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D7.1

The functioning and socio-economic impacts of the EU Emission Trading System: updated evidence and insights

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Abstract

For decades, environmental degradation has been the focus of public opinion, academia, research centers, and institutions. This attention is motivated by increasing awareness of the severe ecological and socio-economic problems caused by climate change. The European Union is one of the most active jurisdictions in addressing these problems, having implemented several measures over the last two decades.

One of the pillars of the European climate policy framework is the EU Emissions Trading System (ETS). In this paper, we investigate the development of that system, as well as its current structure and functioning. In addition to providing an overview of the EU ETS and the new EU ETS 2, we analysed the potential socio-economic impacts of these mechanisms. This is particularly important for EU ETS 2, which will create an emissions market for sectors such as buildings, transport, and small business emitters, where price increases may have a more significant regressive effect.

To study whether this is the case we examine three countries, France, Italy, and Hungary. Through a literature and scenario review, we find that negative effects are expected for vulnerable households in these countries. Recycling carbon market revenues to support vulnerable households can mitigate the adverse effects of EU ETS 2, and the EU's establishment of the Social Climate Fund (SCF) goes in this direction.

Further recommendations to make carbon markets more effective and fairer concern using revenues for low-carbon investments, focusing on carbon removal technologies.

Strengthening international cooperation with non-EU jurisdictions should be promoted to ensure that the system works well by linking the existing carbon markets.

By properly using ETSs, an increasing number of countries may hopefully move towards rapid decarbonisation and, at the same time, achieve a truly just transition in the coming years.

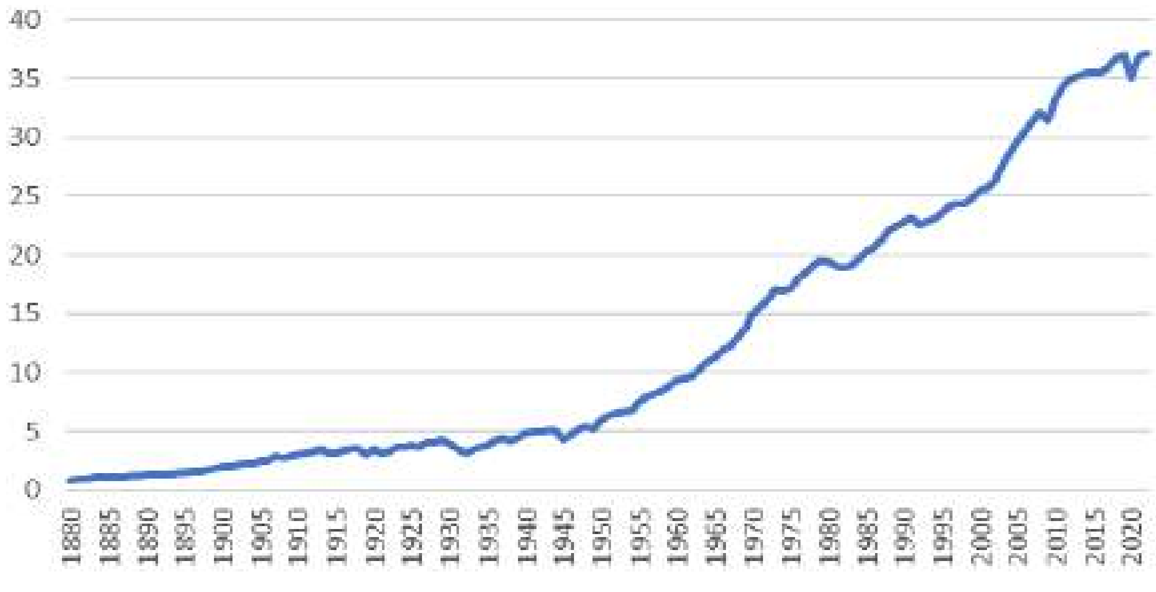
1. Introduction

Since industrialisation, the clear damages caused by human activities increased public awareness of the need to reduce pollution and protect biodiversity. Indeed, there is clear scientific evidence of the responsibility of human action in the rise of global temperatures, and there is an almost unanimous consensus on that.

In this regard, the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) showed that human activities, principally through emissions of greenhouse gases (GHG), have undoubtedly determined global warming, with the world average surface temperature rising by 1.1°C between 2011 and 2020 above 1850–1900.

Indeed, global GHG emissions have continued to increase (Figure 1), due to contributions deriving from unsustainable energy use, land use and land-use change, lifestyles and consumption and production patterns.

