



Estimating cost of Emissions Trading Scheme permits for use in calculating Effective Carbon Rates

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Philip Krantz

+46 10 479 41 58

philip.krantz@scb.se

Maya Spencer

+46 10 479 41 61

maya.spencer@scb.se

Abstract

This paper examines methods for estimating total and industry-level costs associated with payments for ETS-permits use in the calculation of Effective Carbon Rates. The analysis accounts for both freely allocated permits and permits acquired on the secondary market. A method adjusting for freely allocated emission permits is developed, and emissions permit deficits, defined as the volume of emissions that must be covered through permit purchases, are calculated by economic activity (NACE) for the Swedish economy. Examining data from the official ETS-transaction log (now the Union Registry) shows that the vast majority of permits purchased by Swedish companies are traded on the secondary market rather than obtained through government auctions. This finding highlights the importance of explicitly accounting for secondary market transactions when estimating ETS-related costs. Based on these insights, a method for calculating ETS payments, taking both primary market prices and secondary market prices into account is developed and discussed. Furthermore, approaches for capturing the actual price paid for ETS permits on the primary and secondary markets are examined and compared. The paper also reviews relevant data sources in terms of availability and quality, compares the advantages of different estimation methods and addresses timing issues arising from the gap between the time of surrendering permits and the timing of the emissions to which those permits relate.

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1 Introduction

The work presented in this paper was carried out as part of a Eurostat-funded project from 2024 undertaken by Statistics Sweden with the objective to produce national estimates of effective carbon rates (ECR) as part of the reporting on Potential Environmentally Damaging Subsidies (PEDS).

This paper covers the work and findings of the following project objectives:

1. Improve and update measurement methods for Effective carbon rates (ECR)
2. Analyse methods and data sources for measuring emission permits traded on the EU Emission Trading System (EU-ETS) secondary market

More specifically, the main body of work related to the first objective focused on the inclusion of ETS permit costs alongside other environmental taxes in the calculation of effective carbon rates. The research aimed to further refine the estimation of ETS permit costs incurred as a result of fossil fuel combustion. Given the substantial share of emissions allowances that are distributed without payment under the EU ETS, particular attention was devoted to assessing how free allocations should be accounted for when estimating ETS-related costs

We considered methods and data sources for incorporating the secondary market in the ETS variable by way of a literature review and transaction analyses using the Union Registry. The vast majority of general allowances purchased by Swedish installations proved to be purchased on the secondary market, illustrating the importance of accurately depicting the structures and processes of the trading system in our statistics.

2 Background

The Effective Carbon Rate (ECR) is a carbon pricing metric reported as part of Eurostat's Potential Environmentally Damaging Subsidies (PEDS) that measures the cost borne by economic agents per unit of CO₂ emitted from fossil fuel combustion. Within PEDS, the ECR is calculated as the ratio of taxes levied on fossil fuels and CO₂ emissions from fossil fuel consumption. For reporting purposes, the ECR is aggregated by economic activity and fuel type and presented as the Average Effective Carbon Rate (AECR), which represents the average price of fossil fuel combustion in the economy (Eurostat, 2022). The calculation of ECR is described by the following simplified equation and calculated by industry and fossil fuel type:

Eq. 1
$$ECR = Total\ taxes / Emissions\ (CO_2)$$

$$Total\ taxes = Energy\ tax + Carbon\ tax + ETS\ payment$$

Data on emissions from fossil fuel combustion used in the ECR calculation are taken from the Air Emissions Account (AEA). Taxes used in the calculation of ECR consists of CO₂ taxes and energy taxes derived from the production of Environmental Taxes by Economic Activity (ETEA), but also include costs incurred from payments for emission allowances within the EU Emissions Trading System (EU ETS). Here, ETS payments refer to the money paid for emissions by installations subject to the EU ETS, as defined in the guidance material for the PEDS compilation (Eurostat, 2022).

It should be clarified that the calculation of ETS payments, as included in the ECR in PEDS, differs from government revenue from ETS primary auctions. There are two main reasons why government auction revenue is not indicative of the total cost of ETS permit purchases by companies covered by the EU ETS. First, auction revenues are based on allowances allocated to Member States and sold through EU-wide auctions. These auctions are open to all ETS participants, meaning Swedish government revenue includes revenue from sales to companies outside Sweden (European Commission et al., 2015). Therefore, it does not represent the total payments made by Swedish companies, nor does it indicate their participation in primary auctions. Secondly, Swedish companies may also purchase allowances on the secondary market, where prices may be different from the original price paid when the allowance was first auctioned on the primary market. This means that the total cost of companies participating in the ETS will most likely diverge from the government auction revenue. This issue is further discussed and examined at length in chapter 3.3.

The current method is restricted to payments for European Union Allowances (EUA) and does not include payments for Aviation allowances (EUAA) due to lack of data availability. However, an increase in the scope of ETS payments to cover EUAA may be incorporated in the future.

3 Method

3.1 Calculating ETS payments

The method for measuring costs associated EU-ETS in the context of calculating ECR has been revisited and revised. The method used for calculating costs from ETS payments in Sweden's previous PEDS Grants report (Grants call ESTAT-2020-PA8- E-ENVACC) did not consider the large share of allowances that are allocated to industries for free. Instead, it calculated the cost based on the estimated share of emissions covered by the EU ETS for each industry multiplied by the primary market price of EUA permits. This means that previous estimates were based on total surrendered allowances, regardless of whether these allowances were paid for by the emitter or given to the emitter for free. To better capture the cost imposed on emitters from fossil fuel combustion, the new method aims to only capture allowances that are being paid for by Swedish companies in the emissions trading system.

Whereas the previous method relied on industry-level data on total verified emissions, the new method requires detailed micro-level data that shows the amount of free allocation and total verified emissions for each installation covered by the EU ETS. This allows for calculating each installations allowance deficit, meaning the difference between verified emissions and amount of free allowances. Hence, the deficit equals the amount of emissions that the installation needs to cover by purchasing additional allowances. The deficit needs to be calculated for each installation to capture the total cost of allowances. This is because the industry as a whole may have a surplus in allowances from free allocation even though individual installations within that industry have deficits that should be included in the estimation of total ETS payments.

The method for calculating total allowance deficit, i.e. the difference between yearly verified emissions and free allocation, is described by Eq.2. Totals for each industry, by NACE code, is calculated by summing the deficit of each installation (i) and year (y).

