaria. This tax incentive is accompanied by the Residential Energy Efficiency Credit Line, providing loans to individuals/households to realise energy efficiency home improvements. Household can also benefit from the Bulgarian Energy Efficiency Fund providing grants to finance project aiming at improving the energy efficiency and supporting the use of renewable energy in public, industrial and residential buildings.		The tax exemption has a potential positive economic impact. It is beneficial for companies performing energy certification and for the building sector – i.e. companies performing energy efficiency measures (e.g. improvement of insulation) and/or producers / distributors / installers of renewable energy installations.		The tax exemption provides support mainly for households by decreasing their energy costs (following investments in energy efficiency and renewable sources).
Bulgaria Tax exemption for electric vehicles	**Uncertain**	**Uncertain**	**N/A**	**Uncertain**	**No**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	100% exemption from vehicle circulation tax; The measure is for vehicles with fully electric engines only and does not apply to hybrid vehicles. The measure includes electric cars, motorcycles and mopeds, as well as electric vehicles of categories L5e, L6e and L7e,	VAT reductions for electric (30%) and hybrid (15%) vehicles This is considered a main problem in Bulgaria as well as the reason for the slow uptake of more electric vehicles. The infrastructure for charging electric vehicles is rather weak	The tax revenue losses for the state from this measure can be expected to be marginal.	only marginal effects expected	The measure could benefit higher income individuals/households as EVs are more typically more affordable for this group. No specific elements to mitigate this negative effect of low-income individuals/ household have been introduced.	
Czech Republic Registration tax exemption for electric vehicles	**Uncertain**	**Uncertain**	**N/A**	**Uncertain**	**No**	**N/A**
	Not available	Partly complementary to other measures. Some other measures to boost the change towards electric vehicles are in place, such as a reduced VAT for electric cars for businesses, as well as an exemption from vignettes for electric and hydrogen cars. Moreover, charging stations, preferred lanes, and preferred parking spots are developed already in particular in larger cities			The measure could benefit higher income individuals/households as EVs are more typically more affordable for this group. No specific elements to mitigate this negative effect of low-income individuals/ household have been introduced.	
Tax credits on energy efficiency investments (HU)	**Uncertain**	**Yes**	**N/A**	**Uncertain**	**N/A**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	**Leveraging on positive economic effects**	**Mitigation of negative distributional externalities**	**Leveraging on positive distributional effects**
	The national authority has to check the compliance of the tax allowance requested at least once before the end of the third tax year following the date of utilising the tax allowance. Before the start of the project, a preliminary audit has to be carried out to establish the rate of possible energy savings on the planned investment. Projects become eligible for the incentive if their initial energy efficiency goals are met according to a certificate issued by energy auditors	Tax credits on energy efficiency investments are part of the National Energy Efficiency action plan (2017).		According to the Ministry for Innovation and Technology, tax credits on energy efficiency investments are perhaps less popular than expected. The economic impact can be considered negligible. Given that SMEs can have up to 65% of the overall eligible costs refunded, the incentive is likely to incentivise SMEs to invest in energy efficiency. SMEs in general have less financial capacity to undertake such investment projects, therefore the measure is likely to have a higher impact on their end than for larger enterprises who are more likely to be able to finance such projects regardless of additional incentives		
Energy investment allowance (NL)	**Yes**	**Yes**	**N/A**	**Yes**	**N/A**	**N/A**

	Administrative cost should be relatively low given that applications are made online and that the Energy list provides a clear overview of eligible investments each year. The use of a dynamic list makes the regulation flexible, allowing policy to refocus and apply tighter standards if necessary. An OECD report on EIA stated that administrative costs seem to be reasonable small, in particular, for pre-specified technologies. This scheme requires companies to check if their investment is in the eligible Energy list provided by the Netherlands Enterprise Agency every year. For some equipment, they must look for and report it under a generic code or they can submit a proposal for the Energy list of the following year. Applications must be sent through an online platform within 3 months after the company completed the sales agreement. As the scheme exist since 1997, we can qualify it as certain.	This scheme exist since 1997.The tax deduction scheme was originally part of a broader energy tax policy package that was initiated in the Netherlands following the failure to implement a European-wide carbon tax in the early 1990s. Over the past 15 years, the EIA has been one of the pivotal instruments of Dutch energy policy. The Netherlands have several other schemes for companies: - the environmental investment allowance (MIA). Companies can deduct money from taxable profit when they invest in environmentally friendly business assets - the Sustainable Energy Investment Subsidy However, companies cannot apply simultaneously to several of these schemes		As far as is known, the measure has a potential positive effect on the economy. For some companies and entrepreneurs, the measure may provide an incentive to make a definitive investment in more sustainable production systems or goods. This can result in more jobs and demand for more sustainable products and machines. If this development does not lead to a shift in the production of goods and services, but rather creates new jobs, it would probably have a positive effect on the economy.		
Tax incentives for businesses to implement energy-efficient practices (MT)	**Yes**	**Yes**	**N/A**	**Yes**	**N/A**	**N/A**

Name of measure	Ease of implementation	Complementarity & synergies	Economic implications		Distributional implications	
			Mitigation of negative economic externalities	Leveraging on positive economic effects	Mitigation of negative distributional externalities	Leveraging on positive distributional effects
	Malta Enterprise Corporation in collaboration with the Energy and Water Agency shall be supporting undertakings in carrying out investments leading to improved energy-efficiency. Applications are made electronically through a client portal. The Corporation, in collaboration with the Agency, shall determine whether the application meets the requirements Applicants must submit their application form prior to the start of works. The application must be submitted through the Corporation's client portal and include an energy audit carried out by a certified energy auditor. As part of the application, the applicant will be required to provide a full list of assets (with specifications) being purchased, including any additional eligible costs and evidence of the energy efficiency results expected. Applications can be sent until December 2022 which makes the scheme certain for a couple of years.	Launched in 2018, this scheme is part of Malta's National Energy Efficiency Action Plan launched in 2017 which aims to significant energy efficiency improvement measures in the country, in view of achieving the national energy efficiency targets. This scheme is complemented by the energy audits scheme for SMEs launched earlier. In this way, local businesses are encouraged to conduct an energy audit where they can benefit up to €5,000 which in some cases refunds the whole audit cost. This audit will result in a list of recommendations to increase energy efficiency in the business, some of which may be done at zero cost, while others would require minimal or larger investments		The measure is expected to have positive effects on the economy as it supports businesses to introduce innovation which helps improve their sustainability and competitiveness. Apart from the direct financial gains, the schemes would also contribute to economic growth, employment and a cleaner and more secure supply of energy.		