Figure 1: Global annual CO2 emissions in Gt over the period 1880-2022

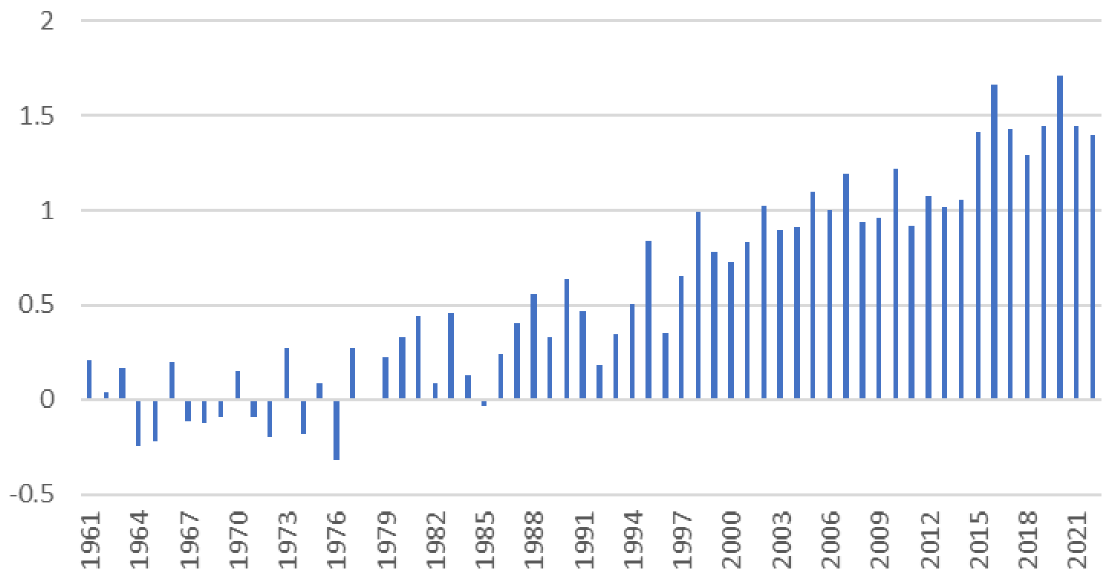


Source: Authors' visualisation based on International Energy Agency (2023)

The continuous emission of GHG is significantly driving global warming, with projections indicating a near-term temperature increase of 1.5°C in various scenarios and modelled pathways. The temperature rise will likely exacerbate multiple concurrent hazards (IPCC, 2023).

As illustrated in Figure 2, global temperatures have consistently increased, especially between 2013 and 2023, when they averaged 1 to 1.5°C higher than the 1951-1980 baseline. The upward trend highlights the urgency for effective decarbonisation strategies. In this regard, climate action has become one of policymakers' priorities, and the 2015 Paris Agreement aims to limit the rise in global temperatures to below 1.5°C through coordinated international efforts (Delbeke et al., 2019).

Figure 2: World temperature change in °C with respect to the baseline 1951-1980



Source: FAOSTAT (2023)

Rockström et al. (2009) identified nine processes that regulate the stability and resilience of the Earth system calling them "Nine Planetary Boundaries" (namely, climate change, biosphere integrity, land system change, novel entities such as toxic substances, freshwater change, stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, biochemical flows). In September 2023, a team of scientists quantified each planetary boundary, revealing that six of the nine suggested quantitative thresholds, which allow humanity to persist in its development and well-being for future generations, have already been crossed. In this report, given the huge influence expected, we are going to focus on the impact of the climate change and the related ETS policies, although as in the SPES framework we think that the loss of biodiversity is another key issue for the future research.

The European and global institutions have recently developed numerous policies and laws addressing climate change mitigation (Schoyen et al., 2023; IPCC, 2023). Indeed, scientists are not alone in considering the preservation of the planet as a key factor to promote an equitable and fair society; governmental institutions at several levels agreed on that point, as testified by global initiatives like the Agenda 2030, or by countries commitments such as the National Determined Contributions (NDCs) in accordance with Article 4, paragraph 12 of the Paris Agreement.

Under the European Climate Law, the EU have translated the intentions of the Paris Agreement into the explicit goal of becoming carbon neutral by 2050 (European Parliament, 2023). The idea refers to the reduction or elimination of CO2 emissions into the atmosphere, achievable through various measures, such as utilizing low-carbon technologies, replacing fossil fuels with renewable energy sources, and enhancing energy efficiency (Allen et al., 2022).

Other continents are moving towards a more sustainable economy with comprehensive but slightly different plans, in line with the UNFCCC Common but Differentiated Responsibilities and Respective Capabilities (CBDR–RC) principle, that recognises the different capabilities and differing responsibilities of individual countries in tackling climate change; the Agenda 2063 implemented by the African Union is one of the main examples (Schoyen et al., 2023).

The aim of this paper is to verify the functioning and socio-economic impacts of one of the most important EU climate policy measures, namely the Emissions Trading System (EU ETS), with a focus on the new established EU ETS 2 for road transport, buildings, small business emitters. Introduced in 2005, the ETS is one of the biggest carbon markets in the world, using a cap-and-trade system to effectively reduce GHG emissions of carbon intensive sectors. The complementary system EU ETS 2 seeks to further extend carbon pricing to further sectors.

The paper is divided into eight sections. Section 2 introduces the theoretical framework of the SPES project to identify its environmental components. Section 3 examines the distributional impacts of climate change. Section 4 explores the history of the EU ETS, from its inception in the first phase to its current fourth phase. Section 5 discusses potential regressive consequences of the EU ETS 2, with detailed analysis provided in Section 6 focusing on three study countries (France, Italy, Hungary). Section 7 presents policy recommendations, emphasising the recycling of EU ETS 2 revenues to support the Social Climate Fund (SCF). Finally, Section 8 concludes.

2. The environmental sustainability in the SPES framework

The academia has long highlighted environmental concerns, notably through crucial works like "The Limits to Growth" by Meadows et al. (1972) and subsequent analyses (Kula, 1997).

In these investigations, the population and industrial output increases are accompanied by rising pollution and huge deployment of natural resources.

Despite criticisms of being overly simplistic and pessimistic (Naudé, 2023), these post-Malthusian perspectives have found acceptance within social sciences. For example, in the field of ecological economics the bioeconomy framework, as discussed by Georgescu-Roegen (1971), Daly (2007), and D'Alessandro et al. (2020), underscores the need for economic systems that respect ecological limits. This approach is different from mainstream economic theories, which explore environmental issues through various lenses, including economic taxation and behavioural economics.

In the first approach, economic strategies like carbon taxes and ETS enjoy the most consensus as effective ways to rein in emissions. The basic idea is to internalize those external costs of environmental degradation that are not, in principle, included in standard economic models. A carbon tax increases the cost of GHG emissions by taxing fossil fuel carbon content directly, thereby increasing the relative price of dirty energy sources like fossil fuels and coal vis-à-vis clean sources. This induces technological innovation within the green industry (Hanley et al., 2019). Similarly, ETS allows companies to buy and sell emission allowances to help in the designing of a market-driven approach for meeting the required emission reduction targets (Hanley et al., 2019).

