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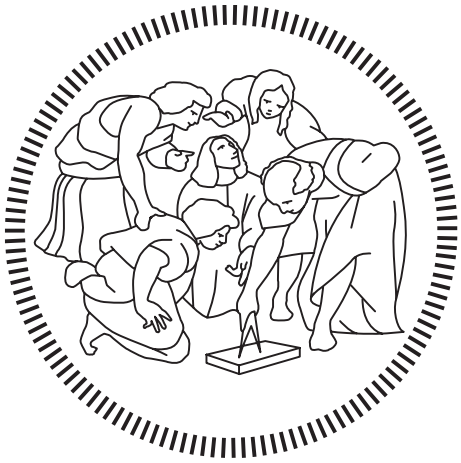

Analysis of the EU - Emission Trading System and its Application in the German and Italian Economy

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Sommario

Numerosi studi hanno dimostrato gli effetti che le emissioni di gas a effetto serra (GHG) hanno sul clima della Terra[1]. Negli ultimi anni questo aspetto è diventato un argomento di preoccupazione per la maggior parte dei governi e molti si sono impegnati a raggiungere la *carbon neutrality* nel prossimo futuro. Gli obiettivi europei per la riduzione delle emissioni sono tra i più ambiziosi e il sistema europeo di scambio delle emissioni (EU-ETS) è uno dei principali strumenti utilizzati dall'Unione Europea per raggiungere questi obiettivi[2]. L'Unione Europea distribuisce sul mercato un certo numero di certificati di emissione (European Union Allowances - EUAs), in parte tramite aste e in parte gratuitamente, secondo precisi criteri di allocazione. Ogni quota equivale al diritto di emettere una tonnellata di CO_2. Si tratta di un meccanismo basato sul mercato, nel senso che le EUA possono essere scambiate liberamente come qualsiasi altra commodity e il prezzo è fissato dal mercato.

L'EU-ETS è il più grande sistema di questo tipo al mondo. Agisce principalmente su due fronti. Il primo consiste nel correggere il sistema economico internalizzando un'esternalità, ovvero le emissioni di gas serra, assegnando loro un costo. Ciò rende i combustibili caratterizzati da alti fattori di emissione relativamente più costosi rispetto alle alternative a minore intensità di carbonio, rendendo più vantaggiosi gli investimenti in decarbonizzazione. Il secondo è la funzione dell'EU-ETS di raccogliere fondi sotto forma di EUAs consegnati ogni anno ad aprile dalle aziende per ogni tonnellata di CO_2eq emessa nell'anno operativo precedente da impianti che rientrano nel sistema di scambio di emissioni. Questi fondi possono essere utilizzati per incentivare la transizione verso un'economia a zero emissioni.

L'obiettivo di questo lavoro è analizzare il funzionamento effettivo del sistema di scambio di emissioni, partendo dalle origini scientifiche e politiche attraverso le quali è stato sviluppato l'EU-ETS, analizzando il suo ciclo di conformità e identificando i principali attori e i loro ruoli. In particolare, si analizza nel dettaglio come le aziende siano tenute a monitorare le proprie emissioni all'interno degli impianti assoggettati a questa misura e si mostra come, a partire dai dati grezzi del consumo di carburante e dalla sua analisi chimica, si calcolino le emissioni di CO_2 per flusso di materiale.

La parte finale del lavoro indaga le differenze tra le implementazioni nei diversi Paesi membri, in particolare Germania e Italia. Attraverso una serie di interviste con esperti dell'EU-ETS con diversi ruoli e provenienti da diverse aziende, il documento identifica le opportunità che si presentano per l'EU-ETS, i suoi punti di forza, i pericoli che ne minacciano

[1] Jim Skea (United Kingdom), Priyadarshi R Shukla (India) et al., «Summary for Policymakers IPCC AR6 WG III».
[2] European Commission, «Delivering the European Green Deal».

il suo sviluppo e le sue debolezze. La tesi discute infine, sulla base di questi ultimi, dei dati resi pubblici e della letteratura esistente, quanto efficacemente l'EU-ETS stia svolgendo il suo ruolo nella decarbonizzazione dell'economia europea. Le interviste hanno dimostrato che gli esperti sono fiduciosi che l'EU-ETS stia già influenzando il processo di decarbonizzazione europeo e che l'EU-ETS sia uno degli strumenti principali per raggiungere gli obiettivi annunciati in materia di azione per il clima. Tuttavia, per raggiungere tali obiettivi è necessario promuovere il processo di decarbonizzazione con altri strumenti, ad esempio come sta facendo la Germania, attraverso un sistema nazionale di scambio di emissioni, o attraverso politiche come l'introduzione della tassonomia europea. È emerso inoltre che la soluzione europea al *carbon pricing* sta diventando un esempio per gli altri Paesi, il lavoro della Commissione europea, il quadro e le metodologie studiate e implementate e testate sono un bene prezioso nella lotta al cambiamento climatico.

Non c'è dubbio che i prezzi molto alti dei crediti di carbonio europei, che il 19 agosto hanno raggiunto un picco di 97,67 euro[3], rendono il mercato di grande interesse per gli investitori. Tuttavia, prezzi così alti per le quote dell'Unione Europea stanno spingendo i gestori degli impianti a uscire dal sistema di scambio di emissioni dell'UE, ad esempio chiudendo caldaie di riserva[4]. Inoltre, le ripercussioni del prezzo elevato delle emissioni di CO_2eq sono assorbite a breve termine dal consumatore finale, poiché i prodotti finali degli impianti EU-ETS tendono a compensare i maggiori costi di produzione vendendo a un prezzo più alto. Questo maggiore onere per il consumatore finale è, come prevedibile, avvertito soprattutto dalle famiglie a basso reddito[5]. Famiglie che stanno già lottando contro l'aumento del costo dei combustibili fossili e l'inflazione crescente.

[3] ICE, «ICE Futures and Options».
[4] Second Appendix, Question 6.
[5] Känzig, «The unequal economic consequences of carbon pricing».

Abstract

Numerous studies have proven the effects that greenhouse gas (GHG) emissions have on the earth's climate. This has, in recent years, become a topic of concern for most governments, and many have pledged to achieve carbon neutrality in the foreseeable future[6].

European emission reduction targets are among the most ambitious in the world and the European Emissions Trading System (EU-ETS) is one of the main tools used by the European Union to achieve these targets[7]. A certain number of allowances are distributed in the market by the European Union (European Union Allowances - EUAs), partly through auctions and partly distributed for free, following precise allocation criteria. Each allowance is equivalent to the right to emit one ton of CO_2 or CO2eq. It is a marked based mechanism, in that EUAs can be traded freely like any commodity, and the price is set by the marked.

The EU-ETS is the largest of such systems in the world. It acts mainly on two fronts. The first one consists in correcting the economic system by internalizing an externality, namely greenhouse gas emissions, by assigning them a cost. This makes fuels characterized by high emission factors relatively more costly than less carbon intensive alternatives, making it more advantageous to invest in green technologies.

The second one is the function of EU-ETS to collect funds in the form of the EUAs delivered each year in April by companies for every ton of CO_2eq emitted in the previous operating year by installations that fall under the emission trading system. These funds can then be used to incentivize the transition to a carbon neutral economy.

Aim of this paper is to analyse how the emission trading system actually works, starting with the scientific and political origins through which the EU-ETS came to be developed and to analyse its compliance cycle and identify its main actors and their roles.

In particular, it explores in detail how the companies are required to monitor their emissions within the facilities in question and shows how, from the raw data of fuel consumption and its chemical analysis, CO_2 emissions per fuel stream are calculated.

The final part of the work investigates the differences between implementations in different member countries, particularly Germany and Italy.

[6] Jim Skea (United Kingdom), Priyadarshi R Shukla (India) e et al., «Summary for Policymakers IPCC AR6 WG III».

[7] European Commission, «Delivering the European Green Deal».

Through a series of interviews held with EU-ETS experts with different roles and from different companies the paper identifies its potential, its strengths, its dangers and its weaknesses [Appendix I-IV].

The thesis finally discusses on the basis of the latter, public data and existing literature how effectively EU-ETS is fulfilling its role in decarbonizing the European economy.

The interviews have demonstrated that experts are confident that the EU-ETS is already affecting the European decarbonisation process and that the EU-ETS is one of the main tools to meet the announced targets on climate action. However, to achieve said targets it is necessary to foster the decarbonisation process with other tools, for example how Germany is doing, through a national emission trading system, or through policies like the introduction of the EU-Taxonomy.

It also emerged that the European solution to carbon pricing is expected is becoming an example for other countries, the work of the European Commission, the framework and methodologies studied and implemented and tested are a valuable asset in the fight against climate change.

There is no doubt that the very high prices the European carbon credits, that on the 19th of August reached a peak of 97,67 euro[8], makes the market of great interest to investors and founds. However, prices this high for European Union Allowances are pushing plant operators to exit the EU-Emission Trading System, for example by shutting down reserve boilers[9]. Moreover, the repercussions of high price on CO_2eq emissions are in the short term absorbed by the final costumer since final products of EU-ETS plants tend to compensate the higher production cost by selling at a higher price. This increased burden on the final consumer is, as can be expected, mostly felt by low-income households[10]. Households that are already struggling with increased cost of fossil fuel and the rising inflation.

[8] ICE, «ICE Futures and Options».
[9] Second Appendix, Question 6.

[10] Känzig, «The unequal economic consequences of carbon pricing».

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Introduction

The papers' objective is to understand how the European Emission Trading System (EU-ETS) is impacting the economies that take part in the emission trading, weather the current implementation is fulfilling its role in the decarbonation of the European economy and finally to determine the major opportunities and risks that the system is facing.

This has been approached in three macroscopic steps, starting with the analysis of the reasons driving EU-ETS and its scientific and political origins, followed by the examination of the inner workings of the EU-ETS compliance cycle, identifying the actors and their roles and the processes that characterise the monitoring, reporting and verification of EU-ETS emissions and ending with an array of interviews with experts that have been working in this field since its conception.

What distinguishes this work from the existing literature is its experienced based approach, aimed to highlight the essential resistances and advantages encountered by the EU-ETS operators.

To give greater value to this work the German and the Italian implementations are compared, being these two economies among the larger emitters in the system.

The interviewed EU-ETS experts have been chosen among both countries, with different roles and from different companies to widen the spectrum of the analysis.

Finally, the results are evaluated considering public data and existing literature to give them an enclosure and support these outcomes.

1. European action against Climate Change

Numerous studies have shown that the anthropogenic contribution to climate change is more than significant. Europe is fighting to reduce its greenhouse gas emissions. In 2021, with the *Fit for 55 Package*, the EU Commission has raised the 2030 greenhouse gas emission reduction target, to 55% compared to 1990.

1.1. The role of the intergovernmental Panel on Climate Change - IPCC

Of great interest for this research are the data collected by the Intergovernmental Panel on Climate Change (IPCC), the worldwide most important research unit on climate changes founded as a United Nations body that counts today 195 member states.

The IPCC studies climate change and, since 1988, has been providing its member states with data and information on the subject, hypotheses, forecasts and models on the development of situations according to the various scenarios envisaged.

It also studies the actions that can be taken with regard to different adaptation, mitigation and emission reduction strategies.

The IPCC in its reports makes the following point: although the environmental situation is now serious, much of it due to human activities, irreparable damage due to global warming can still be avoided.

According to the IPCC's 2021 Report[11], limiting global warming to 1.5° Celsius by the end of the century is still possible, but requires a radical change. While keeping the temperature increase well below 2°C is crucial to avoid the most serious climate impacts. Every fraction of a degree of warming leads to more dangerous and costly consequences. The contribution of politics is crucial, especially if guidelines, directives and interventions come from high-level international contexts. However, it has been decisive in determining greenhouse gas values and numbers, establishing emission markets. The Paris Agreement has gone further, with more countries participating, with targets for mitigation and emission reductions.

A carbon budget has been defined as the amount of carbon dioxide (CO_2) that the Earth could still release into the atmosphere to fall within the 1.5°C limit compared to the values that were found during the pre-industrial period.

While it is true that the planet Earth can absorb a large amount of CO_2 through its terrestrial and marine ecosystems, it is also possible and interesting to calculate the carbon budget, i.e., how much is allowed in terms of new emissions in order not to surpass so called tipping points. Tipping points are defined as those thresholds that if reached would trigger great and mostly irreversible changes in earth's climate system.

There are estimates, for example, regarding the Covid 19 pandemic, which calculate a drop in emissions of 7% on a global scale, due to the containment measures adopted by various governments, while the probably negative effects of wars being fought in different areas of the planet, such as the conflict in Ukraine, have yet to be calculated. Therefore, many factors must be considered that may increase or decrease the amount of greenhouse gas emissions that would theoretically be allowed for the production and energy system. They are priorities, not least because of the decisive values they influence in this calculation, as they can make the crucial difference to achieve the goals of the Paris Agreement.

The risks posed by the IPCC AR6 report relate to multiple scenarios affecting systems and areas of great importance for the balance of the entire planet. Phenomena such as the melting of the polar ice caps, with the consequent rise of the seas, and the acidification of the oceans due to the absorption of CO_2, are now considered to be directly due to anthropogenic causes,

[11] Jim Skea (United Kingdom), Priyadarshi R Shukla (India) et al., «Summary for Policymakers IPCC AR6 WG III».

clearly confirming what was questioned in the previous report, AR5. Government policies-at least those avowedly committed to environmental protection-may not be enough to ensure rapid success in productive sectors that should be pushed harder to limit emissions, including through instruments such as EU-ETS.

IPCC Chairman Hoesung Lee states “We are at a crossroads. The decisions we make now can ensure a liveable future. We have the tools and know-how to limit warming, I am encouraged by the climate actions taken in many countries. There are policies, regulations and market-based instruments that are proving to be effective. If these instruments are scaled up and applied more widely and fairly, they can support deep emission reductions and stimulate innovation […]", mentioning marked based instruments as part of the solution[12].

1.2. Social Cost of Carbon

The latest report from the IPCC states very precisely that climate change mitigation is urgently needed. However, it is not a trivial process to put an economic value on the damage caused by greenhouse gas emissions.

Researchers and modelling experts have provided solutions to this problem.

In the context of this thesis a global study of the problem is more than sufficient, as it is hoped that the European system will serve as an example for the rest of the world. However, one should not forget the geographically heterogeneous distribution of climate damage and the resulting large differences in countries' contributions to the Global Social Cost of Carbon (GSCC).

Through a multilayer model it is possible today to find out the economic costs associated to the damages caused by the emission of one ton of carbon dioxide on a country’s economy.

In the article "Country-level social cost of carbon" published by Katharine Ricke, Laurent Drouet, Ken Caldeira and Massimo Tavoni, the local values of individual countries are estimated, which when added together constitute the GSCC[13]. This is done using climate model projections, empirical estimates of climate-related economic damage and socio-economic projections. Despite being based on pre-2018 data, the estimates show high GSCC values globally with a median exceeding US$ 400/t CO_2eq, which is about five times higher than the current (July 2022) price of a European Union Allowance (EUA). Interestingly, the countries with a higher Country-level Social Cost of Carbon include India, China, Saudi Arabia and the United States[14].

[12] IPCC, «IPCC PRESS RELEASE April 2022».
[13] Ricke et al., «Country-Level Social Cost of Carbon».
[14] Ricke et al., «Country-level Social Cost of Carbon Database explorer».

1.3. European actions

At the time of its establishment, back in 1957, the EEC did not contemplate the environment as a topic in any of the documents produced by its bodies at the time, not until the Paris European Council of 1972 when the first program of action was issued, in which the member states addressed this item together for the first time. However, it was a new international sensibility (in the meantime there had been the *Stockholm Declaration on the Human Environment*), which led Europe to take this first, timid step and immediately, in the following year, to issue the first action program for the environment. With the promulgation of the following two programs, the EEC began to lay the foundations for its own environmental policy. It was initially presented as a top-down policy, with a set of regulations on a few narrow areas, but it has the value to have started controlling the pollution phenomena.

Gradually more important steps forward were taken in 1985 by the Court of Justice ruling on the disposal of waste oils, describing in this act the environmental protection as a "priority aim of the Community'. Two years later the year 1987 was proclaimed the 'European Year of the Environment'. At this juncture, the principles of subsidiarity, damage restoration and prevention were established, as well as three program objectives: environmental protection, rational use of resources and health protection.

The Maastricht Treaty of 1992 presents further advances in defining the European environmental approach: qualified majority voting on environmental issues and the precautionary principle.

Still in those years, the fifth environmental action program was launched[15], which finally prefigures a horizontal approach to the subject, thus involving all the components and reasons that must be considered. The approach changed from sectoral solutions to instead transversal solutions, aiming at a general involvement of companies, citizens, authorities and so on.

With the Amsterdam (1997) and Lisbon (2007) Treaties, environmental protection is considered whenever sustainable development is to be promoted, the focus is set on combating climate change.

From this point on there is a very significant change in strategy: from protection against harmful substances to the struggle to reduce emissions of greenhouse gases, this signals a shift in mentality, being CO_2, the most common GHG, an inert element and not directly dangerous for humans. It is a turning point, at last, European politicians are addressing climate change and there is an awareness of the danger it poses to Europe and humanity.

[15] Official Journal of the European Communities, «Towards Sustainability. A European Community Programme of Policy and Action in Relation to Environment and Sustainable Development».

Previously the focus was on the abatement or capture of toxic substances that are directly harmful to humans, more recently also inert substances that endanger the sustainability of our economy, in the medium/long term, are considered.

In 2010, a ten-year program called 'Europe 2020' was proposed by the European Commission. Based on the relationship between mankind and the environment, the program was aimed at fostering the ecological transition, i.e., transition to a low-carbon economy, using renewable energy sources. The economic priorities identified in this report are: a focus on knowledge and innovation (smart growth); more resource-efficient, greener and sustainable use of resources (sustainable growth); higher employment rate, to increase territorial and social cohesion (inclusive growth)[16].

Five goals are linked to these priorities, such as increasing youth employment, allocating 3 per cent of EU GDP to research and development, reducing emissions by 20 per cent, increasing the share of renewable energy to 20 per cent of the total, and improving energy efficiency by 20 per cent.

One must also remember the 2013 Seventh Union Action Program, which indicated the three priority areas where European action is most needed to protect nature and health from pollution and climate change: biodiversity; low-emission economy and resource efficiency; health and well-being of citizens.

With the idea of combating dangerous climate changes, the Paris Agreement, in 2015, established the global target of striving for global warming below the 2°C threshold, compared to preindustrial age (1950)[17]. Another goal was to provide countries with the means to counter the impact of rising temperatures. The Paris Agreement is the first legally binding agreement on climate change at global level. The EU then subsequently ratified the agreement on 5 October 2016, and it entered into force on 4 November 2016.

The Covid 19 pandemic also had an impact on environmental policies in Europe. The emission levels in the considered period have of great interest: in 2018, against a target of a 20% reduction in emissions compared to 1990, there was a 24% reduction, in 2019 even 31%. This has its causes mostly in the economic consequences of the pandemic, with the suspension and reduction of many economic activities, but it allowed new targets to be set for 2021[18].

[16] European Commission, Europe 2020: the European Union strategy for growth and employment.
[17] European Commission, «Paris Agreement».
[18] European Parliament, «EU progress towards 2020 climate change goals (infographic)».

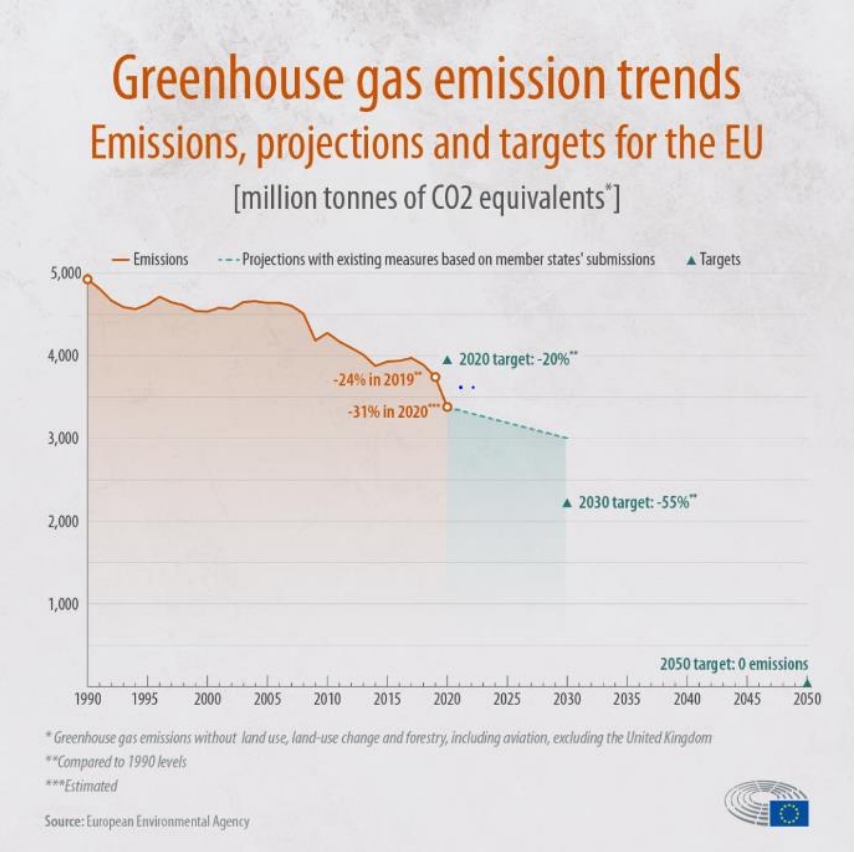


Figure 1. The evolution of greenhouse gas emissions in the EU

The European Parliament's awareness was underlined by its position in December 2020 vis-à-vis the European Commission: The Parliament demanded a stricter 55% and a series of measures to finance the transition in all EU countries. 2021 meant an important change for the European Union in terms of its commitment to the environment. In fact, a binding target enshrined in the 'Fit for '55' package is to reduce emissions by 55% by 2030[19]. The package deals with an overhaul of regulations, with the goal of a European climate neutrality by 2050. In order to finance the Green Deal, the European Commission, in 2020, set up an Investment Plan for a Sustainable Europe, with the aim of attracting public and private investment over the next 10 years, a plan designed specially to favour those regions currently heavily dependent on coal as an energy source.

[19] European Commission, «Delivering the European Green Deal».