ANNEX III: COUNTRY FICHES

Annex III is provided in a separate document.

ANNEX IV: GOOD PRACTICES FICHES

Annex IV is provided in a separate document.

ANNEX V: STAKEHOLDER CONSULTATIONS

Workshops with Competent Authorities

The 1st workshop took place on the 27th of April 2020. It aimed to gather views and feedback from Member States on the selection of tax measures in the inventory developed by the study and on key factors to be considered for benchmarking tax measures. In particular, the participants have discussed the shortlisted measures selected for the benchmarking and identified commonalities of success.

The 2nd workshop took place on the 10th and 11th of September 2020. It aimed to present the finalised benchmarking methodology and jointly reflect on its features and implications. Its objective was to gather views and feedback from Member States on the results of benchmarking applied to the inventory of tax measures and on a preliminary list of good practices. It provided the opportunity to discuss what helps to enhance the political acceptance of measures, and how tax measures fit into the wider policy framework to ensure a green transition.

The workshops targeted representatives of relevant Member State authorities. Representatives of the individual ministries of finance and ministries of the environment have therefore been invited to participate. Representatives of DG TAXUD and the research team also attended the workshops.

Countries represented during the first workshop	Countries represented during the second workshop
• Germany • Slovakia • Czech Republic • Austria • Denmark • Sweden • Luxemburg • Croatia • Cyprus • Slovenia • Ireland • Spain • Finland • Malta • Estonia • Portugal • Belgium • Germany • Bulgaria • Lithuania • Latvia • Poland • Hungary • Italy • Greece • Netherlands	• Austria • Belgium • Bulgaria • Croatia • Czech Republic • Denmark • Estonia • Finland • France • Greece • Hungary • Latvia • Lithuania • Malta • Poland • Portugal • Romania • Slovakia • Slovenia • Spain • Sweden • The Netherlands
Total number of participants from Member States: 47	Total number of participants from Member States: 37

Interviews

Interviews were performed by country experts to validate their mapping and collect further insights on the measures' effectiveness. Country experts further used the interviews to complement the in-depth description of selected measures.

The objectives for the three interviews differed slightly, depending on the stakeholder type. Three distinct questionnaires were available to country experts, so that they could adapt the interview according to the stakeholder.

Interview partner	Objectives
Ministry of finance/ taxation	- Identification of missing tax measures - Identification of effective measures (effective in the sense of reducing GHG emissions, this is important to narrow down the desk research to potential good practices) - Focus on economic and distributional implications of measures, also explore political viability - Identification of additional sources
Ministry of the environment	- Validation of full list of tax measures - Validation of pre-selected measures - Identification of most important harmful subsidies - Identification of additional sources
NGO	- Collection of external views on tax measures - Validate long and short list - Focus should be on effectiveness and political viability, distributional implications if possible - Identification of additional sources

In total, 60 interviews were performed (25 with Ministries of Finance, 18 with Ministries of Environment and 17 with NGOs). Where country experts experienced challenges in arranging interviews, they were asked to compensate through additional desk research to provide complete overview of the tax measures in place.

Country	Ministry of Finance	Ministry of Environment	NGO
Austria			
Belgium	✓	✓	✓
Bulgaria		✓	✓
Croatia	✓	✓	✓
Cyprus	✓	✓	✓
Czechia	✓	✓	✓
Denmark			
Estonia	✓	✓	
Finland	✓		

Country	Ministry of Finance	Ministry of Environment	NGO
France	✓	✓	
Germany			
Greece	✓		✓
Hungary		✓	✓
Ireland			✓
Italy	✓	✓	
Latvia	✓	✓	✓
Lithuania	✓	✓	
Luxembourg	✓	✓	
Malta	✓		
Netherlands	✓		
Poland	✓		
Portugal	✓	✓	✓
Romania	✓	✓	✓
Slovakia	✓	✓	✓
Slovenia	✓		✓
Spain	✓	✓	
Sweden	✓		✓
United Kingdom			✓
Canada	✓		
Iceland	✓	✓	✓
Israel	✓	✓	
Norway	✓		✓
Switzerland			
Total	**25**	**18**	**17**

ANNEX VI: LIST OF TAXES AND TAX INCENTIVES IDENTIFIED

Country	Name of measure	Type of measure	Detailed assessment
AT	Vehicle purchase tax	Tax	
	Duty on vehicle purchase based on fuel consumption	Tax	✓
	CO2 emission component vehicle purchase tax	Tax incentive	
	CO2 emission component recurrent tax on motor vehicles	Tax incentive	
	CO2 emission component company car taxation	Tax incentive	
	Reduced VAT for passenger transport	Tax incentive	✓
	Deduction of VAT charged on purchase of zero-emission cars and zero-emission motorbikes and e-bikes as input tax	Tax incentive	
BE	Vehicle registration tax – regional CO2 components	Tax	
	Vehicle circulation tax	Tax	
	Tax reduction for the acquisition of an electric vehicle	Tax incentive	
	Regional Income tax reduction for roof insulation	Tax incentive	✓
	Income-tax deduction for passive houses	Tax incentive	
	Income-tax reduction for energy-saving expenses in dwellings	Tax incentive	
	Tax reduction on the purchase price of cleaner cars	Tax incentive	
	Deduction of business expenses incurred for the storage of bicycles and electric bicycles	Tax incentive	
	Deduction up to 120% of the expenses for staff collective transport	Tax incentive	
	Reduction of withholding tax on real estate for energy saving buildings (Flanders)	Tax incentive	
BG	Tax exemption for electric vehicles	Tax incentive	✓
	Tax relief for vehicles with high European emissions standard	Tax incentive	✓
	Reduced excise duty on natural gas used as a vehicle fuel	Tax incentive	
	Reduced excise duties for mixtures of biofuel with fuels of oil origin	Tax incentive	
	Tax exemption for buildings with energy certification	Tax incentive	✓
CA	Excise Tax on Fuel-Inefficient Vehicles (Green Levy	Tax	✓
	Federal fuel charge	Tax	
	British Columbia Carbon Tax	Tax	✓
	Accelerated capital cost allowance for clean energy generation equipment	Tax incentive	
	Canadian Renewable and Conservation Expense (CRCE)	Tax incentive	✓
	Car heaven	Tax incentive	
	Scientific Research and Experimental Development Tax Incentive Program	Tax incentive	
	Exempt Sales of Residential Energy Products - PST Exemption (British Columbia)	Tax incentive	
	Public Transit Capital Trust	Tax incentive	
CH	CO2 Levy	Tax	✓
	Performance-related heavy vehicle charge	Tax	
	Motor vehicle tax	Tax	
	Mineral oil tax	Tax	
	Biofuels tax relief	Tax incentive	
	Tax incentives for energy efficient building refurbishments	Tax incentive	