Eq. 2
$$ETS\ deficit_{NACE,y} = \sum (Verified\ emissions_{i,y} - Free\ allocation_{i,y})$$

where: $Verified\ emissions_{i,y} > Free\ allocation_{i,y}$

The main data source for identifying installations covered by ETS is derived from the Swedish Environmental Protection Agency (EPA). The EPA publishes yearly data on each installation covered by EU-ETS, including total reported emissions and free allocation by installation (Swedish EPA, 2025). The same data source, hereafter referred to as the ETS coverage dataset, was used previously but instead relied on industry-level aggregates. An additional benefit of using installation-level data is that it allows for a correct NACE-aggregation, whereas the Swedish EPA's industry-aggregates were not fully translatable into NACE categories. After collecting the data, each installation was assigned a NACE code using data from the Union Registry (n.d.) together with complementary company data from the Swedish Business Register.

One of the challenges in implementing this data into the ECR calculation is that the data from the Swedish EPA include emissions from processes other than fossil fuel consumption, whereas ECR only includes emissions and costs associated with fossil fuel consumption. To deduct the part of the ETS payment that is associated with fossil fuel consumption, the ETS deficit is multiplied by the share of total emissions that comes from fossil fuel combustion in the AEA. The use of AEA data to calculate the ratio of fossil fuel combustion as a share of ETS payments is one of the proposed methods found in the PEDS guidance material (Eurostat, 2022). However, as mentioned in the material, this method assumes that the share of emissions from fossil fuel combustion is the same for installations subject to ETS as for installations that are outside the ETS. This assumption may affect the result, especially for industries where ETS coverage is lower.

After calculating the total ETS deficit by industry using data from the Swedish EPA, it is combined with allowance auction price data to calculate ETS payments. The process is described in the following simplified equation.

Eq. 3
$$ETS\ payments = ETS\ deficit\ (tCO_2e) \times EUA\ price\ (SEK/tCO_2e)$$

Primary auction price data is gathered from the European Energy Exchange (EEX) (2025) and converted to SEK using exchange rate data from Sweden's Riksbank (n.d.).

Figure 1 shows the change in estimated total ETS payments over time, before and after deducting free allowances and adjusting to the share of emission from fossil fuel combustion. Here, the price is calculated based on average yearly auction price on the primary market. The change in the calculation method has led to a significant decrease in

estimated total ETS payments. This is due to both the deduction of free allowances, as well as the adjustment made to only include fossil fuel consumption and thereby excluding other emissions, such as emissions from industrial processes. Estimates using the new method for calculating ETS payments cover 2016–2023. Data covering 2008–2015 can be estimated and supplied at a later date.

Figure 1: ETS payments, original and revised estimate 2016–2023

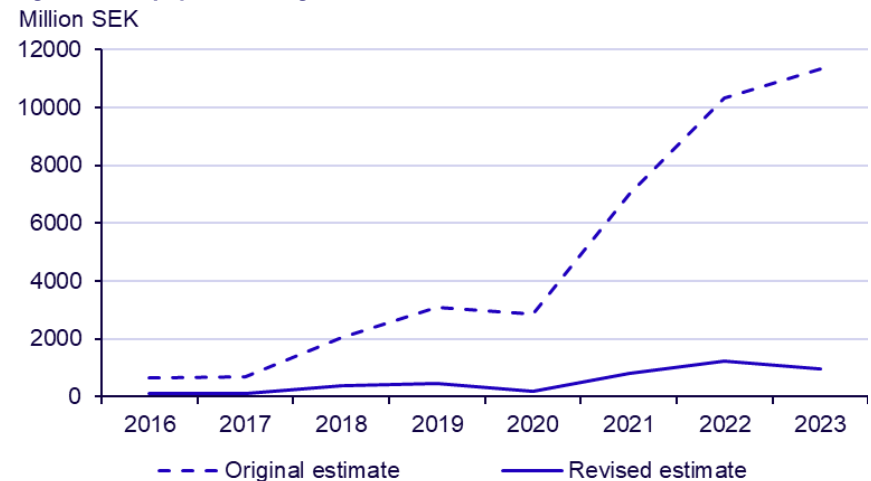
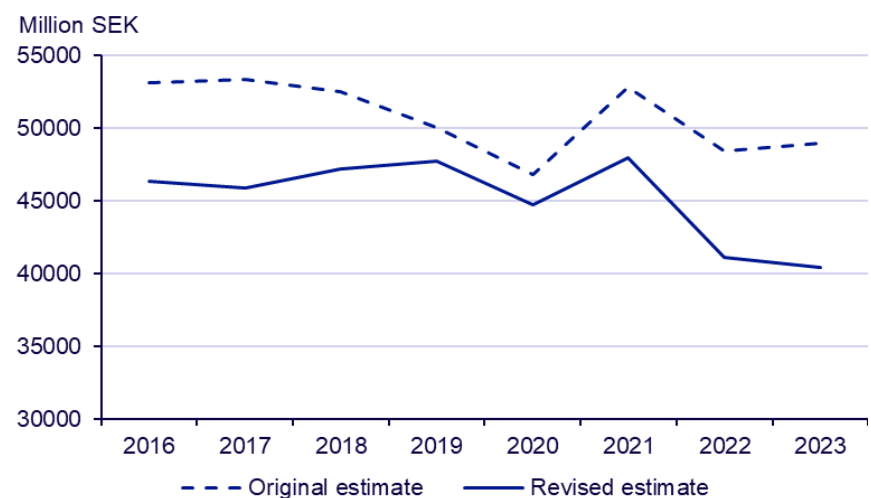


Figure 2 shows the change in ‘total taxes imposed on fossil fuel combustion’, the numerator in the calculation of Effective Carbon Rate (ECR), before and after the implementation of the new method for calculating ETS payments. The change in method can be seen to have a very large effect on ‘total taxes’ in the ECR calculation and should be more reflective of the true cost of companies in the ETS.

Figure 2: Total taxes on fossil fuel combustion, before and after revised method for estimating ETS payments, 2016–2023



3.2 ETS and National Accounts consistency

According to United Nations Statistics Division (2022) ETS permits are to be viewed within The System of National Accounts (SNA) as a tax that is prepaid by corporations until it is received by the government at accrual. In the case of ETS permits, this means that it should be recorded when the emissions occur. However, they suggest the date of surrendering the permit as a proxy for this. The Manual on Government Deficit and Debt (Eurostat, 2023) outlines the practical implementation of recording ETS permits in line with ESA2010 and also suggest recording payments related to ETS permits in the year of surrender. This is consistent with the view of ETS payments being a tax on production. The manual notes the potential problem of a time delay with respect to the time of the actual pollution occurring, however, they conclude that it is a reasonable proxy as long as the differences in emissions from year to years can be assumed to be small and that the time lag is consistent.