2. Introduction to the EU-ETS

The EU-ETS is meant to be one of the main tools of the European Union to combat climate change, it operates in all EU countries plus Iceland, Liechtenstein, and Norway (EEA-EFTA states). It includes around 10,000 installations in the power sector and manufacturing industry, as well as airlines operating between these countries, are subject of the EU-ETS directive and thus must report their emissions compliantly and surrender one European Union Allowance for each ton of carbon dioxide (CO_2 or greenhouse gases expressed in tons of CO_2eq) emitted. This system covers around 40% of the EU's greenhouse gas emissions and is the largest such system worldwide. The graph displayed below shows the percentage quota of the various participating countries on total EU-ETS.[20]

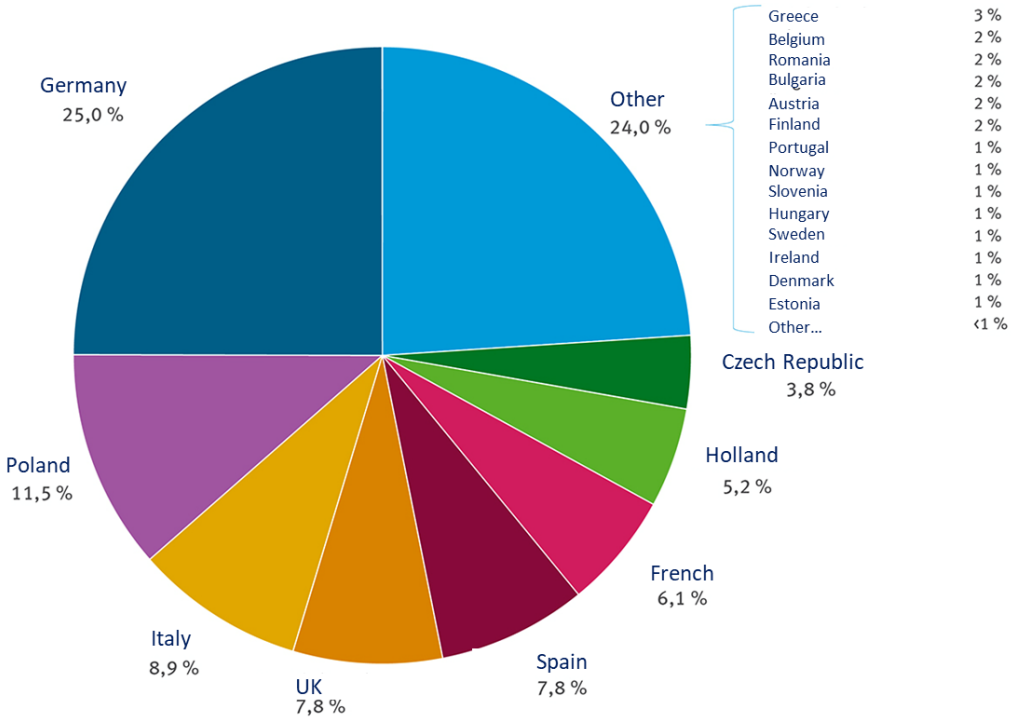


Figure 2. - National distribution of emissions, source DEHSt

Germany is by far the largest EU-ETS emitters, followed by Poland, Italy and the UK. These four together make up more than 50% of all EU-ETS emissions. In the context of this analysis the focus will be set on the German and Italian application of EU-ETS. It is designed to limit the amount of GHG emissions released into the atmosphere, in certain carbon intensive sectors by means of a so called 'cap and trade' mechanism. The “cap”

[20] Deutsche Emissionshandelsstelle (DEHSt), «DEHSt - Official website».

being the total amount of GHG emissions that are allowed to be emitted by all the installations covered by EU-ETS, this overall amount is reduced over time in order to make total emissions fall.

While with “trade” it is referred to how the installations that participate in the EU-ETS can trade emission allowances with one another. Being the number of allowances on the market limited by the EU, the allowances are bound to have a value. Essentially the right to emit one ton of CO_2, is turned into a commodity, which can be traded like any other on most major markets in the EU. The EU-ETS was launched in 2005 and has been divided into 4 trading periods, in 2021 the EU-ETS has entered in the 4th trading period[21].

Figure 3. - The EU-ETS trading periods, sourced from EC Handbook

Yearly, at the end of April, every EU-ETS installation is obliged to surrender at least the number of allowances necessary to cover the verified emissions, emitted the previous calendar year, in the months between January and December. If the operator of the installation should fail to surrender the required allowances heavy fines are imposed. Every year free allowances are distributed to plant operators, that fall under EU-ETS, based on verified reports linking emissions to products that are in danger of carbon leakage or are otherwise entitled to compensation. These free allowances are allocated during April every year, for the same year of operations, based on the data of the previous year. This way if a plant operator manages to decrease its emissions, and achieves a surplus in allowances, this surplus can be kept covering future needs or traded to other operators that may be short of allowances.

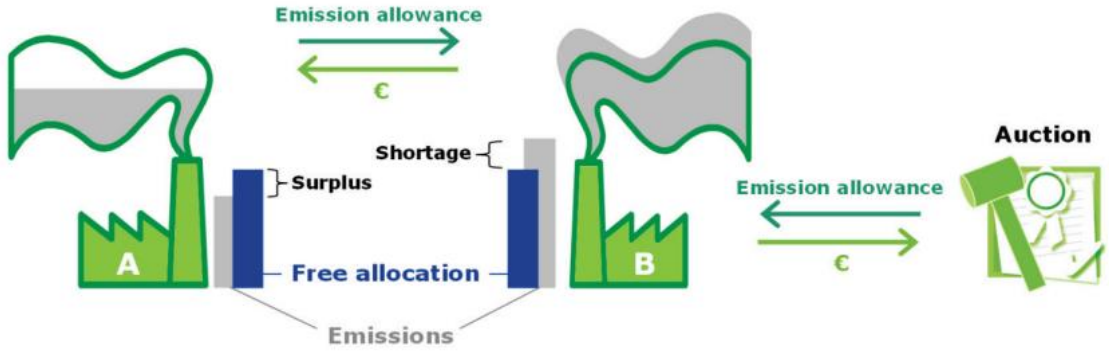


Figure 4. - Surplus and Shortage of Emission Allowances by European Commission

[21] European Union, «ETS Handbook».

The main advantages of trading are that it ensures emissions are cut there where it is most convenient to do so, while bringing flexibility to the market. Furthermore, if the market price is robust, it will trigger greater investments in technologies that allow decarbonisation.

2.1. Actors

There are five principal actors that make the EU-ETS compliance cycle work. Of course, the plant operator, the national authority, the local authority, the independent verifier and the accreditation body.[22]

2.1.1. Operators of installations subject to emissions trading

Those obliged to take part in the EU-ETS are operators of large combustion plants with rated thermal input of more than 20 megawatts, aircraft operators and energy-intensive industrial plants, a complete list of the activities having to surrender emissions allowances is published for example in the Annex 1 of the German Treibhausgas-Emissionshandelsgesetz (TEHG).

Operators of those installations are obliged to report the emissions in accordance with EU-ETS directive[23].

The methods for monitoring emissions must be laid down in a plant-specific monitoring plan by the operator and must be approved by national authority. The approved monitoring plan is the binding basis for emissions monitoring and reporting.

Based on the approved monitoring plan and the monitoring methods specified therein, the operator then yearly determines the emissions of his installation and prepare his annual emissions report.

The operator submits this report to the national authority by 31st March for the previous calendar year, this shift in time is necessary because all data from January to December must be made available and verified. The report must be audited by an accredited inspection body before submission.

In the next step, the installation operator surrenders the quantity of emission allowances corresponding to the emissions caused by its activities in the previous calendar year in tonnes

[22] Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt, «Leitfaden zur Erstellung von Überwachungsplänen und Emissionsberichten für stationäre Anlagen 4. Handelsperiode (2021–2030) des europäischen Emissionshandels».

[23] European Commission, COMMISSION IMPLEMENTING REGULATION (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012.

of CO_2 equivalent (CO_2eq). The emission allowances must be surrendered by 30th April each year for the previous calendar year.

In addition, the reporting obligations to improve the monitoring methodology must be observed. The national authority has the right to verify the information on site at the facility.

Access to the installation must be given and at the request, all necessary documents and information must be made available.

2.1.2. National Authority

Enforcing the European rules made into national law, the main role of the natural authority is to approve and check the monitoring plan of plants operators.

They also must approve any changes that are made to the monitoring plan, the plants structure, and have the possibility to perform so called witness audits.

In Germany the national authority is called *Deutsche Emissionshandelsstelle*, in short DEHSt, under the *Umweltbundesamt*, while in Italy it is the *Comitato ETS,* implementing the 2003/87/CE directive for the *Ministero delle Transizione Ecologica*.

2.1.3. Local Authority

Some tasks may fall to a local authority, especially for issuing approvals or permissions to open new installations or perform changes to existing ones. Being Germany a federal state, the local authority has a strong influence on the approval process for relevant changes in the plants, they also have the right to check and don't approve the Monitoring Plan of an EU-ETS facility. Major changes to the Monitoring Plan must also be approved by both the local and national authorities.

In Germany the plant owner is obliged to send approval requests for relevant changes to both the DEHSt and the local authority.

Installation subject to the scope of application of the TEHG requires an emissions permit, that must be issued by the competent Land authorities. This mechanism ensures that it is the local authorities that decide which installations and activities are to be monitored and with what precision.

For many installations, this is already specified in the *Federal Immission Control Act* (BImSchG), in which case there is no need to apply for an additional permit. The BImSchG permit also defines the boundaries of the plant, which helps define which fuel streams to monitor and include for EU-ETS purposes.

There may, however, be special cases were determining the scope of an EU-ETS installation solely on the basis of the BImSchG may be complicated or even conceptually wrong, in these cases it is advisable to appeal directly to the national authority, i.e., the DEHSt and apply for specific permits, obviously presenting valid supporting evidence. In such instances, an opinion from an accredited environmental certifier is often requested.

2.1.4. Independent verifier

A verifier is, by definition, an “independent third party” that is “commissioned by the installation operator to verify the emissions report” in accordance with EU-ETS directive made into national law.

For every plant subject to EU-ETS directive, each year an emission report must be summited and previously approved by an independent verifier. The Accreditation and Verification Ordinance (Ord.EU 2018/2067; AVR) details the precise tasks of this essential player[24].

Quoting paragraph two “An overall framework of rules for the accreditation of verifiers is necessary to ensure that the verification of operator's or aircraft operator's reports in the framework of the Union's greenhouse gas emission allowance trading system, to be submitted in accordance with Commission Implementing Regulation (EU) 2018/2066 (2), is carried out by verifiers that possess the technical competence to perform the entrusted task in an independent and impartial manner and in conformity with the requirements and principles set out in this Regulation.” it is possible to notice how it is clearly stated that the verifier has to be accredited and must prove to have the necessary technical knowledge to perform its duties.

This accredited verifier main function, with respect to EU-ETS, is to verify the compliance of the emission report to the EU directive, the national law and what previously approved in the monitoring plan. To this effect a risk-based approach should be applied, in order to ascertain with “reasonable assurance” that the total emissions are “not materially misstated” and doing so verifying the report as satisfactory. This is done following a complex procedure, that starting from a risk- and strategic-analysis and is completed with a series of internal reviews, however for the sake of simplicity we will focus on the core steps of the emission auditing process, which with few exceptions are the following two:

The on-site visit: In this first part of the verification process the site and the measuring instruments used are inspected, followed by the monitoring procedures and the systems adopted for handling EU-ETS-relevant data. A series of interviews with the staff of the plant operator are carried out to gain a deeper understanding of the monitoring process.

Data audit: In which in a separate audit the data flows and processes are analysed, which from the data measured or received at the source are used to generate the values entered in the report. In the German case in the Form Management System (FMS). This part has been carried out remotely since the beginning of the COVID-19 pandemic, the work done remotely proved to be functional in this case, because it is more convenient to visualize data

[24] European Commission, COMMISSION IMPLEMENTING REGULATION (EU) 2018/2067 of 19 December 2018 on the verification of data and on the accreditation of verifiers pursuant to Directive 2003/87/EC of the European Parliament and of the Council.

within the plant operator's data management systems, who can simply share the screen to show real-time values.

In Germany the verification report is submitted to the national authority as part of the operator's emissions report, this way it is made sure that the last entry performed in the emission report software (FMS) is executed by the verifier.

The final task for the verifier related to the emission report is to “confirm the correctness of the emissions of an installation entered in the register”.

Analogously, the verifier is in charge of auditing applications for free allowances. These reports are likewise submitted to the competent national authority on an annual basis.

By sharing a similar structure to the emission report, several synergies are gained in the verification of the two reports at close intervals. For example, since it is the same facility, the site visit is often not repeated a second time. However, it must be kept in mind that the data verified in the emission report must serve as the basis for the request for free allowances.

2.1.5. Accreditation Body

We mentioned before that at the time of issuing the emission report and the certificate, auditor agencies must be accredited. This is the main task of the accreditor**.** Any accreditation issued by any accreditation body in an EU Member State can authorize a verifier for the EU-ETS audit activity. The German national accreditation authority is the Deutsche *Akkreditierungsstelle*, in short DAkkS.

The DAkkS has the responsibility to make sure that auditors can perform their work to its full extent and compliantly to all the requirements imposed by the EU commission and the DEHSt. In substance they must ensure that verifiers have all the necessary technical competences and perform their duties impartially and independently. To do this they perform checks of documentation, office, auditing the activity of verification bodies annually.

Accreditation certificates issued by the DAkkS can remain valid for up to five years.

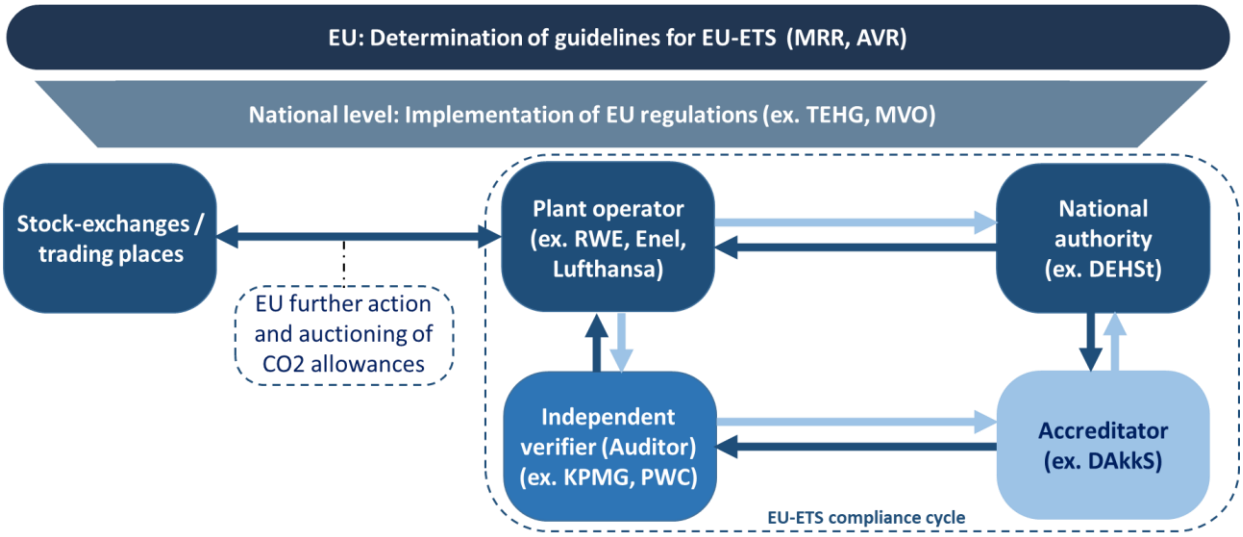


Figure 5. - The EU-ETS compliance cycle

2.2. Compliance Cycle

The term compliance cycle of the European emission trading system refers to the annual Monitoring, Reporting and Verification (MRV) process and the various complementary

workstreams[25]. Previously the main actors involved in these activities and their respective tasks were introduced.

The rules defining the proper implementation of the compliance cycle are collected in two sets of regulations, firstly the 'Monitoring and Reporting Regulation' or MRR and, as far as verifiers and accreditors are concerned, the 'Accreditation and Verification Regulation' or in short AVR[26].

EU-ETS operators are obliged to monitor and report their emissions annually. Before being submitted to the national competent body, this report must be audited by an independent verifier who in turn must be accredited by an official accreditor of one of the states participating in EU-ETS. Only then does the operator of the installation enter the emissions emitted in the year in question into the registry and must provide a quantity of certificates at least equal to the tonnes of CO_2 emitted and certified.

Clearly at this point it is necessary for the plant operator to have sufficient EUAs on his account to cover his emissions and not incur penalties, but apart from this constraint operators are free to buy and sell EUAs on the market.

2.3. Markets and Registers

As explained above, the EU-ETS is a “cap” and “trade” system.

It may be beneficial now to introduce some more entities besides the main actors of yhe compliance cycle that enable this system to function. Specifically, the Union Registry and the main markets where EUAs are bought and sold.

2.3.1. The Union Registry

The Union Registry was designed[27] to document the possession and transaction of EU Allowances, as well as Kyoto certificates. This registry is actually part of a larger, international registry architecture and through the International Transaction Log (ITL) builds the bridge between EU-ETS and other international tools.

[25] European Commission, COMMISSION IMPLEMENTING REGULATION (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012.
[26] European Commission, COMMISSION IMPLEMENTING REGULATION (EU) 2018/2067 of 19 December 2018 on the verification of data and on the accreditation of verifiers pursuant to Directive 2003/87/EC of the European Parliament and of the Council.
[27] European Commission, «Union Registry».

The Union Registry is essentially divided in two sections: the EU Section and the Kyoto Section[28].

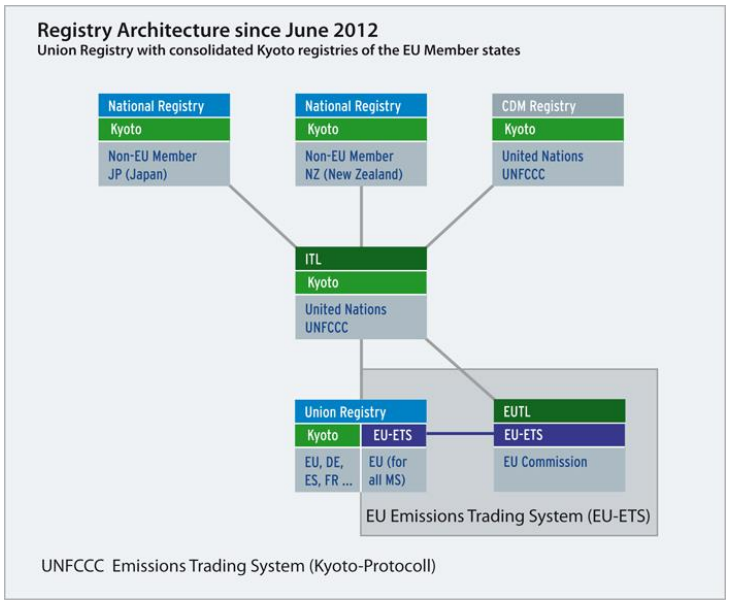


Figure 6. - Registry Architecture since June 2012, source DEHSt

The EU Section is the virtual place where all the process and transactions regarding EU-ETS are performed. It is in this section where the accounts of plant operators of EU-ETS can be found along with holding and trading accounts. It can be helpful to know that all these accounts are characterised by an account identifier starting with EU-100.

These accounts are the only once allowed to hold European allowances and those of the linked Swiss System (these can also be held by Swiss accounts (CH-accounts). During transactions it is the European Transaction Log (EUTL) that performs checks on the compliance of the transaction to EU-ETS rules.

Also accredited EU-ETS verifiers are obliged to have an account in this section of the registry, these accounts on the other hand are characterised by an identifier starting with EU-0. Obviously accounts of this nature are not allowed to hold certificates but are instead used to register or approve verified emissions for operators and aircraft operators in the registry.

European allowances (EUA and aEUA) and those of the linked System of Switzerland can only be held in accounts in the EU ETS section or accounts of the linked system of Switzerland (EU-100 or CH-accounts). When allowance transactions take place, EUTL checks the compliance of the transaction with the rules of EU ETS. ITL is not involved in allowance transactions.

[28] Deutsche Emissionshandelsstelle (DEHSt), «Register Architecture UNFCCC DEHSt.de».

2.3.2. The primary market

Entities eligible to participate in emission allowances auctions are compliance entities (companies and aircraft operators who are obliged to participate in the EU ETS), most categories of market participants are also able to participate in (e.g. credit institutions, investment firms, funds, commodity trading firms without compliance requirements), provided that as bidders they meet the relevant admission requirements as set out in the Auctioning Regulation 1031/2010 (Articles 18 and 19) – which guarantees a fair and open access for all auction participants[29].

2.3.3. Auctioning of European Union Allowances

As stated earlier there are certain admission requirements that must be met to take part at the actioning of EU-ETS allowances. These requirements are listed in the Auctioning Regulation. For example, it is required to open an account in a Union registry and for the entity itself to be established inside the EU.

Also, evidence of personal reliability and professional qualification must be presented and entities desiring to participate at the auctioning of EUAs must be cleared in advance as a trading participant by the clearing house.

For more details on the EU ETS primary market or to view the auctioning calendars it is advised to consult the EU ETS Auctioning Regulation directly.

2.3.4. The secondary market

There is also a secondary market for emission allowances, the access to this market is less restricted however the trading modality changes slightly[30].

In Germany the EEX offers access to the secondary market and it is not the only venture offering the possibility to trade with EUAs indirectly.

Besides the EEX also the Dutch ICE Endex and the Norwegian Nasdaq Oslo offer the possibility to make a series of short-term contracts called “daily futures” or “spot”, to set futures with various maturities, and options on futures.

The standardised size for all derivates is set at 1.000 allowances.

2.4. Surrendering EUAs in Germany

This section focuses on the yearly cycle of receiving and surrendering emission allowances, while the surrendered allowances are determined by the yearly monitoring and verification process, it often happens that the herein described processes are handled by completely

[29] Official Journal of the European Union, Auctioning Regulation - 32010R1031 - EN - EUR-Lex.
[30] ICE, «ICE Futures and Options».

different departments of installation operators compared to the monitoring and reporting. The cycle described is based on DEHSt deadlines but should be applicable for all EU-ETS plant operators.

At the very beginning, the DEHSt transfers a certain amount of free emission allowances, EUAs, for the current calendar year to the corresponding installation accounts in the Union Register of companies subject to EU-ETS. So, the first thing registered is a positive flux of EUAs[31]. Only then, if more tonnes of CO_2eq emissions are generated than the allocated EUAs, which is - especially now, in the 4th trading period, the most common case a shortfall in EUAs that must be made up by the end of the trading year occurs. However, if the annual CO_2 emissions of a plant are below the amount of allocated EUAs due to production decreases or efficiency increases, the company in principle "achieves" an EUAs surplus, which can be freely disposed of. This happened often for industrial installations in the first trading periods.

It should be noted that the quantity of free allocations the operator receives for the years from 2021 to 2025 were computed by using a cross-sector correction factor specified by the European Commission. This will inevitably lead to an annual reduction in the allocated free EUAs.

The amount of CO_2 emissions generated in a calendar year must be reported to DEHSt by means of an emissions report that has to be submitted by March 31 of the following year. The report must be verified by an external independent and accredited verifier. Based on the CO_2 emissions stated in the report, the corresponding number of EUAs must then be submitted by April 30 of the following year. The plant operators under EU-ETS are also obliged to submit the notifications for the past year operations regarding any changes in capacity on time in January of the current year.

Until April 30, 2021, the possibility was offered to participate in the European emissions trading and to buy corresponding EUAs (so-called EU Emission Allowances - EUA) or to purchase them, to a certain extent, via project-based mechanisms in order to compensate for an existing shortfall according to the Greenhouse Gas Emissions Trading Act (TEHG).

However, in the 4. trading period, meaning since the surrendering year of 2022, Certified Emission Reductions (CERs) and Emission Reduction Units (ERUs) can no longer be used for a levy or exchange in the EU ETS. For this reason, transactions with CERs and ERUs will no longer be possible on EU 100 accounts as of 01.05.2021. From May 2021 on, only transactions with CERs and ERUs from EU 100 accounts to accounts in national Kyoto registries or between Kyoto accounts as well as voluntary cancellations are possible.

The project-based mechanisms are emission certificates, CERs and ERUs, which are issued for the successful implementation of climate protection projects in developing and newly industrializing countries. The use of CERs and ERUs was limited to a quantity of 22% for

[31] Deutsche Emissionshandelsstelle (DEHSt), «DEHSt - Official website».

the 3rd trading period of the respective installation-related EUAs allocation from the 2nd trading period, doing so assured that a high gap between freely allocated allowances and GHG emissions produced would at least partially be covered by the purchase of EUAs. This is not possible anymore because given the announced European targets for fighting climate change the EC has decided to priorities the decarbonisation of its own economy.

2.5. Allocation of free certificates

All operators who receive a free allocation of emission allowances must submit an Annual Allocation Data Report to the respective national authority by 31st of March of the following year. However, operators are not obliged to request free allowances. In some cases, operators do not deem it necessary or worthwhile.

Due to delays in the publication of the data reporting guidelines in 2022 in Germany for the DEHSt's application for free allocations in the 4th trading period, it was possible, to deliver the annual report on allocations until 30/04/2022 without incurring penalties or any negative consequences. To greatly simplify the concept with this report the plant operator documents what products are responsible for emissions and in what quantity and proportion.