CY	Vehicle annual circulation tax	Tax	✓
	Vehicle registration tax	Tax	
	Withdrawal of old cars and/or purchase new electric cars	Tax incentive	✓
CZ	Motorway vignette and tax for vehicles.	Tax	
	Car re-sale tax for old and used vehicles	Tax	
	Road tax	Tax	
	Reduced VAT on electric cars for businesses	Tax incentive	✓
	Registration tax exemption for electric vehicles	Tax incentive	✓
	Reduced VAT rate for alternative fuels (CNG)	Tax incentive	
	Reduced income tax for entrepreneurs on the purchase of electric car (by being able to depreciate it faster and at a larger total price)	Tax incentive	
	Exclusion from paying property tax for 5 years if heating system switched to renewable energy sources.	Tax incentive	
	Exclusion from paying property tax for renewable energy plants or other functions directly improving the environment.	Tax incentive	
	Exclusion of paying income tax for activities to do with recycling and waste disposal associated with PV (solar) energy generation.	Tax incentive	
	Straight line depreciation of PV (solar) energy generation assets for up to 240 months of 100% cost of the asset.	Tax incentive	
	Reduced tax rate in the value-added tax for environmentally friendly goods and services	Tax incentive	
DE	Vehicle tax	Tax	✓
	Renewable energy levy	Tax	✓
	Tax break for electric vehicles	Tax incentive	
	Tax break for electric and hybrid company cars	Tax incentive	
	Reduced tax rate for local public transport under the Electricity Tax Act	Tax incentive	
	Reduced VAT rate for long distance public transport	Tax incentive	
DK	Weight / fuel consumption tax	Tax	
	Excise duty on raw materials	Tax	
	Liability Insurance tax	Tax	
	Road toll	Tax	
	CO 2 tax	Tax	✓
	One-time service charge	Tax	
	Tax on packaging materials	Tax	
	Charge of advertising printed matter	Tax	
	Nitrogen oxide charge (NOx)	Tax	✓
	Tax on mineral oil	Tax	
	Weight-based and Green Vehicle Owner Tax	Tax	
	Charge of certain growth promoters	Tax	
	Tax incentive to invest in renewable energy	Tax incentive	✓
	Vehicle acquisition tax exemption for fuel-cell electric vehicles	Tax incentive	
	Vehicle acquisition tax reductions for battery electric vehicles (BEV) and plug-in electric vehicles (PHEV)	Tax incentive	
	Temporary deduction in PIT for private users of BEV and PHEV	Tax incentive	
EE	Carbon Tax	Tax	✓
	Heavy goods vehicle tax linked to CO2 emissions	Tax	
	Renewable-energy charge	Tax	✓
	Biogas and biomethane excise duty exemption	Tax incentive	
	Fringe benefit taxes for company cars tied with a car's age and power capacity	Tax incentive	

EL	Tax on motor vehicle usage	Tax	
	Vehicle registration tax	Tax	✓
	Tax reform with a development dimension for the Greece of tomorrow	Tax incentive	✓
	Special Consumption tax on diesel fuel	Tax incentive	✓
ES	Tax on fluorinated greenhouse gases	Tax	✓
	Vehicle registration tax	Tax	✓
	Voucher for the use of public transport when commuting to work, deduced from personal income tax	Tax incentive	✓
	Personal income tax deduction in company car	Tax incentive	
FI	Motor vehicle registration tax	Tax	✓
	Excise on fuels and electricity (carbon tax)	Tax	✓
	Motor vehicle circulation tax	Tax	
	Tax relief for electricity produced for the direct use of rail services	Tax incentive	
	Reduced energy content tax rate for heat produced in co-generation of heat and power (CHP)	Tax incentive	
	Tax relief for employer-subsidised public transport tickets	Tax incentive	✓
	Vehicle tax refund for lorries transported by rail (combined transport)	Tax incentive	
	Excise tax exemption for biogas and wood-based fuels	Tax incentive	
FR	Domestic consumption tax on energy products (TICPE)	Tax	
	Domestic Tax on the Consumption of Natural Gas (TICGN)	Tax	
	Vehicle Registration Tax for Regions	Tax	
	Corporate Passenger Vehicle Tax (CPT)	Tax	
	Tax on the provision of petroleum products for strategic storage	Tax	
	Special fuel tax in the French overseas departments	Tax	
	Special tax on road vehicles (axle tax)	Tax	
	General tax on polluting activities - Fuel levy	Tax	
	Domestic consumption tax on hard coal, lignite and coke (TICC)	Tax	
	Annual tax on the most polluting vehicles	Tax	
	Purchase tax on used vehicles	Tax	
	Climate energy contribution (Carbon tax)	Tax	✓
	Incentive tax relating to the incorporation of biofuels	Tax	
	Additional tax on registration cards	Tax	
	VAT reduction (VAT of 5.5%) for work to improve the energy quality of residential premises	Tax incentive	
	Reduced domestic consumption tax rate for E85, a gasoline fuel containing between 65% and 85% ethanol	Tax incentive	
	Reduced domestic consumption tax rate for E10, gasoline fuel with up to 10% ethanol content	Tax incentive	
	Ecotax (Ecological malus for vehicles)	Tax incentive	✓
	Energy Transition Tax Credit (Crédit d'impôt transition énergétique (CITE))	Tax incentive	✓
	Relief from property tax on existing buildings (TFPB)	Tax incentive	
HR	Special tax on motor vehicles	Tax	✓
	Motor Vehicle Circulation Tax	Tax	
	CO2 emissions on non-ETS stationary sources	Tax	✓
	Exemption of excise duties on electrical energy used for railway and public transport	Tax incentive	✓