In the second approach, the nudging theory proponents support doing delicate incentives or subtle pushes for going green rather than forceful economic measurements to modify behaviour. This can be done through several ways, such as default options, information disclosure, and making the decision process simple. For example, if recycling bins are placed in strategic places with proper labels, it may gently push individuals to recycle more. Nudging can steer people toward more sustainable decisions without costing them much money by simply changing the environment where decisions take place. In essence, it recognizes that human behaviour is complex and can be harnessed to achieve positive environmental outcomes at low cost (Thaler, 2018).

A key concept in the environmental economic discussion is the Environmental Kuznets Curve (EKC). The EKC describes a relationship between environmental quality and economic development: environmental degradation initially worsens with economic growth but begins to improve once a certain income level is reached, suggesting that economic growth can eventually lead to better environmental conditions (Hanley et al., 2019). However, the existence and validity of the EKC are debated, as its applicability varies with different environmental indicators, ecosystems, economic contexts, regulatory frameworks, and technologies. The trends observed in the EKC can vary greatly depending on the environmental indicator used, such as water or air pollution (Borghesi, 2019).

The theoretical approaches mentioned so far are different but also, in some respects, complementary. They share a large part of the basic assumptions, namely: a) there is a global environmental problem caused by human activity; b) policy instruments must be used to limit harmful ecological consequences; c) social sciences, and specifically economics, can provide key instruments to mitigate the problem.

Starting from the sustainability debate, the Sustainable Human Development (SHD) paradigm proposed by Haq in the first UNDP report in 1990, and subsequently updated, includes environmental sustainability among its four pillars, along with productivity, equity, and participation & empowerment (UNDP, 1990; Haq, 1995).

Building upon this contribution, an extended version of the SHD was elaborated within the SPES project by Biggeri et al. (2023). This new theoretical outline differs from the original in that, in addition to providing a fifth pillar called Human Security, it includes the basic elements of the 2030 Agenda, made explicit by the five P's (People, Prosperity, Partnership, Planet and Peace), and the actors in the process, identified as Business, Academia, Government, Civil Society, and the Natural Environment, following the quintuple helix perspective (Carayannis et al., 2012).

Figure 3 summarizes the SPES framework. In the figure, ecological elements are defined as follows:

Environmental sustainability: the practice of responsibly managing and preserving natural resources and ecosystems, ensuring a balance between current and future well-being.

Planet: the promotion of regenerative economic practices, sustainable consumption and production patterns, conserving biodiversity, combating climate change, managing natural resources responsibly, and protecting ecosystems to ensure the planet's resilience, considering the limits set by planetary boundaries.

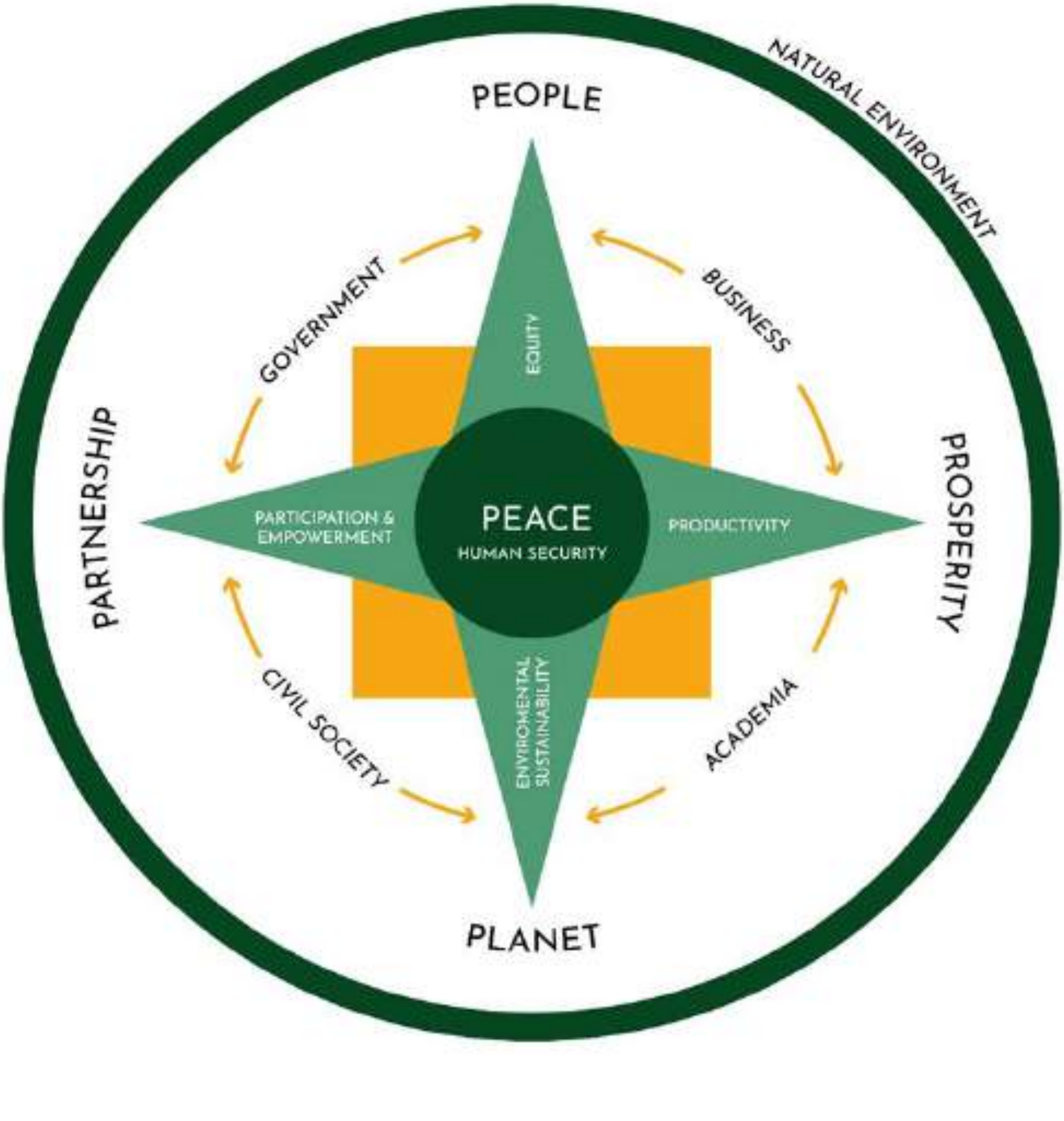
Natural environment: the totality of various plants, animals, and other natural resources and serves as the 'natural capital' for the other four helices. It could be argued that the natural environment is the most significant source of knowledge and innovation, as it forms the basis for human existence (König et al., 2021). This concept highlights the interaction, co-development, and co-evolution of society and nature.