The allocation data report is based on a plant specific pre-approved document that states the methodology, the measurement devices and the modality and processes involved in the monitoring of data[32]. The Methodology report finalizes methods for the monitoring and reporting of activity rates. It is structured based on allocation elements, such as district heating, products at carbon leakage risk, and products that are not at carbon leakage risk. This sets the basis for allocation of free allowances. This report tends to be more complicated and less standardised than the Emission Report, but is very important for operators because it may allow them to receive back some of the allowances surrendered, that with current prices could be worth many millions of euros.

[32] Deutsche Emissionshandelsstelle (DEHSt).

3. *Monitoring and Reporting of ETS Emissions*

One of the most virtuous aspects of the EU-ETS is the emission monitoring system developed for it. This enables a large number of installations to measure and report their emissions with reasonable precision. By following an installation-based approach, a common framework can be adapted to various sectors, which include very different installations[33].

3.1. Different participating activities

The installations are categorized based on their activity and based on the order of magnitude of their rated carbon footprint. The following table, created by rearranging the information's made available in the German law: "*Gesetz über den Handel mit Berechtigungen zur Emission von Treibhausgasen* -(Treibhausgas-Emissionshandelsgesetz - TEHG) Anhang 1"*[34], gives a better understanding of the affected sectors and plants.

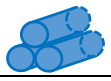
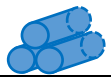
Table 1. - Activities listed in the German TEHG, Anhang 1

Nr.	Icon	EU-ETS Activities	Emissions	Lower limit
1		**Combustion units** for the combustion of fuels with a total rated **thermal input of 20 MW or more** in one installation, unless specified in one of the following numbers.	**CO_2**	**20 MW**
2		**Installations for the production of electricity, steam, hot water, process heat or heated flue gas** by the use of fuels in a combustion installation (such as a power station, combined heat and power station, heating plant, gas turbine installation, combustion engine installation, other combustion installation), including associated steam boilers, with a **rated thermal input of 50 MW** or more.	**CO_2**	**50 MW**
3		**Installations for the production of electricity, steam, hot water, process heat or heated waste gas** by the use of *coal,*	**CO_2**	

[33] Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt, «Leitfaden zur Erstellung von Überwachungsplänen und Emissionsberichten für stationäre Anlagen 4. Handelsperiode (2021–2030) des europäischen Emissionshandels».

[34] Umweltbundesamt, TEHG Gesetz über den Handel mit Berechtigungen zur Emission von Trei.

		*coke, including petroleum coke, coal briquettes, peat briquettes, fuel peat, untreated wood, emulsified natural bitumen, fuel oils, gaseous fuels (in particular coke oven gas, mine gas, steel gas, refinery gas, synthesis gas, petroleum gas from the tertiary extraction of crude oil, sewage gas, biogas), methanol, ethanol, untreated vegetable oils, vegetable oil methyl esters, untreated natural gas, liquefied petroleum gas, public gas supply gases or hydrogen* with a rated **thermal input of more than 20 MW but less than 50 MW** in a combustion installation *(such as a power plant, combined heat and power plant, heating plant, gas turbine installation, internal combustion engine installation, other combustion installation), including associated steam boilers.*		**50 MW > x > 20 MW**
4		**Installations for the production of electricity, steam, hot water, process heat or heated flue gas** by the use of solid or liquid **fuels other than those referred to in No. 3** in a combustion installation (such as a power station, combined heat and power station, heating plant, gas turbine installation, combustion engine installation, other combustion installation), including associated steam boilers, with a rated **thermal input exceeding 20 MW but less than 50 MW**.	**CO_2**	**50 MW > x > 20 MW**
5		**Combustion engine installations for the propulsion of working machines** using *heating oil, diesel fuel, methanol, ethanol, untreated vegetable oils, vegetable oil methyl esters or gaseous fuels (in particular coke oven gas, mine gas, steel gas, refinery gas, synthesis gas, petroleum gas from the tertiary extraction of petroleum, sewage gas, biogas, untreated natural gas, liquefied petroleum gas, gases from the public gas supply, hydrogen)* with a rated **thermal input of 20 MW or more.**	**CO_2**	**20 MW**
6		**Gas turbine** (GT) **installations** for the propulsion of machinery for the use of EL heating oil, diesel fuel, methanol, ethanol, untreated vegetable oils, vegetable oil methyl esters or gaseous fuels (in particular coke oven gas, mine gas, steel gas, refinery gas, synthesis gas, petroleum gas from the tertiary extraction of crude oil, sewage gas, biogas, untreated natural gas, liquefied petroleum gas, gases from the public gas supply, hydrogen) with a rated **thermal input of more than 20 MW.**	**CO_2**	**20 MW**
7		Installations for the **Distillation or Refining or Other Processing of Petroleum** or Petroleum Products in Petroleum or Lubricant Refineries.	**CO_2**	**N/A**
8		Installations for the **Dry Distillation of Hard Coal or Lignite** (Coking Plants).	**CO_2**	**N/A**
9		Installations for **roasting, melting, sintering or pelletising metal ores.**	**CO_2**	**N/A**
10		Installations for the production o**r melting of crude iron or steel**, including continuous casting, whether or not using concentrates or secondary raw materials, **with a melting capacity of 2,5 tonnes or more per hour**, whether or not operated in integrated steelworks.	**CO_2**	**2,5 t/h**

11		Installations for the **production or processing of ferrous metals** (including ferro-alloys) when operating **combustion units** with a total rated **thermal input of 20 MW or more**, other than those specified in point 10; processing includes, in particular, *rolling mills, reheating furnaces, annealing furnaces, forging shops, foundries, coating and pickling lines*.	**CO_2**	**20 MW**
12		Plant for the **production** of raw **aluminium**.	**CO_2, PFC**	**N/A**
13		Installations for **smelting, alloying** or **refining** of **non-ferrous metals** operating combustion units with a total rated **thermal input** (including fuels used as reducing agents) equal to or **exceeding 20 MW.**	**CO_2**	**20 MW**
14		Installations for the **production of cement clinker** with a production capacity **exceeding 500 tonnes per day in rotary kilns** or **50 tonnes per day in other furnaces**.	**CO_2**	**500 t/day**
15		Installations for the **calcination of limestone**, magnesite or dolomite with a production capacity exceeding **50 tonnes** of quicklime, calcined magnesite or calcined dolomite **per day**.	**CO_2**	**50 t/day**
16		Installations for the **manufacture of glass**, including that made from waste glass, including installations for the manufacture of glass fibre, with a **melting capacity exceeding 20 tonnes per day**	**CO_2**	**20 t/day**
17		Installations for **firing ceramic products** with a **production capacity exceeding 75 tonnes per day**	**CO_2**	**75 t/day**
18		Installations for the **melting of mineral substances**, including installations for the production of mineral fibres, with a **melting capacity exceeding 20 tonnes per day.**	**CO_2**	**20 t/day**
19		Installations for **drying or firing gypsum or for the production of gypsum plasterboard** and other gypsum products when operating **combustion units** with a total rated **thermal input of 20 MW** or more.	**CO_2**	**20 MW**
20		Installations for the **production of pulp** from wood, straw or similar fibrous materials	**CO_2**	**N/A**

21		Installations for the **production of paper**, **board or cardboard** with a **production capacity exceeding 20 tonnes/ day**.	**CO_2**	**20 t/day**
22		Installations for the **production of industrial carbon black** when operating **combustion units with a total rated thermal input of 20 MW** or more.	**CO_2**	**20 MW**
23		Installations for the **production of nitric acid**	**CO_2, N_2O**	**N/A**
24		Installations for the **production of adipic acid**	**CO_2, N_2O**	**N/A**
25		Installations for the **production of glyoxal or glyoxylic acid**	**CO_2, N_2O**	**N/A**
26		Installations for the **production of ammonia**	**CO_2**	**N/A**
27		Installations for the production of: a) **basic organic chemicals** *(alkenes and chlorinated alkenes; alkynes; aromatics and alkylated aromatics; phenols, alcohols; aldehydes, ketones; carboxylic acids, dicarboxylic acids, carboxylic anhydrides and dimethyl terephthalate; epoxides; vinyl acetate, acrylonitrile; caprolactam and melamine)*; or b) **polymers** *(polyethylene, polypropylene, polystyrene, polyvinyl chloride, polycarbonates, polyamides, polyurethanes, silicones)* With a **production capacity** exceeding **100 tonnes per day**	**CO_2**	**100 t/day**
28		Installations for the **production of hydrogen or synthesis gas** by reforming, partial oxidation, water gas shift reaction or similar processes with a production capacity exceeding 25 tonnes per day	**CO_2**	**25 t/day**
29		Installations for the **Production** of **Sodium Carbonate** and **Sodium Hydrogen Carbonate**	**CO_2**	**N/A**

30		**Installations for the capture of greenhouse gases (CCS plants)** *from installations referred to in points 1 to 29 for the purpose of transport and geological storage in an underground storage facility pursuant to Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC and Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC and 2008/1/EC of the European Parliament and of the Council and Regulation (EC) No 1013/2006 (OJ L 140, 5.6.2009, p. 114).*	**CO_2**	**N/A**
31		**Pipeline facilities for the transport of greenhouse gases** for the purpose of geological storage in a storage site approved in accordance with Directive 2009/31/EC	**CO_2**	**N/A**
32		Storage site for the **geological storage of greenhouse gases** approved in accordance with Directive 2009/31/EC	**CO_2**	**N/A**

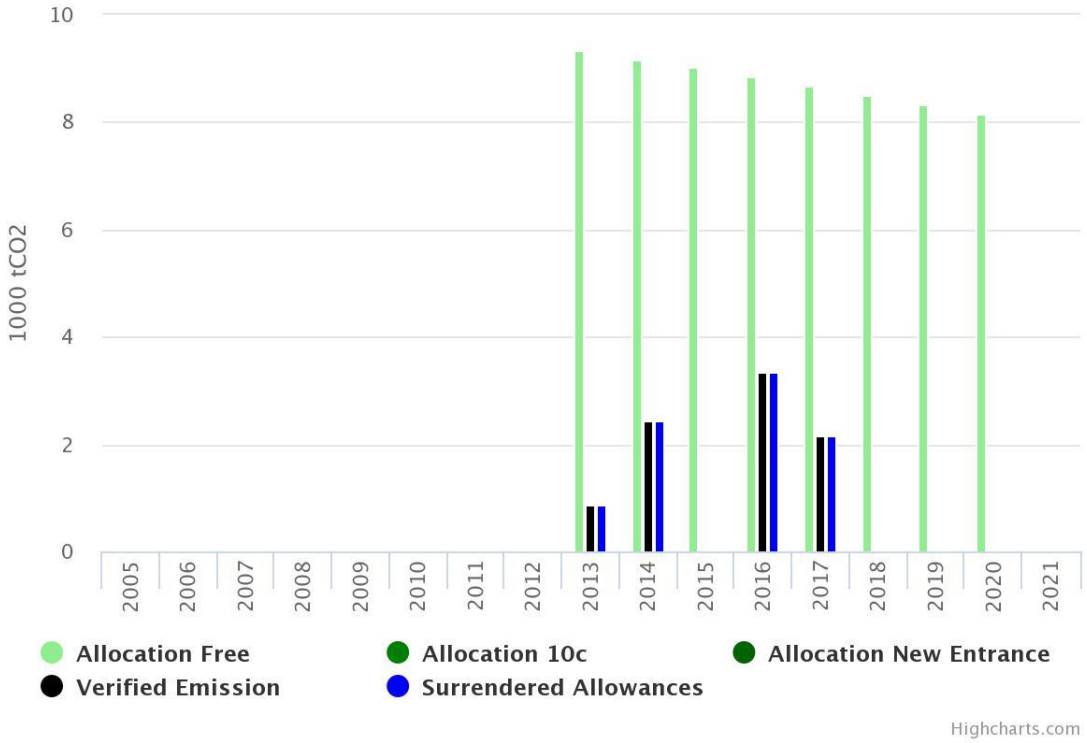
33		**Flights departing from or arriving at an aerodrome situated in a territory of a State party to the Agreement on the European Economic Area**. This does however **not include**: a) Flights performed exclusively for the purpose of... aa) **reigning monarchs** and their immediate families, bb) **Heads of State, Heads of Government and Government Ministers** of a non-Member State of the Agreement, to of a State not being a member of the Agreement **(on an official mission)** b) **military flights** in military aircraft and customs and police flights; c) search and **rescue flights, fire-fighting flights, humanitarian flights and emergency medical flights**, if authorised by the appropriate competent authority; d) flights conducted exclusively under visual flight rules as defined in §§ 28 and 31 to 34 of the Air Traffic Act; e) **flights** during which the aircraft **returns to the aerodrome** of departure **without a stopover**; f) **training flights** conducted exclusively for the purpose of obtaining a pilot licence or a cockpit crew rating, provided that this is indicated in the flight plan; these flights shall not be used for the carriage of passengers or cargo or for the positioning or transfer of aircraft; g) flights performed exclusively **for the purpose of scientific research or the inspection, testing or certification of aircraft or equipment**, whether airborne or ground-based; h) flights performed by aircraft with a **maximum take-off mass of less than 5700 kilograms**; i) **flights operated under public service obligations** as defined in Article 16 of Regulation (EC) No 1008/2008 on routes within the outermost regions referred to in Article 349 of the Treaty on the Functioning in the European Union or on routes with an offered capacity not exceeding 30 000 seats per year; j) flights not already covered by points (a) to (i) performed by an aircraft operator providing scheduled or non-scheduled air **transport services to the public for remuneration, carrying passengers, freight or mail** (commercial aircraft operator), provided that; aa) that aircraft operator operates fewer than 243 such flights in each of the periods January to April, May to August and September to December in any calendar year; bb) the total **annual emissions from such flights** by that aircraft operator are less t**han 10 000 tonnes**; this exemption does not apply to flights performed exclusively for the carriage, in the exercise of their functions, of reigning monarchs and their immediate families and of Heads of State, Heads of Government and Government Ministers of a Member State of the Agreement on the European Economic Area; and k) until 31 December 2030, flights not falling under points (a) to (j) performed by a **non-commercial aircraft operator** whose flights have total annual emissions of **less than 1 000 tonnes**.	**CO_2**	**[-]**

It has to be noted that the EUTL has a slightly different numeration, starting with number 10 (aviation) and ending with Number 99.

Furthermore TEHG-activities 1 to 6 are aggregated into one EUETL-activity Nr. 20 “Combustion” and TEHG-activity NR. 13 is split into two EUTL-activities. For further information the reader is free to consult the ANNEX I of the EU-ETS directive (02018R2066 — EN — 01.01.2021 — 001.001)[35].

Note also that a lower limit is clearly defined for many activities. Different indicators such as the rated thermal input or melting capacity in tonnes per hour or the estimated production rate are used to identify the limit. For some categories, however, this limit does not exist. The rationale behind this decision is obvious, especially when considering activities that risk emitting not only CO_2 but also, N2O.

This, however, caused that in the third phase there were installations, which were required to participate in EU-ETS, but which produced little or no greenhouse gases and even received free certificates. These activities were therefore able to make a profit from the sale of certificates, not because of a particularly virtuous behaviour, but because of the very nature of the installation. This happened mostly in plants belonging to the chemical industry[36].



[35] European Commission, COMMISSION IMPLEMENTING REGULATION (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012.

[36] Jan Abrell, «EUETS.INFO Project».

Figure 7. - Example German Cyclohexanon-Plant data from EUTL made available by EUETS.INFO

In the picture above a real example of an existing Cyclohexanol plant is displayed that during the 3rd trading period received many more EUAs than emissions it produced, some years not even emitting at all, but still receiving a slowly decreasing number of allowances.

In the fourth phase, these design 'errors' of the EU-ETS mechanism were and are being corrected due to the iterative development of this tool through a trial-and-error process. This continuous correction process is also one of the reasons why the number of EU-ETS plants in Germany in 2021 decreased compared to 2020.

3.2. Classification of Installations and Material Streams

The minimum requirements for the monitoring of GHG emissions are determined using a tier-based structure. The higher the rated emissions of the installation and the respective substance streams the higher the level of precision required for the monitoring.

3.2.1. Classification of installation

To be able to provide a rated emission quantity the emissions of the previous years are used as basis. However, in order not to underestimate possible emissions, the worst case is considered[37]. All CO_2 produced is included, even that which has historically been transferred to other plants, and the emission savings achieved in the past using biomass are not taken into account, since it is assumed that production takes place using 100% fossil fuels. In cases where the data of the previous year are not available or significant changes to the plant make the data obsolete, operators are allowed to make a conservative estimate of the average annual emissions.

The MRR distinguishes between installations of category A, B and C[38]:

- **Category A** installations:

[37] Deutsche Emissionshandelsstelle (DEHSt), «DEHSt - Official website».
[38] European Commission, COMMISSION IMPLEMENTING REGULATION (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012.

These installations emit less than 50,000 t CO_2eq/ year and are so called low emitters, installations of these categories are allowed to use tiers defined in Annex V of the MRR directive.

- **Category B** installations:

The emissions of the installations that fall under this category are comprised between 50,000 and 500,000 t CO_2eq/year

- **Category C** installations:

The installations of this category emit more than 500,000 t CO_2eq/year, these are the strongest emitters and are therefore to be monitored the more closely.

Table 2. - Installation categories, data from DEHSt

Installation categories		
A	B	C
x < 50.000 tCO2eq/year	50.000 < x < 500.000 tCO2eq/year	x > 500.000 tCO2eq/year
x being the rated annual emissions of the installations		

3.2.2. Classification of material streams

Similarly, to the classification of installations, material streams are categorised according to the annual emissions attributed to each material stream by estimation on historical data (when available and reasonable).

Generally, material streams are the streams of fuels consumed that cause CO_2 emissions in the combustion process. However, there can also be reactants that through a chemical reaction go on to produce greenhouse gases. In these cases, a calculation method is generally used that differs from the standard method, namely the material balance method.

Once again, the estimation must be conservative and the amount of CO_2eq transferred to other plants is also taken into account, and the biomass factor is always considered to be zero (100% fossil fuels assumption). In the case of mass balances, the sum of the carbon content of all input and output flows is computed. Output flows have a positive sign and input flows a negative sign.

Material flows are divided into three categories[39]:

- De-minimis streams:

These streams are characterised by emissions of less than 1,000 t CO_2eq per year, or otherwise less than 2% of the plant's total annual emissions, provided that the 2% remains less than 20,000 tonnes per year.

In these cases, activity data and each calculation factor can be determined by using conservative estimates instead of using tiers.

Sometimes however data monitored with precision matching a defined tier are already available to the operator without additional effort and are used instead.

- Emission weak streams:

These streams are characterised by emissions of less than 5,000 t CO_2eq per year, or otherwise less than 10% of the plant's total annual emissions, provided that the 10% remains less than 100,000 tonnes per year.

- Emission strong streams:

All remaining streams fall into this category, subject to the highest monitoring standards.

[39] European Commission.

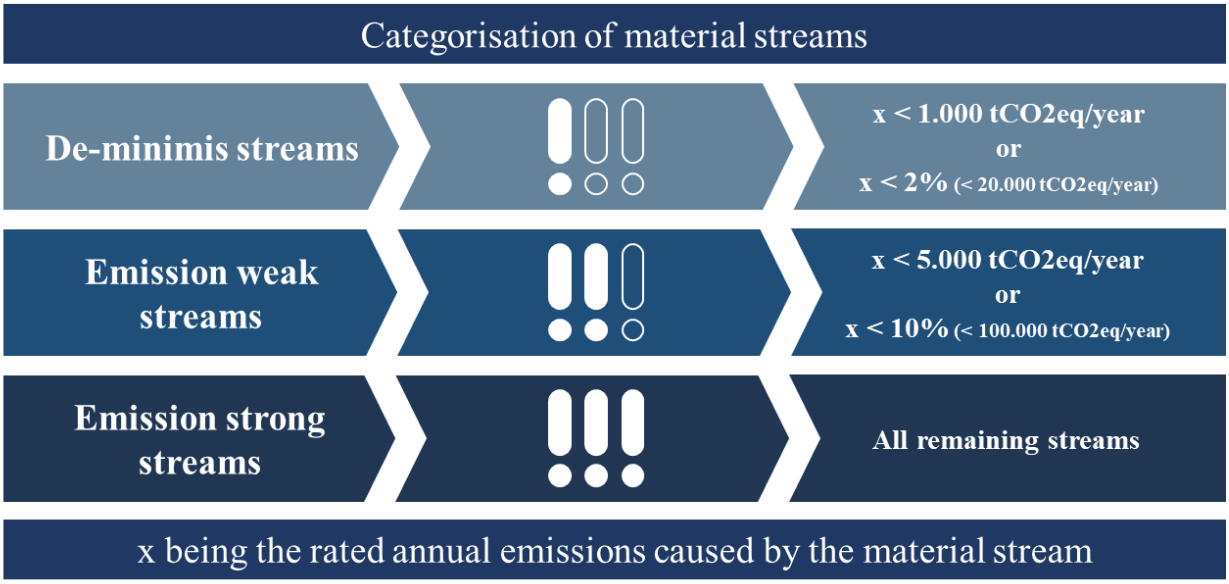


Figure 8. - Material streams categories, data from DEHSt

3.3. Small emitters

Small emitters that are very close to the 20MW limit are permitted some simplifications. It is up to the national authority to decide to what extent.

For Aircraft operator those operators whose flights emit less than 25.000 tonnes of CO_2 per year or operating less than 243 flights for three consecutive four-month periods, are considered a "small emitter". As small emitters they are entitled to determine their fuel consumption and CO_2 emissions using a simplified monitoring tool called Eurocontrol and verify their emissions by using data from the EU ETS support facility, without any modification. In this case a special manner of verification can be used and emission values are approved in accordance with the deliberations of the national Competent Authority.

3.4. The Monitoring Plan

The monitoring plan is the basis of the annual emission report. It describes the emission sources and the methods for determining emissions. In principle, the monitoring of emissions must be transparent, complete, comparable, consistent, and accurate.

In Germany, in order to facilitate the preparation of monitoring plans, the DEHSt provides forms in the FMS (Form Management System), which request the necessary details, data and information in a pre-structured manner. In the event of a significant change, the monitoring plan must be adjusted without delay. As far as possible, significant changes have to be notified to the National Authority prior to their implementation.

If an operator in Germany already applies a modified method prior to its notification, the DEHSt retrospectively approves the modified monitoring plan only within limits. It applies that the retroactive effect of an approval may not extend back further than the 01.01. of the current monitoring period.

Usually flow diagrams to better understand the material streams, products and the positions and functions of metering devices are attached to the MP. Below a simple example was reconstructed. In the displayed case a turbine is used to produce electric energy, alimented by natural gas and biomethane. The heat of the exhaust gases is than further exploited in a Water Heater, to heat a water feed that is split into the one stream for district heating and one remaining stream used to feed a boiler, powered by heating oil combustion and producing high pressure steam for an industrial client. This is a simple plant with only two material streams. In praxis plants can have many more, and flow diagrams can get more complicated[40].