	Differentiated height of excise tax on natural gas, electricity and solid fuels	Tax incentive	
	Registration tax exemption for hybrid and electric vehicles	Tax incentive	
HU	Vehicle Registration Tax – Exemptions for electric, hybrid and zero emission vehicles	Tax incentive	✓
	Tax credits on energy efficiency investments	Tax incentive	✓
	Exemption from company car tax for passenger cars registered with green registration plate (i.e. low emission vehicles)	Tax incentive	
	Transcription exemptions for passenger cars registered with green registration plate (i.e. low emission vehicles)	Tax incentive	
	Municipal discounts: free parking, free entry to certain closed areas for passenger cars registered with green registration plate (i.e. low emission vehicles)	Tax incentive	
	Exemption of vehicle tax for passenger cars registered with green registration plate (i.e. low emission vehicles)	Tax incentive	
	Vehicle registration tax	Tax	
IE	Irish carbon tax	Tax	✓
	Irish vehicle registration tax	Tax	✓
	Irish motor tax	Tax	
	1999 Duty on other sorts of oil (revised 2010)	Tax	
	2001 Public Service Obligation Levy	Tax	
	National oil serve agency levy 2009	Tax	
	Incentives for EV vehicles	Tax incentive	
	Accelerated Capital Allowance for Energy Efficiency Equipment (ACA)	Tax incentive	✓
IS	Carbon tax	Tax	✓
	Motor vehicle tax	Tax	
	Excise on import of motor vehicles and petrol	Tax	
	Tax incentives for climate friendly cars and fuel	Tax incentive	✓
	Tax incentives on bikes and electric bikes	Tax incentive	✓
IL	Green tax on the purchase of cars	Tax	✓
	Purchase tax on cars reduction for electric and hybrid vehicles	Tax incentive	✓
	Tax on fuels	Tax	
	Company income tax reduction for R&D in the field of renewable energy	Tax incentive	✓
	Accelerated depreciation for solar facilities	Tax incentive	
	Tax benefit for electric and hybrid company cars	Tax incentive	
	Tax benefit for e-buses	Tax incentive	
	Zero purchase tax on e-motorcycle	Tax incentive	
IT	Tax on the registration of vehicles (IPT)	Tax	
	Motor vehicle circulation tax	Tax	✓
	Tax on polluting vehicle acquisition (Ecotassa)	Tax	
	Tax on electricity consumption for households and businesses	Tax	
	Tax on single-use plastics (Plastic tax)	Tax	
	Incentives for the acquisition of low emissions vehicles (Ecobonus)	Tax incentive	
	Deduction for the installation of charging stations for electric vehicles	Tax incentive	
	Personal income tax allowance for public transport	Tax incentive	
	Reduced rate in the municipal tax on real estate (ICI)	Tax incentive	
	Tax credit for costs incurred in R&D, innovation and design activities	Tax incentive	✓
	Fiscal deductions for the promotion of energy efficiency in buildings	Tax incentive	

	Tax credit for biomass heating systems	Tax incentive	
	Exemption from excise duty for electricity produced with plants powered by renewable sources with available power greater than 20 kW	Tax incentive	
	Fiscal deduction for interventions of landscaping of uncovered private areas of existing buildings, building units, fences, construction of irrigation systems, wells, green roofs and gardens (Green bonus)	Tax incentive	
	personal income tax allowance for public transport	Tax incentive	
LT	Taxes and excise duties on fuel	Tax	
	Exemption from excise duty on biofuels	Tax	
	Environmental pollution tax	Tax	✓
	Motor Vehicle Tax	Tax	
	Compensation for installation of PV panels	Tax incentive	
	Compensation of building renovation to increase energy efficiency	Tax incentive	
	VAT reduction for household heating	Tax incentive	
	Compensation for a replacement of inefficient boilers in individual households	Tax incentive	
	Compensation for the installation of facilities to produce electricity from renewable energy sources	Tax incentive	✓
LU	Road Tax	Tax	✓
	“Kyoto cent” surcharge on road fuel sales earmarked for Climate and Energy Fund	Tax	
	Tax on company cars for private use	Tax	✓
	Sustainable mobility deduction	Tax incentive	✓
	Investment tax credit for zero emission cars	Tax incentive	✓
LV	Carbon tax (Natural resource tax on CO2 emissions)	Tax	✓
	Natural resource tax on coal, coke and lignite	Tax	
	Natural resource tax on End-of Life Vehicles	Tax	
	Natural resource tax on natural gas injected into geological structures	Tax	
	Vehicle circulation tax	Tax	✓
	Company car tax	Tax	
	Natural resource tax – Exemption from the Payment of Tax for the Emission of Carbon Dioxide- Renewable resources)	Tax incentive	
	Excise tax on oil products - Reduced tax rate for biofuels and products containing biofuels at high concentration (fuel E85)	Tax incentive	
MT	Vehicle Registration tax	Tax	✓
	Annual circulation tax	Tax	
	Tax incentives for businesses to implement energy efficient practice	Tax incentive	✓
	Registration tax exemption for electric vehicles	Tax incentive	
	Annual circulation tax exemption for electric vehicles	Tax incentive	
NL	Motor vehicles tax (Motorrijtuigenbelasting)	Tax	
	Tax in connection with mineral oil stocks	Tax	
	Tax on heavy vehicles	Tax	
	Tax on passenger cars and motor bicycles (BPM)	Tax	
	Storage for Sustainable Energy and Climate Transition (ODE)	Tax	✓
	Surcharge on energy to promote sustainable energy	Tax	
	Motor vehicles tax (Motorrijtuigenbelasting) exemption for EV	Tax incentive	