In Sweden's previous PEDS Grants report's method for ECR, estimated ETS payments were recorded as an emission tax for the year the emissions occur. For consistency with ESA2010, we investigated the effects of reporting ETS payments with a one-year lag in the present report, similarly to how they are reported in Sweden's national accounts. The numerator of the ECR equation can thus be described with the following equation:

Eq. 4 $Taxes\ fossil\ fuel\ combustion_t = ETS\ payments_{t-1} + fossil\ fuel\ taxes_t$

Eurostat suggests that the reported value should be based on the value at its issuance. This makes sense when viewing ETS payments as a tax on production consistent with ESA2010. The market price after issuance has no effect on government revenue and is therefore not relevant in this view. However, since ECR in PEDS aims to capture the cost imposed on emissions from fossil fuels, the price at issuance and the resulting government revenue are not necessarily representative of the price paid by the installations subject to the ETS. The government revenue in relation to ETS are from auction revenues, and there is no implicit guarantee that this revenue comes from Swedish installations purchasing ETS permits at auctions (i.e., the primary market). We return to this question in our examination of the ETS secondary market in Ch. 3.3.

For the purpose of capturing the correct time period for both auction price at issuance and market price, i.e. the price in the secondary market, we made an adjustment to the time frame from which average prices are calculated. Our previous method for calculating average prices on the primary market was to record the average per calendar

year. This does not consider the actual period between issuance and surrender of ETS permits in which permits are continually auctioned and traded on the primary and secondary market. According to European Parliament & Council of the European Union (2023), the deadline for surrendering permits was April 30th each year up until 2024 when it was postponed to September 30th. Based on the assumption that permits for a particular emission year are continually bought and traded up until date of surrender, an alternative approach is proposed. This approach entails calculating average prices based on the date following the previous compliance cycle's surrender deadline and including prices up until the subsequent date of surrender. This adjustment makes the prices used for estimating the ETS-variable more reflective of reality.

Table 1 shows the difference in calculated average primary market prices when calculated from the first auction after the last surrender date to the last auction date before the surrender deadline in the following year. The data covers 2012-2023 when the surrender date was April 30th. Average yearly prices are thus calculated from all auctions from May 1st (t) to April 30th (t+1). This is compared to our previous method of calculating the price based on all auctions in a calendar year. Price data is gathered from EEX (2025) and prices in SEK are calculated using monthly average exchange rates published by Sveriges Riksbank (n.d.)

Table 1: Average primary market EUA auction price, 2012-2023

	Jan-dec			May-Apr		
Year	SEK	EUR	Auction dates	SEK	EUR	Auction dates
2012	62.0	7.1	2012/01/03 - 2012/12/18	47.2	5.5	2012/05/08 - 2013/04/30
2013	37.9	4.4	2013/01/07 - 2013/12/17	42.8	4.9	2013/05/02 - 2014/04/29
2014	53.8	5.9	2014/01/07 - 2014/12/16	58.6	6.3	2014/05/02 - 2015/04/30
2015	71.2	7.6	2015/01/08 - 2015/12/17	62.5	6.7	2015/05/05 - 2016/04/29
2016	49.7	5.2	2016/01/11 - 2016/12/16	48.5	5.1	2016/05/03 - 2017/04/28
2017	55.8	5.8	2017/01/09 - 2017/12/15	75.1	7.7	2017/05/02 - 2018/04/30
2018	159.6	15.6	2018/01/08 - 2018/12/17	227.7	21.9	2018/05/03 - 2019/05/02
2019	261.7	24.7	2019/01/07 - 2019/12/16	261.2	24.5	2019/05/02 - 2020/04/30
2020	255.6	24.4	2020/01/07 - 2020/12/14	313.2	30.4	2020/05/05 - 2021/04/30
2021	549.1	54.1	2021/01/29 - 2021/12/20	679.0	66.2	2021/05/04 - 2022/04/29

	Jan-dec			May-Apr		
Year	SEK	EUR	Auction dates	SEK	EUR	Auction dates
2022	852.1	80.2	2022/01/10 - 2022/12/19	894.5	82.1	2022/05/02 - 2023/04/28
2023	958.9	83.6	2023/01/09 - 2023/12/18	857.8	74.5	2023/05/02 - 2024/04/30

Source: EEX (2025) and Sveriges Riksbank (n.d.)

Table 2 shows the effect on the numerator in ECR, *Taxes imposed to fossil fuel combustion*, when ETS payments are recorded in the year of surrendering the permits, i.e., the ETS-variable having a one-year lag from the current year's emissions (t-1) and compares this to when the numerator is calculated with the ETS payments recorded in the year of the emissions they are supposed to cover occur (t). The former alternative (t-1) is equal to how ETS payments are recorded in Sweden's national accounts, founding our rationale for making this adjustment. In addition, Table 2 also shows the effect of calculating prices using average yearly prices on the primary market per calendar year (Jan-Dec) as compared to calculating prices using average yearly prices per compliance cycle (April_(t)-May_(t+1)).

To conclude, we performed two adjustments to the time frames related to the ETS-variable of ECR – (1) recording the payments in the year of surrender – for consistency with Sweden's national accounts which records ETS-related revenues similarly, and – (2) adjusting the time frame for calculating average yearly prices of ETS permits – allowing for results closer to the actual costs imposed on installations subject to the ETS. Although ETS payments in ECR here deviate from how they are registered in national accounts, i.e. the cost imposed on Swedish installations as opposed to Swedish government revenue from auctions, we argue that the former alternative adds more value when the aim is to include the “money paid by the installations” as stated in the guidance material for the PEDS compilation (Eurostat, 2022).

Table 2: ECR numerator, i.e. taxes imposed on fossil fuel combustion (mSEK), 2021-2023

Year	2021	2022	2023
ETS payments (t), avg price (Jan-Dec)	48 743	41 767	41 111
ETS payments (t-1), avg price (Jan-Dec)	48 158	41 325	41 389
ETS payments (t), avg price (April-May)	48 930	41 828	41 009
ETS payments (t-1), avg price (April-May)	48 205	41 513	41 450

3.3 Incorporating the ETS secondary market

The second objective was to investigate the possibility of integrating data on secondary market trading within the EU-ETS. The task was undertaken by the way of a literature review on the structures and processes pertaining to the primary and secondary market, followed by analyses of transactions registered in the Union Registry (n.d.a) (formerly known as the ETS Transaction Log), which together formed the basis for a proposed way of calculating ETS whilst taking free allocation, primary and net secondary market purchases into account. The impact on the ETS variable in ECR from considering the secondary market is presented as such.

