Paper

Effective Carbon Rates by Manufacturing Industries and Household Consumers in the Netherlands

Mark de Haan,
Olaf Koops

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Explanation of symbols

Empty cell	Figure not applicable
.	Figure is unknown, insufficiently reliable or confidential
*	Provisional figure
**	Revised provisional figure
–	(between two numbers) inclusive
0 (0.0)	Less than half of unit concerned
2023–2024	2023 to 2024 inclusive
2023/2024	Average for 2023 up to and including 2024
2023/'24	Crop year, financial year, school year, etc., beginning in 2023 and ending in 2024
2021/'22–2023/'24	Crop year, etc., 2021/'22 to 2023/'24 inclusive

Because of rounding, some totals may not correspond to the sum of the separate cells.
Revised figures are not marked as such.

Colophon

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1. Introduction

Emissions of greenhouse gases lead to global warming and climate change. Governments have various policy instruments at their disposal to mitigate greenhouse gas emissions. One often referred to distinction is using either the carrot (subsidies) or the stick (taxes) to redirect consumer and producer behavior in a climate friendly direction. Wilbrink & Butler (2024) and Withagen & van der Meijden (2022) explain that subsidies may help to some extent, but taxes on fossil energy use and greenhouse gas emissions will be indispensable in the process of climate change mitigation. The Netherlands Bureau for Economic Policy Analysis (2019) conclude that most of the economic literature point at carbon pricing as the most effective and efficient instrument for climate mitigation policy.

At the same time, the ongoing discussion on fossil fuel subsidies indicate the length of the stick may vary substantially between the various agents in the economy. The tax exempted and discounted use of fossil fuel consumption in several industries has raised not only concerns about getting CO2 prices right but also about fairness: which economic agents should pay the price of the energy transition? Abandoning fossil subsidies, including fossil tax discounts and exemptions, is currently addressed as a sustainable development goal.[1]

Dieperink & de Haan (2024) conclude that accounting for fossil fuel subsidies is probably not a statistician's job, as descriptive statistics are not meant to estimate the unpaid amounts of taxes that *should* have been payed. Particularly in the Dutch case of energy taxes, which has a rather sophisticated stratification of decreasing tax rates depending on the amounts consumed, the selection of a reference rate (what should have been paid) is a normative choice which importantly determines the outcomes.

The OECD (2023) developed a metric, the effective carbon rate (ECR), to calculate the price governments put on greenhouse gas emissions. ECRs are able to explain developments and divergences in carbon tax levels while avoiding the thorny issue of 'what should have been paid'. The OECD does so by measuring taxes on fossil fuel use and on greenhouse gas emissions per unit of greenhouse gas emitted.

$$ECR = \frac{\substack{taxes\ (minus\ subsidies)\ on\ fossil\ energy\ use \\ and\ on\ greenhouse\ gas\ emissions}}{greenhouse\ gas\ emissions}$$

In this definition we make (between brackets) a reference to subsidies. The possible role of explicit fossil subsidies in ECRs is explained later on in this paper.

As shown in the OECD publications, ECR level differences may be examined between the different economies and so-called sectors (transport, electricity, industry, buildings, agriculture). Brink & Vollebergh (2023) estimate ECRs following a similar type of sectoring in correspondence with the Dutch environmental policy domains: electricity production, manufacturing industries, transportation, urban environment and agriculture.

However, ECRs can also be estimated at the level of the various types of producers and consumers as observed in an economy. The grouping of economic activities based on the international standard industry classification (ISIC, or NACE in Europe) is the point of departure of this paper. This aligns to guidance from Eurostat (2024b) in which the estimation of ECRs are advocated as part of EU statistical program on environmentally harmful subsidies.

[1] Indicator 12.c.1 | UNEP

In this paper we first examine differences in the composition of ECRs as presented in other publications. In a second step we put forward what is in our opinion the most suitable definition for the case of the Netherlands. Subsequently we discuss developments in ECRs at national and industry branch level, based on national accounts and environmental accounts data as regularly published by Statistics Netherlands.

The structure of the paper is as follows. The following section (2) provides a discussion on the conceptual underpinnings of ECRs. Section 3 presents the results for the Netherlands and for individual industries and consumer households in the Dutch economy. Section 4 winds up with conclusions and recommendations for future work.

2. Concepts

2.1 System of Environmental Economic Accounting (SEEA)

The internationally standardized statistical framework on environmental economic accounting (SEEA-CF, UN et al, 2014) provides a valuable data source for ECR calculations. The SEEA consist of a range of accounts dealing with various aspects of environmental-economic relationships such as accounts for emissions to air, material flows, natural resources and environment related expenditures including taxes and subsidies.

The greenhouse gas emissions accounts' classification by industries corresponds one-to-one to the national accounts supply-use and input-output tables. The latter tables contain the required information on taxes levied on products, e.g. excise taxes, and those levied on production activities, e.g. carbon taxes and taxes resulting from the EU emission trading system (ETS).

The SEEA may contribute in at least two ways to the consistency of ECRs:

1. Both the coverage of taxes (numerator) and greenhouse gas emissions (denominator) refer to all resident economic activities (production, consumption) in an economy, guarantying a uniform demarcation of the ECR's numerator and denominator. It should be noted that it is not unusual for producers and consumers to pay taxes on products to foreign tax authorities for example when these products are purchased abroad. Ideally, also these tax flows should be brought into scope.
2. In the SEEA framework the recording of both environmental taxes and greenhouse gas emissions follow the ISIC.

Even though the SEEA contains a definition of environmental taxes, it does not separately identify those taxes specifically connected to climate change mitigation nor taxes to be addressed in the numerator of ECRs. The scope of these taxes (and subsidies) are discussed in the subsequent subsection of this paper.

The Dutch environmental accounts on greenhouse gas emissions and on environmental taxes are consistent with the SEEA methodology, supplemented by refined guidance provided by Eurostat in the context of the mandatory data transmissions of member states to the EU which include air emission accounts and the accounts for environmental taxes.