	Commuter allowance for bikes and public transport	Tax incentive	
	Registration tax (BPM)exemptions and reductions for PHEV	Tax incentive	
	Tax relief for investments in environmentally friendly technology	Tax incentive	✓
	Energy investment allowance	Tax incentive	✓
NO	CO2 Tax (on Mineral products)	Tax	✓
	Tax on CO2 emissions in petroleum activities on the continental shelf	Tax	
	Environmental tax on greenhouse gases HFC and PFC	Tax	✓
	Motor vehicle registration tax – imputed CO2 component	Tax	
	Imputed tax on emission permits	Tax	
	Motor vehicle registration tax – imputed NOx component	Tax	
	Tax on NOx emissions, excl petroleum sector	Tax	
	Tax on NOx emissions in the petroleum sector	Tax	
	Sulphur tax	Tax	
	Road usage tax on diesel	Tax	
	Road usage tax on petrol	Tax	
	Road tax on natural gas and LPG	Tax	
	Tax on the final treatment of waste	Tax	
	Environmental taxes on beverage packaging (metal, glas, carton, plastic)	Tax	
	Base tax on disposable beverage packaging	Tax	
	Environmental tax on mineral oils	Tax	
	Environmental tax on tetracloreten	Tax	
	Environmental tax on tricloreten	Tax	
	Electricity tax	Tax	
	Annual weight-based tax on vehicles	Tax	
	Annual tax on motor vehicles	Tax	
	Base-tax on mineral oils, etc.	Tax	
	Re-registration tax on motor vehicles	Tax	
	Tax on air traffic passengers	Tax	
	Mileage tax for diesel vehicles	Tax	
	Tax exemptions for vehicle registration (EV)	Tax incentive	✓
PL	Carbon Tax	Tax	✓
	Emission charge on fuels	Tax	✓
	Income tax break for thermo-modernisation of single-family residential buildings	Tax incentive	✓
	Elimination of excise duties for electric and hydrogen cars	Tax incentive	
	Reduced VAT rate on PV installations (from 23% to 8%)	Tax incentive	
	Reduced VAT rate for public passenger transport (from 23% to 8%)	Tax incentive	
PT	Vehicle registration tax (ISV)	Tax	✓
	Vehicle circulation tax (IUC)	Tax	
	Add-on circulation tax (IUC) for highly polluting vehicles	Tax	
	Carbon tax (additional to ISP)	Tax	✓
	Exemption of ISV and IUC for Electric Vehicles (EV)	Tax incentive	✓
	Reduction of ISV for PHEV (Plug-in Electric Vehicles)	Tax incentive	
	Deductibility of VAT of EV and PHEV (different rates) for companies	Tax incentive	
	Additional taxation on vehicle acquisitions above certain value for companies	Tax	
RO	Taxes on pollutant emissions into the atmosphere	Tax	✓
	Exemption of means of transportation tax for electric vehicles	Tax incentive	✓

	50% deduction for vehicle tax for hybrid means of transportation (according to the decision of the local Council)	Tax incentive	
SE	Sulphur tax	Tax	
	Landfill tax	Tax	
	Congestion tax	Tax	
	Tax reduction for micro production of renewable energy	Tax incentive	
	Lower benefit value on cars with advanced environmental technology	Tax incentive	
	Bonus-malus-system for new light vehicles	Tax incentive	✓
	Co2 based vehicle tax	Tax	✓
	CO2 tax	Tax	✓
	Tax exemption on biofuels	Tax incentive	
	Waste incineration tax	Tax	
SI	Slovenia Carbon Tax	Tax	✓
	Motor Vehicles Tax Act – Car taxation based on CO2 emissions (registration tax)	Tax	✓
	Tax exemption for biofuels	Tax incentive	✓
	BEV's pay the lowest (0,5%) rate of tax on motor vehicle (registration tax)	Tax incentive	
	Exemption for BEV from the payment of annual fees for the use of roads (ownership tax)	Tax incentive	
SK	Tax incentive under the Motor Vehicle Tax (EVs & alternative propellants)	Tax incentive	✓
	Favourable depreciation rates for battery and plug-in-hybrid vehicles	Tax incentive	✓
UK	First Year Rates of the Vehicle Excise Duty (Ved)	Tax	✓
	Carbon Price Support (CPS) Rates of the Climate Change Levy	Tax	✓
	Enhanced Capital Allowances for Energy-Saving Technologies: Tax Scheme for Businesses	Tax incentive	✓
	Company Tax Benefits for Zero- or Low-Emission Vehicles	Tax	
	Reduced VAT-Rate for Energy-Saving Materials Permanently Installed in Residential or Charity Premises	Tax incentive	
	Standard Rates (SRs) of the Vehicle Excise Duty (VED)	Tax	
	Company tax benefits for Transport infrastructure	Tax incentive	
	Company Tax for Company Cars - Class 1A National Insurance Contributions (NICs)	Tax	
	The Landfill Tax	Tax	

ANNEX VII: EXTERNAL REVIEWS

Two external reviewers were asked to provide an independent and external quality control of the report. Both reviewers commented and provided a critical review of the draft final of the report, the validity, relevance and adequacy of the findings, conclusions and recommendations. The general comments provided by external reviewers can be found below and explanations on how their inputs were considered in the report are presented in the following table.

Comments from external reviewers	Response
Detailed comments in the report itself by the external reviewers	All detailed comments provided directly in the report were addressed.
The literature on the social cost of carbon deserves some deeper reflections too, in relation to the appropriate tax rates for carbon, now and in the coming years, and how these suitably may complement energy taxes.	We feel that a detailed presentation of the numerous estimations of the social costs of carbon would go beyond the scope of the report.
The summary of the theoretical debate in section 2.2.3 is rather brief and omits important recent contributions. Jaeger (in Milne and Andersen, 2012) is a good overview and identifies important shortcomings in some of the early literature).	We integrated some additional references.
According to Goulder the distinction is between weak, strong and also intermediate forms of the DD hypothesis. While the strong form is controversial, and the weak form is close to trivial, the intermediate form should not be neglected in the report.	We added the intermediate form of the DD.
Section 2.2.8 addresses revenue recycling as a m eans to compensate for introducing carbon taxes, and the section could usefully be extended considering more carefully the different approaches available. The report should moreover consider the case made for ex-post compensation of low-income groups.	Revenue recycling is addressed at several passages of the report. The OECD argument of ex-post recycling e.g. is referred to in chapter 2.2.6
It would have been nice if the relevance of environmental taxation (and hence also of taxes addressing GHG emissions) as a legitimate means to raise revenue would have been emphasized more.	We feel that there is no adequate place in the report to explicitly address in more detail the revenue raising aspect of environmental taxation; however, it is addressed whenever revenue recycling options and a potential double dividend are discussed.
The comparison of ETS and taxation is very concise. To my mind it is not an integral part of the study but if it should stay in, it should also include a theoretical comparison and reflect the instrument choice literature.	A detailed theoretical comparison of ETS and carbon taxation would go beyond the scope of the study.
The critique on the ETD is well placed but it should not be forgotten that the ETD provided a higher carbon price than the EU ETS during the times when the EU allowance prices were low.	This comment is true and now acknowledged in the report.
The report reviews both carbon and energy taxes but despite concluding on the need for broader policy packages, it does not consider the possible interaction effects between these closely related taxes. If carbon taxes complement energy taxes, and vice versa, the report should consider more carefully the criteria for setting energy tax rates to be internally consistent (per unit of gigajoule),	The comment is true that individual measures should ideally be part of broader policy packages, and that measures within the policy packages are aligned with each other. However, the focus of this report is not to develop suggestions for such policy packes, but rather to explore and assess what (individual) measures exist. The element of internal consistency has been added in the report to stress this poitn again.