Literature review

Emission unit allowances (EUAs) are released to the market in two ways – free allocation and auctioning – where the latter represented almost 52% of the total supply in 2021 (Nissen et al., 2023). The auctioning process takes place on the common auction platform, which since year 2012 has been the Leipzig-based EEX for the large majority of countries participating in the EU-ETS. Up until year 2020, the London-based ICE Futures Europe (ICE) served as the opt-out platform for the UK. Germany and Poland have also opted out of the common auction platform, however still using EEX to auction their share of allowances. Parties eligible to bid at the primary market auctions include ETS operators (compliance buyers), banks and investment firms acting on behalf of compliance buyers (European Commission et al., 2015).

The EU-wide transaction log, Union Registry, tracks the allocation, issuance, holding, transfer, surrender and accounting of EUAs, along with other unit types such as aviation allowances (EUAs), certified emission reductions (CERs) and emission reduction units (ERUs). Transaction data is available with an approximate 3-year lag, which at the time of writing means that we can analyse transactions between January 2005 and September 2022. Auctioned EUAs are transferred from the EU Auction Account managed by the European Commission to the successful bidder via the auctioning platforms' clearing systems. In the case of EEX, European Commodity Clearing AG (ECC) acts as clearing house (European Securities and Markets Authority, 2022). They first receive auctioned EUAs in one of their three Auction Delivery Accounts (ECC AG Auction Delivery Account EU, ECC AG Auction Delivery Account PL, or ECC AG Auction Delivery Account DE), which thereafter transfers auctioned EUAs to ECC's holding account, ECC AG Handel. It is the holding account that subsequently delivers auctioned EUAs to the successful bidder. In the case of ICE, ICE Clear Europe Ltd served as clearing house, receiving auctioned EUAs in their Auction Delivery Account (UK Auction Trust Account – DECC), which thereafter

transferred EUAs to the successful bidder via ICE's various Clearing Members and their accounts (ICE Futures Europe, n.d.).

On the secondary market, companies may trade EUAs amongst one another. Beyond compliance users and financial institutions acting on behalf of clients, other parties active on the secondary market include traders, brokers, additional clearing houses and central securities depositories. Most of the trading on the secondary market is in the form of derivative contracts, including EUA futures, as opposed to the purchasing of physical EUAs on the spot market (European Securities and Markets Authority, 2022). Derivative contracts are offered by trading venues which again includes EEX, along with ICE Endex and Nasdaq Oslo. In 2021, the former two venues held around 85% and 15% of the market share respectively, whilst the latter held around 0.03% (ibid.). Secondary market transactions are cleared by the same clearing systems for EEX and ICE as with their primary market transactions, meaning that the transferring account name will show up as ECC AG Handel or ICE Clear Europe in the Union Registry.

Transaction analyses

To integrate data on EUA trading on the secondary market, the details gained from the literature review were employed in transaction analyses in the Union Registry. The intent was to differentiate between EUAs reaching Swedish installations by purchases on the primary and secondary market, respectively, as well as to estimate the number of EUAs leaving Swedish installations as sales on the secondary market. The latter factor is deemed critical in measuring the actual cost imposed on installations within a given compliance cycle, given that allowances issued in the third trading period were valid indefinitely, meaning that they can be banked in operator holding accounts and saved for future usage (European Commission, n.d.b). Operators could furthermore exchange international credits acquired from outside the EU-ETS for EUAs up until year 2021 (Swedish Energy Agency, 2025).

The dominant position of ICE Endex to EEX's secondary market transactions, and the many times greater primary auction volumes of EEX's to ICE's, formed the basis of an assumption that all incoming transactions from ECC AG Handel were the result of primary market purchases. Furthermore, ICE's clearing process, either transferring units via their Clearing Members or directly to bidders via the ICE Europe Clearing Limited, complicated the tracking of their auction deliveries. Neither the literature review nor the transaction analyses yielded a reliable way to trace the path of unique EUAs reaching Swedish operator accounts in the Union Registry. The registry only provides details on unique transactions, such as the transferring/acquiring *account holder* (typically the operator names), transferring/acquiring *account name* (typically the installation name, or a name indicating that it's the operator's "trading account"), the transferring/acquiring

account's country, as well as the number of emission units transferred and the dates of the transaction. When observing transactions reaching Swedish installations, this means that the transferring counterpart may be a middleman instead of (1) another company selling their surplus allowances, or instead of (2) ECC AG Handel or ICE Clear Europe Ltd (the aforementioned auction houses' clearing accounts). This complicates the process of understanding how many EUAs installations truly purchase at the primary and secondary market, but the potential consequences are mitigated by the fact that banks purchasing EUAs at auctions on behalf of clients take a brokerage fee, which could be argued to move the transaction into the realm of the secondary market. Namely, all companies subject to the ETS have the option to participate in auctions directly themselves.

Regarding secondary market prices, weekly averages are available with a 6-month lag from ICE via the International Carbon Action Partnership (ICAP) website (n.d.). The downloadable data covers January 2019 through mid-2025. Annual average primary market prices are presented in the European Environment Agency's annual report named "Trends and projections in the EU-ETS". The numbers presented in the annual reports are consistently consistent with the average primary market prices available from both EEX and ICE auction records, further supporting our conclusion that ICE's data on secondary market prices is a viable source. The annual (calendar year) primary and secondary market prices are presented in Table 3 for the years where both were available.

Table 3: Average primary and secondary market prices, 2021-2023 (calendar year)

Text	Primary market		Secondary market	
	SEK	EUR	SEK	EUR
Year				
2019	261.7	24.7	263.6	24.9
2020	255.6	24.4	257.3	24.5
2021	549.1	54.1	539.1	53.1
2022	852.1	80.2	861.8	81.1
2023	958.9	83.6	980.1	85.4

Source: EEX (2025) and ICE (via ICAP, n.d.)

The Union Registry allows for filtration by, for example, transaction type (e.g., allocation or surrender); transferring account details; and acquiring account details. However, while available by drilling through unique transactions, there is no option to filter for specific unit types (i.e., EUAs, EUAAs, CERs, or ERUs) at the search stage. The filter settings used for compiling the transaction lists representing primary market purchases, secondary market purchases, and secondary market sales, are available below. The timescale was limited to 2019 to

2022 given the aforementioned temporal constraints in secondary market price data and Union Registry transaction logs.

Primary market purchases:

- Acquiring registry: Sweden
- Transferring Account Name: ECC AG Handel
- Timescale: January 2019–September 2022

Secondary market purchases:

- Acquiring registry: Sweden.
- Transfer type: 10 (internal transfer of unit/supplementary program transaction), 3 (external transfer of unit between registries).
- Supplementary transaction type: 0 (no supp).
- Timescale: January 2019–September 2022

Secondary market sales:

- Transferring registry: Sweden.
- Transfer type: 10 (internal transfer of unit/supplementary program transaction), 3 (external transfer of unit between registries).
- Supplementary transaction type: 0 (no supp).
- Timescale: January 2019–September 2022

The transaction lists were exported to Excel where further processing occurred with the intention to exclude transfers of unit types other than EUAs to the greatest possible extent. Transactions between accounts held by the same operator were also excluded, as suggested by Lehmann and Schleich (2025), given that these can assumed to result of organisational motives as opposed to trade-related ones. The full Excel processing scheme is available in Appendix B.