The data on (environmental) tax receipts, as obtained by Statistics Netherlands from the Dutch government, is generally considered to be of high quality. In the case of the Netherlands, data on taxes and subsidies, as recorded in the various macroeconomic statistics such as government finance statistics, national accounts and environmental accounts, are at all times fully consistent. In other words, for each and every tax category, it is assured that the sum of tax outlays of businesses and households, as recorded in the national and environmental accounts, will be consistent with the tax receipts of government as recorded in government finance statistics.

As the ECR metric is defined as a ratio between taxes and emissions, the choice of taxes and emissions categories is addressed in the following two subsections. As part of this selection exercise we refer to the following literature:

i. Eurostat guidance on environmental taxes (2014a) and tentative guidance on potentially harmful subsidies and effective carbon rates (2024b);

ii. OECD (2023);

iii. Brink & Vollebergh (2023).

Our preferred method is referred to as option (iv).

At the moment of drafting this paper the most recent outcomes of the Dutch national accounts are the years 2022 (definitive estimates) and 2023 (preliminary estimates). We prefer using the latest definitive (2022) results for the comparison of methods.

2.2 Numerator: taxes minus subsidies

(i) Eurostat

Eurostat collects data obtained from the member states on environmental taxes by economic activity (ETEA) and defines (Eurostat, 2024a) environmental taxes as follows:

“A tax whose tax base is a physical unit (or a proxy of a physical unit) of something that has a proven, specific negative impact on the environment, and which is identified in the European System of Accounts (ESA) (..) as a tax.”

Eurostat also explains that “Other possible criteria, such as the purpose stated by the tax legislator, the name of the tax or the earmarking of the revenue for environmental purposes are less suitable and more difficult to use in practice.”

Eurostat (2024b) recommends the following subset of environmental taxes to be included in ECRs:

- Carbon-specific taxes, where the tax base relates to the carbon content of the fuel;
- Excise taxes on fossil fuels and similar. As long as expressed in monetary units/physical unit or specifically stated out as taxing fossil fuels products, those taxes must be included.
- Payments associated to the ETS, recorded according to the ETEA guidelines.

(ii) OECD

In its latest (2023) publication the OECD includes the following three tax categories in their estimates:

- Fuel excise taxes;
- Carbon taxes, which are explained as follows: “Here, the term “carbon tax” covers the broad range of all taxes that apply to greenhouse gases (including taxes on fluorinated gases (F-gases), for instance)”
- Permit prices resulting from ETS. Figure 2.A.2 (OECD, 2023) seems to indicate that the value of permits distributed for free are being subtracted. This issue is further discussed in box 1 below.

In line with Eurostat, the OECD’s focus is on pricing instruments that apply to a base that is directly proportional to fossil energy use or greenhouse gas (GHG) emissions. Taxes and fees are excluded when they are only partially correlated with energy use or GHG emissions such as vehicle purchase taxes. Production taxes on the extraction or exploitation of energy resources (e.g. severance taxes on oil extraction) are not within the scope of instruments covered either, as supply-side measures are not directly linked to domestic energy use or emissions.

The OECD recommends to include only ‘specific taxes’, i.e. taxes that apply per unit of good as opposed to ad-valorem taxes which depend on the good’s price. According to the OECD, the adjective ‘specific’ also implies that the tax should elevate the relative prices of carbon-intensive goods vis-à-vis other goods and services. In line with these two criteria, value added taxes (VAT) or sales taxes remain out of scope.

Our understanding of the OECD definition is that the Dutch energy tax is out of scope. However, figure 2.4. in OECD (2023) indicates that taxes on gas are included. Also, figure 2.A.2 in OECD (2023) shows for the Netherlands an ECR of almost 100 euros per ton of CO2 equivalent. This may indicate that in the case of the Netherlands the energy tax is included after all. Despite these concerns, in figure 1 below, we stick to our interpretation of the OECD definition referred to above, even though in practice this interpretation may be wrong.

(iii) Brink & Vollebergh (B&V)

Brink & Vollebergh follow a bottom up analysis by which quantities of fossil energy consumption are taken as the point of departure, subsequently multiplied by their corresponding tax rates. In their analysis they address the following tax categories:

- Excise taxes on oil products
- Energy tax on electricity and gas
- Coal tax
- Waste tax
- ETS related taxes based on average year prices of permits
- Carbon tax (manufacturing industry)

This selection includes, compared to Eurostat and OECD guidance, a wider range of taxes. For example, the energy tax on electricity which is indirectly and partly related to CO2 emissions is for that reason put aside by Eurostat and OECD. However, value added taxes are not addressed by B&V either.

(iv) de Haan & Koops (deH&K)

As representatives of a national statistical office, our selection of taxes should obviously comply with the common international statistical definition of environmental taxes. However, regarding the recent Eurostat (2024b) guidance on ECRs, we permit ourselves some degree of freedom to examine which tax categories in the case of the Netherlands appropriately belong in ECRs. Our observations are the following:

Excise taxes on car fuel. As the tax base is the amounts (liters) of fuel consumed this tax category should be included in ESRs in correspondence with all three approaches referred to above.

Energy tax. In the case of the Netherlands, an energy tax is levied on electricity and on gas consumption. Also in this case the tax base represents the physical amounts of gas and electricity consumed. Eurostat (2024b) excludes taxes on the production and use of electricity. One may consider bringing the taxes on the use of electricity in scope by assigning the CO2 emissions resulting from power generation to the electricity consumers. However, as each unit of CO2 should be accounted for once, this reallocation of emissions would disturb the ECRs of electricity producers. So, in line with the Eurostat (2024b) guidelines, we include the energy tax on gas but leave out the energy tax on electricity.

In 2023 the Dutch government put a cap on the prices of gas and electricity to protect vulnerable households from increasing electricity and heating costs. This policy measure is in the Dutch national accounts recorded as a subsidy on (energy) products. For gas the corresponding compensation, mostly to households, amounted to almost 2.6 billion euros. For the year 2023 we included this subsidy, of course with a negative sign, in de ECR's denominator.