It is worth mentioning that while the planet denotes a critical area of action and environmental sustainability represents its corresponding objective, the natural environment is conceived as a live actor affecting all pillars of SHD and related processes (Biggeri et al., 2023). The three elements combined show how critical the environmental aspects are in guiding the transition towards a new development paradigm. They also illustrate that the natural environment is the most important feature of all, to be preserved from the stresses to which it has long been subjected.

This framework responds to increasingly pressing demands coming not only from the academic world but also from civil society. The UNDP and University of Oxford report entitled “People’s Climate Vote 2024” indicates a growing global concern about climate change, with 53% of respondents expressing increased anxiety compared to the previous year. In Least Developed Countries (LDCs), this figure rises to 59%, contrasting with 50% in G20 nations. The survey shows that over 56% of the global population thinks about climate change daily or weekly, illustrating its pervasive presence in people’s minds. Additionally, 69% of individuals reported that climate change impacts significant life decisions, such as where to live and work (United Nations Development Programme, 2024).

People’s worrying is understandable: the current carbon emissions projected from existing fossil fuel infrastructure, without further abatement efforts, will outstrip the remaining carbon budget for limiting warming to 1.5°C with a 50% probability (IPCC, 2023). So, substantial rapid cuts in CO2 emissions sustained over time are required to significantly slow global warming within around 20 years.

Figure 3: SPES Framework and its ecological elements



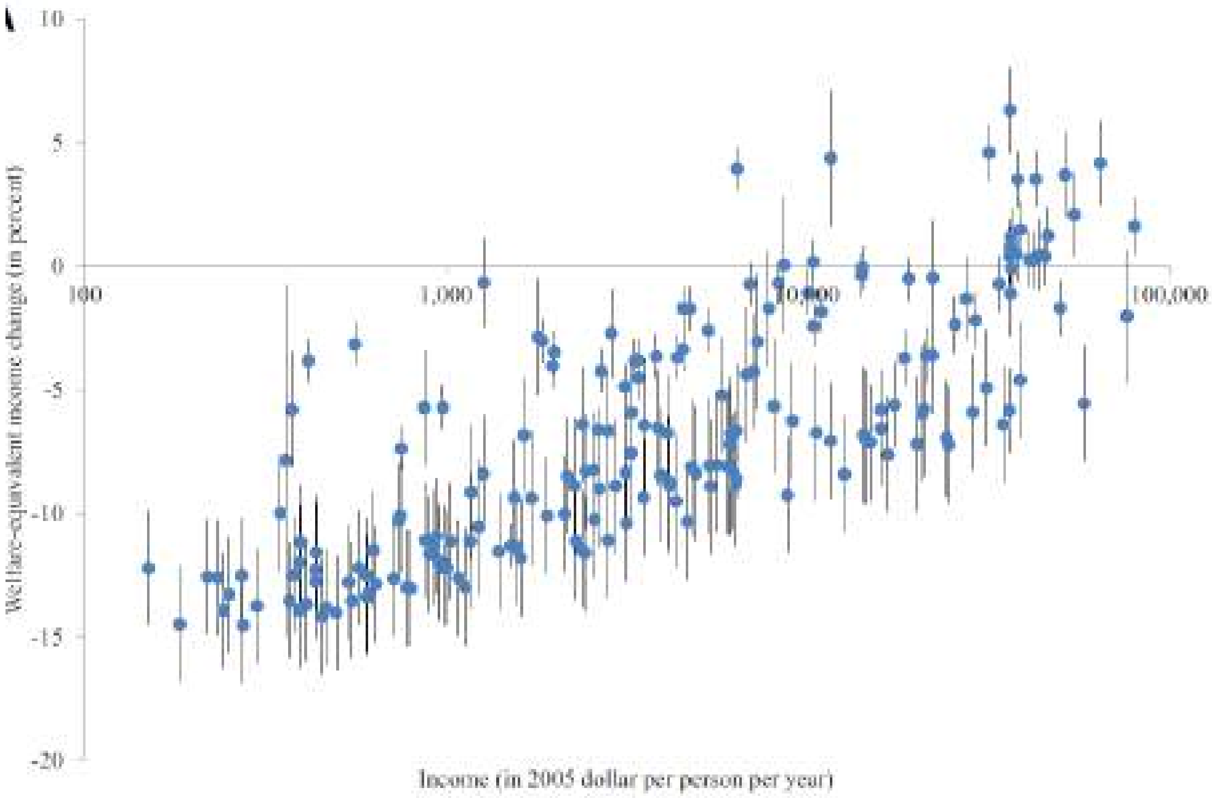
Source: Biggeri et al. (2023)

3. Distributional impacts of climate change

In this paper we will analyse the functioning and socio-economic impact of a particular climate policy instrument, namely carbon pricing. Before doing so, however, it is useful to remember that climate policies, although imperfect and improvable, respond to the need to mitigate the distributional effects of climate change. As early as 2006, Mendelsohn et al. pointed out that the effects of climate change were particularly relevant for poorer and more vulnerable populations.