Net primary purchases are already given at this stage, as installations do not sell permits on the primary market. In contrast, net secondary purchases had to be calculated at the installation level, subtracting secondary market sales from secondary market purchases for each installation where a deficit was noted by Eq. 2.

The proposed way forward was now to create a weighted average EUA price, considering the fraction of units purchased at the primary market (PM), the fraction of units purchased at the secondary market (SM), and the average primary and secondary EUA prices, for all of those installations where an ETS deficit was evident by Eq. 2. The weighted average price (W.A.P) was calculated using equations 5 and 6 and was subsequently to be employed in the calculation of the ETS variable.

Eq. 5

$$1 = \frac{\text{No. of units purchased (PM)}_{i,y} + (\text{No. of units purchased (SM)} - \text{No. of units sold (SM)})_{i,y}}{\text{Total deficit}_{i,y}}$$

Eq. 6

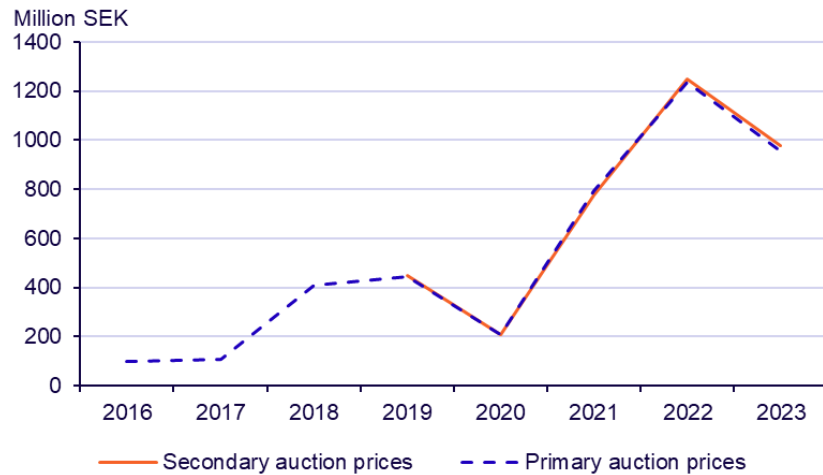
$$W.A.P = \frac{\text{No. of units purchased (PM)}_{i,y}}{\text{Total deficit}_{i,y}} \times \text{Price}_{PM,y} + \frac{\text{Net purchase (SM)}_{i,y}}{\text{Total deficit}_{i,y}} \times \text{Price}_{SM,y}$$

An initially surprising finding of the transaction analyses was that only one Swedish operator seems to have acquired EUAs on the primary market between years 2016 and 2022. A relatively low primary market participation could however be observed overall whilst assessing the EEX's EUA Primary Market Auction Reports. For example, in 2021, there were on average 23 participating bidders per primary market auction, and for that same year, we could identify ECC AG Handel transactions to 114 unique account holders using the Union Registry. This means that the primary market prices, and thereby the W.A.P, are of marginal relevance for the ETS variable in Sweden's case. The relevance could however be greater for a country like Germany, which in 2023 accounted for more than half of the successful bids at EEX EUA auctions (European Securities and Markets Authority, 2024).

We also experienced some difficulties with the results of the equation preceding W.A.P (Eq. 5), where the net number of units purchased on the primary and secondary market divided by the total deficit equals 1 as long as operators only purchase EUAs to cover their ETS deficit. Whilst applying this fraction at the installation- or company-level, it appeared that many Swedish operators seemingly either sell or purchase many more EUAs on the secondary market than what we had assumed, leading to results far below 0 or far above 1 for a large share of installations or companies. Applying the fraction at NACE-level yielded better looking results, but the process is evidently surrounded by some data or methodology issue requiring further attention.

Taken together, the specific objective of incorporating the secondary market in the ETS variable was satisfied to the extent possible for the time being, by simply multiplying the ETS deficit by secondary market prices for all years where we had data on both. This entails a practical assumption that all EUAs purchased by Swedish installations were purchased on the secondary market, although, in reality, one company was found to purchase allowances on both markets. The impact of incorporating secondary market prices in the ETS estimation is illustrated in Figure 3.

Figure 3: ETS payments, primary and secondary market, 2016-2023



4 Results

This section covers the finalised ECR estimates incorporating the changes described in the previous subchapters. Here, two different versions of the ECR are presented; one including ETS payments based on primary market prices, and another based on secondary market prices. Both are compared to the original method based on data reported in the latest PEDS questionnaire.

Both versions of the revised ECR include method for calculating ETS payments after deducting free allocation of permits (Eq. 2). ETS payments are reported with a one-year lag and calculated using prices based on average price between subsequent dates for surrendering the permits, as described in chapter 3.2.

Table 11 and 12 present the Average ECR (AECR) estimates by NACE and year. Table 11 reports the results based on primary-market ETS prices, while table 12 provides the corresponding estimates using secondary market prices. As previously noted in ch 3.2, the revised ETS payment data cover the period 2016–2023. With ETS payments being reported with a one-year lag, this means that estimates in table 11 cover 2017–2023. Because ETS payments are reported with a one-year lag, the AECR estimates presented here span the years 2017–2023. Due to lack of available ETS price data, as noted in ch 3.3, the AECR estimates presented in table 12 span the years 2020–2023. Comparing the two shows us that the differences are minimal, which is in line with the previous results presented in figure 3.