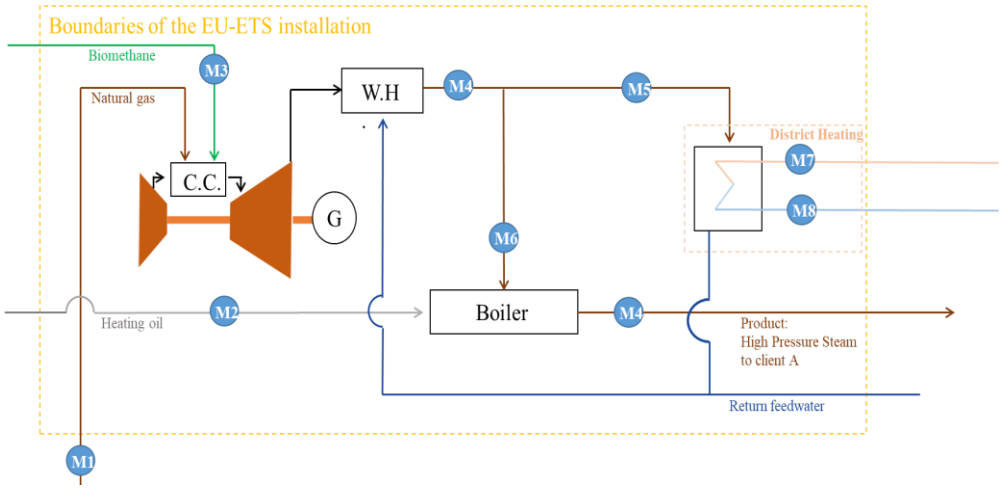


Figure 9. - Example of Flow Diagram for a very simple Heat and Power Plant

3.5. Determination of the permitted level of uncertainty

The determination of the overall uncertainty for a monitoring procedure is an important step to ensure the quality of the reported data.

Uncertainty tiers are determined based on the forecasted CO_2 emissions of a fuel stream, the category of the installation and of the fuel stream in the MRR directive and thus the overall

[40] EUROPEAN COMMISSION DIRECTORATE-GENERAL CLIMATE ACTION Directorate B – Carbon Markets & Clean Mobility Unit B.2 – ETS (II): Implementation, Policy Support & ETS Registry, «Quick Guide for Stationary Installations».

uncertainty of the monitoring process of a material stream must be equal or higher to the required one. With only few reasonable exceptions.

In the case of an installation of Category A at least the tiers listed in Annex V have to be taken as reference. This holds true also for those material streams that are commercially standard fuels and where a calculation factor is required.

Else the highest tiers are defined for the general case in the MRR directive Annex II, where a Table can be found that sets uncertainty thresholds for tiers to which the operator of the plant has to be compliant. (Example in Table 1). This refers to what stated in Article 28(1), Article 29(2), and Annex IV, of the same Regulation[41].

Thus, an uncertainty threshold is set defining the maximum permissible uncertainties for the determination of source streams over a reporting period.

The most common definition is the one that refers to 'Combustion of fuels and fuels used as process input', this definition is also applied to all plant types that are not explicitly listed in Annex II.

Table 3. - extract from Table (1), Annex II, MRR directive

Activity/source stream type	Parameter to which the uncertainty is applied	Tier 1	Tier 2	Tier 3	Tier 4
Commercial standard fuels	Amount of fuel [t] or [Nm^3]	± 7,5 %	± 5 %	± 2,5 %	± 1,5 %

The tiers go from Tier 1 to Tier 4, being the fourth tier the one with the lowest uncertainty and thus the one assuring the best monitored precision.

3.5.1. Error propagation

It is reasonable to introduce the subject about the calculation of uncertainties since it is an integrating part of the EU-ETS approach to emission monitoring and reporting, although it is not purpose of this paper to go into a complete list of all calculation methods. The accuracy of the monitoring is one of the characteristics that make EU-ETS stand out compared to other

[41] European Commission, COMMISSION IMPLEMENTING REGULATION (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012.

tools and while consuming a lot of resources ensures results that not underestimate the amount of GHG emissions released into atmosphere. Since the reported data can only possibly be as precise as the raw data used to compute the final quantities of GHG emissions it is relevant to recall some basics of error propagation calculation.

Measurements are expressed using an uncertainty. For example, the best estimate of a volumetric flow $\dot{W}$ measured by a turbine gas flow meter is 13.991 Nm3 but due to uncertainty, the flow might be as small as 13.956 Nm3 or as large as 14.026 Nm3.

$\dot{W}$ can be expressed with its uncertainty using eighter absolute uncertainty notation:

$$\dot{W} = 13.991 \pm 35$$

Or the percentage uncertainty notation:

$$\dot{W} = 13.991 \pm 0{,}25\%$$

It is appropriate to introduce the concept of distribution, since the spread of a set of measurements can take on different types of distribution depending on the phenomenon measured and boundary conditions.

Lo E. states in his publication that the Gaussian error propagation (GEP) can be used to determine the error or uncertainty produced by multiple and interacting measurements analytically[42]. In his research he demonstrates that the technique is especially useful for processes that involve step-by-step calculations, where measurements taken at a smaller temporal or spatial scale are used to estimate a value at larger scales.

In practice when the distribution function is unknown or it can be assumed that at least no normal distribution exists and it is necessary to calculate the uncertainty by means of Gaussian error propagation, the uniform, or rectangular, distribution is often used.

[42] ERNEST LO, «Ecological Monographs - 2005 - GAUSSIAN ERROR PROPAGATION APPLIED TO ECOLOGICAL DATA POST-ICE-STORM-DOWNED WOODY».

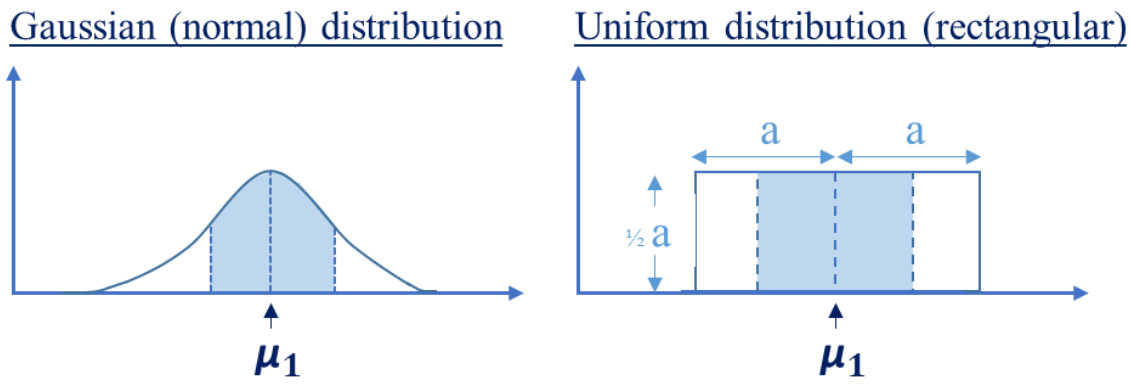


Figure 10. - Gaussian and Rectangular distribution

The assumption of a rectangular distribution for individual influencing variables when calculating the uncertainty of an input variable can be correct and sensible in correct and reasonable in some cases (e.g., for the influence of the ambient temperature).

In contrast to a normal distribution, the probability is equally distributed within the interval. For the conversion into a standard uncertainty, the value must be divided by 1.73. The standard uncertainty calculated in this way can then again be regarded as normally distributed and be offset against the other standard uncertainties to form a combined uncertainty according to error propagation.

Depending on whether the quantities are determined by several different (independent) measuring devices or one and the same (dependent) measuring instrument, the appropriate error propagation formula shall be applied[43]:

Case 1: Formula for independent uncertainties:

$$U_Y = \sqrt{(\frac{dY}{dX_1} + U_{x1})^2 + (\frac{dY}{dX_2} + U_{x2})^2 + \cdots + (\frac{dY}{dX_n} + U_{xn})^2}$$

- U_Y Total Uncertainty of the inlet quantity Y
- $\frac{dY}{dX_1}$ Sensitivity coefficients
- $U_{x1} \ldots U_{xn}$ Expanded relative standard uncertainty of the influence quantity X_1 to X_n

[43] Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt, Leitfaden zur Erstellung von Überwachungsplänen und Emissionsberichten für stationäre Anlagen 4. Handelsperiode (2021–2030) des europäischen Emissionshandels.

Case 2: Formula for dependant uncertainties:

$$U_Y = (\frac{dY}{dX_1} + U_{x1}) + (\frac{dY}{dX_2} + U_{x2}) + \cdots + (\frac{dY}{dX_n} + U_{xn})$$

- U_Y Total Uncertainty of the inlet quantity Y
- $\frac{dY}{dX_1}$ Sensitivity coefficients
- $U_{x1} \ldots U_{xn}$ Expanded relative standard uncertainty of the influence quantity X_1 to X_n

This is crucial in order to be able to determine the total uncertainty of the quantities reported. This is computed during the process of creating a monitoring plan and does not have to be performed annually unless relevant changes are made to the plant or to the measuring devices used. Operators that are obliged to report their emissions annually as part of the EU-ETS have to simply follow the procedures approved in the monitoring plan.

3.5.2. Special cases

There are of course some exceptions. Knowing that not all installations are obliged to monitor their fuel consumption with the same precision it follows that those installations, with low emissions, are permitted to determine the annual input quantity of a substance on basis of invoice data and estimated inventory changes without having to present proof of uncertainty. This can also be true for single fuel streams, that are considered low emitters.

If the input quantity of a material stream is determined exclusively by one or more calibrated/conformity-tested measuring devices, it can be assumed as a simplification, that the highest tiers are complied with and as such an individual uncertainty assessment can be avoided.

Furthermore, instances where the cost is disproportionate or there is a technical infeasibility the usual requirements for monitoring precision can be relaxed.

The costs of a measure are considered disproportionate if they exceed its expected overall benefits.

In Germany for the calculation of the overall benefits the National Authorities provides general guidelines.

For material flows (or amounts), the improvement factor is calculated as the difference between the uncertainty currently achieved and the uncertainty of the required level

multiplied by the average emission quantity of the considered substance stream over the last three years[44].

$$Benefit = (U_a - U_0)\ [\%] * \sum_{3\ years} m_{CO2} \left[\frac{t}{year}\right] * C_{fix}\ [€/(t_{CO2}/year)]$$

Where:

- $U_a - U_0$ the difference between the uncertainty currently achieved and the current uncertainty.
- m_{CO2} is the emission quantity produced in a year.
- C_{fix} is set at 20 $€/(t_{CO2}/year)$

3.6. Monitoring of Emissions in Germany

For monitoring the emissions of an installation, the operator of the installation may, depending on the greenhouse gas, choose between calculation-based methods and/or continuous emission measurement.

Calculation methods include the standard method and the mass balance method.

The overall emissions of the plant are obtained by adding the emissions of all the material streams and mass balances that characterize the installation. It may be that CO_2 produced within the boundaries of one installation is transmitted to another EU-ETS installation instead of being emitted into the atmosphere. In this case, of course, the CO_2 component transmitted must be taken into account and subtracted from the CO_2 produced.

$$\dot{M}_{CO2_{tot}} = \sum_{n}^{i=0} \dot{M}_{CO2_i} + \sum_{m}^{i=0} \dot{M}_{CO2_j} - \dot{M}_{CO2_{transmitted}}$$

Where:

- $\dot{M}_{CO2_i}$ is the mass of CO_2 emitted by the material stream in the reporting year' $[t_{CO2/year}]$

[44] Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt.

- n is the number of material streams monitored in the boundaries of the installation
- $\dot{M}_{CO2_j}$ is the mass of CO_2 computed through the mass balance j in the reporting year [$t_{CO2_{/year}}$]
- m is the number of material balances needed to report all the remaining emissions
- $\dot{M}_{CO2_{transmitted}}$ is the mass of CO_2 that is transmitted to another EU-ETS installation during the reporting year. (For example, to a carbon capture and storage facility or to a chemical industry plant requiring CO_2)

3.7. Standard Method of Emission Calculation

The standard method of emission calculation is widely used and adapts particularly well to combustion plants.

If emissions are calculated according to this method, the installation operator determines them based on the fuel or material input or the production volume of the installation and additional calculation factors that are going to be explicated in the following paragraphs.

For the fossil emissions from the combustion of a material stream, the operator shall determine the yearly feed of the stream i used and multiply it by the net calorific value and the corresponding emission factor and fossil share[45].

$$\dot{M}_{CO2_i} = \dot{F}_{in,i} * \hat{H}u_i * \hat{E}F_i * FS_i * OF_i$$

Where:

- $\dot{M}_{CO2_i}$ is the mass of CO_2 emitted by the material stream in the reporting year' [$t_{CO2_{/year}}$]
- $\dot{F}_{in,i}$ is the feed of the stream i [1000Nm3 or t_{fuel}]

[45] Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt.

- $\hat{H}u_i$ is the is the weighted average net calorific value of the material stream i [GJ/1000Nm3 or GJ/t_{fuel}]
- $\hat{E}F_i$ is the weighted average of the emission factor of the stream i
- FS_i is the fossil share of the stream i (100% - Biomass Fraction %)
- OF_i is the oxidation factor of the stream i

The European Commission published the following explanatory table to give a general idea of how the values are determined according to the Tier[46].

Table 4. - Determinaion of relevant values published by EC in the EU-ETS Handbook

Tier Level	Activity Data		Emission Factor	Biomass Fraction	Oxidation Factor
	Maximum uncertainty in fuel amount	Net Calorific Value			
Tier 4	± 1.5%	Factors determined by analysis	Factors determined by analysis	Factors determined by analysis	Factors determined by analysis
Tier 3	± 2.5%				
Tier 2	± 5%	Country specific factors / value from fuel invoices	Country specific factors / proxy values from analysis		Country specific factors
Tier 1	± 7.5%	Standard factors from Annex VI of the MRR	Standard factors from Annex VI of the MRR	Standard factors	1

3.7.1. The fuel feed

The fuel feed is the basis on which the calculation of the emission is built on. In some cases, where we do not have a combustion process a material input or the production volume are used instead of the fuel consumption. However, for the sake of simplicity this quantity will be referred to as "feed" from now on. In the monitoring plan, the plant operator has described in detail the procedures and instruments through which the feed is determined.

While in previous section tiers were introduced, explaining how for every fuel stream a separate monitoring method is used. The level of overall uncertainty can change depending on the carbon intensity of the stream and the quantity processed.

It can vary greatly, from the simplest case, in which the quantity is rated, often based on historical data, to more complicated scenarios, where the feed is measured continuously.

[46] European Union, «ETS Handbook».

As a rule, the more approximative the monitoring gets the more conservative are the values used. For example, natural gas material consumptions of large power production plants are often massive and therefore expected to cause large amounts of CO_2 emissions and are hence required to be monitored with the highest precision possible.

On one single site there might be different EU-ETS installations and sometimes even installations that do not fall under EU-ETS regulation. The gas meters might not measure the quantity consumed by the EU-ETS installation directly. In praxis this is often the case. The relevant monthly values are then computed automatically by a software or must otherwise be calculated by qualified personnel, transparently and clearly based on measured data. So that the accredited auditor can verify the correctness of the calculations.

The meters used to measure the gas flow can be different, depending on the design flow rate. Two examples of commonly used meters are for instance ultrasonic gas flow meters and turbine gas flow meters. The measurements read by those meters are normalized by flow computers considering temperature and pressure corrections. Being the specific volume affected by those variables.

$$\dot{F}_{in,i}\left[\frac{1000Nm3}{year}\right] = f(T,P)$$

Once a way has been found to calculate the feed quantities of the material stream in question, using calibrated and verified measuring instruments, which allow for the necessary accuracy, the calculation of the individual monthly values and the final annual value is a trivial summation.

$$\dot{F}_{in,i} = \sum_{12}^{j=1} \dot{F}_{in,ij}$$

Where:

- $\dot{F}_{in,i}$ is the total feed of the stream the stream i measured for the reporting year[1000Nm3 or t_{fuel}]
- $\dot{F}_{in,ij}$ is the feed of the stream i measured for the month j [1000Nm3 or t_{fuel}]

Once this has been done the monthly data of the feed are to be combined as follows with the remaining factors to find the best approximation of the annually emitted mass of CO_2eq.

3.7.2. The calorific value

The calorific or heating value is defined as the heat released by combustion of a unit amount of fuel at constant pressure and temperature. It can be expressed on molar, mass or volumetric basis. It is a positive quantity equal and opposite to the standard combustion enthalpy, which, is negative.

Two heating values can be defined depending on the assumption on the physical state of H2O in the product stream:

- Higher Heating Value or HHV under the assumption that the water in the product stream is liquid
- Lower Heating Value (LHV or Hu) under the assumption that the water in the product stream is vapour.

The difference between these two quantities is equal to the latent heat of vaporization of the product water:

$$\mathrm{LHV} = \mathrm{Hu} = \mathrm{HHV} - 2.500\ (\mathrm{U} + 9\mathrm{H})\ [\mathrm{kJ/kg}]$$

Where:

- U is the mass percentage of moisture
- H is the mass percentage of hydrogen in the fuel
- 2500 kJ/kg is the latent heat of vaporization of water (at 0°C).

Since smoke temperature is usually higher than dew temperature, the Lower Heating Value (Hu) is the quantity that in praxis corresponds to the heat released and this is also the one that is relevant for the monitoring and reporting of EU-ETS emissions.

Generally, calorific values are established by an accredited external laboratory and are made available to the plant operator on a monthly basis. In Germany the DEHSt provides an Excel Tool to determine the minimal required number of yearly analytics[47].

However, these values could also be monitored continuously by either the fuel supplier or the plant operator, in some cases, where the monitoring of Hu and EF is implemented using calibrated and verified measuring instruments an external laboratory is not needed. The correct method to be applied to every material stream in every plant can be looked up in the installation specific monitoring plan.

[47] Deutsche Emissionshandelsstelle (DEHSt), «DEHSt - Official website».

For natural gas streams the LHW is often determined through bomb calorimeters. The plant operators receive monthly analyses. Usually, it is the same laboratory and the same analysis, containing values for both the calorific value and emission factor of the fuel.

$$\hat{H}u_i = \frac{\sum_{12}^{j=1} \dot{F}_{in,ij} * Hu_{ij}}{\sum_{12}^{j=1} \dot{F}_{in,ij}}$$

Where:

- $\hat{H}u_i$ is the is the weighted average net calorific value of the material stream i [GJ/1000Nm3 or GJ/t_{fuel}]
- Hu_{ij} is the calorific value for the stream i measured for the month j
- $\dot{F}_{in,ij}$ is the feed of the stream i measured for the month j [1000Nm3 or t_{fuel}]

- Since the summation of the feed of the stream i for the month j over the months 1 to 12 is the annual feed, $\dot{F}_{in,i}$, it can be said that:

$$\hat{H}u_i = \frac{\sum_{12}^{j=1} Hu_{ij} * \dot{F}_{in,ij}}{\dot{F}_{in,i}}$$

Thus, the annual weighted average of the calorific value can be computed.

3.7.3. The emission factor

The emission factor expresses the amount of CO_2eq GHG gases emitted per unit of eighter heat released or mass consumed or produced. For combustion processes where natural gas is used as a fuel it is expressed in t CO_2eq/GJ of heat of combustion released. The emission factor can be rated or taken from the standard values provided by the national authority in case of de-minimis streams.

In Germany it is the DEHSt that in the 4th appendix of "Leitfaden zur Erstellung von Überwachungsplänen für stationäre Anlagen – 4. Handelsperiode (2021–2030)[48]" that providing the list of standard value. Here follow some examples of the values listed therein:

Table 5. Examples for standard values of emission factors provided by the DEHSt

Substance	EF [t CO_2/GJ]
Lignite dust from the Rhineland	0,100
Diesel fuel	0,074
Liquefied gas (100 % propane)	0,0647
Liquefied gas (100 % butane)	0,0663
Natural Gas	0,056

It is apparent by comparing standard values that the EF of lignite dust sourced in the Rhineland (DE) is 1,79 times higher than the EF of natural gas. Physically this describes the carbon intensity of a substance, the unit of GHG emissions released for every unit of useful effect produced by said material, in this case heat of combustion produced.

For most emission week and emission strong streams the EF is determined as a weighted average of monthly emission factors provided by monthly analyses. To give one example, for natural gas streams, values of the EF are most commonly obtained by gas chromatography.

In the very common case where we have a combustion process and the values of Hu and EF are provided monthly the average emission factor for the reporting year is computed as such:

$$\hat{\mathrm{E}}\mathrm{F}_{\mathrm{i}} = \frac{\sum_{12}^{j=1} \dot{\mathrm{F}}_{\mathrm{in,ij}} * \mathrm{Hu}_{\mathrm{ij}} * \mathrm{EF}_{\mathrm{ij}}}{\sum_{12}^{j=1} \dot{\mathrm{F}}_{\mathrm{in,ij}} * \mathrm{Hu}_{\mathrm{ij}}}$$

[48] Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt, «Leitfaden zur Erstellung von Überwachungsplänen und Emissionsberichten für stationäre Anlagen 4. Handelsperiode (2021–2030) des europäischen Emissionshandels».

Where:

$\hat{E}F_i$ is the yearly weighted average emission factor of the material stream i [tCO_2eq/GJ]

$\hat{H}u_i$ is the is the weighted average net calorific value of the material stream i [GJ/1000Nm3 or GJ/t_{fuel}]

$\hat{E}F_{ij}$ is the monthly emission factor of the material stream i for the year j [tCO_2eq/GJ]

Hu_{ij} is the calorific value for the stream i measured for the month j

$\dot{F}_{in,ij}$ is the feed of the stream i measured for the month j [1000Nm3 or t_{fuel}]

Since:

$$\bar{Q}_i = \dot{F}_{in,i} * \hat{H}u_i = \sum_{12}^{j=1} \dot{F}_{in,ij} * Hu_{ij} \quad [GJ]$$

The equation can be rewritten as following by introducing the quantity $\bar{Q}_i$ as the Heat released by the combustion of the material stream i during the reporting year. Dimensionally this quantity is an energy or to be more precise an energy flow expressed in GJ/year.

$$\hat{E}F_i = \frac{\sum_{12}^{j=1} \bar{Q}_{ij} * EF_{ij}}{\bar{Q}_i}$$

Looking at this formula it becomes apparent that the yearly emission factor is computed as a weighted average, weighted, not on the mass or volume like the Hu, but on the energy or Heat released through combustion.

3.7.4. The fossil share

The fossil share**,** FS_i , is calculated as 100 per cent minus the creditable biogenic carbon content, “C” also called "biogenic share".

$$FS_i = 100\% - C_i$$

Where C is the biogenic share of the total released heat, computed as

$$C_i = \frac{\dot{F}_{bio,i} * \hat{H}u_{bio,i}}{\dot{F}_{fossil,i} * \hat{H}u_{fossil,i} + \dot{F}_{bio,i} * \hat{H}u_{bio,i}} * 100\ [\%]$$

3.7.5. The oxidation factor

The oxidation factor, OF_i, in praxis, in Germany, is based on the Annex 2 Part 1 TEHG, and is set at the value 1.

$$OF_i = 1$$

The overall emissions of the plant are obtained by adding the emissions of all the material streams and mass balances that characterize the installation. It may be that CO_2 produced within the boundaries of one installation is transmitted to another EU-ETS installation instead of being emitted into the atmosphere. In this case, of course, the CO_2 component transmitted must be taken into account and subtracted from the CO_2 produced.

$$\dot{M}_{CO2_{tot}} = \sum_{n}^{i=0} \dot{M}_{CO2_i} + \sum_{m}^{i=0} \dot{M}_{CO2_j} - \dot{M}_{CO2_{transmitted}}$$

Where:

$\dot{M}_{CO2_i}$ is the mass of CO_2 emitted by the material stream in the reporting year' $[t_{CO2/year}]$

n is the number of material streams monitored in the boundaries of the installation

$\dot{M}_{CO2_j}$is the mass of CO_2 computed through the mass balance j in the reporting year $[t_{CO2/year}]$

m is the number of material balances needed to report all the remaining emissions

$\dot{M}_{CO2_{transmitted}}$ is the mass of CO_2 that is transmitted to another EU-ETS installation during the reporting year. (For example, to a carbon capture and storage facility or to a chemical industry plant requiring CO_2.)

The plant operator has then to correctly use the received values and combine them with the gas consumption, building the yearly weighted averages for Hu and EF. It has to be noted that the Hu is mass or volume weighted, while the EF is energy weighted.

These values are entered in the FMS as Input values and the software automatically gives back the emitted CO_2.

The final part is usually done in excel sheets that may look similarly to the following example, that is meant to portrait the calculation for one natural gas material stream.