ETS. All CO2 emissions under the EU ETS cap and trade system require the surrender of an emission permit. As ETS taxes are directly related to CO2 emissions, they obviously belong in the numerator of ECRs. In our analysis all data on taxes are directly obtained from the Dutch system of national accounts which are, as already mentioned, in full correspondence with government finance statistics and the environmental accounts. However, we make an exception of ETS taxes and this choice is motivated in box 1. Eventually figure 1 below presents three types of ETS tax estimates. ETS-I represents the estimates based on tax receipts as obtained from government finance statistics. ETS-II represents estimates based on the amounts of surrendered permits valued at the average annual permit price. This is what we understand the estimation of B&V resembles. ETS-III equals the estimation of B&V, however, we subtract from this estimate the amounts of freely submitted permits which represent in our minds a 'subsidy' in the broader (non-System of National Accounts, SNA) sense. As already mentioned, the OECD (2023) seems to follow a similar approach.

Box 1
The recording of CO2 emission permits under the EU ETS

The international national accounting standards (SNA, ESA) do not acknowledge the free allocation of emission permits as an economic transaction. This is unfortunate as the permits made freely available is an elementary feature of the EU ETS at present. Its purpose is to let companies in the manufacturing industries gradually adapt to increasing CO2 prices without being forced to move their businesses outside of the EU ('carbon leakage'). Particularly at industry branch level these freely submitted permits cannot be ignored without the risk of overstating ECRs. In this paper ETS related taxes are calculated as the amounts of CO2 emitted under the cap, multiplied by the average year price of pollution permits. In addition, ETS 'subsidies' are estimated as the annual amounts of freely submitted permits equally multiplied by the average year price.

In case the SNA would have acknowledged the event of a freely assigned permit as an economic transaction, and we think there is a strong case to do so, the required transaction type would probably not be a *subsidy* but instead a *capital transfer*. As a pollution permit represents an asset (a stock of value), the transfer of an asset for free is usually accounted for as a capital transfer.

The valuation of ETS taxes in this paper also differs from SNA guidelines. According to the latter, even though the tax must be recorded at the moment CO2 emissions take place, its value should represent the issuing price, the price at which governments put permits in the market. If a permit was issued for free, its surrender cannot lead to a tax, even though in a subsequent step this permit may have been transacted in the market. So, we argue that from an emitter's cost perspective, the SNA guidelines do not lead to meaningful statistics.

In addition, the Netherlands appear to be a net importer of ETS permits. The Dutch CO2 emission levels under the ETS are surpassing the amounts of permits distributed for free or auctioned by the Dutch authorities. These foreign purchases are not included in the ETS tax receipts of the Dutch government and are also ignored in the national accounts ETS tax estimates.

Finally, Our ETS taxes estimates, as presented in this paper, are based on the permit price at the moment CO2 emissions take place. This is the moment in time at which the obligation to surrender a permit emerges. The SNA recommends to value the tax based on the actual preceded government receipts. The ETS subsidies are based on the prevailing market prices at the moment the permits free of charge are made available to the CO2 emitters. The valuation method applied in this paper is not only easier to implement but is also, to our opinion, conceptually sound, again particularly from an emitter's cost perspective. And tracing back the prices at which governments originally auctioned the permits appears to be a major measurement challenge. In national accounting practice, these prices are often approximated by using time lag adjustments.

Value added tax (VAT). According to the international environmental accounting standard (SEEA-CF, 4.157), VAT is excluded from environmental taxes. The OECD (2023) provides two arguments for this:

- VAT is an ad valorem tax so its base is not a quantity but instead a money value;
- VAT is a generally applied tax not specifically targeting climate change harmful commodities.

However, the SEEA-CF (4.158) also explains that VAT may amplify the size of for example excise and energy taxes when VAT is calculated on a price that includes both taxes. In response we added the non-deductible VAT on excise and energy taxes which is particularly relevant for the ECRs of household consumers. As market producers will be deducting VAT on their purchases, VAT has an elevating effect on the fossil energy prices of consumer households and government bodies only.

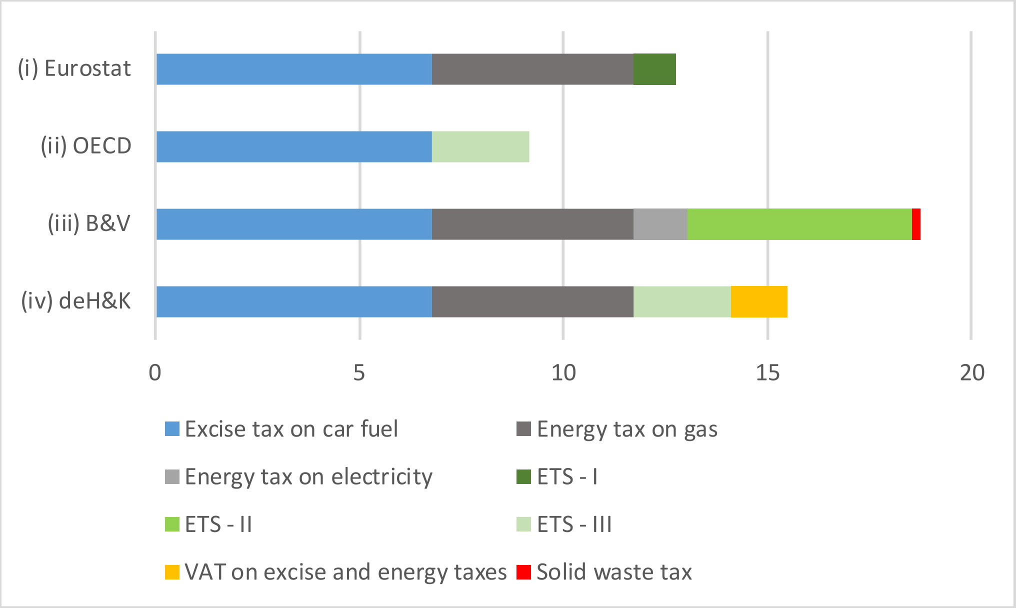
B&V also include the Dutch *solid waste tax* (afvalstoffenbelasting). As this tax is neither connected to fossil fuel use, nor directly to greenhouse gas emissions, we ignore this tax which seems in line with Eurostat (2024b). As in recent years the size of the government receipts from either the *coal tax* or *carbon tax* are negligible, we ignore these two tax categories as well.