Table 11: Average ECR with primary auction ETS prices, by NACE, 2017-2023

	2017	2018	2019	2020	2021	2022	2023
Households as final consumers	2 360.4	2 464.6	2 507.7	2 533.0	2 585.4	2 374.7	2 484.1
Corporations (Total NACE)	1 166.3	1 222.3	1 348.9	1 510.5	1 483.3	1 351.8	1 309.0
NACE A Agriculture, forestry and fishing	1 629.0	1 747.4	1 729.9	1 641.1	1 674.7	1 398.6	1 024.2
NACE B Mining and quarrying;	1 254.6	1 479.3	1 496.2	1 806.9	2 111.0	2 208.3	2 306.1
NACE C Manufacturing	812.7	941.6	1091.8	1075.8	1066.7	1 312.6	1 361.2
NACE D Electricity, gas, steam and air conditioning supply	308.8	419.2	799.8	1403.4	785.0	1 221.6	712.4
NACE E Water supply, sewerage, waste management and remediation activities	2 111.2	2 162.1	2 112.6	2 045.6	2 121.3	1 825.2	1 786.6
NACE F Construction	1 910.2	1 941.5	1 928.2	1 923.0	1 973.5	1 657.2	1 695.1
NACE G Wholesale and retail trade; repair of motor vehicles and motorcycles	2 034.7	2 111.2	2 144.4	2 163.4	2 224.1	1 994.7	2 072.3
NACE H Transportation and storage	914.7	903.7	937.2	1332.0	1314.4	783.9	730.4
NACE I-U Services (except wholesale and retail trade, transportation and storage)	2 144.6	2 222.2	2 254.0	2 270.6	2 418.8	2 159.7	2 230.9
Average (Corporations + households)	1 533.8	1 589.3	1 703.9	1 846.9	1 822.6	1 642.9	1 636.5

Table 12: Average ECR with Secondary market ETS prices, by NACE, 2020-2023

	2020	2021	2022	2023
Households as final consumers	2533.0	2585.4	2374.7	2484.1
Corporations (Total NACE)	1509.8	1483.8	1353.0	1306.1
NACE A Agriculture, forestry and fishing	1641.1	1674.7	1398.6	1024.2
NACE B Mining and quarrying;	1806.0	2112.5	2208.3	2305.2
NACE C Manufacturing	1075.2	1067.8	1315.1	1354.9
NACE D Electricity, gas, steam and air conditioning supply	1384.4	787.6	1231.5	692.1
NACE E Water supply, sewerage, waste management and remediation activities	2045.6	2121.3	1825.2	1786.6
NACE F Construction	1923.0	1973.5	1657.2	1695.1
NACE G Wholesale and retail trade; repair of motor vehicles and motorcycles	2163.4	2224.1	1994.7	2072.3
NACE H Transportation and storage	1332.0	1314.4	783.9	730.4
NACE I-U Services (except wholesale and retail trade, transportation and storage)	2270.6	2418.8	2159.7	2230.9
Average (Corporations + households)	1 846.4	1 823.0	1 643.8	1 634.4

5 Concluding discussion

This paper presents methodological improvements to the estimation of Effective Carbon Rates (ECR), with a focus on ensuring accurate inclusion of costs incurred by the EU emission trading system (EU ETS). It is our view that the revised calculation method of deducting free allowances and calculating ETS permit deficit per installation is a more accurate representation of the cost of fossil fuel combustion for companies covered by the EU ETS.

The main difficulty faced when implementing this method was allocating the ETS coverage dataset from the Swedish EPA to specific NACE codes as well as allocating the ETS payment to a specific fuel type. This was addressed by distributing the ETS payments based on share of emissions for each NACE category. However, as previously noted, this assumes that emission share per fuel type is equal across companies inside and outside the EU ETS which is an oversimplification. A more accurate method would be to link specific emission data from AEA to each installation covered in the ETS data from the Swedish EPA. We could however not locate the information necessary to do this. We do however believe that the new method for calculating ETS payments is a significant improvement as compared to the previous method. The revised method leads to significantly lower estimates of the cost of ETS permit and hence lower ECR estimates, as shown in figure 1 and 2. This is to be expected following the exclusion of free permits from the cost calculation.

Ch. 3.2 provided a general overview of the treatment of ETS permits within the framework of SNA and ESA2010. To better align the inclusion of ETS payments in ECR calculations with this framework, we propose two straight-forward adjustments. The first is to report ETS payments in the year of surrendering the permits. This means that ETS payments are included in the ECR estimation with a one-year time lag, which is in-line with the view of ETS payment as a pre-paid tax on production that is first realised upon surrender. It is also consistent with how ETS is reported temporally within national accounts. The second suggested adjustment is to record ETS-prices from the date of issuance until surrendering the permits. As primary auctions are ongoing until the surrender date it seems reasonable to assume that permits are being traded up until the last auction before surrender. This approach may therefore more accurately capture the prices actually paid by ETS-covered companies, since permits can be purchased well into the year after the emissions they are intended to cover have occurred. These two adjustments are easy to implement and do not require any additional data sources or increase the time burden.

The proposed method for incorporating EU-ETS secondary market data in the calculation of ETS payments and ECR was found to be heavily reliant on transactions data from the Union Registry. We encountered a number of obstacles in attaining and processing the required registry data for this purpose, which likely impacted our findings. The lack of certain functions in the registry, such as an option to filter for only EUA unit types, may have impacted the fraction equation's nominator and thereby the fraction result (Eq. 5) to some capacity. Although not too much, seeing as the Union Registry Holdings at the time of analysis (December 2025) largely comprises of general allowances: EUAs (97.56%), followed by a small fraction of aviation allowances (EUAAAs) which account for less than 2%, other units making up the remainder.

The fact that, at least to our knowledge, one cannot trace EUAs to auction deliveries, further comprised an obstacle in reliably estimating the number of units purchased on the primary market. In the present report, we base our estimation on transactions originating from ECC AG Handel, the European Energy Exchange's clearing system account, which may lead to correct conclusions in many cases. The result is however not certain, again due to our inability to trace EUAs to auction deliveries, seeing as the same clearing system is used for secondary market transactions originating at the EEX trading venue where derivative contracts such as EUA futures are traded. A similar issue was discovered whilst attempting to tackle auction deliveries from the UK's opt-out platform, ICE, which delivered auctioned EUAs via a set of clearing members to whom auction participants were required to have an established connection (ICE Futures Europe, n.d.). Estimating Swedish acquisitions on the ICE primary market auctions would thus entail further investigation into the clearing members of ICE Clear Europe, and whether these are, for example, country specific. This could possibly help narrow the array of accounts needed to be assessed as transferring counterparts in Swedish acquisitions of EUAs. Nonetheless, also here is the primary and secondary markets' use of the same clearing systems a complicating factor, one that the possibility to trace EUAs to auction deliveries could help amend. Without a way to trace EUAs to auction deliveries, we could not think of a way to estimate auction-originating EUAs without large manual efforts.