Rising global temperatures negatively affect many aspects, like agricultural income and labour supply, and lead to increased mortality rates (including infant mortality) and civil conflict risks (Carleton & Hsiang, 2016). At the social level, the ongoing climate change influence the interaction between people, amplifying interpersonal and intergroup violence, and potentially leading to institutional failure. The poorest nations, which are among those most exposed to climate change, suffer most from this situation (Tol, 2021).

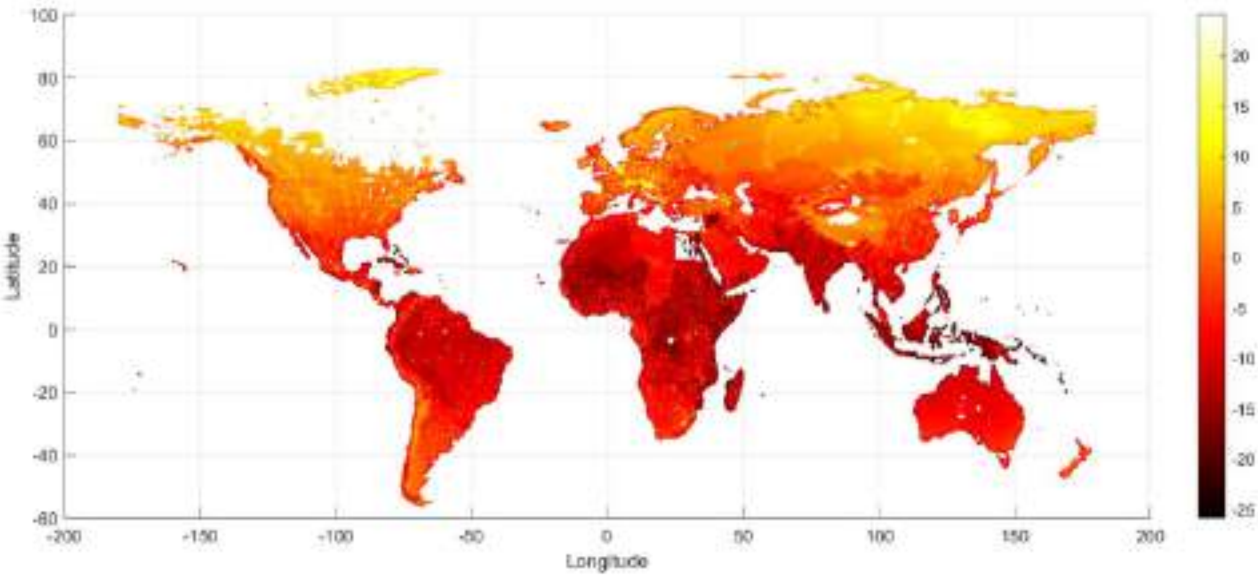
Figure 4: Distributional impact of climate change at country level



Source: Tol (2021)

Figure 4 illustrates the economic impact of climate change for a 2.5 ◦C warming for countries as a function of their income, while Figure 5 reveals the economic impact (% income) of climate change for a 2.5 ◦C warming at regional level.

Figure 5: Distributional impact of climate change at regional level



Source: Tol (2021)

At both levels, poorer countries/regions have more negative impacts from rising temperatures than richer areas. This pattern likely extends to poorer individuals within those countries. These individuals often work outdoors, have poorer health, and lack access to heating and air conditioning. Public goods like coastal protection and irrigation typically favour the affluent, mirroring the vulnerability seen between countries within individual nations (Tol, 2021).

In addition to rising temperatures, ongoing global warming increases climate risk by increasing the likelihood of extreme events such as storms, floods, droughts. Indeed, the atmosphere, ocean, cryosphere, and biosphere have all seen significant and swift changes over the last decades. Several weather extremes and climate change induced by humans are already being felt in every part of the world. This has resulted in numerous negative effects, losses, and harm to both people and the environment. When modelling the temperature dose-response function, taking variability and extremes into account increases global economic losses by almost two percentage (Waidelich et al., 2024). Again, particularly impacted are vulnerable communities, who have historically made the least contribution to climate change (IPCC, 2023).

At the European level, a complex climate policy framework (Fridhal et al., 2023) aims to respond to perceived criticalities and thus counteract climate change, to achieve climate neutrality. One of the pillars of EU climate policies is the ETS. In the next section, we will analyse this mechanism, highlighting how it works and how it can be applied to achieve the continent's decarbonisation goals.

Carbon Pricing

Carbon pricing is one of the ways to deal with high GHG emissions by assigning a value to the carbon content in fossil fuels. The primary rationale or theory underlying carbon pricing takes foundation from the concept of externalities—negative externalities, wherein social and environmental costs from production and consumption are not internalized or reflected in market prices. Carbon pricing internalizes these externalities and aligns the private costs with the social costs, providing businesses and households with incentives to reduce the carbon footprint (Hanley et al., 2019). There are two mainstream ways of carbon pricing: carbon taxes and cap-and-trade systems. A carbon tax directly charges the user, especially from purchasing fossil fuels, for the carbon content. This sends the price signal for the investments in technologies that are low in emissions and energy-efficient practices. In contrast, a cap-and-trade system sets up a market for the number of emissions that can be let out; it is a limitation on the total emissions among sources, with firms buying and selling the needed permits. In such a manner, this is equivalent to a system in which it would be possible for firms to finance emissions over their determined allowance (Delbeke, 2024).