Our understanding of the various proposed ECR numerators, as estimated for the year 2022, are summarized in figure 1. The modifications we would like to propose in response to the Eurostat (2024b) guidelines are twofold:

- Adopting alternative estimates for ETS as explained in box 1;
- Adding the non-deductible VAT on excise taxes as recommended in the SEEA-CF.

As a result, our estimate is 2.7 billion euros higher than an estimate based on the Eurostat definition. The sum of taxes we are able to assign to the ECRs' numerator for 2022 is 15.5 billion euros.

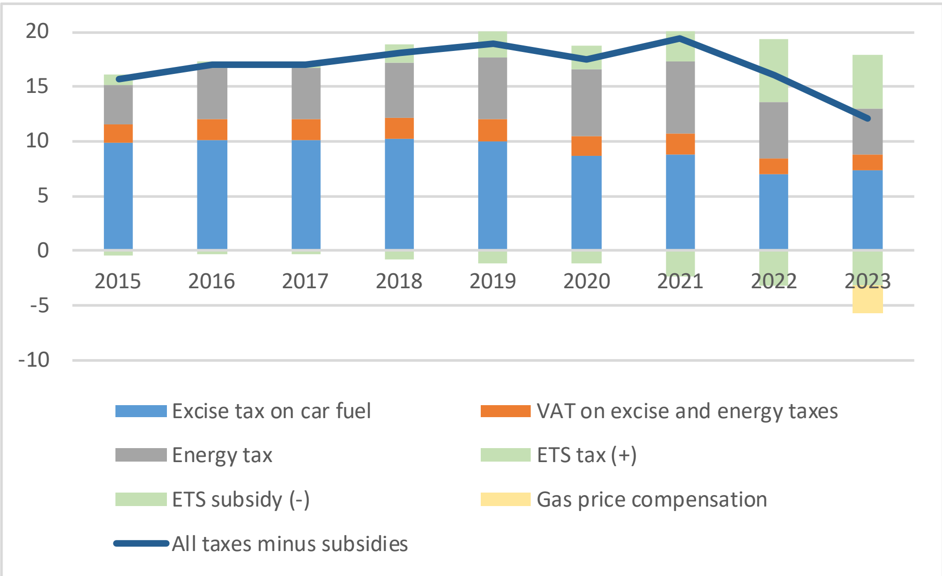
Figure 1
Taxes brought within scope of the various ECR definitions as exposed in the case of the Netherlands, reference year 2022, amounts in billion euros.



source: Statistics Netherlands and own calculations

Figure 2 shows that up to 2021 the ECR related tax amounts gradually increase over time. However, after 2021 the figure shows a decline. In 2023 the ECR related taxes show a decrease due to the temporary price cap on gas prices in that year, resulting in an energy subsidy of almost 2.6 billion euros. Without this temporary price compensation, the ECR would still be marginally lower than the 2022 rate. Figure 2 also highlights the increasing significance of ETS over time, both in terms of taxes and subsidies. These developments are the result of on average rising ETS permit prices.

Figure 2
Taxes minus subsidies on production and consumption brought by deH&K within scope of the ECRs, amounts in billion euros (converted to a 2023 price level)



source: Statistics Netherlands and own calculations

Data from the Dutch Emissions Authority indicate that in 2023 CO2 emissions under the ETS cap decreased substantially. This has a dampening effect on the contribution of ETS taxes to ECRs, even though the average annual permit price increased from 81 euros in 2022 to 85 euros in 2023.

2.3 Denominator: greenhouse gas emissions

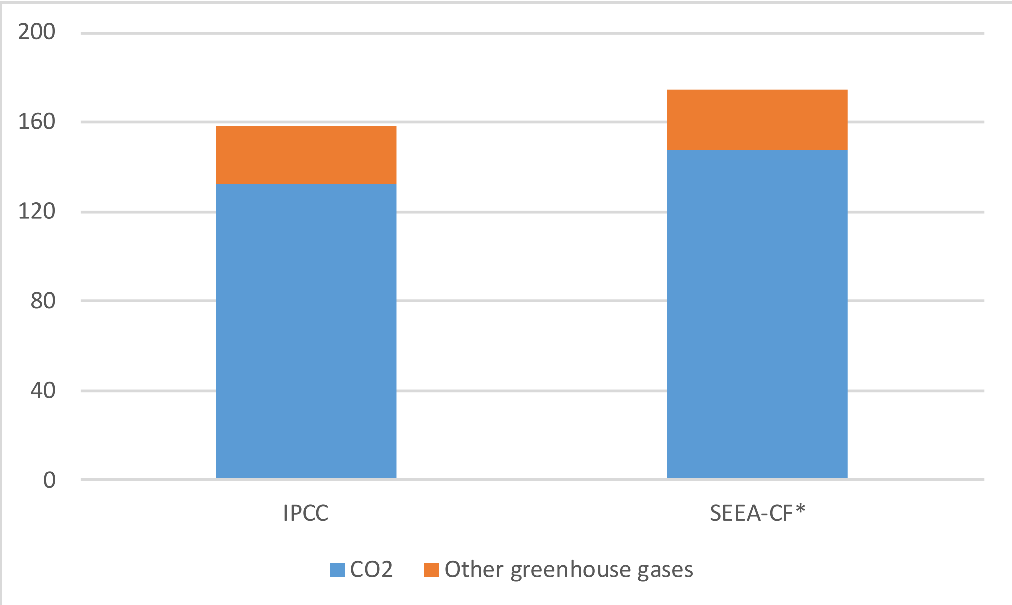
The denominator of ECRs can be defined in many ways but the following two choices are probably the most important ones:

- One may either follow the IPCC or SEEA-CF definition of greenhouse gases. The IPCC follows a territorial demarcation while the SEEA-CF looks at the emissions of resident economic activities in an economy. The SEEA-CF definition aligns with the SNA demarcation of domestic economic (production and consumption) activity, in concordance with gross domestic product. The SEEA-CF definition is helpful when the objective is to calculate ECRs at the level of ISIC (or NACE) industries. The difference between the IPCC and SEEA totals is due to the CO2 emissions from international aviation and maritime transport which is included in the SEEA-CF figure, as far as resident aviation and shipping companies is concerned, but not in the IPCC figure. Under IPCC, bunkering is reported separately from the national totals. The ECRs of the OECD and B&V are IPCC based. Eurostat recommends for the ECR denominator the use of the SEEA-CF air emission accounts.