Comments from external reviewers	Response
while underpinning EU targets for energy efficiency.	
The terminology of 'tax incentives' is rather unfortunate, as incentives are provided as well with environmental taxes as with the deductions in tax liability that are meant to be in focus under this heading, for this reason it should be considered to change into more conventional terminology by referring to 'tax expenditures' (cf. Surrey, 1973).	We take note of this comment. As the term 'tax incentives' was used by the Terms of References and throughout the implementation of the study, we prefer to maintain this term. That said, the definition of the scope of the study has been extended and contains a definition of key terms, including tax incentives.
While the draft report rightly points to the concerns that may arise with the use of such indirect subsidies, a deeper analysis of the opportunities to their use could be provided, e.g. in relation to EU state aid rules and OECD and WTO principles for the use of subsidies. An excellent exposition of the principles and practices of tax expenditures is available in the recently published book 'Tax expenditures and environmental policy' (by H. Ashiabor) which could be reflected.	An assessment of tax incentives with regards to EU state aid rules and WTO principles has not been performed, as this was not the focus of this study.
The mapping of environmentally-related taxes on transport currently focuses on passenger vehicles, but there are also taxes on heavy goods vehicles and light commercial vehicles that could be included – as well as in relation to aviation.	We take note of the comment and added a paragraph at the end of section 3.2.2 which provides further details on the tax base applied to commercial vehicles.
In order to facilitate the work of civil servants to find 'inspiration abroad' by examining other measures, I think it would be most helpful to provide a list of the tax laws used.	We included Annex VI which provides as suggested the detailed list of taxes and tax incentives identified in the study.
The methodology for identifying best practice examples of tax expenditures is somewhat crisp and should be refined based on a more systematic translation of theoretical justifications for the use of subsidies, with a more analytic and systematic recap of the conditions under which the use of public financial support (subsidies) is acceptable. Specifically the case for using off-budget (tax expenditures) versus on-budget subsidies requires deeper analytical attention. The literature cautions rightly against the lack of transparency that can be related to the former.	The methodology is now more clearly and explicitly linked to the findings from the literature review. The question whether to use tax incentives or subsidies is an interesting and important question. During the mapping of tax measures, we saw that some countries clearly prefer the one over the other. While the literature review briefly touches on th this point, we do not assess and compare the two types of measures more systematically, as this would be outside of the scope of this study.
Any kind of subsidy needs financing by means of other taxes, and if these do not internalize externalities, they are likely to be distortionary, thus reducing overall economic activity and possibly welfare, which needs mentioning.	This is explicitly mentioned now.

Comments from external reviewers	Response
The methodological assumption of a high score for a large tax break seems misleading, as any subsidy should be measured against the expected impact (cost-effectiveness relative to GHG abatement and co-benefits). It is questionable whether measures for which no such estimate is available should be able to qualify as best practice	We agree that this point is an important limitation in our assessment of tax incentives. It partly stems from gaps in research that our literature review highlighted, and partly from the fact that the ideal tax break is highly contingent on national circumstances. We revised the text to discuss this limitation more clearly. Note that weighting has been applied to the individual design features identified (see the Methodological Annex), where the element of generosity has received a lower weight to limit the effect of this criterion on the overall ratings.
Considering the limited analysis and data availabl e relating to tax expenditures, the report seems better served by shortening the list to only 2-3 cases of best practice, while the best practice list relating to environmental taxes could usefully be extended.	The selection has been adjusted and includes 7 taxes and 3 tax incenitves now.
It is commendable that the study developed two separate best practices, one for taxes and one for tax incentives.	
Since the presumed objective of an environmental tax is also to have a positive impact upon the climate, it would be good to examine if there are other ways to put the identified best practices into perspective. One could, for example, have compared the tax rate against suggested carbon prices to realize the Paris Agreement objectives. Arguable this is of course not a perfect solution	This is an interesting comment, and one could indeed compare the tax rate against the carbon prices to realise Paris agreement objectives for carbon taxes (five carbon tax rates in our study meet the objective). However, such exercise would not be possible for most of the mapped measures due to their diversity and different units of tax rates.
It would have been useful to have a list of suggestions where additional research would be necessary to offer policy makers a research agenda.	The discussion of the literature and its findings highlights some elements that could be part of the future research agenda. Two points we consider as particularly important and mention in the conclusions and executive summary are ex-post evaluations of existing measures and more research on tax incentives, including on their cost-effectiveness.
It would also have been useful to give decision makers an indication on what is currently being done in terms of carbon pricing is sufficient to reach the Green deal/Paris agreement objectives. Moreover, it would have been interesting to also mention that the Hinkley Point case (C 594/18) may offer EU Member States more possibilities to avoid state aid issues and hence offer them more and better opportunities to design effective fiscal instruments to curb GHG emissions.	We fully agree that an assessment of current efforts vis-à-vis the objectives of the Green Deal and Paris Agreement is important for Member States to understand if they need to step up their efforts. However, this has not been the focus of this research project.
It should be clarified, however, if the country fiches were prepared by the core team and if it was sent back for comments again to the country researchers.	We detail in the Methodological Annex (Annex 1) the methodology used for the country fiches: a preliminary mapping was conducted by the core team, country experts complemented and extended the mapping (desk research, interviews) and the core team compiled all these information into country fiches. Member State representatives had the opportunity to receive the full country fiches and provide further comments and suggestions. 6 Member States made use of this opportunity.