Table 6. – Simulation of a calculation of final values for emission report

	Fuel consumption	Hu	EF	Q	M(CO_2)
	1000 Nm3	GJ/1000Nm3	tCO_2/GJ	GJ	tCO_2
Jan	18998,18182	32,67834	0,055982747	620829,0448	34755,71518

Feb	17478,32727	32,47638	0,056782664	567632,7983	32231,70229
)Mar	16338,43636	32,35673	0,05512937	528658,374	29144,60311
Apr	15958,47273	32,85678	0,056782646	524344,0275	29773,64125
Mai	17858,29091	31,89567	0,055368263	569602,1536	31537,88185
Jun	19378,14545	31,67392	0,055975629	613781,8289	34356,82388
Jul	21657,92727	32,54912	0,05612385	704946,4738	39564,30994
Aug	20518,03636	31,99482	0,0566219	656470,8802	37170,62853
Sep	19758,10909	32,48337	0,056782491	641809,9681	36443,56845
Oct	18618,21818	31,45732	0,056970394	585679,2472	33366,37747
Nov	20138,07273	31,56789	0,055968794	635716,4647	35580,28385
Dec	19188,16364	31,98526	0,055678376	613738,4028	34171,9575
Reporting year	**225888,4**	**32,1540**	**0,05619**	**7.263.215,614**	**408.120**

	Data from verified metering or fuel supplier
	Data from accredited laboratory or fuel supplier
	Computed quantities

	Computed annual data to be entered in the FMS
	Data automatically calculated by FMS

In order to report the annual emissions according to the standard method the operator is required to correctly compute weighted annual values for the mass or volume consumed, for the heating value and for the emission factor. Hereby it must be remembered that the heating value of the fuel is weighted on the total volume (or mass, in the cases where the quantity of fuel burned is reported by using masses).

In Germany these values and, in cases where there is a biogenic component, the Fossil Share are entered in the correspondent sections of the Formular Management System (FMS), for every material stream, the amount of CO_2 produced is calculated automatically by the software and cannot be entered or changed manually.

The verifier is however able to leave comments behind in the FMS.

3.8. Calculation of emissions under the mass balance methodology

If emissions are calculated with the aid of a mass balance, the installation operator shall determine the quantity of CO_2 that is attributed to the individual material flows entering or

leaving the mass balance (mass balance elements). This is introduced in Article 25 of the MRR[49].

$$\dot{M}_{tot} = \sum_{j=0}^{m} \dot{M}_j^{out} - \sum_{i=0}^{n} \dot{M}_i^{in}$$

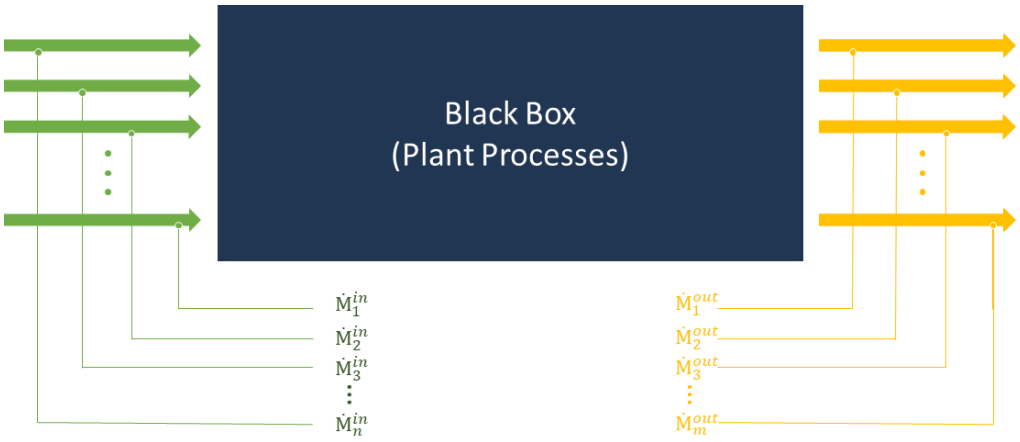


Figure 11. - The Mass Balance methodology

The plant operator multiplies the data relative to the activity of the materials entering or leaving the boundaries of the mass balance with the relative carbon content and a correction factor equal to 3,664 t_{CO2}/t_C.

$$\dot{M}_i = \sum_{j=1}^{12} \dot{F}_{ij} * Cc_{ij} * 3{,}664\ [t_{CO2}]$$

Where:

- $\dot{M}_i$ describes the potential CO_2 mass carried by any given material stream i in the reporting year.

[49] European Commission, COMMISSION IMPLEMENTING REGULATION (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012.

- $\dot{F}_{ij}$ is the mass flow for the activity i entering or exiting the boundaries of the mass balance in the month j [$t_{material(i)}$]
- Cc_{ij} is the carbon content of the stream i measured in the month j, often this quantity is fixed and comes from tables or else is defined in the monitoring plan.
- The factor of 3,664 t_{CO2}/t_C represents the ratio between the Molar Mass of carbon dioxide and the Molar Mass of carbon.

Being, the Molar Mass of CO_2:

$$MM_{CO2} = 44{,}01$$

And the Molar Mass of C:

$$MM_C = 12.0107\ g/mol$$

The potential mass of CO_2 generated by one ton of C, assuming a complete conversion of C, is 3,664 times the mass of C, being:

$$\frac{MM_{CO2}}{MM_C} = \frac{44{,}01}{12{,}0107} = 3{,}664\ [t_{CO2}/t_C]$$

The carbon content of a generic stream i is strictly related to the composition of the stream. It can be determined continuously or through monthly analysis but often it is a standard value.

In Germany the DEHSt provides this kind of values for a number of substances in the appendix 4 of "Leitfaden zur Erstellung von Überwachungsplänen für stationäre Anlagen – 4. Handelsperiode (2021–2030)" along other standard proprieties[50].

Table 7. - Examples of Cc standard values from the DEHSt

Substance	Cc [tC/t]
Lignite dust from the Rhineland	0,540

[50] Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt, Leitfaden zur Erstellung von Überwachungsplänen und Emissionsberichten für stationäre Anlagen 4. Handelsperiode (2021–2030) des europäischen Emissionshandels.

Diesel fuel	**0,862**
Liquefied gas (100 % propane)	**0,817**
Liquefied gas (100 % butane)	**0,827**

Basically, equation (Xi) describes the potential CO_2 mass carried by any given material stream.

The mass balance is a conservative, simple, yet effective way to compute the CO_2 emissions in cases where the standard method is not applicable. The major drawback is that it implicitly assumes that every atom of C released into the atmosphere is converted into CO_2.
In other words, the potential CO emissions are reported as CO_2 emissions.

3.9. Continuous Emission Monitoring (CEM)

The continuous emission monitoring is one of the many examples of the important role that digitalisation playing in the decarbonization process. Most CEM devices offer quantitative and selective measurement of a series of gases among which there are CO, CO_2, SO2, NOX, N2.

Players that offer this kind of measurement devices are many for example Siemens AG, ABB Automation GmbH, Fer Strumenti Srl and Dr. Födisch Umweltmesstechnik AG. These instruments can achieve high stabilities, accuracies and reliabilities and are often part of modular completely pre-engineered systems. In theory these solutions should reduce the monitoring effort for plant operators. In the monitoring of EU-ETS GHG emissions is possible and, in some cases, necessary to measure the GHG emissions continuously.

Hereby both the concentrations of relevant components in the gas stream and the volumetric flow of the flue gas stream must be monitored. This is mandatory in those installations where N2O emissions are to be monitored, but also for those streams of CO_2 that are captured and led to Carbon Capture and Storage plants (CCS) and for CO_2 emissions that occur through regeneration of catalysts and flexic cores, the application of continuous emission measurements shall be mandatory.

For these applications of continuous emission monitoring, an accompanying calculation is not required. However, if this method of monitoring GHG emissions is used for other applications as part of the EU-ETS compliance cycle an independent calculation is needed.

With the approval of the national authority, the operator can used one of the methods previously introduce for the accompanying calculation, or a combination of those methods

as long as gaps and double counting are avoided effectively and the method is permitted for the monitored activity under the MRR[51].

3.10. The German Formular-Management-System (FMS)

The German FMS is a software designed by the DEHSt with the goal to standardise reporting of emissions. It also should help plant operators to deliver error free emission reports[52]. The FMS allows different type of access to different types of users: Plant operators and independent verifiers can work on the same report inside the FMS at different times and with access to different functions. The main users are the plant operators and the independent verifiers, users are allowed to pass on the right to edit the respective reports between each other. This often is an iterative process. While giving the reporting process a very well-defined structure, this can also make removing simple mistakes quite time consuming, for both, the plant operator and the auditor side.

Experts state that year after year the FMS has become more reliable, however users still experience difficulties with the software occasionally and it has been known to present "bugs" from time to time. When the process is completed the operator's entries and the inspection notes of the inspection bodies are available to the other role partner for reading.

The FMS isn't only designed to support users in the reporting and monitoring of EU-ETS emissions, but its functions support the entire compliance cycle of EU-ETS. Furthermore, the same system is used for the national emission trading system the nEHS.

3.11. Secure communication

In Germany after the emission reports have been verified and commented by the independent verifier. The verifier zips the emission report and signs it and sends it using the Virtual Post Office of the DEHSt the so called Virtuelle Poststelle (VPS) to the plant operator, who adds his own signature and sends the unopened zip to the national competent authority. The VPS system is a core element of the Basiskomponente Datensicherheit BundOnline of 2005.[53] It is built to be a central security gateway and communication server in the area of E-government. Allowing secure, traceable and confidential communication (OSCI protocol) and a legally compliant electronic communication in accordance with SigG (qualified

[51] European Commission, COMMISSION IMPLEMENTING REGULATION (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012.
52 Deutsche Emissionshandelsstelle (DEHSt), «DEHSt - Official website».
53 Deutsche Emissionshandelsstelle (DEHSt).

electronic signature = QES). The activation of a VPS mailbox has to be done through the DEHSt. Users must send an e-mail containing all necessary contact details to a DEHSt email address (vpsfreishaltung@dehst.de). Once this has been done the DEHSt performs a check and if no duplicate mailboxes are found the mailbox is activated.

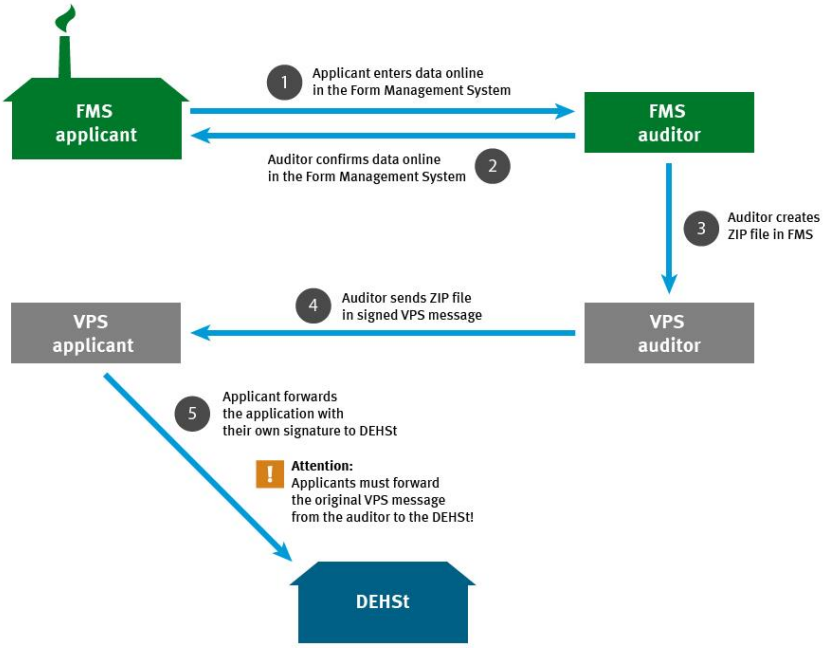


Figure 12. - German secure comunication process, source: DEHSt official web

4. Experts' evaluation of EU-ETS

4.1. Interviews with the experts

The thesis research work has been enriched through some interviews and questionnaires with experts working specifically with EU-ETS in the practice field since a long time and who observed its evolution through the various exchange periods.

4.1.1. Operators of large power production plants

The first interview subject is a trading desk manager for EUAs of a major utility. It is very important for his work to observe the trend and forecast of the monitored data during the EU-ETS compliance cycle and accordingly adjust and decide on appropriate actions. The full interview can be found in the first appendix[54].

The interviewed specialist considers the EU-ETS a very enlightened instrument, so efficient that, in his words, it has "changed the narrative about fossil fuel management in Europe".

He also explains how the EU-ETS mechanism had difficulty getting started, with certificates issued exceeding actual market needs. Certificate prices collapsed to near zero at the time and only by using the Market Stability Reserve (MSR) the price trend could be reversed[55].

The European Union defines the Market Stability Reserve as a long-term solution, that began operating in January 2019. It serves to address the surplus of allowances and is meant to improve the system's resilience to major shocks by adjusting the supply of allowances to be auctioned. Allowances that were backloaded in the past could be transferred to the reserve rather than auctioned off, likewise unallocated allowances can also be transferred to the reserve.

Another indicator that the interviewed expert mentioned is how strong the focus on climate change of large utilities is mirrored in the job market. When he started working in this field, about fifteen years ago in the same utility where he works now, there were no jobs related to carbon emissions and sustainability, whereas today they are the most in-demand positions.

Despite all expectations, the EU-ETS instrument turned out to be advantageous for producers and industrialists. The first positive outcome for producers was to find themselves, the following year, with a portfolio of certificates to sell. These deposit flows provided liquidity to producers in many sectors, also benefits companies in crisis; a fact that certainly helped to gain the industrial lobbies. Through several steps, including some traumatic ones, the main

[54] First Appendix – Interview I
[55] European Commission, official webpage.

problems with the system have been removed, and its implementation has led the company toward greater dynamicity, helping to realize a very high level of growth.

The interviewee points out that the reaction of the certificate market to the outbreak of the war between Russia and Ukraine was completely unpredictable. At the time, it was expected that prices would collapse because of the conflict. Instead, since the European Union has remained strongly against climate change, the "strategic value" of CO_2 emissions has also increased, precisely because of the problems caused by the war, including in the ecological field.

He also points out that currently the monitoring and reporting process is becoming so complex that only large companies have the resources to create specific departments able to keep up with the tasks required. However, the expert still believes that the system is well designed but he points out that the largest limitation is that only Europe and a few other countries have to be compliant to this scheme. Despite Europe's moderate incidence on global emissions, this system has in his opinion the potential to act as a trailblazer.

It is necessary for Europe to show the effectiveness of this systemic approach to the problem to the world, hoping that the economic conjunctures and the market will lead to ecological and carbon-free choices, throughout the world economic system.

One more important factor that is pushing towards a rapid reduction in the use of fossil fuels is the search for energy independence on the part of some powerful industrialised countries, that lack these raw materials, such as, for example, Germany and Italy. The search for independence in geopolitical terms should greatly accelerate the shift to renewable sources.

Ideally the experts envision the future possibility to exchange certificates worldwide.

The interview reveals how, for the company in which he works, the technological transition towards clean energy sources is experienced as a strong problem, treated with significant resources and a lot of managerial will. He himself has always shown great confidence in EU-ETS, despite difficult circumstances (Brexit, Covid 19, the Russian-Ukrainian war) and points out that also the EU itself remains optimistic about it, with the system proving more than resilient, sustaining the high price level.

He does however point out a risk, linked to the high prices of the EUAs saying that this could become an obstacle, driving out of the system small and medium-sized companies that are not structured for the study and management of EU-ETS. Another risk is obviously, beyond ethical evaluations, and for the very future of EU-ETS, one must hope, more than any other future event, for a speedy end to hostilities in Ukraine.

4.1.2. Operators of Small/Medium EU-ETS Installations

A. an Energy Manager in the Energy Markets & Regulations department of a major player in the Italian market, organised the call and introduced me to his colleagues B. and C. who are responsible for the monitoring end reporting of emissions for a large European company

that operates many small and medium sized thermal and power plants, for hospitals, the public sector and to a lesser extent some industrial plants. The plants are generally owned by the customer, while the company is the owner of the management of these plants. The full interview is to be found in the Second Appendix.

In older contracts their company is still economically responsible for CO_2 emissions, however, it is a trend in newer ones that the owners of the plant take over the CO_2 emissions and that together with the operational management a consulting service for EU-ETS management or other regulatory services is offered.

They tell us that it is not often so clear to whom the economic responsibility for CO_2 emissions belong, in some cases is necessary to appeal to the European Commission. There are cases in which the concept of plant and production unit and of technical connection in the case of the transfer of streams to other closely located plants is questionable.

Interviewed expert C. was at the forefront of the data collection and preparation of EU-ETS, for both the emission report and the free certification requests. Following this through the various Stages of the European Emission Trading System (1-4) and she reveals that in the 1st phase they started with 23-24 EU-ETS plants and as today are down to 6, of which two are close to exiting the Emission Trading system.

She explains that management has changed a lot, especially since the OPT OUT option was introduced in Italy for small plants that serve mainly hospitals.

The strongest consequence of entering the 4th Trading Period where the strong price increase and the sharp reduction of free certificates allocated, this were also the main reasons behind the decision to exit EU-ETS where possible.

Furthermore, they noticed that the filling out the necessary forms for the request of free allocation of certificates for each plant has become an onerous task and that communication with the relevant authorities was not always straightforward.

For the installations belonging to hospitals they operate, the request for exclusion and the new OPT OUT forms have led to further bureaucratic difficulties but have made it possible to benefit from a higher emission limit and from the possibility to perform a financial compensation of the emissions instead of the restitution of allowances, which compared to the current prices for EUAs in 2021 is more advantageous.

Speaking of the accuracy required in emissions monitoring for the purpose of emissions reporting, expert B. is of the opinion that it is adequate and approves of the important role that is given to calibration certificates for measuring devices that are required for the measuring instruments used. To obtain the best results it is important to find and use the most appropriate method and source of data, cooperation with the certifier made it possible to switched from verifying invoices to verifying internal data. This made it possible to work more efficiently, as the data used internally are more accurate than the suppliers' invoices.

Expert C. points out the importance of raising awareness about how important this work is to combat climate change among the people working in the field, who are often responsible

for entering data or reading measurements. It is often not at all trivial to gain access to the data, both with internal operators and gas suppliers.

When asked whether in their opinion EU-ETS is an effective tool to reach the EUs announced goals against climate change expert C. tells us that in her opinion it is, although some rules should be changed to include more plants and operator B. adds that the system is effective, but there is always a difference between saying and doing, the EU-ETS has an important economic impact, perhaps too much so, many operators, especially those with plants at the 20 MW limit, have left the EU-ETS and that the way the system is currently constructed, it is the individual citizen who suffers the consequences of the increase in the price of CO_2.

In his opinion companies themselves have an interest in being more environmentally virtuous but raising the price too high risks making the path unsustainable for operators of smaller plants. Companies should be induced to be more virtuous, without the cost of this being excessively passed on to the end customer.

Many operators, where they are allowed to do so, have simply reduced the size of 'oversized installations' in order to exit the EU-ETS a process that does not impact the actual emissions of the installation. For larger installations, of course, it is a different matter. In these cases, it was necessary to adopt other technologies where possible. For example, changing gas boilers with biomass-fuelled boilers or using at least some biomethane where possible.

The interviewed experts do believe that EU-ETS is certainly very useful on the environmental level and the externally imposed methodologies are of great help in giving structure to the consumption data and the resulting CO_2 emissions.

Their hopes for the future of EU-ETS are that in the future the market will stabilise, and that it will no longer be subject to these price fluctuations, so that companies will be pushed to invest more in decarbonisation. They add that it would also help if there were more simplifications at the bureaucratic level, and that the questions on the forms were clearer and easier to interpret.

The main risk the interviewed experts identify are an excessive increase in price, which on the one hand risks triggering undesirable mechanisms and on the other risks burdening the weaker sections of the population too much and a further increase in bureaucratic complications related to the operation of EU-ETS should be avoided.

4.1.3. Interview with an independent verifier

The third interview was with an experienced accredited and independent verifier, working in Germany. The full transcript of this interview can be found in the Third Appendix[56].

[56] Third Appendix - Interview III

She explains how the national authority makes sure that the independent verifiers have the technical knowledge to perform the verification for the specific scope of every plan.

She also mentions that in the 4th trading period partly design errors in the national implementation of the compliance cycle were fixed within the DEHSt and how installations with 0 emissions that nevertheless received allocations were removed from the system.

The change from the 3rd to the 4th trading period also implied a lot of additional work as a consequence of the new Monitoring Plans for the 4th Trading Period.

The new requirements meant additional new trainings and new guidelines, new internal tools, that had to be processed under time pressure. In 2022 the guidelines were realised with some delay by the DEHSt and so it was allowed to submit the reports for the data relevant for the allocation of free allowances without any negative consequences.

The interviewed expert also had the opportunity to work on projects of GHG emissions monitoring outside the EU-ETS framework and noticed that as matter of fact in those projects the same emissions monitored and computed following the standards of the GHG protocol in t CO_2eq where lower than the emissions monitored and reported using EU-ETS guidelines. This is attributed to the fact that for EU-ETS emissions are tested with reasonable assurance and that conservative values are used in order not to underestimate the GHG emissions.

She is very optimistic about the importance of the EU-ETS in reaching the EU targets against climate change, saying: **"**We are part of the EU's largest economic instrument to fight climate change." However, she also states that in order to reach the announced targets it is necessary to support the achievements of EU-ETS with other policies and tools. She also believes that the EU-ETS does have an impact on strategic decisions of companies subject to EU-ETS, pushing towards decarbonisation. In here opinion a better cooperation with DEHSt and a more uniform reporting across countries would benefit the European Emission Trading System.

While the gradually more complex reporting is becoming an issue and poses a risk for the system itself. The many exceptions and the various special cases are confusing and require resources that could be put to better use.

Also, this expert believes that this trend will soon require plant operators to have a specialised reporting team, exclusively available for EU-ETS and she warns that this may not always be possible.

4.2. Questionnaire to the experts

Similar questions to the once that have been posed to the experts in the frame of the interviews where shared through a network of experts working in carbon pricing. The full excel print of the questionnaire is made available as Fourth Appendix[57].

To better evaluated and understand the answers to the questionnaire the experts where ask to answer some introductory questions.

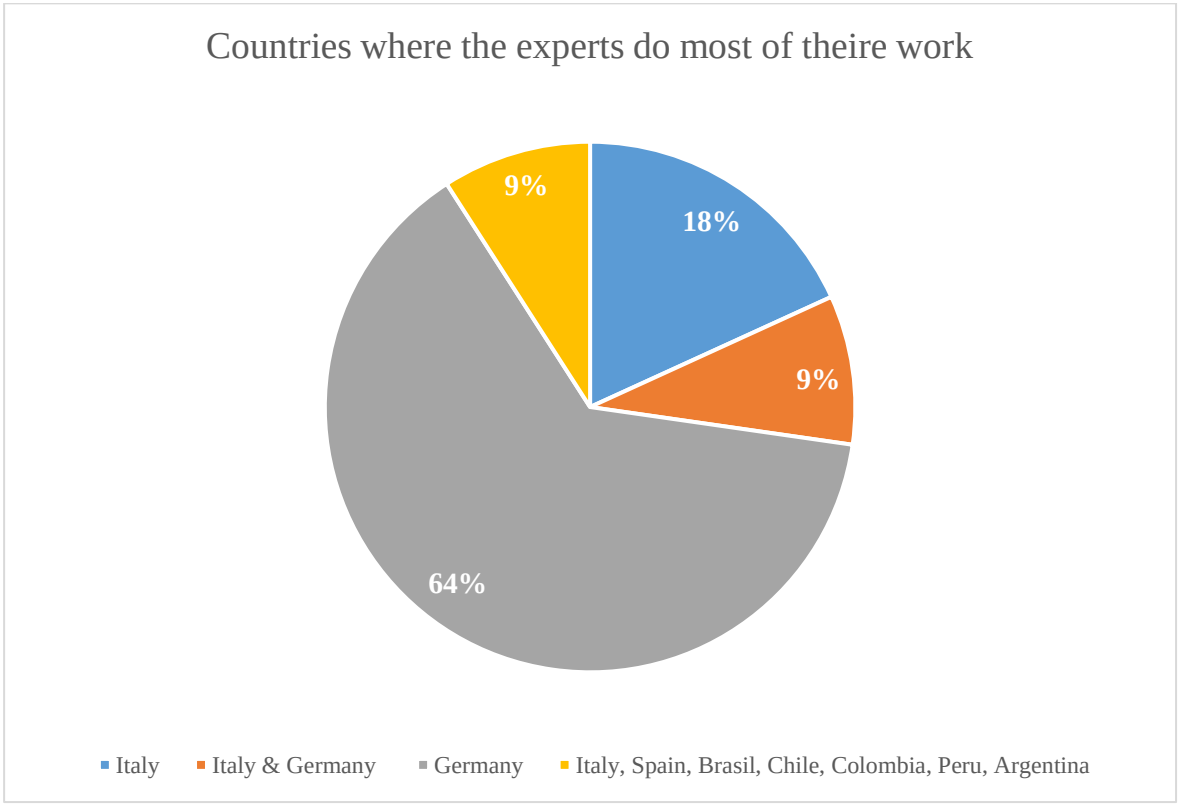


Figure 13. - Countries where experts taking the questionnaire work.