A carbon tax is often seen as more efficient than a cap-and-trade system due to its predictable pricing, straightforward implementation, and broad coverage across sectors. However, it faces significant hurdles, including political resistance, potential economic impacts, and social equity concerns, as it directly raises fossil fuel costs and can disproportionately affect lower-income households. These are the reasons why a carbon tax is always hard to implement at EU level. On the other hand, cap-and-trade systems are more politically feasible and provide clear emissions limits by capping total emissions and allowing trading of permits. They offer flexibility and cost-effectiveness but come with challenges like price volatility, administrative complexity, and the risk of market manipulation.

4. EU ETS state of the art

The EU ETS is the leading cap-and-trade programme in the world, accounting in 2022 for 44% of global carbon revenues (I4CE, 2024). Its scope is to reduce emissions by providing companies with an incentive to adopt clean alternatives. The mechanism aims to price carbon. The EU sets a total emissions cap, and issues allowances for emissions, with companies exceeding the entitlement being forced to acquire more allowances. Companies reducing emissions can trade unused permits. Over time, the total pollution credit cap decreases, encouraging corporations to reduce emissions and to seek cost-effective cleaner alternatives.

After its confirmation through Directive 2003/87/EC on a scheme for GHG allowance trading within the Community, adopted on 13 October 2003, the EU ETS underwent four distinct phases. It was launched in 2005 as the world's first emissions trading scheme and remained the largest in scope until China launched its own in 2021. To function, it establishes an adequate infrastructure to monitor, report, and assess emissions from the installations covered. During its initial phase, the system was primarily at a pilot stage, with emissions reduction allowances distributed for free to companies in specific industrial sectors (e.g., power generation, iron and steel, glass and cement, accounting for about 45% at that time of the EU's total GHG emissions (European Commission, 2007)), with low penalties for non-compliance.

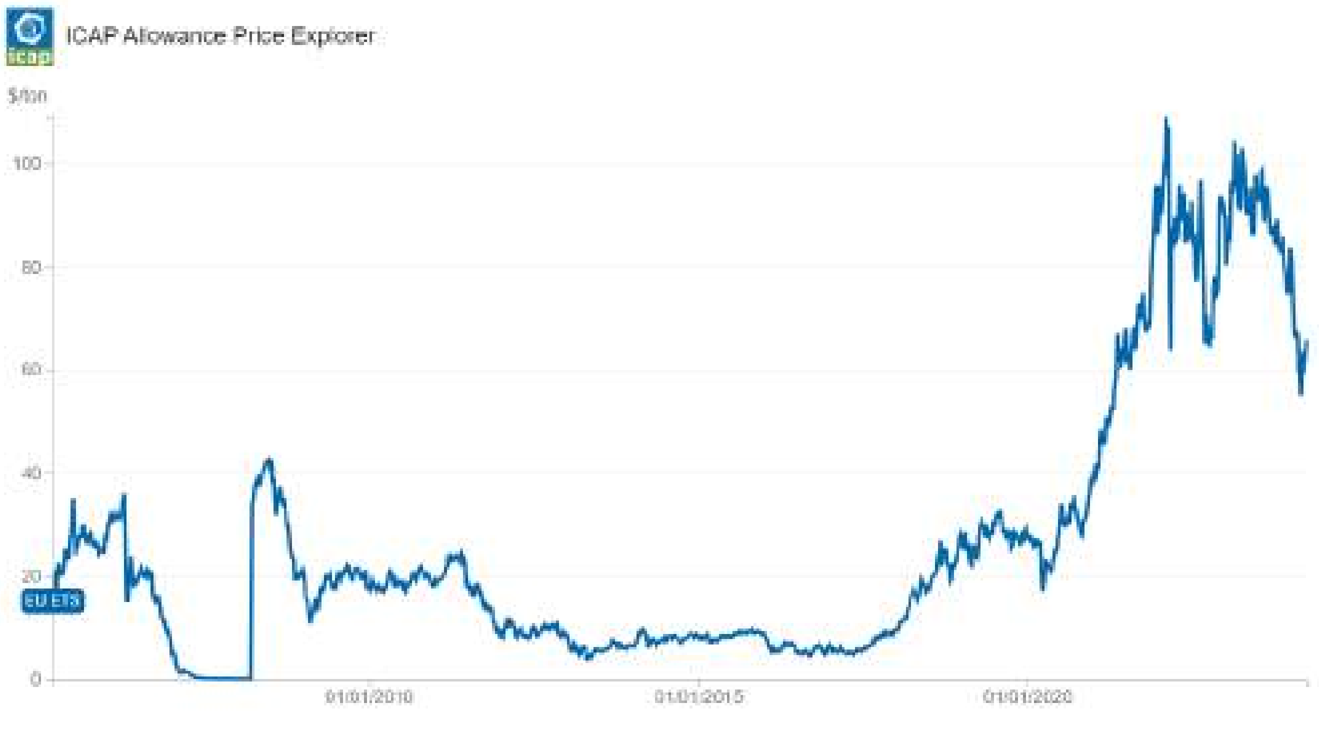
The second phase (2008-2012) saw improvements in the EU ETS design, introducing a more structured allocation of allowances and expanding the list of sectors included (i.e., aviation in 2012). Besides the EU Member States (MS), Iceland, Liechtenstein, and Norway joined the system as well. In addition, the proportion of free allocation of allowances decreased, auctioning of allowances became a more significant feature, and the penalty for non-compliance rose from €40 to €100 per ton. Regarding data monitoring and reporting, a Union-wide registry substituted national registries, and the European Union Transaction Log (EUTL) replaced the Community Independent Transaction Log (CITL) for recording all installations and transactions taking place in the market. The EU lowered further the cap on allowances to drive emission reductions. However, new challenges emerged, including the global monetary crisis that affected carbon markets. This crisis, which reduced emissions more than expected, was primarily to blame for the excess of allowances. As a result, there were fewer incentives to cut emissions due to falling carbon prices, leading to a structural and long-lasting surplus of allowances and low carbon prices below €10/ton.