- Another choice is which types of greenhouses gases to include. The OECD and B&V include all greenhouse gases. Eurostat recommends to focus on CO2 emissions from fuel combustion only. Currently, the environmental accounts of the Netherlands does not have the distinction between process and combustion related emissions. As ETS does not seem to make this distinction either, we are not convinced excluding process emissions would be conceptually sound. However, we removed in our ECR estimates the CO2 emissions from biomass combustion.

In line with Eurostat (2024b) the focus in this paper is on CO2 emissions. Our argument for doing so is that in the case of the Netherlands taxes seem to address either fossil fuel use or CO2 emissions. To our knowledge there is no tax addressing the emissions of other types of greenhouse gases so we can safely assume that the ECRs of methane and nitrous oxide are zero. By focusing on CO2 only, the numerator and denominator of the ECR are strictly comparable.

Figure 3
Greenhouse gases according to IPCC and SEEA-CF definitions, amounts in billion kilograms of CO2 equivalents, reference year 2022.



*) In correspondence with our ECR calculations, biomass combustion is excluded from the SEEA-CF based recording of CO2 emissions.
source: Statistics Netherlands

The choice of numerator is decisive for the kind of sectoral breakdown one may pursue. The OECD (ii) and B&V (iii) follow the IPCC definition and by doing so the logical breakdown, as exposed in their publications, is by the various emission domains such as agriculture, electricity, industry, buildings and transport.

Eurostat advocates the compilation of ESRs based on SEEA and in that case the ISIC is used to present sectoral details.

IPCC emission reports and SEEA emission accounts are complementary and so are the two corresponding ECR approaches. For greenhouse gas emissions their concordance is well explained by Eurostat.[2] A useful feature of the SEEA-based accounting approach is that the domestic and international activities of water and air transport activities of resident companies are brought into scope. For the Netherlands, the SEEA-based ECRs of both transport industries

[2] Greenhouse gas emission statistics - air emissions accounts - Statistics Explained (europa.eu)

are below 10 euros (see the results in Sector 3 below). Both transport activities belong to the largest Dutch carbon energy consumers.

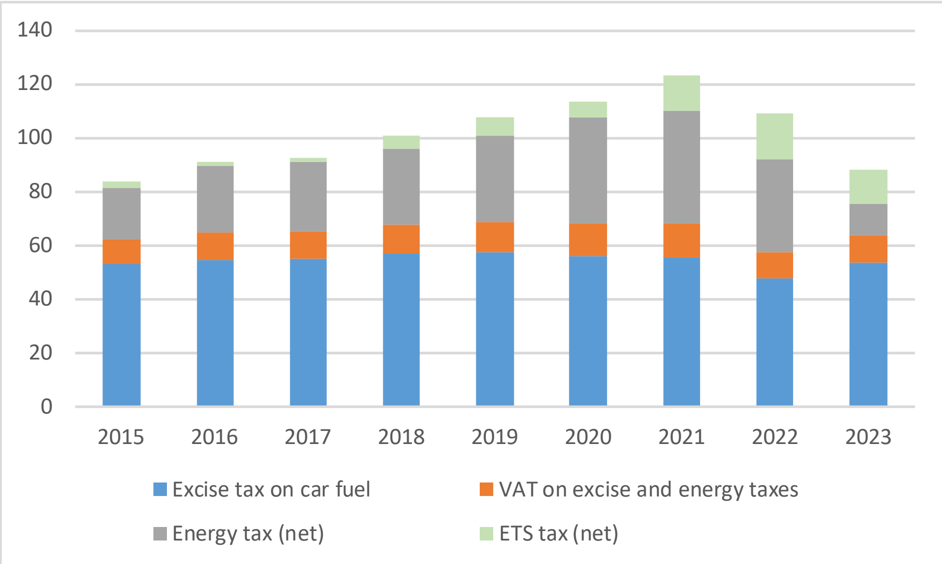
The 2023 data on SEEA-based CO_2 emissions as used in our ECR estimates are tentative and extrapolated based on IPCC emissions data for 2022 and 2023 which were already available on the website of Statistics Netherlands when drafting this paper.

3. The results

3.1 Macro developments

According to our calculations, the average ECR of the Dutch economy increased from 84 euros per metric ton of CO2 in 2015 to 123 euros in 2021 (converted to a 2023 price level). The main cause of the increase in ECR was the increase of the energy tax rates on gas. In the last two years, due to lower excise tax rates on car fuel in 2022 and the energy price compensation in 2023, the ECR fell back to a level of 88 euros in 2023. Please be aware that the ETS taxes are net of ETS permits distributed for free. In figure 4 the subsidy related to price compensation in 2023 is subtracted from the energy tax. Without this subsidy, the ECR in 2023 would have reached a value of 107 euros per metric ton of CO2.

Figure 4
Effective carbon rates at the level of the Dutch economy: producers and household consumers, in euros per emitted ton of CO2 (converted to a 2023 price level).