Mostly the interviewed experts work in Germany and Italy.

[57] Fourth Appendix - Questionnaire

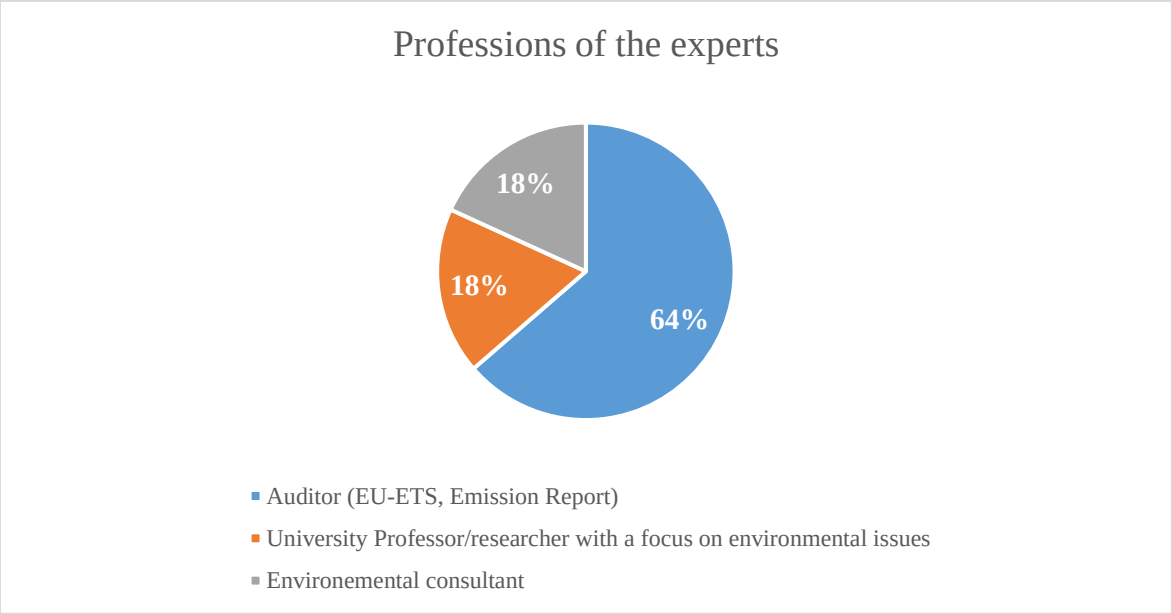


Figure 14. - Profession of experts taking the questionnaire.

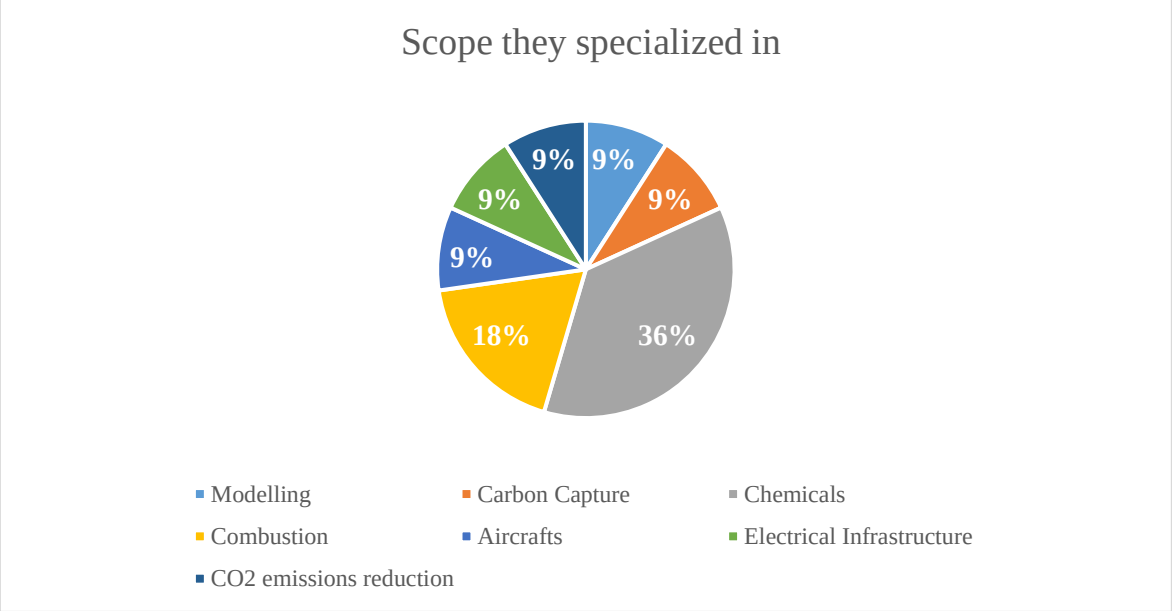


Figure 15. Specialization of experts taking the questionnaire.

The answering experts have worked with the EU-ETS from different point of views and specializing in different 'scopes', many are Auditors, but some are university professors or researchers that have studied carbon pricing methods and some others work in environmental consulting.

When asked if the transition from the third to the fourth phase of EU-ETS entail any major difficulties and if so, different experts working in different industries had different answers.

One expert working in academia said that not much literature is present on this.

While auditors working as independent verifiers in the EU-ETS compliance cycle say that

the new guidelines and requirements have resulted in an increase in the amount of testing. As it required new monitoring plans and a lot of clarification. An auditor also points out that the free allowances allocated have been reduced and the linear reduction factor was raised from 1.74 to 2.2.

On the other hand, an environmental consultant states that no difficulties were introduced in his activity. Indeed, the inclusion of more industrial sectors in the ETS system widens the range of possible customers for his company.

The experts have been asked if the accuracy of the monitoring of emissions for EU-ETS is appropriate and the vast majority is of the opinion that indeed it is.

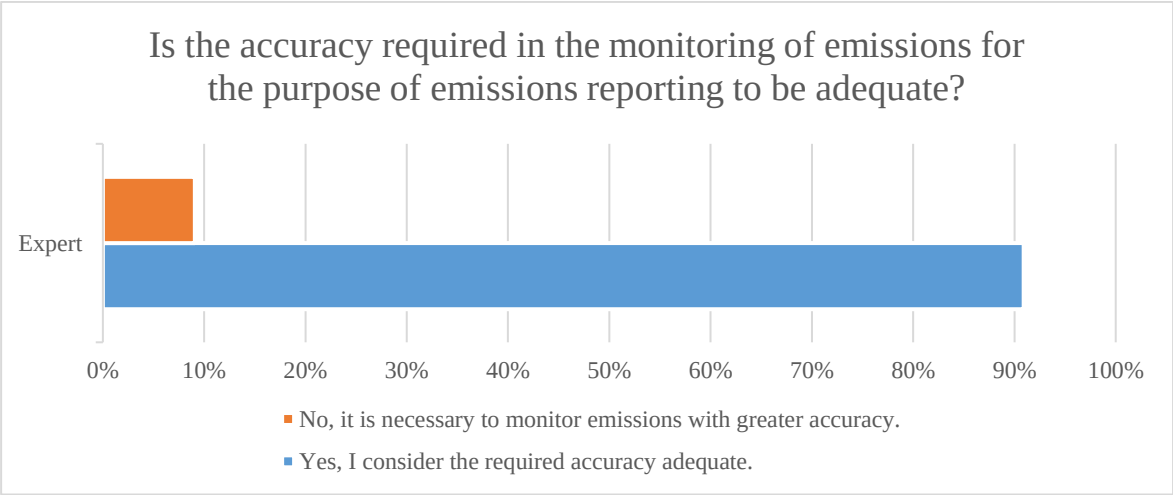


Figure 16. Experts evaluating the accuracy required in the monitoring of emissions.

All experts that took the questionnaire agree that the EU-ETS has the potential to contribute towards the announced targets against climate change, but alongside other targets. A few are even more positively oriented towards the European 'cap' and 'trade' tool and when asked if the Emission Trading System is an effective way to contribute to the ambitious climate targets the European Union has pledged itself to, they answer: "Yes, the EU-ETS is already and will be in the future a key tool for reducing anthropogenic emissions." and "Absolutely yes, the EU-ETS is the main tool to reach Net Zero on time".

When asked if the EU-ETS impacts companies that operate one or more EU-ETS facility experts seem to agree it does, however, most believe the impact of carbon pricing is of secondary importance.

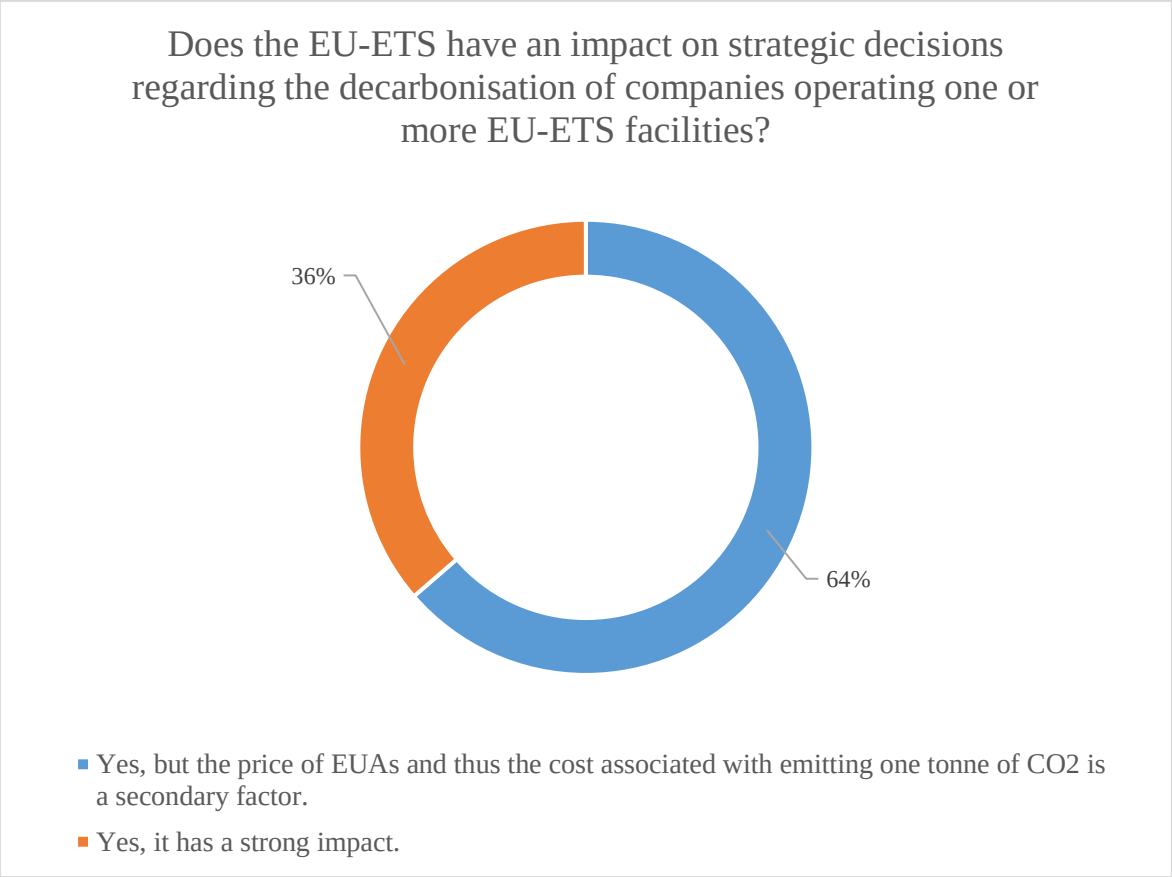


Figure 17. Experts evaluating the impact of EU-ETS on strategic decisions on decarbonization.

Some experts have expressed several hopes for the future of EU-ETS:

- "That it will be soon able to take into account emissions taking place outside of EU."
- "Less bureaucracy."
- "Uniform, cross-country reporting that is simple and straightforward for all parties."
- "I hope EU ETS can lead to development of strategies which causes sharp reductions in emissions and application of those strategies."
- "I hope the most recent developments in regards of the price of energy of fossil origin don't deter us in the chosen path to steadily increase the price of issued EUAs. So, we can continue our journey to a net zero Europa independent of the situation of the worlds markets."
- "As regarding most legislations, the bureaucracy needs to be made quicker and more user-friendly."
- "I hope that also smaller companies and factories will be included in the system, so that decarbonisation can be applied in all industrial sectors."
- "A well thought-out ETS reform is needed to protect EU energy suppliers from price Shocks and support their energy transition."

Some have written down some of what they believe to be the major risks for the EUs carbon pricing tool:

- "Low price of carbon emissions."
- "Companies migrating to countries without EU-ETS."
- "Reporting is becoming increasingly difficult and detailed, so that experts are needed on both the auditor and the plant operator side. However, training for this is not easy and requires a lot of experience."
- "Keeping the Balance between further increasing the price of EUAs without losing our competitiveness on the world stage and the related carbon leakage that would come with such a situation."
- "Reallocation of Key industries to countries with less regulations."
- "EU ETS is a strong tool against pollution related to the major industrial sectors. What I currently see is that decarbonisation is often costlier that CO_2 cost itself, leaving companies with no choice other than keep polluting as they are."
- "Risks in investment decisions as the Development of the CO_2 certificate price cannot reliably forecasted."

Particularly interesting is the feedback of an environmental consultant working in Italy who says that, in his/hers experience, often the cost of decarbonising production is too high and companies have no choice but to keep polluting at a higher cost.

5. *Analysis of the EU-ETS*

As was to be expected with the economic recovery after the COVID-19 pandemic the overall EU-ETS emissions from stationary installations have risen by 7,3%[58]**.** However, the growth was such to surpass the value of EU-ETS registered before the pandemic in 2019 (4,4% higher than 2019)[59].

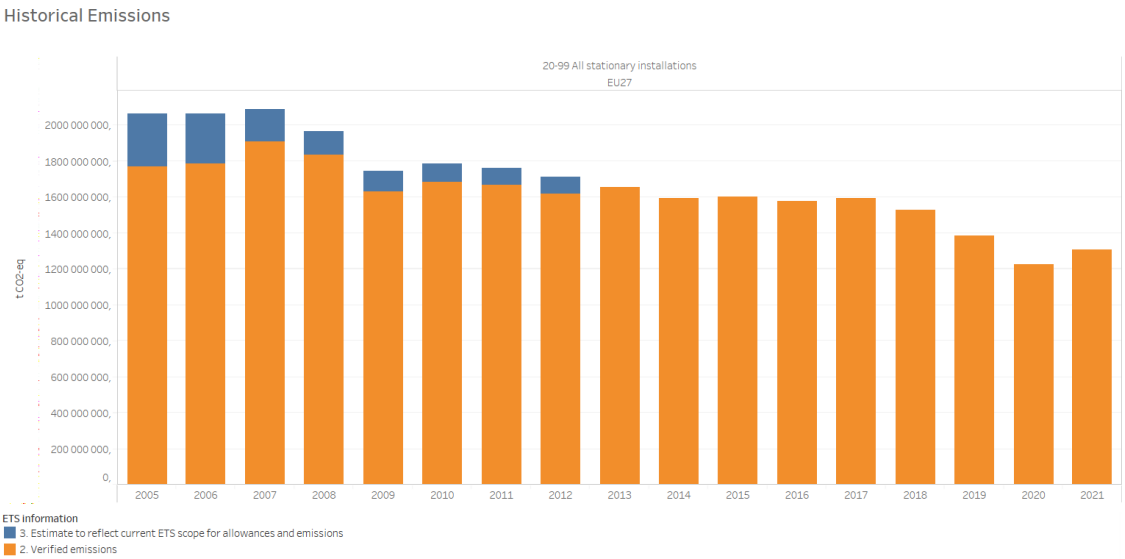


Figure 18. - Verified Emissions with corrections to reflect current scopes from EC data viewer.

Above the trend of EU-ETS verified emissions is displayed, the blue portion of the bar represents the correction of the emissions verified at the time considering current sectors included in EU-ETS.

While specifically EU-ETS emissions in Germany have risen by 11% compared to the previous year. This is attributed mainly to the economic recovery after the sanitary crisis. In Germany however EU-ETS emissions have sunken, however slightly (only two percent, compared to 2019, data from the DEHSt)[60]. This is one more indicator that might point to the fact that EU-ETS is not affecting every economy in the same way.

Focusing on the German data of EU-ETS (data taken from the DEHSt and the EU data viewer) we can observe how the overall installations participating in EU-ETS have diminished. From 1.871 in 2020 to 1.732 in 2021[61]. This can be attributed to at least two factors. The first is that the DEHSt has, as the interview with the independent verifier

[58] DEHSt, «Greenhouse Gas Emissions in 2020 - Executive Summary».
[59] European Environment Agency, «EU-ETS data viewer».
[60] Deutsche Emissionshandelsstelle (DEHSt), «DEHSt - Official website».
[61] European Environment Agency, «EU-ETS data viewer».

confirmed, corrected some design-errors removing this plant operators from EU-ETS that do not emit GHG emissions as a consequence of their operations, but were included in the EU-ETS because of the category/sector of the plant and as a consequence revived free allowances without having to give up any. The second factor is that with the rising prices and the fewer free allowances distributed many plant operators that operated at the limit of 20 MW did everything that was possible to exit the EU-ETS. This has emerged especially in the second interview.

However, EU-ETS it impossible to question the growing importance of the European carbon market, to understand it's scale it is sufficient to know only in Germany, in 2021, 5,3 billion Euro were collected in form of 101 million EUAs.

5.1. SWOT Analysis

5.1.1. Strengths of the EU-ETS

Starting from the strengths of EU-ETS it has emerged clearly from all interviews with the experts, all answers to the questionary, the authors personal experience in the field and what evidence could be found in literature, that emission trading is believed to be an effective tool to combat climate change, the system clearly makes it less convenient to invest in carbon intensive technologies and especially for large installations it incentivizes the use of renewable technologies[62]. The system is particularly well designed for large utilities and large installations that can afford to have a specialized department and train qualified personal, due to the increasing complication of the monitoring and reporting, all interviewed experts agree on this subject[63].

One more great strength of the emission trading system is the structure and procedures developed for monitoring and reporting emissions.

Also, the tool has demonstrated to be more than resilient, the prices of EUAs stayed strong even after the beginning of the Russian-Ukrainian war, the expert interview in the first appendix, is proof of the European commitment towards the climate action goals and of how strongly politicians, investors and operators believe in this tool[64].

5.1.2. Weakness of the EU-ETS

But EU-ETS has of course some weaknesses too, as the interviews with the experts pointed out, small plant operators struggle with the monitoring process and the reporting process,

[62] DEHSt, «Greenhouse Gas Emissions in 2020 - Executive Summary».
[63] Appendix First to Third
[64] Johanna Lausen et al., «Trading activities and strategies in the European carbon market».

that is becoming gradually more complicated. With the start of the 4th trading period new guidelines, new monitoring plans and new requirements have made a lot of clarifications needed and the competent authorities struggle with the workload connected to these.

In Germany, the FMS, while helping the standardisation of reports and building a bridge between EU-ETS and national carbon pricing tool, creates difficulties for plant operators and verifiers, often requiring a manual transfer of critical information, and making reporting standards and efforts unequal between member states of the EU. It is also pointed out by one specialist and confirmed by the research of "The unequal economic consequences of carbon pricing." by Känzig [65]. This interesting paper explains how carbon pricing affects emissions, economic aggregates, and inequality. By exploiting institutional features of the EU-ETL and high-frequency data the author identifies carbon policy shocks[66]. On one hand explaining the relationship between a tighter carbon pricing regime and the consequent significant increase in energy prices, persistent fall in emissions and an uptick in green innovation, but on the other showing how rising prices of European Union Allowances causes a temporary fall in economic activity that is borne unequally across society. Meaning that poorer households are forced to lower their consumption significantly while richer households are less, if at all, affected. Poor households are more exposed because of the higher share that energy expenses have on their income and because often it is this section of the population that suffer the most in when certain industries move to other countries, close or are forced to produce less.

5.1.3. Opportunities that EU-ETS might exploit

There are many opportunities connected to the EU-ETS, first among all is that it has the potential, if combined with other tools to help Europe keep the ambitious goals announced by the commission, experts working in different roles of the EU-ETS compliance cycle seam indeed to agree on this point.

Furthermore, Europe and the EU-ETS can become an example for other countries. Acting as a ground breaker for other emission monitoring systems and carbon markets. One day maybe even leading to uniform cross-country reporting and overseas exchange of allowances between countries located on completely different continents (Interview I, II and III).

The road to climate-neutral economies is not free of difficulties but introducing carbon pricing tools derivates of EU-ETS, to new jurisdictions could do a great deal to help along that path. There are published studies that assess the readiness of several jurisdictions to carbon pricing implementation based on a number of variables.

[65] Känzig, «The unequal economic consequences of carbon pricing».
[66] EUTL, «ETS Database».

In the Interim report "Carbon Pricing Potential in East and South Asia", published September 2022 by the German Environmental Agency underscore the importance of framework conditions for carbon pricing to be feasible and effective[67].

5.1.4. Threats looming on the EU-ETS

Several threats exist that could be a danger to EU-ETS; the unexpectedly high prices of the European carbon credits are making small emitter that are very close to the 20 MW limit undertake all possible measures to exit EU-ETS. This emerges clearly from the interviews with the experts in Appendix II who manage various small to medium sized installations.

The volatility, that on one hand makes the carbon market more interesting and potentially profitable for the expert interviewed in Appendix I, can makes it more difficult for plant operators to take operative decisions and make large investments focused on decarbonisation, as stated by expert B in the Appendix II, who states "I hope that in the future the market will stabilise, and that it will no longer be subject to these price fluctuations, so that companies will be pushed to take action."

Figure 19. ICE Endex, EUA Futures taken from the official website.

A Graph taken from the official ICE website, one of the ventures offering a second carbon market for EUAs displayed above, shows the growing trend in the past few years, but also the strong fluctuations of on single European Union Allowance that on the 19th of August reached a peak of 97,67 euro[68]. Obviously also a low price of carbon credits would endanger the effectiveness of the system, this is one reason why the MSR has been introduced.

[67] Doda et al., «Carbon Pricing Potential in East and South Asia».
[68] ICE, «ICE Futures and Options».

One more great danger for the emission trading system, and obviously not just for the system, the ongoing war between Russia and Ukraine. Apart of humanitarian and ethical reasons, the war will unavoidably lead to a higher consumption of carbon intensive fossil fuels like lignite in the short term, especially in countries like Germany that depend strongly on the import of Russian natural gas.