To address this issue of the second phase coming also from the previous general financial and industrial crisis, the European Commission proposed and ETS Phase 3 (2013-2020). One of the main initiatives of this phase was the "backloading" in 2014. The measure involved postponing the auctioning of a certain number of carbon allowances, effectively reducing the number available on the market. By reducing the supply of allowances, the EU aimed to increase their scarcity, which would, in turn, drive the price of carbon allowances and incentivise industries to reduce their emissions. The decision to implement backloading faced political and industry opposition, but it was eventually approved in April 2014. Backloading was seen as a short-term measure to stabilise the carbon market, and it did succeed in increasing the carbon price within the EU ETS, albeit temporarily.

In its third phase, the EU ETS entered a more mature stage. The cap-and-trade system became more stringent by reducing further the overall emissions cap. Auctioning of allowances turned into the default method of allocation instead of free allocation: the Commission estimated that 57% of the total amount of general allowances were auctioned in phase 3 (EC, 2023a). In the meantime, additional sectors (e.g., petrochemical, aluminium, and ammonia) and gases (e.g., nitrous oxide and perfluorocarbons) were included in the scope of the system. To boost the transition to a low-carbon economy, the third phase placed a strong emphasis on funding opportunities related to low-carbon innovation with the Innovation fund, and the modernisation of the energy system, through the Modernisation Fund.

Following this temporary intervention, the EU has implemented another tool to strengthen the EU ETS, the Market Stability Reserve (MSR), to address the long-term oversupply issue and provide a more robust and effective system to strengthen the price signal of the EU ETS. January 2019 saw the establishment of this mechanism as a long-term remedy for the excess of allowances. The MSR automatically adjusts the supply of allowances by placing allowances in a reserve when there is an oversupply and releasing them back into the market when there is scarcity. By modifying the number of allowances to be auctioned based on allowances in circulation in the market, the reserve aims to strengthen the system's resistance to significant shocks. The MSR automatically adjusts the supply of allowances by placing allowances in a reserve when there is an oversupply and releasing them back into the market when there is scarcity. This mechanism contributed to the allowance price rising from around 20 to more than €100 per ton of CO_2eq in less than two years, as shown in Figure 6 However, some adjustments may be needed in the future (Borghesi et al., 2023).

Figure 6: EU ETS price ups and downs



Source: ICAP (2024)

The fourth phase of EU ETS, which encompasses 2021 to 2030, aims to intensify efforts to reduce carbon emissions. The achievement of this goal implies a significant increase in the pace of emissions cuts, shifting from an annual reduction rate of 1.74% in the third phase to 4.3% from 2024-2027 and to 4.4% from 2028-2030.[1] The objective is to achieve a total reduction of emissions by 62% by 2030 compared to the baseline year 2005. The fourth phase of the EU ETS also focuses on refining and improving the mechanisms to counter carbon leakage. In order to reduce the number of industrial sectors at risk of carbon leakage, the EU updated the official list of sectors and sub-sectors considered to be at a significant risk of carbon leakage. Additionally, energy producers in low-income MS are granted free allowances to help facilitate their shift towards cleaner energy production methods. Furthermore, it is complemented by a new carbon border mechanism to tackle the risk of carbon leakage and incentivise other countries to adopt more ambitious climate policies (Regulation (EU) 2023/956 establishing a carbon border adjustment mechanism).

The new provisions of EU ETS emanating from the Fit For 55 Package[2] can be summarised in:

- a quicker decrease in the system's emissions allowances;
- a more gradual phase-out of free allowances for specific industries;
- its expansion to include emissions from shipping;
- the implementation of the global carbon offsetting and reduction scheme for international aviation (CORSIA) through the EU ETS;
- an increase in money allocated to the Innovation and Modernisation Funds;
- the revision of the market stability reserve.

Furthermore, a brand-new independent ETS, hereafter named EU ETS 2, covering road transport, buildings, and small industry emitter is expected to enter into force in 2027, and could be gradually integrated into the existing system.

Aligning regulation with the increasingly ambitious climate objectives has been long and tortuous, as this can be seen at the European level. However, in the era of the European Green Deal, the European Council and Parliament did not substantially alter the original proposals of the European Commission, despite the tensions over the COVID pandemic and the energy crisis provoked by the Invasion of Ukraine.

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[1] These are the reduction factors currently applicable at the time of writing (June 2024). Prior to the adoption of the reform of the EU ETS of the Fit For 55 Package, the reduction rate was foreseen to be of 2.2% per year in phase 4.

[2] The changes are featured in the following acts published in January and May 2023:

- Directive (EU) 2023/959 amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve;
- Regulation (EU) 2023/957 of amending Regulation (EU) 2015/757 in order to provide for the inclusion of maritime transport activities in the EU ETS;
- Directive (EU) 2023/958 amending Directive 2003/87/EC as regards aviation's contribution to the Union's economy-wide emission reduction target and the appropriate implementation of a global market-based measure;
- Decision (EU) 2023/136 amending Directive 2003/87/EC as regards the notification of offsetting in respect of a global market-based measure for aircraft operators based in the Union.