Comments from external reviewers	Response
In numerous cases throughout the report there is reference to insights from working papers, for which it is not clear whether they have been subject to peer review. For the summary of theoretical literature it is recommended to abstain from including 'grey' sources, while they should be accorded less weight in the overview of empirical studies	For this study, we looked at a wide range of existing studies, academic articles, and other research. It is true that this also includes 'grey' literature. As discussed throughout the report, evidence is scattered, especially for certain effects of tax measures, ex-post evaluations, and tax incentives in general. We therefore consider grey literature as a relevant source of information.
The report could be improved through a better an d more rigorous reference to existing EU sources, such as the report 'Transport taxes and charges in Europe' (2019) published by DG MOVE.	References to additional EU sources, including the one mentioned, have been added.

Review from Reviewer #1

General comments

The present study provides a very comprehensive overview of the theory and practice on the use of environmental taxes and tax expenditures for environmental policy as a basis for identifying some good practice examples from use of tax policy instruments in EU Member States and beyond. The study must be commended for an excellent overview of evidence available from academic studies on what have become pertinent issues for the use of tax policy instruments for implementing the EU Green Deal and meeting the ambitions of the Paris Agreement, i.e. as relating to the GHG reducing effectiveness and distributional implications of introducing environmental taxation or tax expenditures. The report moreover takes strides with complex topics such as the competitiveness impacts of the various tax measures, their innovation effects, the risks of carbon leakage and opportunities to enhance overall welfare through emulations in the tax systems. These are topics for which a comprehensive international literature has evolved over the past twenty-five years, and to synthesize it adequately is no small challenge. Some recommendations are made in the following for completing the draft report in accordance with the terms of reference.

The draft report is strongest on the aspects relating to environmental taxation, whereas in relation to so-called tax incentives more work will be needed to bring it up to an acceptable level of rigor, even if considering that the literature and studies available are more limited in this area. The terminology of 'tax incentives' is rather unfortunate, as incentives are provided as well with environmental taxes as with the deductions in tax liability that are meant to be in focus under this heading, for this reason it should be considered to change into more conventional terminology by referring to 'tax expenditures' (cf. Surrey, 1973). These are off-budget subsidies provided via reduced tax liabilities, and while the draft report rightly points to the concerns that may arise with the use of such indirect subsidies, a deeper analysis of the opportunities to their use could be provided, e.g. in relation to EU state aid rules and OECD and WTO principles for the use of subsidies. Moreover, an excellent exposition of the principles and practices of tax expenditures is available in the recently published book 'Tax expenditures and environmental policy' (by H. Ashiabor) which could be reflected.

The methodology for identifying best practice examples of tax expenditures is somewhat crisp and should be refined based on a more systematic translation of theoretical justifications for the use of subsidies, with a more analytic and systematic recap of the conditions under which the use of public financial support (subsidies) is acceptable. Specifically the case for using off-budget (tax expenditures) versus on-budget subsidies requires deeper analytical attention. The literature cautions rightly against the lack of transparency that can be related to the former. Finally, any kind of subsidy needs financing by means of other taxes, and if these do not internalize externalities, they are likely to be distortionary, thus reducing overall economic activity and possibly welfare, which needs mentioning.

The methodological assumption of a high score for a large tax break seems misleading, as any subsidy should be measured against the expected impact (cost-effectiveness relative to GHG abatement and co-benefits). It is questionable whether measures for which no such estimate is available should be able to qualify as best practice. Considering the limited analysis and data available relating to tax expenditures, the report seems better served by shortening the list to only 2-3 cases of best practice, while the best practice list relating to environmental taxes could usefully be extended. The pragmatic methodology for identifying best practice examples of environmental taxes is acceptable

Specific comments

In numerous cases throughout the report there is reference to insights from working papers, for which it is not clear whether they have been subject to peer review. For the summary of theoretical literature it is recommended to abstain from including 'grey' sources, while they should be accorded less weight in the overview of empirical studies.

The report could be improved through a better and more rigorous reference to existing EU sources, such as the report 'Transport taxes and charges in Europe' (2019) published by DG MOVE. The mapping of environmentally-related taxes on transport currently focuses on passenger vehicles, but there are also taxes on heavy goods vehicles and light commercial vehicles that could be included – as well as in relation to aviation. Studies on environmental fiscal reform and environmentally harmful subsidies published by DG ENV over the past 6-7 years offer valuable data too. Moreover, Eurostat's National Tax List can be used to check whether the inventory of taxes in each Member State is complete (consider also the separate list of minor taxes), as compared to the report's primary source (OECD's PINES database that relies on voluntary reporting). The overview of VAT rates in all Member States, specifying reduced rates for energy and transport, published by TAXUD is relevant too.

The report reviews both carbon and energy taxes but despite concluding on the need for broader policy packages, it does not consider the possible interaction effects between these closely related taxes. If carbon taxes complement energy taxes, and vice versa, the report should consider more carefully the criteria for setting energy tax rates to be internally consistent (per unit of gigajoule), while underpinning EU targets for energy efficiency. The literature on the social cost of carbon deserves some deeper reflections too, in relation to the appropriate tax rates for carbon, now and in the coming years, and how these suitably may complement energy taxes.

The potential welfare-enhancing effects of environmentally-related taxes that can internalize unpriced externalities are considered both in section 2.2.3 and 2.3.4. While the overview of studies in the latter section is comprehensive, the summary of the theoretical debate in the former section is rather brief and omits important recent contributions (Jaeger (in Milne and Andersen, 2012) is a good overview and identifies important shortcomings in some of the early literature).

According to Goulder the distinction is between weak, strong and also intermediate forms of the DD hypothesis. While the strong form is controversial, and the weak form is close to trivial, the intermediate form should not be neglected in the report. It states that whether using an internalising environmental tax to replace a distortionary tax offers opportunity for a welfare improvement depends on the specific properties of the distortionary tax in question – in other words on context and circumstances. Parry (Pollution taxes and revenue recycling, JEEM 29: 64-77) shows that a promising approach is to recycle revenues to lower employers' social security contributions.

Section 2.2.8 addresses revenue recycling as a means to compensate for introducing carbon taxes, and the section could usefully be extended considering more carefully the different approaches available. Recycling for lowering of social security contributions versus income taxes have different implications for different target groups. Energy-intensive businesses are often not labor-intensive and could benefit from revenues being recycled for advisory services, or for investment in fuel shifting or energy efficiency (cf. UK's Carbon Trust Fund). The report should moreover consider the case made for ex-post compensation of low-income groups.