The fraction where installation or company net purchases on the primary and secondary markets are divided by their total deficit (Eq. 5) would equal to 1 if installations or companies only purchased allowances to cover for their deficit. As described in Ch. 3.3, this was not the case. Our thoughts as to why the results were able to stretch below 0 (indicating a net negative purchase of EUAs whilst having a deficit) largely revolve around the fact that companies, i.e. account holders in the union registry, can save unused EUAs for future use. This

could mean that Swedish companies for whom the fraction result was negative have a number of banked EUAs in their holding accounts, enabling them to sell more than what they purchase whilst the data on annual free allocation, verified emissions and resulting deficits composed by the Swedish EPA point to the companies having a deficit during the year in question. Other possible reasons for fraction results skewed beyond 0 or 1 are briefly described below:

- **ETS coverage dataset issue:** The dataset on free allocation, verified emissions and resulting deficits composed by the Swedish EPA might lack some installations, bringing the company-level fraction above 1 as the company might have purchased EUAs to installations not present in the ETS coverage dataset.
- **Intra-organisational transfers:** The hypothetical scenario where a company “trading account” transfers the EUAs needed to cover the deficit to the installation account. The installation account had earlier sold its share of free allocation for a profit. Given that our data processing scheme excluded intra-organisational transfers, the resulting net purchased amount at installation level risks becoming negative. This error source could be amended by calculating the net purchased number on company-level, although this would depend on our ability to match every installation under a company with a row in the ETS coverage dataset.
- **Deletion of allowances:** ETS operators with a deficit may purchase and subsequently delete/cancel excess allowances as a climate measure, effectively “tightening the cap”. Neither allowance deletion (supplementary transaction type 90) nor allowance cancellation (transaction type 4) were included in our filtering scheme, as detailed in Ch. 2.4. This might have skewed some of our fraction results above 1.

We recommend that any member country that wishes to incorporate trading on the EU-ETS secondary market in their ETS variable take these error sources into account whilst working on the fraction (Eq. 5). The W.A.P methodology could be of particular interest for countries where primary market purchases are more common, such as Germany, which in 2023 accounted for 57% of all primary market purchases (European Securities and Markets Authority, 2024). Instead of relying on the ETS coverage dataset, an alternative route could have been to compile a complete list of free allocation, match it to installation-level verified emissions (AEA), and calculate the deficits ourselves. This would have bypassed the issue of not being able to match a large share of rows when merging the ETS coverage dataset with our net SM dataset. Solving the issues described would entail a leap forward in establishing a more accurate estimation of ETS-related costs.

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Appendix A

Table A1: Average ECR with primary auction ETS prices (mSEK), 2017-2023

NACE	2017	2018	2019	2020	2021	2022	2023
A01	1581.3	1731.2	1705.5	1613.2	1652.8	1401.3	1006.9
A02	1833.7	1917.6	1890.1	1790.8	1824.0	1516.1	1124.1
A03	139.3	138.3	149.3	150.6	152.1	127.7	130.1
B05-B09	1254.6	1479.3	1496.2	1806.9	2111.0	2208.3	2306.1
C10-C12	975.5	1171.7	1274.5	1280.9	1436.7	1710.5	1719.5
C13-C15	1421.1	1663.3	1698.6	1718.1	1802.7	1774.2	1806.9
C16	1831.5	1812.3	1854.4	1845.2	1902.2	1607.7	1607.5
C17	1305.4	1538.4	1755.5	1815.5	2270.6	3788.9	3225.6
C18	1831.6	1840.6	1826.5	1941.9	2041.5	1841.0	1928.8
C19	80.0	86.8	155.0	146.1	111.9	194.6	300.4
C20-C21	1117.3	1456.3	1765.9	1510.0	1970.5	2405.1	2585.0
C22	1170.9	1353.8	1412.4	1411.8	1640.1	1672.1	1724.4
C23	767.8	964.7	1122.6	1140.9	1217.3	1404.2	1479.5
C24	1137.7	1393.0	1513.2	1562.1	1678.9	1989.5	2234.3
C25	1481.7	1632.5	1715.7	1731.0	1830.2	1717.4	1776.7
C26	1884.7	1947.0	1966.1	1979.0	2052.2	1781.3	1883.3
C27	1647.2	1743.3	1805.8	1820.5	1873.3	1695.8	1753.9

NACE	2017	2018	2019	2020	2021	2022	2023
C28	1503.4	1622.2	1685.5	1694.1	1736.6	1662.9	1707.1
C29	1238.5	1407.2	1495.3	1501.2	1557.3	1618.1	1639.0
C30	1722.7	1821.6	1866.9	1952.9	2079.2	1908.4	1898.7
C31-C32	1706.4	1876.2	1808.1	1823.0	1708.0	1537.3	1755.4
C33	1929.1	1976.6	1972.1	1957.8	2020.0	1710.7	1743.1
D35	308.8	419.2	799.8	1403.4	785.0	1221.6	712.4
E36	1898.6	1929.8	1915.8	1891.1	1946.3	1617.7	1638.1
E37-E39	2135.1	2186.7	2136.6	2068.0	2146.1	1852.1	1808.4
F41-F43	1910.2	1941.5	1928.2	1923.0	1973.5	1657.2	1695.1
G45-G47	2034.7	2111.2	2144.4	2163.4	2224.1	1994.7	2072.3
H49	1850.6	1887.4	1887.7	1872.8	1931.5	1624.6	1660.5
H50	700.3	476.8	560.2	846.6	837.3	568.7	419.7
H51	0.9	0.9	1.0	2.5	1.9	1.5	0.6
H52-H53	1804.2	1799.8	1827.5	1830.0	1894.7	1593.3	1618.0
I55-I56	2084.7	2151.7	2188.8	2213.4	2293.1	2053.7	2139.4
J58	2181.7	2283.5	2326.1	2381.2	2510.4	2313.7	2451.3
J59-J60	2251.4	2348.4	2395.0	2421.3	2492.6	2248.6	1984.5
J61	1917.8	1968.6	1985.7	2042.4	2119.4	1867.6	1930.3
J62-J63	2158.4	2263.5	2323.6	2391.6	2498.7	2304.7	2422.2
K64	18 469.9	33 800.0	35 021.8	39 749.0	63 994.4	62 599.0	59 505.8
K65	2157.6	2213.0	2238.2	2313.6	2476.0	2283.4	2418.1
K66	2078.8	2194.6	2259.6	2327.0	2463.6	2234.8	2413.8
L68	1892.4	1944.6	2028.7	1933.5	2022.5	1841.5	1895.6
M69-M70	2089.2	2182.4	2226.3	2293.5	2442.3	2230.9	2366.1
M71-M72	2053.0	2111.0	2139.3	2160.6	2248.6	1986.0	2070.8
M73-M75	2212.1	2293.3	2317.8	2341.8	2416.5	2180.3	2276.7
N77	1963.9	2062.1	2063.0	2096.6	2243.0	1981.2	2074.6
N77	2002.1	2047.4	2061.1	2062.4	2130.9	1842.7	1906.8
N78-N82	2200.2	2286.3	2314.3	2358.1	2432.5	2197.0	2306.7
P85	2235.4	2342.7	2385.5	2423.5	2501.6	2285.1	2384.8
Q86	2179.4	2280.8	2326.6	2364.4	2460.4	2243.5	2361.7
Q87-Q88	2115.6	2179.1	2185.2	2189.5	2243.6	1861.1	1802.3