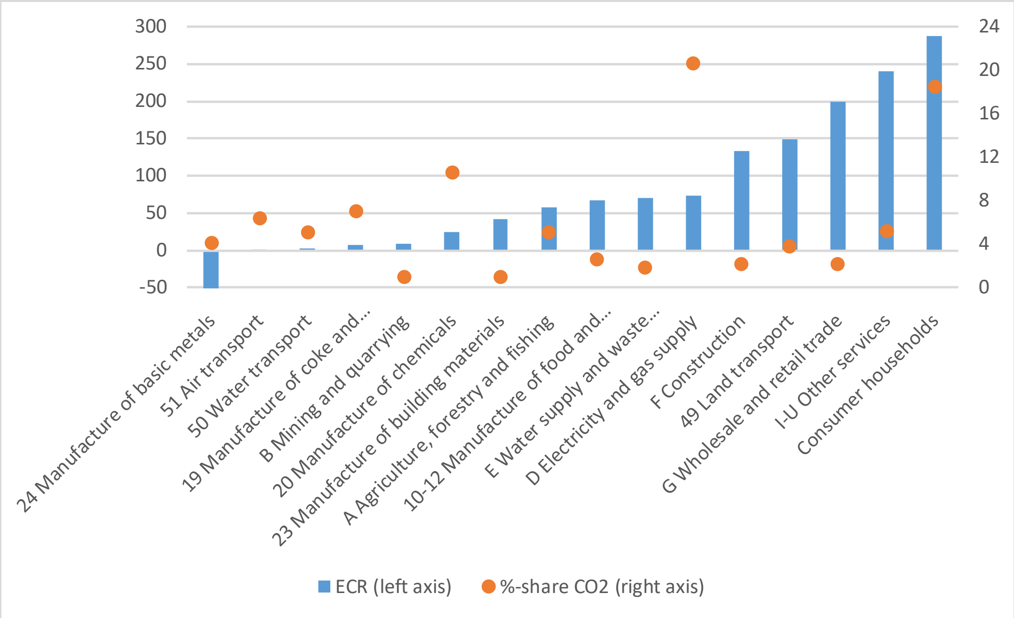
source: the Dutch national and environmental accounts and own calculations.
The ETS figures are based on net taxes (taxes minus subsidies)
The price compensation in 2023 is subtracted from energy taxes.

3.2 Developments at industry branch level

One objective of this paper is to calculate ECRs also at the level of industries and household consumers. The expectation is that, in this way, differences in these rates are revealed between the various categories of CO2 emitters in the Dutch economy. The discussion on fossil fuel subsidies is addressing a situation in which significant amounts of CO2 emissions are not, or are hardly, taxed while other CO2 polluters are confronted with substantive tax rates.

Figure 5 confirms the existence of a wide variation of ECRs in the case of the Netherlands. We prefer presenting in this figure the year 2022 instead of 2023 as the results of the latter year are still provisional. On the left end side we find industries which are hardly taxed while on the right end side we observe ECRs above a hundred euros. The ECR of consumer households in 2022 reaches 288 euros. The orange dots in figure 5 indicate the size of an industry in terms of their shares in CO2 emissions released in 2022 by the Dutch economy. The first four industries on the left end side are good for almost 24 percent of all CO_2 emissions at tax rates far below 10 euros per ton of CO_2.

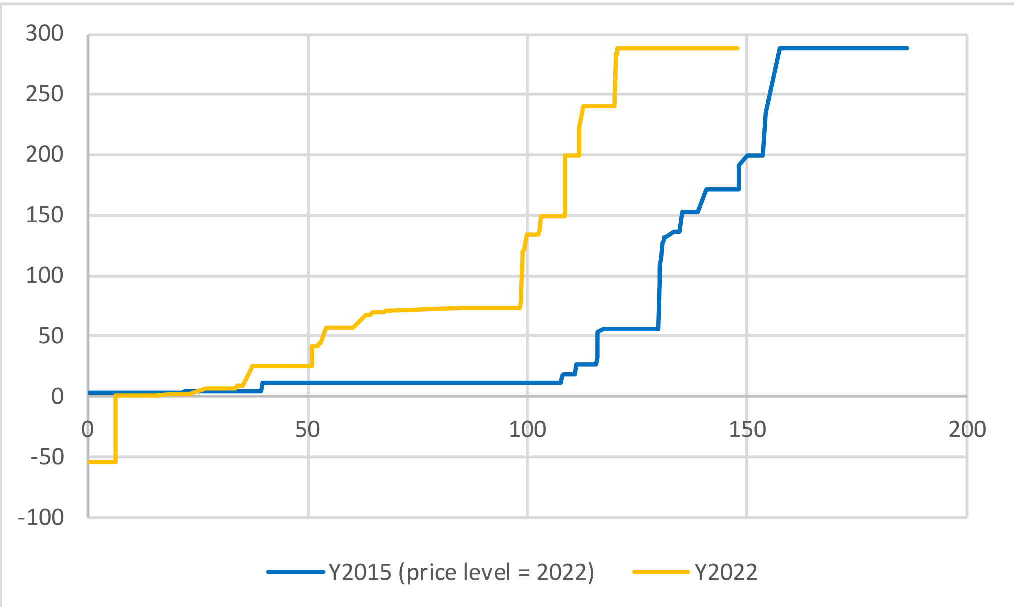
Figure 5
ECRs of those industries (and consumer households) with a CO_2 emissions share larger than one percent, year 2022. Left axis: euros per ton CO_2. Right axis: percentage share of CO_2 emissions



source: own calculation based on data from Statistics Netherlands

Figure 6 compares the carbon prices in 2022 with those of 2015, adjusted for inflation. Again, the industry branch specific ECRs are ranked according to their size. Industries with the lowest (or even negative) tax rates are found at the left end of the figure while industries with the highest ECRs are found at the right end side. With the help of annual consumer price indexes, the 2015 tax rates are converted to an 2022 average price level.

Figure 6
Real differences in effective carbon rates among the various industries and consumer households in the Dutch economy, x-axis: billion kg of CO_2 (cumulative),
y-axis: ECRs in euros per ton of CO_2, ranked in size



source: own calculation based on data from Statistics Netherlands

The good news is that CO2 emissions have been curbed from 186 (in 2015) to 148 billion kilograms of CO2 in 2022, a reduction of 20%. Another positive outcome is that in the period 2015-2022, and measured in real terms, carbon prices have increased substantively for a wider range of industries.

Perhaps a less favorable outcome is that the first 50 billion kilograms of CO2 emissions are in 2022 still only modestly taxed with rates still far below 50 euros per ton. And the first 35 tons of CO2 are taxed below 10 euros per ton. Still, these results are an improvement compared to the 2015 situation when more than 100 billion kilograms of CO2 were taxed below a rate of 20 euros (converted to a 2022 price level).