The higher prices for fossil fuels combined with the high prices of carbon credits risk to penalise low-income households dearly[69].

5.2. Comparison with national total emissions for Germany and Italy

Comparing the total national GHG emissions in CO2eq, taken from the database provided by Our World in Data[70], with the emissions covered by EU-ETS for Germany and Italy[71], data from the EUTL, it is apparent that not in all countries the emission trading has the same effect. It is possible to notice a difference, between these two major countries within the EU, while in Italy the share of national emissions covered by EU-ETS remains around 40% the German penetration of EU-ETS goes from around 57% in 2018 to 50% in 2020. This difference is to be attributed mainly to the energy the structure of the two economies. Germany has a higher percentage of heavy industry that have a higher rated thermal input and are therefore installations tend to be subjects to EU-ETS more than in countries like Italy that have an economy built largely on small to medium sized realities.

In addition, it has to be considered that Germany started a national carbon pricing in 2021, that will also cover those smaller plants that are not covered by EU-ETS and sectors that are not yet part of EU-ETS.

[69] Second Appendix – Interview II
[70] Our World in Data, «CO2 Emissions».
[71] EUTL, «ETS Database».

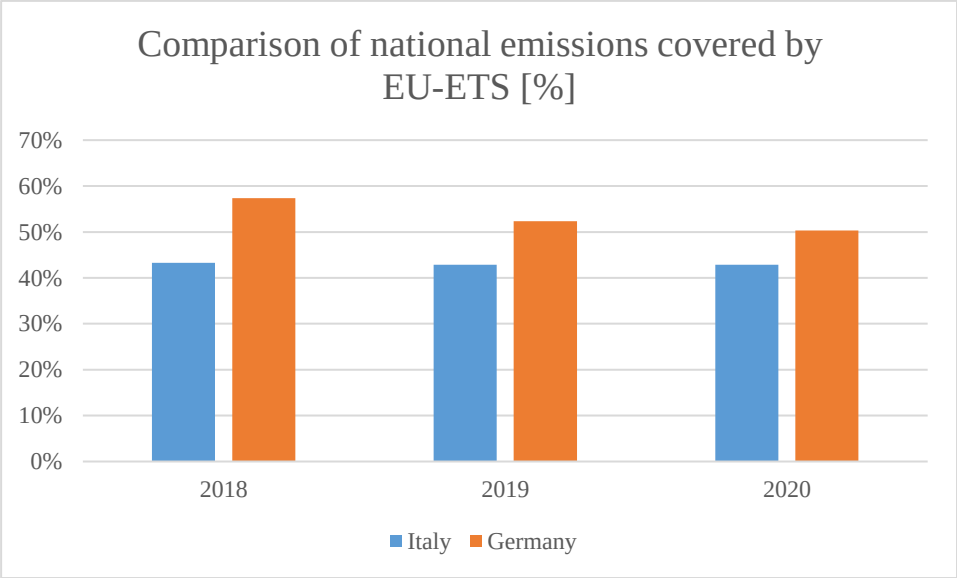


Figure 20. - Comparison of national emissions covered by EU-ETS [%]

This difference is to be attributed mainly to the energy the structure of the two economies. Germany has a higher percentage of heavy industry. These industrial facilities require plants that have a higher rated thermal input and therefore installations tend to be subjects to EU-ETS more than in countries like Italy that have an economy built largely on small to medium sized businesses.

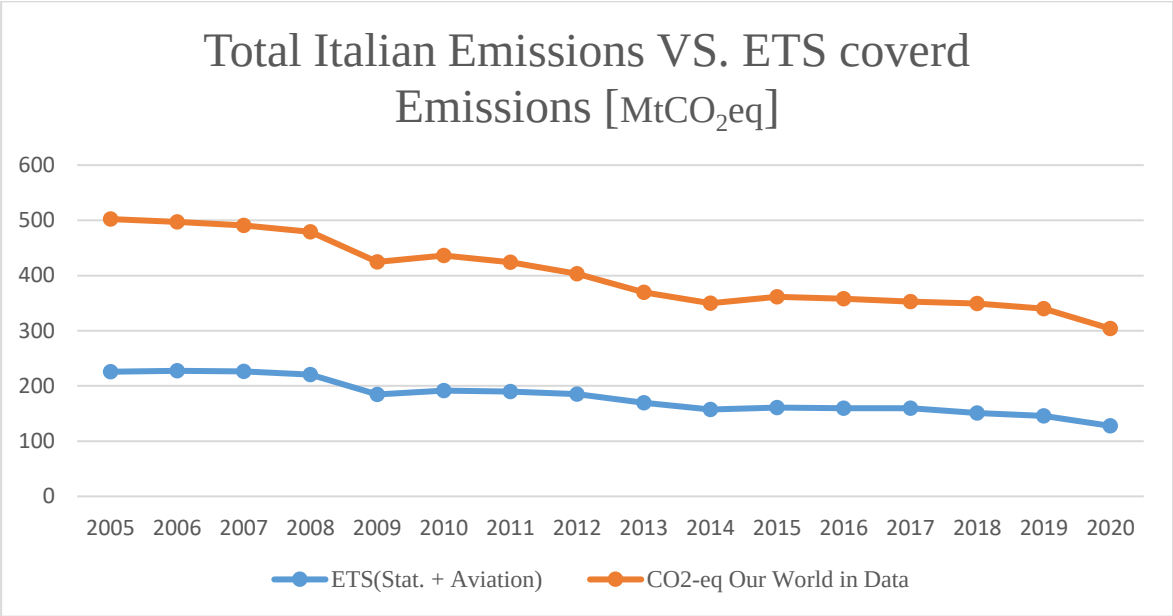


Figure 21. - Total Italian Emissions OWiD VS. ETS covered Emissions [$MtCO_2eq$].

In Italy the emission reduction trend is quite sharp, the geographical and geological richness in sources for renewable energy is surely one of the reasons for this trend.

Also, it can be noticed that the two curves follow roughly the same trends, and it is interesting to observe how the overall emissions seem to have a higher sensibility to changes. One might attribute this to a certain resistance to change that characterizes larger installations like many of those covered by EU-ETS.

EU-ETS emissions data are available also for 2021 in Italy showing a 4% increase from 2020 to 2021, this is as in Germany mainly attributed to the economic recovery from the pandemic, reaching 131,4 MtCO2 in 2021. Compared to pre-pandemic values emissions however have decreased by 7% in Italy72.

Remembering what was written in chapter two about the benefits of having a cap-and-trade carbon pricing tool. Countries like Italy might benefit from the EU-ETS, since the trade of certificates should allow to focus resources where decarbonising is more convenient. Also, this shows that while the percentage of EU-ETS share on the overall national emission is lower, Italy is able to decarbonize faster than Germany.

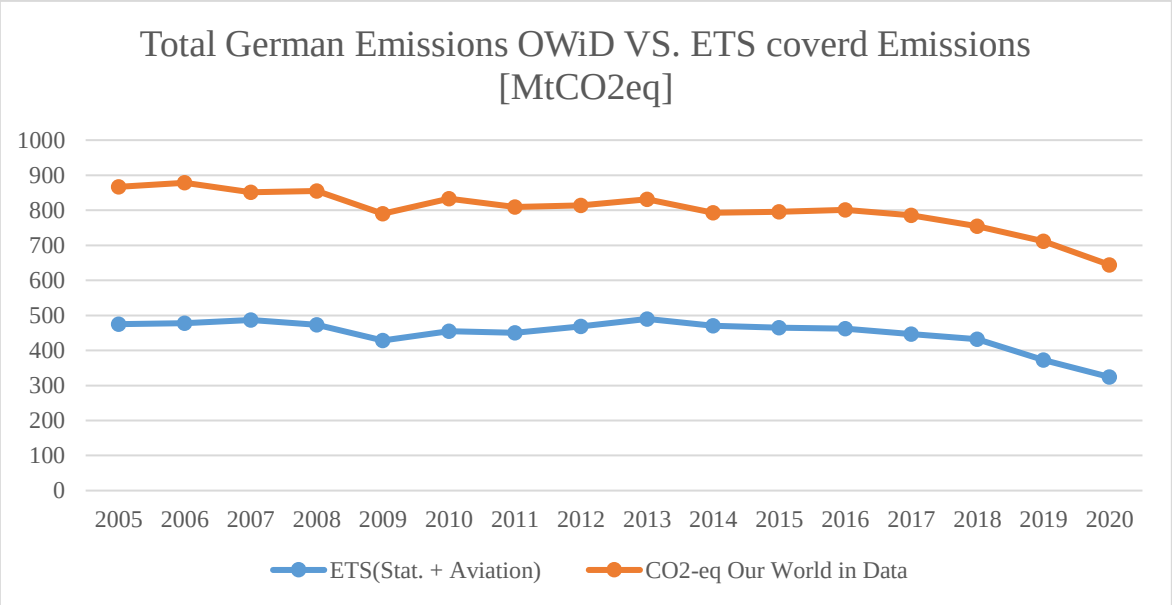


Figure 22. - Total German Emissions OWiD VS. ETS coverd Emissions [tCO2eq].

In Germany national emissions have also fallen following the overall trend of EU-ETS up to 2020. Data are not yet available for 2021, but it is known that EU-ETS emissions have risen. Germany non the less shows a great commitment towards the European goals to combat climate change. In addition to this it must be considered that Germany started a national carbon pricing in 2021, that will also cover those smaller plants that are not covered by EU-ETS and sectors that are not yet part of EU-ETS. This is done in the hope of further increase the decarbonisation process of the German economy.

[72] EUTL.

5.2.1. Introduction to the national German trading system

As stated in the national official guideline provided by the DEHSt, on 01.01.2021, the national emissions trading system (nEHS) was launched in Germany, introducing the pricing of CO2 emissions. Notice that it is the same competent authority for both the national and the European trading system[73].

The two systems overlap on many occasions, that is why the communication between the systems is crucial, both systems use the same tool the FMS, obviously with different applications.

In addition, while the operators of participating plants in the European Emissions Trading Scheme (EU-ETS) determine and report the direct emissions from their plants through a downstream approach, the emissions in the nEHS are determined indirectly via the quantities of fuel sold or purchased from the market (upstream approach). Therefore, overlaps between national and European emissions trading are unavoidable. Two options are provided in these cases:

- Avoidance of double charging through advance deduction of fuel volumes.
- Subsequent compensation of double-charged fuel quantities.

In 2021 and 2022, only certain fuels are reportable in the nEHS: gasoline, aviation gasoline, gas oil (heating oil EL, diesel), heating oil S, liquid gas and natural gas. Obviously in these phases only quantities of these fuels, that are subject to CO2 costs due to the nEHS, are eligible for an advance deduction or compensation.

Germans NA is using the know-how and the lessons learned from the application of EU-ETS to design and operate the national emission trading.

5.3. Conclusion

In conclusion based on the feedback from experts that was gathered in the interviews, public data and existing literature it is possible to say that EU-ETS is as matter of fact an effective tool to decarbonise the European economy and is largely fulfilling its role in decarbonizing the European economy, working to some extent even better than expected.

The interviews have demonstrated that experts are confident in the EU-ETS tool, especially for large utilities, that are among the largest emitters, it is affecting the strategic decisions on investments and so speeding up the decarbonisation process. The claim that EU-ETS is

[73] European Environment Agency, «EU-ETS data viewer».

one of the main tools to meet the announced targets on climate action is mirrored by the information collected, but to achieve said targets it is necessary to foster the decarbonisation process with other tools. Germany has launched a national emission trading system, to extend the reach of countrywide carbon pricing, but also other tool like the introduction of the EU-Taxonomy will help the transition towards a green Europe[74].

To achieve a larger and a more effective carbon pricing the EU-ETS also should become an example for other countries outside the EU. Experts believe EU-ETS is already doing so and publish studies confirm that conditions for the introductions of a carbon pricing tool exist at least in some countries in East and South Asia[75]. To properly achieve communicating systems the monitoring and reporting standards should be comparable, in order to allow trades in allowances. The work of the European Commission, the framework and methodologies studied, implemented, and tested are an asset in the fight against climate change. On this topic it must be noted that many plant operators and independent verifiers are suffering under the growing burden associated to monitoring, reporting and verifying. Especially in Germany, a country that on many fronts is a best practice in the application of carbon pricing, the specially developed software to simplify and standardise MRV[76] procedures, is yet complicating the process. However also interviewed Italian players, especially small to medium sized operator are experiencing difficulties. This on the other hand creates the market for new consulting jobs as stated in the interview in appendix IV and in one answer to the questionnaire.

However, the EC should consider that a very high price of European carbon credits, that on the 19th of August reached a peak of 97,67 euro[77], while making the market of great interest to investors and founds is pushing plant operators to exit the EU-Emission Trading System, for example by shutting down reserve units, like for example reserve boilers. This kind of operations do not reduce the effective emissions of a plant but instead tend to go against European goals. Most alarming is that the repercussions of a high price of the right to emit one ton of CO_2 are in the short term absorbed by the final costumer[78]. Since, most large producers are affected similarly, to keep profits stable companies tend to - at least partially - raise the costs of final products, produced in plants that fall under EU-ETS, to compensate the higher production costs. This, while on one hand creating the driving potential to find less carbon intensive ways of production, and thus in theory decarbonising the economy by the markets most basic laws, is on the other hand a transformation process that takes time. In the meantime, this generates an increased burden on the final consumer. While some aspects are desired, since ideally product costs being affected by the cost of emissions should make it more convenient for the consumer to choose products with a lower carbon footprint or at least consume less carbon intensive products.

[74] Deutsche Emissionshandelsstelle (DEHSt), «DEHSt - Official website».
[75] Doda et al., «Carbon Pricing Potential in East and South Asia».
[76] Deutsche Emissionshandelsstelle (DEHSt), «DEHSt - Official website».
[77] ICE, «ICE Futures and Options».
[78] Känzig, «The unequal economic consequences of carbon pricing».

However as can be expected, this is mostly felt by low-income households. Households that are already struggling with increased cost of fossil fuel and the rising inflation. Policymakers should consider this, even if EU-ETS is not the cause of this problem and probably not the best tool to provide a solution to this particular social issue, the higher energy prices and the consequences for struggling industries and low-income households pose a threat to the system and should be address.

First Appendix – Interview I

Interview with the manager of the European Emission Allowances Trading desk of a large European utility. Speaking from the viewpoint of a plant operator is Expert I, who specializes in the trading of EUAs. His focus is not on the monitoring and verification process of emissions but on the market trends of the monitored data.

1. "In what terms do you deal with ETS in your work?"

"I will now explain what my job consists of, so you can immediately understand my potential ability to answer your questions. I manage the desk that trades EU-ETS allowances for my company a large European Utility.

I consider this to be a very enlightened tool, which was set up by the European Union to set the threshold of fossil fuels that a company can use, and which has changed the narrative regarding the management of such fuels in Europe.

If you have a certain type of business, you need to, burn a certain amount of fossil fuels and the European Union recognises and gives you a certain number of EUAs. If you have a virtuous behaviour, you start to have a surplus of these certificates, which you can sell on the market; otherwise, to be able to operate your business you have to buy these certificates from other companies, which have shown virtuous behaviour.

Initially, the EU-ETS mechanism had difficulties getting started, with the issuance of these certificates exceeding the real market need, in the period 2007-2008. The market, due to the normal laws regulating it, caused the prices of these certificates to plummet to near zero at the time.

When I started working in this field, in the same company where I work today, about fifteen years ago, CO_2 emission related jobs in utilities did not exist at all, whereas today, they are among the most requested."

2. "In your company, how do you approach the preparation of data for reporting CO_2 emissions and data for the allocation of free allowances?"

"To simplify further with an example, I can practically call myself a trader, who, when certain conditions arise in the company, researchers from the specialized departments in my company who study the company's needs and market the trends, come to me after they have collected the verified data they come to and ask to purchase allowances.

I take action and try to make short- and medium-term strategic decisions about buying and selling in the market. I know the market and I have sold other commodities and have enough

experience to be able to move in these speculative buys and sells, while also trying to make a certain profit for the company.

Let's say that what I am interested in most is a kind of speculation about what companies will do or how they will move in this area.

It's an important business: volatility has value for companies, especially in the last two/three years.

I come in when all the games have been played. "I trust the EC when it provides the data" and I work like those traders who work by trading stocks without knowing the balance sheets of the companies or without knowing specifically the products of these companies. The data I am interested in is the trend and the prediction of the data being monitored.

The free certificates are issued -and estimated- the year before for the year after, with the tug on their actual value being better defined over time, based on the performance shown as we go along. All of this is still standing for one reason only: because this mechanism has turned out - contrary to what many people thought, to be extremely advantageous precisely for manufacturers and industrialists, paradoxically the very ones who, initially, in 2007, had opposed the initiative, because they had been induced to curb production. But, in practice, the first consequence for producers was to find themselves, the following year, with a portfolio of certificates to sell. These deposit flows proved to be very important, because they were able to provide cash for producers in many sectors, benefiting even companies in crisis, one step away from closure.

Thus, the industrial lobbies that had opposed, through their political representatives in parliament, the use of these instruments, placing themselves in stark contrast to the environmentalist front, soon found themselves in favour as well, feeling that they actually benefited from the mechanism.

Of course, the whole mechanism had, especially in the early days, to be calibrated against the realities of the market. The surplus of existing certificates had to be disposed of in several stages, even traumatic ones, which led to the creation of a very dynamic market, so much so that it recorded very high growth. Today, it is a very rich market, with many industrial interests, so that what is happening today is what one would never have imagined at the beginning of the issuance of the certificates, with those who opposed them now becoming the system's first supporters.

Absolutely unpredictable was the reaction of the certificate market when the war between Russia and Ukraine broke out. Personally, I had believed from the outset in the collapse of quotations, thinking that all interest in environmental issues would collapse in the face of the fear of a conflict fought on Europe's doorstep, by important countries with strong connections to the strongest Western economies.

Instead, the EU is supporting prices by all means and, as a trader, I honestly did not expect such a reaction. But in fact, there is a growth in the 'strategic value' of CO_2 emissions, precisely because of the problems caused, also in the ecological field, by the damage of war.

Regarding the processing of data, an operation that is totally entrusted, by the EU, to companies, a situation has arisen whereby those who really have the means and professionalism to carry out these tasks are almost exclusively large companies. These alone, in fact, can dispose of entire departments responsible for acquiring and studying data."

3. "In your opinion, is the implementation of the Emissions Trading Scheme an effective way to contribute to the ambitious climate targets that the European Union has committed to and does the EU-ETS have an impact on the strategic decisions regarding decarbonisation of companies operating one or more EU-ETS plants?"

"If, on the other hand, I am asked whether the system is good, I'd say yes. I think it is very effective and functional. There is only one problem, and not a minor one: It only interests and is only followed by Europe, which is responsible for only 20 per cent of the world's emissions.

But I don't think it is, despite the small percentage in Europe, of little consequence. A good system is acting as a forerunner, or at least it is doing so for China, which must quickly combat an environmental situation that millions of Chinese are experiencing on their skin: smog, water and air quality, climatic situations that have never been seen before. China must therefore act quickly and will take this model as a starting point. So, even if I am sure that this is not the most optimal system, I believe that it can still be considered as a kind of preliminary action -to others more functional to the objective- that can in any case provide useful and effective results. Europe needs to show and convey to the world the effectiveness of this systemic approach to the problem, at least in the initial or intermediate stages. Hopefully, then, the economic conjuncture and the market itself will point towards ecological, carbon-free choices, through choices that will act as a quick and effective spur to the world economic system itself.

Another reason that may push for a drastic reduction in the use of fossil energy sources is that of energy independence on the part of some industrialised, advanced countries that lack these raw materials, such as, for example, Germany and Italy. The pursuit of geopolitical independence should push faster towards a conversion of energy sources, aiming towards renewable sources, freeing even economically important countries from political subordination to other nations, among other things, not even too politically stable."

4. "What hopes do you have for the future of EU-ETS?"

"Interventions, admittedly a little utopian, would be those that hypothesise an exchange of certificates, a sale from Europe to China for example, which among other things would also have a function aimed at balancing the balance of payments, today unbalanced in favour of the Asian giant.

For my company, the technological transition to clean energy sources is experienced as a strong issue that is being dealt with with significant resources and a lot of managerial will."

5. “In your opinion, what are the main risks related to EU-ETS?”

“Personally, I have always had great faith in the EU-ETS, despite difficult circumstances (Brexit, Covid 19, the Russian-Ukrainian war). And I have to say that the EU itself remains optimistic about it, with the system proving more than resilient, sustaining the price level. The high prices of EUAs, however, besides being a target, can be an obstacle, driving out of the system all those small and medium-sized companies that are not structured for the study and management of EU-ETS:

The final consideration is that, beyond ethical considerations and for the very future of EU-ETS, one must hope, more than any other future event, for a speedy end to hostilities in Ukraine.”

Second Appendix – Interview II

In this interview the opinion of a big European player in the energy management market are captured. Expert A, Energy Manager in the Energy Markets & Regulations department, organised the call and introduced the author of this thesis to his colleagues Expert C. and Expert B. who were and are more specifically concerned with EU-ETS. The interviewees manage the monitoring and reporting for a series of small to medium size plants that fall under EU-ETS.

1. “In what terms do you deal with ETS in your work?”

Expert B.:

Responsible for Energy Regulations on a national level, which includes EU-ETS.

“The company mainly deals with the management of thermal power plants, for hospitals, the public sector and to a lesser extent some industrial plants. The plants are generally owned by the customer, while the company is the owner of the management of these plants.

In older contracts our company is still economically responsible for CO_2 emissions, however, it is a trend in newer ones that the owners of the plant take over the CO_2 emissions and that together with the operational management our offer includes a consultant service for EU-ETS management or other comparable systems.

There are cases where the economic responsibility for CO_2 emissions must be established by the TAR, sometimes appealing to the European Commission.

There are well-known cases, e.g., judgments, in which the debate in the case concerned the economic responsibility for CO_2 emissions, but in particular the concept of plant and production unit and technical connection in the case of the transfer of a plant within a production area was at issue.

Expert C. was at the forefront of data collection and preparation of emission reports, both for EU-ETS and free certification requests. Following this through the various Stages of the European Emission Trading System (1-4). “

Expert C.:

“Considering that we started with 23-24 EU-ETS plants in the first Phase and as of today (in the 4th Phase) we find ourselves with 6 plants under EU-ETS, 2 of which are close to being reduced below 20 MW and therefore leaving the Emission Trading System.

Over the 4 phases, management has changed a lot, especially since the OPT OUT option was introduced for small plants that serve mainly hospitals.”

2. “Did the transition from the third to the fourth phase of the EU-ETS entail any difficulties and, if so, which ones?”

Expert B.:

“Of course, the price increase and the sharp reduction of free allowances.

These were the main reasons for the decision to exit EU-ETS where possible.

Furthermore, with the transition from the third to the fourth phase, filling out the necessary forms to establish the free quotas for each plant was a very onerous task. Mainly because it was not clearly defined how it was to be done, clarifications with the ministry and the European Union were necessary, and communication with the relevant authorities was not always straightforward.”

Adding that:

“As we largely operate installations that serve the energy needs of hospitals, we had the possibility through the EU ETS Directive (Art. 27) to be excluded from the ETS for small installations ("small emitters" or "OPT OUT" installations) with emissions of less than 25,000 tonnes CO_2 equivalent per year as long as more than 25 per cent of the heat produced is not sold to third parties.”

“The request for exclusion and the new OPT OUT forms have led to further bureaucratic difficulties, but have made it possible to benefit from a higher emission limit and from the possibility of financial compensation instead of restitution, which compared to the current prices for compliance for 2021 is more advantageous.

Also, for OPT OUT there was a significant increase in complexity of managing the reporting of CO_2 emissions, when introduced OPT-OUT did not require verifier verification, now it does.”

3. “Do you think the accuracy required in emissions monitoring for the purpose of emissions reporting is adequate?”