NACE	2017	2018	2019	2020	2021	2022	2023
R90-R93	2235.1	2313.1	2342.3	2349.8	2402.4	2141.3	2217.0
S94-T98	2282.5	2493.4	2489.6	2522.8	2562.3	2400.4	2485.8
U99	1581.3	1731.2	1705.5	1613.2	1652.8	1401.3	1006.9
Households	2360.4	2464.6	2507.7	2533.0	2585.4	2374.7	2484.1
Average AEER	1 987.0	2 376.0	2 447.4	2 570.4	3 114.4	2 978.4	2 939.6

Table A2: Average ECR with secondary auction ETS prices (mSEK), 2020-2023

NACE	2020	2021	2022	2023
A01	1613.2	1652.8	1401.3	1006.9
A02	1790.8	1824.0	1516.1	1124.1
A03	150.6	152.1	127.7	130.1
B05-B09	1806.0	2112.5	2208.3	2305.2
C10-C12	1280.5	1438.6	1713.5	1716.0
C13-C15	1718.1	1802.7	1774.2	1806.9
C16	1845.0	1902.5	1608.0	1607.5
C17	1815.2	2271.6	3791.5	3221.1
C18	1941.9	2041.5	1841.0	1928.8
C19	145.6	112.7	197.7	290.7
C20-C21	1509.3	1971.5	2409.1	2577.8
C22	1411.8	1640.1	1672.1	1724.4
C23	1139.0	1220.1	1406.4	1474.7
C24	1561.7	1679.9	1991.5	2230.2
C25	1730.9	1831.2	1718.0	1775.2
C26	1979.0	2052.2	1781.3	1883.3
C27	1820.5	1873.3	1695.8	1753.9
C28	1694.1	1736.6	1662.9	1707.1
C29	1500.9	1557.6	1620.2	1636.3
C30	1952.9	2079.2	1909.7	1898.3
C31-C32	1823.0	1708.0	1537.3	1755.4
C33	1957.8	2020.0	1710.7	1743.1
D35	1384.4	787.6	1231.5	692.1
E36	1891.1	1946.3	1617.7	1638.1
E37-E39	2068.0	2146.1	1852.1	1808.4

NACE	2020	2021	2022	2023
F41-F43	1923.0	1973.5	1657.2	1695.1
G45-G47	2163.4	2224.1	1994.7	2072.3
H49	1872.8	1931.5	1624.6	1660.5
H50	846.6	837.3	568.7	419.7
H51	2.5	1.9	1.5	0.6
H52-H53	1830.0	1894.7	1593.3	1618.0
I55-I56	2533.0	2585.4	2374.7	2484.1
J58	2213.4	2293.1	2 053.7	2 139.4
J59-J60	2381.2	2510.4	2 313.7	2 451.3
J61	2421.3	2492.6	2 248.6	1 984.5
J62-J63	2042.4	2119.4	1 867.6	1 930.3
K64	2391.6	2498.7	2 304.8	2 422.1
K65	39 749.0	63 994.4	62 599.0	59 505.8
K66	2 313.6	2 476.0	2 283.4	2 418.1
L68	2 327.0	2 463.6	2 234.8	2 413.8
M69-M70	1 933.5	2 022.5	1 841.6	1 895.5
M71-M72	2 293.5	2 442.3	2 230.9	2 366.1
M73-M75	2 160.6	2 248.6	1 986.0	2 070.8
N77	2 341.8	2 416.5	2 180.3	2 276.7
N77	2 096.6	2 243.0	1 981.2	2 074.6
N78-N82	2 062.4	2 130.9	1 842.7	1 906.8
P85	2 358.1	2 432.5	2 197.0	2 306.7
Q86	2 423.5	2 501.6	2 285.1	2 384.8
Q87-Q88	2 364.4	2 460.4	2 243.5	2 361.7
R90-R93	2 189.5	2 243.6	1 861.1	1 802.3
S94-T98	2 349.8	2 402.4	2 141.3	2 217.0
U99	2 522.8	2 562.3	2 400.4	2 485.8
Households	1 613.2	1 652.8	1 401.3	1 006.9
Average AECR	2 570.0	3 114.7	2 979.0	2 938.5

Appendix B

Complete data processing scheme in Excel

The data cleaning scheme involved the exclusion of some accounts where we with certainty could claim that transactions to or from them were not trade related. Other accounts were excluded due to only ever transferring Certified Emission Reduction units, as opposed to EUAs. We attempted to clean out any transfers of EUAs by employing **Excel Formula 1** seen below. The transaction IDs of any transactions highlighted as result of this filtration had to be cross-checked using the Union Registry, ensuring we only filter out actual transactions of EUAs.

Transfers to and from accounts “Statens Energimyndighet” and “Sveriges kontoföringsmyndighet” were excluded due to not being tied to trade related transfers. The former is Sweden’s Energy Agency which acts as the administrator of Sweden’s national holdings, while the latter mainly receives units under the transaction type “4 (cancellation), which go into the account “frivillig annullering” (voluntary cancellation). “Account 2050 – CERs” was observed to only ever be involved in transfers of CERs.

Outgoing (sales):

- Transferring registry Sweden
- Transaction type: 10, 3
- Supp type: 0
- **Unit type:** EUA (see how EUAs were excluded below)
- **Exclude intra-group:** where source account holder = destination account holder
- **Exclude accounts:**
 - Statens Energimyndighet
 - 2050 – CERs
 - Sveriges kontoföringsmyndighet

- **Exclude registry:** CDM

Incoming (purchases):

- Acquiring registry Sweden
- Transaction type: 10, 3
- Supp type: 0
- **Unit type:** EUA (see how EUAs were excluded below)
- **Exclude intra-group:** where source account holder = destination account holder
- **Exclude accounts:**
 - ECC AG Handel (Primary Market purchase)
 - 2050 – CERs
 - Statens Energimyndighet
- **Exclude registry:** CDM

Excel Formula 1:

EUAs cannot be filtered out, the approach is instead to remove all transactions where one counterpart has EUA-related terms in the name, see formula below. Cross-check transaction ID's in Union Registry.

```
=LET(
    termer;
    {"airlines";"airline";"luft";"air";"airway";"airways";"aviation";"aircraft";"aircrafts";"jet"
    };
    harI; SUMMA(OMFEL(--(SÖK(termer; I26)>0); 0));
    harN; SUMMA(OMFEL(--(SÖK(termer; N26)>0); 0));
    OM(ELLER(harI>0; harN>0); "Ja"; "Nej")
)
```