Based on data from the Dutch Emissions Authority we estimated that in 2022 the basic metals industry receives on balance a CO2 subsidy of 50 euros as in this industry the freely obtained permits surpass the amounts of CO2 emissions.

Box 2
Why does the basic metals manufacturing industry show negative ECRs?

The free allocation of ETS allowances in the EU is based on performance benchmarks and production data of similar types of ETS installations. Less performing installations are stimulated to improve their energy and emission efficiency while the top performers may receive more allowances than needed to compensate their emissions. The ECR of the Dutch basic metals manufacturing industry is negative but there is reason for this outcome. The largest producer in this industry outsources the transformation of residual gases to another producer where it is used to generate electricity. This transformation also generates CO2 emissions. The allocation mechanism of free allowances is based on a 'standard' steel manufacturing installation in which the residual gases are processed onsite. The statistical implication of this arrangement is that while all free allowances are assigned to the basis metals manufacturing industry, the corresponding CO2 emissions are partly assigned to this industry and for the remainder, those related to the transformation of residual gases, to the electricity supply industry.

Box 3
What is in case of the Netherlands the highest possible ECR?

In the Netherlands the excise taxes on car fuel and the energy tax on gas are the largest contributing taxes to ECRs. In the case of consumer households the magnitude of both taxes is further amplified by the presence of value added taxes. The tax rate per unit of CO2 of petrol is higher than that of diesel. The significance of taxes on petrol and on natural gas is illustrated in the example below. The data refer to the year 2022.

	Natural gas	Petrol
Energy tax (€/m3), first (highest) bracket	€ 0,36	
Excise tax (€/liter)		€ 0,82
Value added tax on excise and energy taxes (21%)	€ 0,08	€ 0,17
Tax per unit of product	€ 0,44	€ 0,99
CO2 emission factors (CO2/m3 or liter)	1,779	2,233
Tax per kg of C02	€ 0,24	€ 0,44
Tax per 1000 kg of CO2	€ 244,86	€ 444,33

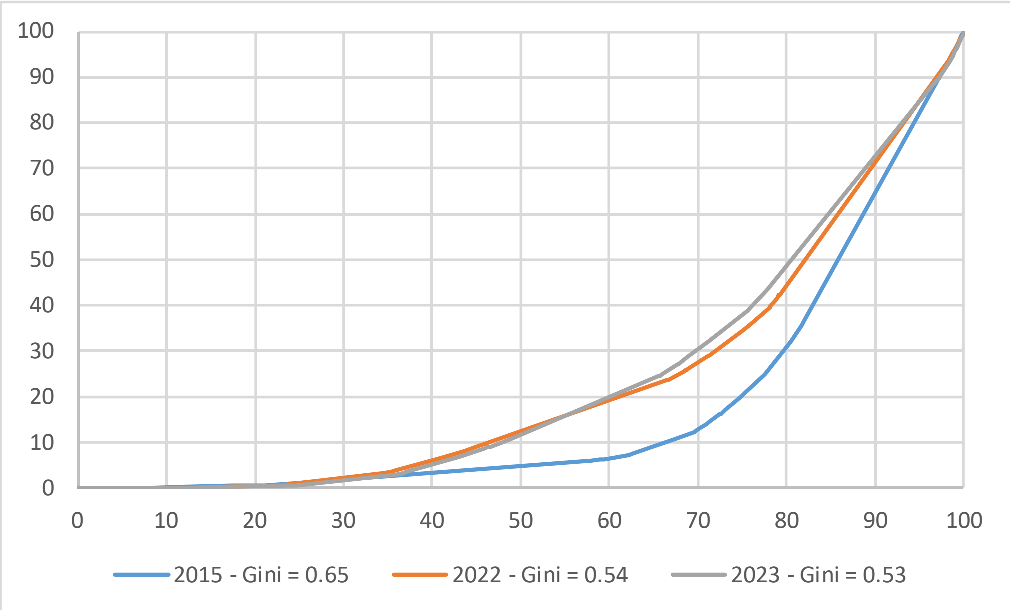
The tax rate per metric ton of CO2 resulting from petrol combustion (€444.33) is 80 percent higher than that of natural gas (€244.86). In other words, a household consuming no other fossil energy products than petrol would face an ECR of almost 450 euros. Theoretically, a producer in the highest tax bracket and under the ETS could face at maximum an ECR of 245 (energy tax on gas) + 81 (permit price) = 326 euros. In other words, an amount of 450 euros per metric ton of CO2 is probably the highest possible rate in 2022. The highest estimated ECR in 2022, the one for consumer households, equals 288 euros.

The five industry branches with the lowest ECRs in 2022 are the basic metals manufacturers, electrical equipment manufacturers, water and air transporters and the manufacturers of petroleum products. With the exception of electrical equipment manufacturers, the other four are all significant CO2 emitters.

The five industry branches with the highest ECRs are land transport, wholesale and retail trade, other services and consumer households. Figure 6 shows that in real terms the ECRs of consumer households were in 2015 and 2022 almost of equal size.

In figures 5 and 6 we aggregated the results of a range of services industries into 'other services'. For the small CO2 emitters in this group, the individual ECRs as derived from the national account (numerator) and environmental accounts (denominator) may be prone to minor mismatches, leading occasionally to less credible ECRs.

Figure 7
Lorenz curves in which the cumulative shares in CO2 emissions are linked to the cumulative shares in taxes on CO2 emissions.



source: own calculation based on data from Statistics Netherlands

Another way to look at differences in carbon taxation throughout the economy is by way of so-called Lorenz curves in which the cumulative amounts of CO2 emissions are linked to the cumulative amounts of taxes on these emissions. The smallest tax contributors are found at the left end side of the figure, the largest at the right end side. The results are scaled to a hundred so the graph represents in both dimensions cumulative percentage shares. The Gini coefficients referred to in Figure 7 represent a measure of inequality. A coefficient of zero indicates equal ECRs for all CO2 emitters. A rate of one means one emitter pays all taxes while all the others are exempted. The rates presented in figure 7 indicate reasonable amounts of inequality in the case of the Netherlands, however, over time this situation is improving.