The report on p. 19 observes that "stock-flow-interactions pose as behavioral constraints affecting the efficiency of taxes" and later on refers back to this statement a couple of times, e.g. in context of the tenant-owner dilemma. This is rather vague and to the reader it is far from clear what is meant here, while the case for applying policy instrument packages to GHG abatement could be made more persuasively based on a broader set of arguments and references to literature.

The statement on p. 29 that "no clear recommendation for the use of tax incentives can be derived from a theoretical perspective" is not a good representation and can be qualified by reflecting the Greene and Braathen table – e.g. positive externalities provide a case. Moreover, OECD cautions against violating the polluter-pay principle; subsidies/financial support should be provided only for measures going beyond a defined baseline of required pollution controls. This would apply also to tax expenditures as a subgroup of subsidies.

Review from Reviewer #2

The report constitutes an important source of information and inspiration for countries that seek to employ or improve their fiscal tax instruments to reduce GHG emissions. Particularly in situations where both the society and the overall economy is hard pressed to reduce emissions, to become more sustainable and when additional financing sources are badly needed, this report will undoubtedly find much interest.

This review will comment on the validity, relevance and adequacy of the findings, conclusions and recommendations made in the report. I address these points by taking the set objectives as the starting point of the review.

The study has four objectives: 1) Take stock of current state of research; 2) Map tax measures that incentivise individuals/companies to reduce emissions; 3) Identify good practice examples; 4) concrete policy recommendations to enhance efforts to reduce GHG emissions in the EU effectively.

With regard to the objective of taking stock of current state of research has been addressed in chapter 2 by means of an extensive literature review of relevant theoretical and empirical literature. The authors have also integrated these findings in the ongoing policy debate. The work is though and of a high standard. It would have been nice if the relevance of environmental taxation (and hence also of taxes addressing GHG emissions) as a legitimate means to raise revenue would have been emphasized more.

Due to Covid-19, Member State the debt levels are rising sharply and finance ministers will be needing to find new sources to raise money. The environmental steering effect of taxes can be in conflict with the objective to raise funds.

The comparison of ETS and taxation is very concise. To my mind it is not an integral part of the study but if it should stay in, it should also include a theoretical comparison and reflect the instrument choice literature. The critique on the ETD is well placed but it should not be forgotten that the ETD provided a higher carbon price than the EU ETS during the times when the EU allowance prices were low. The employed methodology (desk research) is adequate and the work produced is sound.

The objective of mapping relevant tax measures to reduce emissions is addressed in chapter 3. The chapter presents an extensive number of fiscal measures including taxes, tax incentives and harmful taxes from 33 countries. The chapter is well-structured and contains several overview tables and figures that serve the objective of giving an overview. More detailed information on the tax measures (such as the tax rate) can then be found in the annexes. In order to facilitate the work of civil servants to find 'inspiration abroad' by examining other measures, I think it would be most helpful to provide a list of the tax laws used. This is all the more relevant since the report is going beyond what is contained in the PINE database, the World Bank's Carbon Pricing Dashboard and EEA research. The employed methodology is adequate. It should be clarified, however, if the country fiches were prepared by the core team and if it was sent back for comments again to the country researchers. This would have provided an additional safeguard to avoid mistakes. From the methodology description it was not clear if the fiches were validated by the MS representatives. An opportunity for MS representatives to react to a presentation and ask for the respective country fiche is of course sufficient but an in-build validation loop would have been even more desirable. The employed methodology, combination of drawing from reports, data bases, knowledge from country experts and to have direct feedback via workshops is well thought through.

Chapter 4 addresses the objective of identifying good practice examples. This is done by means of a two-step approach. First all the measures identified were ranked according to their environmental effectiveness, and then in a second step they are assessed on the basis of their political viability, also taking into account the diversity of existing measures. It is commendable that the study developed two separate best practices, one for taxes and one for tax incentives. The employed methodology is sound, and it is excellent that MS representative had the possibility to validate information within the framework of a workshop. The focus on design features to identify good practices with an additional consideration of environmental impacts where possible – is understandable and it bears tribute to the fact that empirical evidence on specific fiscal measures are not always available. As acknowledged by the authors, this does reduce the actual validity of the findings regarding the best practices but cannot be resolved otherwise. This is therefore something to be addressed in further research. Given that it is beyond the scope of the research to fill the empirical gaps, a focus on design features (augmented by additional empirical studies where available) is expedient and viable. Since the presumed objective of an environmental tax is also to have a positive impact upon the climate, it would be good to examine if there are other ways to put the identified best practices into perspective. One could, for example, have compared the tax rate against suggested carbon prices to realize the Paris Agreement objectives. Arguable this is of course not a perfect solution, but might help to indicate that even following current best practices might fall short of what is needed to address the climate change challenge, let alone the ambitious long term targets of the European Green Deal.

Communication has been identified as a critical element for public acceptance. The research design is not geared to evaluate this. It might have been addressed via semi-structured interviews in the validation phase of the project but was probably rightly left out as proper and extensive research on this topic would be more helpful for civil servants in designing their respective domestic policies.

Chapter 5 addresses objective 4 and develops conclusions and concrete policy recommendations to enhance efforts to effectively reduce GHG emissions in the EU. The conclusions are sound and directly based upon the discussions made in the report.

The recommendations essentially suggest to examine what other countries are already doing to reduce GHG emissions and examine where one falls short and to see what one could be doing about it. Moreover, in terms of design suggestions one should aim at taxing GHG emissions directly and to give priority to tax incentives. These recommendations are also sound.

Similarly calling upon countries to engage in an active exchange of experiences and coordination to reduce GHG emissions is expedient. The call for more research is also well placed. It would have been useful to have a list of suggestions where additional research would be necessary to offer policy makers a research agenda.

It would also have been useful to give decision makers an indication on what is currently being done in terms of carbon pricing is sufficient to reach the Green deal/Paris agreement objectives. Moreover, it would have been interesting to also mention that the Hinkley Point case (C 594/18) may offer EU Member States more possibilities to avoid state aid issues and hence offer them more and better opportunities to design effective fiscal instruments to curb GHG emissions.

In light of the elements stated above, I conclude that the report is well researched and well written. The chosen methodology is sound. The authors have made relevant findings and sound recommendations. The study therefore achieved what it set out to do. Below I have still listed a number of additional elements and suggestions to improve it further.

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