Expert B.: “In my opinion it is adequate. I think it makes a lot of sense that calibration certificates are required for the measuring instruments used.”

Expert C.:

“Finding the most appropriate method and source of data can make all the difference.”

Expert B.:

“Working with the certifier, in the third phase, they switched from verifying invoices to verifying internal data. This was a sensible step and made it possible to work more efficiently, as the data used internally is more accurate than the suppliers' invoices, where estimates and corrections are often made, and it also saved time that would have been lost in communication with the supplier.”

Expert C.:

“I agree with what has been said by Expert B., she adds that it would be advisable to raise awareness among the people working in the field, who are often responsible for entering data or reading measurements. By communicating that it is an important job, to know and reduce company emissions. It is often not at all trivial to find the data, both with internal operators and gas suppliers.”

4. “In your company, how do you approach the preparation of data for reporting CO_2 emissions and data for the allocation of free allowances?”

Expert B.: “As explained above, the preparation of reports and the filling in of forms for EU-ETS is carried out by experienced personnel who have followed the entire development of EU-ETS and who collect and manage all data for all installations. The reporting principle then is quite simple, and is based on fuel consumption.”

5. “In your opinion, is the implementation of the Emissions Trading Scheme an effective way to contribute to the ambitious climate targets that the European Union has committed to?”

Expert C.: In my opinion it is, although some rules should be changed to include more plants.

Expert B.: “The system is effective, but there is always a difference between saying and doing, the EU-ETS has an important economic impact, perhaps too much so, many operators, especially those with plants at the 20 MW limit, have left the EU-ETS.

Moreover, in the end, the way the system is currently constructed, it is the individual citizen who suffers the consequences of the increase in the price of CO_2.

Think of airline tickets, in which I have recently seen the cost of CO_2 emissions highlighted separately.

Companies themselves have an interest in being more environmentally virtuous, but raising the price too high risks making the path unsustainable for operators of smaller plants.

Companies should be induced to be more virtuous, without the cost of this being excessively passed on to the end customer.”

A.M.: “I was told that the European Commission itself was surprised by the current prices, perhaps they expected slightly lower prices around 50 to 60 Euro/t CO_2...”

Expert B.: “As an international group, we regularly receive price estimates for EUAs from a dedicated department based abroad, in recent years these forecasts have always been exceeded.”

6. “In your opinion, does the EU-ETS have an impact on the strategic decisions regarding decarbonisation of companies operating one or more EU-ETS plants?”

Expert B.: “In part yes, but many operators, where they are allowed to do so, have simply reduced the size of 'oversized installations' in order to exit the EU-ETS. For larger installations, of course, it is a different matter.”

7. “Does the rise in EUA prices lead to the evaluation of decarbonisation technologies? Which do you consider to be the most effective?”

Expert B.: For larger plants, it was necessary to adopt other technologies where possible. For example, changing gas boilers with biomass-fuelled boilers or using at least some biomethane.

8. “What hopes do you have for the future of EU-ETS?”

Expert B.: EU-ETS is certainly very useful on the environmental level and as a working method used.

The externally imposed methodologies are of great help in giving structure to the consumption data and the resulting CO_2 emissions.

I hope that in the future the market will stabilise, and that it will no longer be subject to these price fluctuations, so that companies will be pushed to take action.

Expert C.: I agree with what Expert B. said, and I hope that there will be more simplifications at the bureaucratic level, and that the questions on the forms will be clearer and easier to interpret.

9. "In your opinion, what are the main risks related to EU-ETS?"

Expert B.: An excessive increase in price, which on the one hand risks triggering undesirable mechanisms and on the other risks burdening the weaker sections of the population too much.

Expert C.:

In addition, a further increase in bureaucratic complications related to the operation of EU-ETS should be avoided.

Third Appendix – Interview III

In the following pages follows the transcript of an interview with an experienced auditor for a verified and accredited verification body in Germany (Expert III).

1. "In what terms do you deal with ETS in your work?"

"As part of an accredited verification body I do my part in the EU-ETS compliance cycle. Auditing and certifying the emissions reported by plant operators. In Germany to be nominated as an EU-ETS auditor and also to remain one after the nomination it is mandatory to attend to information exchanges and seminars approved by the DEHSt.

In our organisation we have a "Head of the Verification Body" responsible for the entire verification point. Verifiers are appointed for specific sectors and "scope", after having accumulated the necessary skill and experience in those sectors. To audit an installation that falls under a certain scope the lead auditor needs to be accredited for that scope."

2. "Did the transition from the third to the fourth trading period of the EU-ETS cause difficulties and if so, which ones?"

"Partly design errors in the national implementation of the compliance cycle were fixed within Deutsche Emissionshandelsstelle (DEHSt).

For example, installations with 0 emissions that nevertheless received allocations were removed from the system. This happened for installations that produced very little emissions and through heat released by chemical process produced district heating or products at risk of carbon leakage.

There was a lot of additional work as a consequence of the new Monitoring Plans for the 4th Trading Period, with new requirements, new trainings, not only for plant operators but also internal for us verifiers, new guidelines that had to be processed under time pressure. This year in 2022 was the first year where the methodology for the 4th trading period had to be followed in the monitoring and reporting of the emissions of 2021. The guidelines were realised with some delay by the DEHSt and so it was allowed to submit the reports for the data relevant for the allocation of free allowances up until the 30th of April without any negative consequences for the plant operator and or the verifier, one month later compared to the official deadline, the 31st of March. Most plants operators had to take advantage of this extra time.

All our internal tools and working papers have to be reworked and partially made completely anew."

3. "Do you consider the accuracy of emissions monitoring required for emissions reporting to be reasonable?"

"Yes, because for EU-ETS we do reasonable assurance testing and the accuracy is therefore very high.

If the necessary accuracy is not given then DEHST usually provides for conservative mark-ups, in order not to underestimate emissions.

I also have had the opportunity to work on projects of GHG emissions monitoring outside the EU-ETS framework and I noticed that as a matter of fact in those projects the same emissions monitored and computed following the standards of the GHG protocol in tCO_2eq where lower."

4. "How do you go about preparing the data for the CO_2 emissions report and the data for the allocation of free allowances in your company?"

"As we are an accredited independent verifier, we follow a strict internal process to make sure that we proceed in a transparent and professional manner.

We start by development of an engagement proposal, once a contract has been signed and we have received a mandate to verify the emissions for a client we prepare the engagement, starting with the planning, the risk analysis, and the strategic analysis. We proceed by collecting and reviewing the necessary permits and communication with national authority, the DEHSt. In most cases we have a site inspection for which we prepare an audit report, and after that we perform an audit of the data of all relevant materials, plants, product streams, and all other relevant data. Finally, we can perform the verification, this always

undergoes the review by the lead auditor, a separate review by an "independent auditor", by the engagement manager and by the engagement partner. Only after this approval process is completed the report is considered verified and is dispatched by means of VPS to the plant operator."

5. "In your opinion, is the use of the Emissions Trading Scheme an effective means of contributing to the ambitious climate targets to which the European Union has committed itself?

"Yes. We are part of the EU's largest economic instrument to fight climate change.

To achieve the climate targets, of course it is necessary to support the achievements of EU-ETS with other policies and tools. The EU-taxonomy, for example could be one of said tools."

6. "Do you think the EU ETS has an impact on strategic decarbonisation decisions of companies operating one or more EU ETS installations?

"Yes, I think so, the direct effect for the industry is not always a focus on decarbonisation, but more about saving costs. I still believe sensibilisation on sustainability should be addressed more."

7. "Do the rising prices for EUAs lead to the evaluation of decarbonisation technologies? Which do you think is the most effective?

"Yes, I do. However, determining which one is the most effective is not a simple task. It always depends on the specific installation and other variables."

8. "What are your hopes for the future of the EU ETS?"

"A more transparent cooperation with DEHSt and more uniform reporting across countries.

And obviously companies becoming more and more sustainable."

9. "What do you think are the biggest risks associated with the EU ETS?"

"The gradually more complex reporting is becoming an issue. The many exceptions and the various special cases tend to create confusion and make the process of monitoring reporting and verification ever more time consuming. For example, when products are divided using NACE codes and PRODcom codes.

From an operator's point of view, according to this trend, soon a specialised reporting team will be required exclusively available for EU-ETS and not all operator is willing or capable to create such a department."

Fourth Appendix – Questionnaire

Table 8. Results from the questionnaire

Expert	In which country do you conduct most of your work?
a	Italy
b	Germany
c	Germany
d	Germany
e	Germany
f	Germany
g	Germany, Italy
h	Germany
i	Italy, Spain, Brasil, Chile, Colombia, Peru, Argentina
j	Italy
k	Germany

Expert	To which of the following categories do you belong?
a	University Professor/researcher with a focus on environmental issues
b	Auditor (EU-ETS, Emission Report)
c	Auditor (EU-ETS, Emission Report)
d	Auditor (EU-ETS, Emission Report)
e	Auditor (EU-ETS, Emission Report)
f	Auditor (EU-ETS, Emission Report)
g	Auditor (EU-ETS, Emission Report)
H	Environmental consultant
I	University Professor/researcher with a focus on environmental issues
J	Environmental consultant
K	Auditor (EU-ETS, Emission Report)

Expert	Did the transition from the third to the fourth phase of EU-ETS entail any major difficulties and if so, which ones?
A	Not much literature is present on this
B	
C	n/a. Started only on the 4th phase
D	new guidelines and requirements have resulted in an increase in the amount of testing. As it required new monitoring plans and a lot of clarification.
E	I didn't work in the third phase.
F	
G	Not much, mostly regular paperwork
H	
I	
J	No difficulties were introduced in my activity. Indeed, the inclusion of more industrial sectors in the ETS system widens the range of possible customers for my company.
K	Shrinking Supplemented of EUAs. Increase of the linear reduction factor from 1.74 to 2.2

Expert	In what topic/topics do you consider yourself to be an expert?
A	Modelling
B	Carbon Capture
C	Chemicals
D	Chemicals
E	Combustion
F	Chemicals
G	Chemicals
H	Aircrafts
I	Electrical Infrastructure
J	CO_2 emissions reduction
k	Combustion

Expert	Do you consider the accuracy required in the monitoring of emissions for the purpose of emissions reporting to be adequate?
a	Yes, I consider the required accuracy adequate.
b	Yes, I consider the required accuracy adequate.
c	Yes, I consider the required accuracy adequate.
d	Yes, I consider the required accuracy adequate.
e	Yes, I consider the required accuracy adequate.
f	Yes, I consider the required accuracy adequate.
g	Yes, I consider the required accuracy adequate.
h	No, it is necessary to monitor emissions with greater accuracy.
i	Yes, I consider the required accuracy adequate.
j	Yes, I consider the required accuracy adequate.
k	Yes, I consider the required accuracy adequate.

Expert	In your company, how do you approach the preparation of data for the CO2 emissions report and data for the allocation of free allowances? (If you are not an installation operator, which of the following do you consider to be the best solution)
a	In modelling studies, we use average carbon intensities by sector taken from input-output analysis
b	We have a specialised in-house department that takes care of the data and reports for all our ETS installations.
c	The data are prepared by the combined effort of internal staff and external consultants. The internal staff is specific to every single EU-ETS plant.
d	We have a specialised in-house department that takes care of the data and reports for all our ETS installations.
e	We have a specialised in-house department that takes care of the data and reports for all our ETS installations.
f	We have a specialised in-house department that takes care of the data and reports for all our ETS installations.
g	We have a specialised in-house department that takes care of the data and reports for all our ETS installations.
h	The data are prepared by the combined effort of internal staff and external consultants. The internal staff is specific to every single EU-ETS plant.
i	
j	In-house staff and outsourced consultants take care of all ETS installations in parallel
k	We have a specialised in-house department that takes care of the data and reports for all our ETS installations.

Expert	In your opinion, is the application of the Emission Trading System an effective way to contribute to the ambitious climate targets the European Union has pledged itself to?
A	Yes, the EU-ETS is already and will be in the future a key tool for reducing anthropogenic emissions.
B	The EU-ETS has the potential to make a contribution towards the announced climate targets, alongside other factors.

C	The EU-ETS has the potential to make a contribution towards the announced climate targets, alongside other factors.
D	Yes, the EU-ETS is already and will be in the future a key tool for reducing anthropogenic emissions.
E	The EU-ETS has the potential to make a contribution towards the announced climate targets, alongside other factors.
F	Absolutely yes, the EU-ETS is the main tool to reach Net Zero on time.
G	The EU-ETS has the potential to make a contribution towards the announced climate targets, alongside other factors.
H	The EU-ETS has the potential to make a contribution towards the announced climate targets, alongside other factors.
I	The EU-ETS has the potential to make a contribution towards the announced climate targets, alongside other factors.
J	The EU-ETS has the potential to make a contribution towards the announced climate targets, alongside other factors.
K	The EU-ETS has the potential to make a contribution towards the announced climate targets, alongside other factors.

Expert	In your opinion, does the EU-ETS have an impact on strategic decisions regarding the decarbonisation of companies operating one or more EU-ETS facilities?
A	Yes, but the price of EUAs and thus the cost associated with emitting one tonne of CO_2 is a secondary factor.
B	Yes, it has a strong impact.
C	Yes, it has a strong impact.
D	Yes, but the price of EUAs and thus the cost associated with emitting one tonne of CO_2 is a secondary factor.
E	Yes, but the price of EUAs and thus the cost associated with emitting one tonne of CO_2 is a secondary factor.
F	Yes, it has a strong impact.
G	Yes, but the price of EUAs and thus the cost associated with emitting one tonne of CO_2 is a secondary factor.
H	Yes, it has a strong impact.
I	Yes, but the price of EUAs and thus the cost associated with emitting one tonne of CO_2 is a secondary factor.
J	Yes, but the price of EUAs and thus the cost associated with emitting one tonne of CO_2 is a secondary factor.
K	Yes, but the price of EUAs and thus the cost associated with emitting one tonne of CO_2 is a secondary factor.

Expert	Are the rising prices of EUAs having an impact on the evaluation of one or more of the following technologies?
A	All of the above
b	Carbon Capture
c	All of the above

d	All of the above
e	Renewable energies
f	All of the above
g	All of the above
h	Plant revamping
i	Renewable energies
j	All of the above
k	Renewable energies

Expert	What hopes do you have regarding the future of the EU-ETS?
a	That it will be soon able to take in to account emissions taking place outside of EU
b	
c	Less bureaucracy
d	uniform, cross-country reporting that is simple and straightforward for all parties.
e	I hope EU ETS can lead to development of strategies which causes sharp reductions in emissions and application of those strategies.
f	I hope the most recent developments in regards of the price of energy of fossil origin don't deter us in the chosen path to steadily increase the price of issued Eua's. So, we can continue our journey to a net zero Europe independent of the situation of the worlds markets.
g	As regarding most legislations, the burocracy needs ti be made quicker and more user-friendly
h	
i	
j	I hope that also smaller companies and factories will be included in the system, so that decarbonisation can be applied in all industrial sectors.
k	A well thought-out ETS reform is needed to protect EU energy suppliers from price Schocks and support their energy transition

Expert	What do you consider to be the major risks connected with the EU-ETS?
a	Low prices
b	
c	Companies migrating to countries without EU-ETS
d	reporting is becoming increasingly difficult and detailed, so that experts are needed on both the auditor and the plant operator side. However, training for this is not easy and requires a lot of experience.
e	Low price of carbon emissions.
f	Keeping the Balance between further increasing the price of Eua's without losing our competitiveness on the world stage and the related carbon leakage that would come with such a situation.
g	Reallocation of Key industries to countries with less regulations
h	
i	

j	EU ETS is a strong tool against pollution related to the major industrial sectors. What I currently see is that decarbonisation is often costlier that CO_2 cost itself, leaving companies with no choice other than keep polluting as they are.
k	Risks in investment decisions as the Development of the CO_2 certificate price cannot reliably forecasted

Expert	To the best of your knowledge, does the EU-ETS also cover indirect emissions such as pipeline leaks?
a	I think it does not
b	
c	No
d	I'm not sure, but conservative charges are always used to reduce uncertainties. In addition, losses must be expected for each material flow.
e	
f	No
g	I don't know
h	
i	I don't think so
j	In my knowledge it does not.
k	No

Expert	In your opinion, is the price of EUAs set to rise in the medium to long term?
a	Yes, it will.
b	Yes, it will.
c	Yes, it will.
d	There are too many uncertainties to give a well-founded answer.
e	There are too many uncertainties to give a well-founded answer.
f	Yes, it will.
g	There are too many uncertainties to give a well-founded answer.
h	No, the price will go down in the medium to long term.
i	There are too many uncertainties to give a well-founded answer.
j	Yes, it will.
k	Yes, it will.

Expert	What do you think are the main factors influencing the price of EUAs?
a	Market Stability Reserve i.e., EU political strength on climate issue
b	
c	Amount of the EUAs & the current political situation in Europe and the world

d	this can be very different and is to be considered in the individual case
e	
f	In think main factor is the overall supply and abundancy of Eua's.
g	The current climatic situation and the political climate are both affecting the price of EUAs
h	
i	
j	The current energy transition needs due to the Russian war is pushing governments towards decision that are not decarbonisation-related but instead are focused on reducing energy cost. In general, I think ETS CO_2 price is strongly influenced by the global urges, and CO_2 related ones seem to be of secondary attention right now.
k	Stricker climate targets and limited quotas for emission certificates are a mayor price driver

Acronyms

EU-ETS: EU Emission Trading Scheme

EEC: European Economic Comunity

GHG: Greenhous Gas

CO_2: Carbon dioxide

CO_2eq: Carbon dioxide equivalent

EUA: European Union Allowance

EUTL: European Transaction Log

MP: Monitoring Plan

FMS: Form Management System

MSR: Market Stability Reserve

MR: Methodology Report

MRV: Monitoring, Reporting and Verification (MRV)

MRR: Monitoring and Reporting Regulation (Regulation (EU) 2018/2066)

AVR: Accreditation and Verification Regulation (Regulation (EU) 2018/2067)

EGD I: AVR Explanatory Guidance (EGD I)

GD III: Verification Guidance for EU ETS Aviation (GD III)

NAB: National Accreditation Body

NCA: National Certification Authority

CA: Competent Authority

GD: Guidance Document published on the Commission's website 11 EA European Co-operation for Accreditation

EC: European Commission

KGN: Key Guidance note published on the Commission's website

FAR: Free Allocation Rules (Commission Delegated Regulation (EU) 2019/331)

ALCR: Commission Implementing Regulation on annual activity level data (Commission Implementing Regulation (EU) 2019/1842)

nEHS: Germanies national emission trading system

Bibliography

DEHSt. «Greenhouse Gas Emissions in 2020 - Executive Summary», maggio 2022

Deutsche Emissionshandelsstelle (DEHSt). «DEHSt - Official website». Consultato 1 settembre 2022. https://www.dehst.de/EN/home/home_node.html

———. «Register Architecture UNFCCC DEHSt.de», s.d. www.dehst.de

Deutsche Emissionshandelsstelle (DEHSt) im Umweltbundesamt «Leitfaden zur Erstellung von Überwachungsplänen und Emissionsberichten für stationäre Anlagen 4. Handelsperiode (2021–2030) des europäischen Emissionshandels (2021)»

Doda, Dr Baran, William Acworth Ernst Kuneman, Emma Krause, Dr Anatole Boute, e Dr Jackson Ewing. «Carbon Pricing Potential in East and South Asia», s.d., 65

ERNEST LO. «Ecological Monographs - 2005 - GAUSSIAN ERROR PROPAGATION APPLIED TO ECOLOGICAL DATA POST-ICE-STORM-DOWNED WOODY». Groupe de Recherche en Ėcologie Forestière inter-universitaire (GREFi), Department of Biology, McGill University, 1205 Docteur Penfield, Montre´al, Que´bec H3A 1B1 Canada, 2005

European Commission. COMMISSION IMPLEMENTING REGULATION (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012 (2021). https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02018R2066-20210101&from=EN

———. COMMISSION IMPLEMENTING REGULATION (EU) 2018/2067 of 19 December 2018 on the verification of data and on the accreditation of verifiers pursuant to Directive 2003/87/EC of the European Parliament and of the Council (2021). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018R2067-20210101

———. «Delivering the European Green Deal». Consultato 1 settembre 2022. https://ec.europa.eu/clima/eu-action/european-green-deal/delivering-european-green-deal_en

———. Europe 2020: the European Union strategy for growth and employment. Consultato 1 settembre 2022. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:em0028

———. «Monitoring, reporting and verification of EU ETS emissions». Information. Consultato 1 settembre 2022. https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/monitoring-reporting-and-verification-eu-ets-emissions_en

———. «Paris Agreement». Consultato 1 settembre 2022. https://ec.europa.eu/clima/eu-action/international-action-climate-change/climate-negotiations/paris-agreement_en

———. «Union Registry». Consultato 1 settembre 2022. https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/union-registry_en

EUROPEAN COMMISSION DIRECTORATE-GENERAL CLIMATE ACTION Directorate B – Carbon Markets & Clean Mobility Unit B.2 – ETS (II): Implementation, Policy Support & ETS Registry. «EU ETS Monitoring and Reporting Quick Guide for Stationary Installations», 1 marzo 2022

European Environment Agency. «EU Emissions Trading System (ETS) data viewer». Consultato 1 settembre 2022. https://www.eea.europa.eu/data-and-maps/dashboards/emissions-trading-viewer-1

European Parliament. «EU progress towards 2020 climate change goals (infographic)». Consultato 1 settembre 2022 https://www.europarl.europa.eu/news/en/headlines/society/20180706STO07407/eu-progress-towards-2020-climate-change-goals-infographic

European Union. «ETS Handbook», 2015

EUTL. «ETS Database», s.d

ICE. «ICE Futures and Options». Consultato 1 settembre 2022. https://www.theice.com/products/197/EUA-Futures/data?span=1

IPCC. «IPCC PRESS RELEASE April 2022», 4 aprile 2022

Jan Abrell. «EUETS.INFO Project». Provides information on the EU-ETS. EUETS.INFO. Consultato 1 settembre 2022. https://www.euets.info/

Jim Skea (United Kingdom), Priyadarshi R Shukla (India, e J. A. et al. «Summary for Policymakers IPCC AR6 WG III Subject to Copyedit SPM-1 Total Pages: 63 WORKING GROUP III CONTRIBUTION TO THE IPCC SIXTH ASSESSMENT REPORT (AR6)». *Summary for Policymakers IPCC AR6*, s.d. https://doi.org/10.1016/0005-2760(75)90151-4

Johanna Lausen, Dominik Glock, Dr. Roland Geres, Simone Lischker, Marcus Ferdinand, e Alina Mihai. «Trading activities and strategies in the European carbon market». Section V 3.3 Economic Aspects of Emissions Trading, Monitoring, Evaluation Nadine Pauly, Dmitri Lewandrowsk, 2022

Känzig, Diego. «The unequal economic consequences of carbon pricing», gennaio 2022.

Official Journal of the European Communities. «Towards Sustainability. A European Community Programme of Policy and Action in Relation to Environment and Sustainable Development», s.d

Official Journal of the European Union. Auctioning Regulation EUR-Lex - 32010R1031 - EN - EUR-Lex. Consultato 1 settembre 2022. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010R1031

Our World in Data. «CO2 Emissions», 2022. https://ourworldindata.org/

Ricke et al. «Country-level Social Cost of Carbon Database explorer». Consultato 1 settembre 2022. https://country-level-scc.github.io/explorer/

Ricke, Katharine, Laurent Drouet, Ken Caldeira, e Massimo Tavoni. «Country-Level Social Cost of Carbon». *Nature Climate Change* 8, n. 10 (ottobre 2018): 895–900. https://doi.org/10.1038/s41558-018-0282-y

Umweltbundesamt. TEHG | Gesetz über den Handel mit Berechtigungen zur Emission von Trei. Consultato 1 settembre 2022. http://gesatz.de/gesetze.aspx?gesetz=TEHG