One significant development in de 2015-2022 period is the increasing ECRs for the electricity producers which are induced by the payments for ETS emission permits. This contributed to the 11 percent point decline in the Gini coefficient between 2015 and 2022. Ironically, introducing a subsidy on CO2 emissions for those facing high ECRs while lead to decreasing inequality as well. The small decline in the Gini coefficient between 2022 and 2023 is triggered by the gas price compensation in 2023 of which households benefit the most. However, this levelling effect was partly counterbalanced by additional subsidies resulting from freely submitted ETS emission permits.

3.3 The ECRs of the largest CO2 emitters in the Netherlands

Figure 8 below presents the outcomes of the eight largest CO2 emitters in the Dutch economy. The letters and number in the titles of figure 6 refer to NACE codes used by Eurostat. Figure 8 presents seven types of industries and households. In 2023 these eight activities are together responsible for more than three-quarters of all CO2 emissions generated by the Dutch economy in that year. Consumer households come second in terms of amounts of CO2 emitted, after the energy supply industry. The manufacturers of chemicals are together the third largest group of emitters in the Dutch economy.

Figure 8
The ECRs of the eight largest CO2 emitting activities in the Netherlands, converted to 2023 prices. Please be aware of the scale differences in each of the graphs, left (CO2 emissions in billion kg) and right (ECRs in euros per metric ton of CO2)

Figure 8 confirms the substantive differences in ECRs among the various economic activities. Consumer households are in recent years on average confronted with ECRs around 300 euros. Such ECRs are a magnitude higher than those found for the other seven largest CO2 emitting producers of which the ECRs in 2023 vary between -90 and 76 euros. Not only the energy tax rates of small scale natural gas consumers, such as households, are the highest, households also pay VAT on their energy and fossil fuel taxes.

The CO2 emissions of water and air transport activities remain almost untaxed which is the outcome of international regulations. Recently the Netherlands introduced a flight tax for (non-transfer) passengers departing from Dutch airports. Following Eurostat guidance, as the flight and not the aviation fuel represents the tax base, the flight tax is out of scope in our ECR calculations.

The manufacturing industries still benefit from free emission permits which has a lowering effect on their ECRs. The ETS in the EU at present is particularly targeting the electricity supply sector and as a result this industry is confronted with increasing ECRs over time, reaching a value of 76 euros in 2023. This ECR increase coincides with a substantive reduction of CO2 emissions from the electricity producers in the 2015-2023 period.

4. Conclusions and suggestions for further work

One objective of this paper is to show that effective carbon rates (ECRs) are an effective way to measure carbon pricing. The ECRs seem to be a sound statistical answer to the public demand for data on fossil subsidies. The ECRs calculated on an industry-by-industry basis bring into scope the tax exempted and discounted uses of fossil fuels in the Dutch economy, which lead for some industries to low, or even negative, ECRs. These low ECRs are particularly found in industries with above average fossil energy input, and subsequently, relatively high CO2 output.

The paper reviews the discussion on the types of taxes that should be brought into scope of the ECR's numerator. We adopted in our estimates for the Netherlands the guidance provided by Eurostat, however we made the following two adjustments:

- adding the non-deductible VAT on excise taxes and energy taxes;
- a modified recording of ETS related taxes (and subsidies) as the SNA recording conventions seem less suitable for ECR calculations.

Whatever, the outcome of this discussion, we welcome an internationally harmonized tax list for ECRs.

Although we understand the logic behind Eurostat's narrow selection of ECR taxes, in the case of the Netherlands a number of additional tax categories is equally addressing climate change abatement policy. Examples are the energy tax on electricity and the taxes on purchases and ownership of vehicles with combustion engines. The Dutch energy tax on electricity use is only indirectly linked to CO2 emissions and not to the full extent. However, how to assign the taxes on fossil fuel generated electricity use to CO2 emissions at the stage of power generation is not straightforward.

Even though the base of the tax on new vehicle purchases in the Netherlands takes into consideration the carbon efficiency of the vehicle (emitted CO2 per driven kilometer), it requires a number of analytical steps to assign this tax to emissions resulting from driving a car. In other words, in descriptive (official) statistics, the narrow Eurostat definition seems to make sense. However, in additional analytical steps one may pursue broadening the scope of ECRs.

Another issue, not addressed in the Eurostat guidance, is the recording of *explicit* subsidies on fossil energy use or CO2 emissions. In the case of the Netherlands, and in our calculations, we subtracted the following two kinds of subsidies from the ECR's numerator:

- The market value of freely allocated ETS permits;
- The government induced price compensation for gas in 2023 which is in the Dutch national accounts recorded as a subsidy on products (electricity and gas).

In other countries one may find similar kinds of explicit subsidies which require attention in the compilation of ECRs.

Concerning the ETS's denominator, the recommendation of Eurostat is to select the subset of CO2 emissions from the air emissions accounts that is associated with fossil fuel combustion (use side). In response, we have excluded the CO2 emissions from biomass. However, we do not understand the reason behind excluding also CO2 emissions from industrial processes as these seem to be equally taxed in the EU ETS. This issue may require further examination.

The OECD and B&V bring all greenhouse gases into scope. We would argue this extension is particularly appropriate in countries where also emissions of methane, nitrous oxide or any other greenhouse gas, are directly taxed.

We do not think that ECRs should either follow IPPC or SEEA definitions as we believe both have their merits and can be used in a complementary way. For the calculation of ECRs for different industries and households we recommend SEEA definitions because of its consistency with the national accounts framework, including its data on taxes minus subsidies.

Finally, we have shown that in the case of the Netherlands the ECRs of household consumers are often higher than those of many of the producers. However, expanding taxes on the producers' greenhouse gas emissions may have repercussions for consumer prices as producers may try to adjust their sales prices accordingly. So-called input-output analyses may be helpful to investigate the possible effects of changes in ECRs on consumer prices. We are considering addressing this analysis in our future work.

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