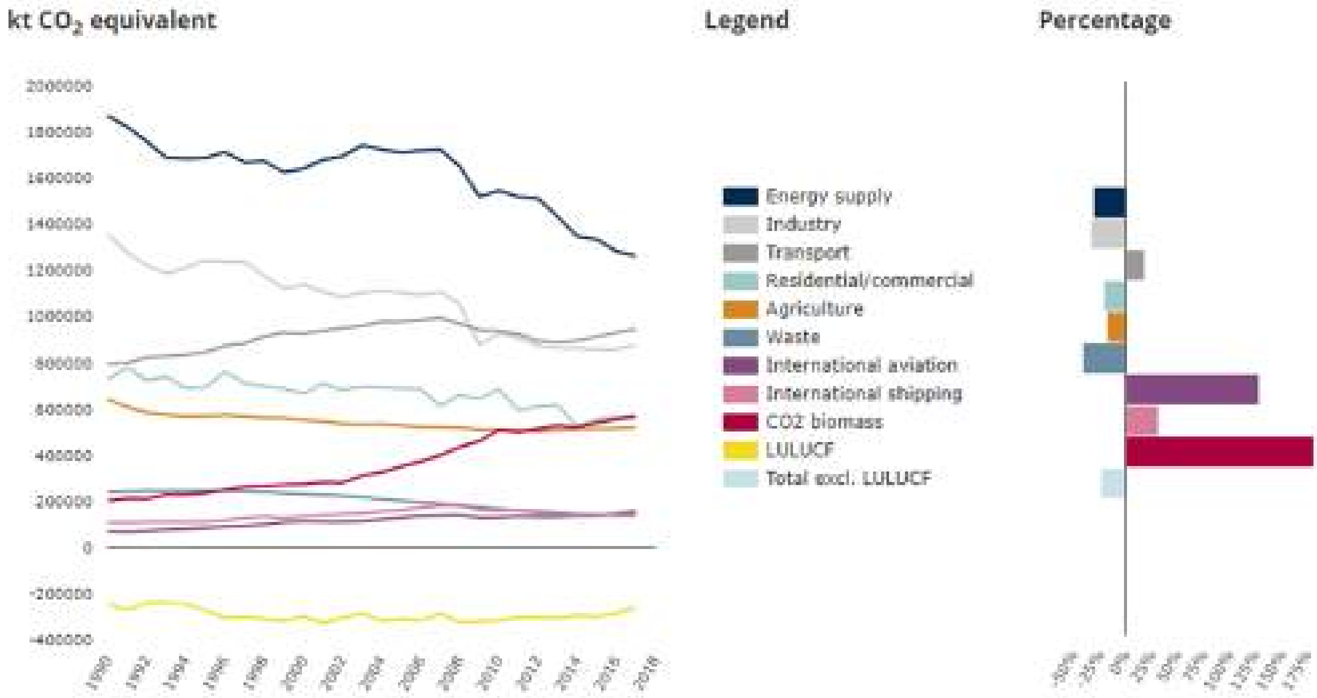
5. Distributional concerns of EU ETS 2

The ETS-covered sectors have experienced a substantial decline in emissions compared to other sectors (Figure 7).

In 2022, stationary sources within the EU ETS contributed to 37% of the total GHG emissions in the European Economic Area. Since the EU ETS started in 2005, emissions from these sources have dropped significantly. This reduction is driven by several factors, including an increasing carbon price, a shift away from coal due to changing fuel prices, and policies promoting renewable energy. Additionally, reduced energy demand, influenced by energy efficiency measures, lower demand for certain industrial products, and global events like the 2008 economic crisis and the COVID-19 pandemic has played a crucial role. In 2022, emissions fell by 24 megatonnes of CO2 equivalents compared to 2021, though they remained above the 2020 levels, marking a 37% decrease from 2005 (European Environment Agency, 2023). Furthermore, as of April 2, 2024, data from EU Member States indicate that ETS emissions in 2023 decreased by 15.5% compared to 2022. This reduction brings ETS emissions to approximately 47% below the levels recorded in 2005, positioning the system well to meet the 2030 target of a 62% reduction (European Commission, 2024). Conversely, other sectors not covered by the ETS recorded an increase of CO2 emissions, despite technological improvements. Transport, for example, showed no reductions over the period 2005-2021, and an increase of over 2% between 2022 and 2023.

For this reason, the EU decided to cover further sectors with the new EU ETS 2, with the aim to contribute to tackling climate change.

Figure 7: CO2 emissions by sector in Europe



Source: European Environment Agency (2019)

In add, implementing the EU ETS2 would achieve around 25% of the efficiency gains compared to a fully integrated emissions trading system by 2030 (Rickels et al., 2023).

However, the outcome of these policies is only sometimes equitable, and their distributional impacts should be carefully considered (Fredriksson & Zachmann, 2021).

In general, climate change mitigation policies can have significant social impacts, potentially increasing inequality if not carefully designed and implemented. The risk of adverse social outcomes, such as worsening inequality, is higher in contexts with existing high levels of poverty and economic disparities (Markkanen & Anger-Kraavi, 2019).

Low-income and vulnerable populations may bear a disproportionate burden as they may face adverse economic and social consequences from policy-induced changes in energy costs, employment opportunities, and living conditions (Aldy & Stavins, 2012). If not properly managed, the transition towards a greener economy can also lead to job displacement in carbon-intensive industries, affecting low-income communities that heavily rely on these industries (Fragkos et al., 2021).

The EU ETS as a market-based policy instrument is no exception, as it may have regressive effects if not accompanied by proper compensation measures. While such policies are often progressive in developing countries due to limited energy access among poorer households, the transition can exacerbate inequality as access improves (Shang, 2023). Energy-intensive industries, such as steel and cement production, may experience increased costs, potentially leading to carbon leakage, job losses and economic challenges in those sectors. A carbon market can lead to higher energy prices, too, which in turn affects everyone's budgets, especially those of the poorest households. Some of the costs of the suppliers would pass the cost on consumers' bills, increasing the cost of living (EPG, 2022).

The most vulnerable households would suffer from a triple cost since they: a) spend a more considerable percentage of their income on carbon-intensive goods; b) are less likely to embrace low-carbon technology due to higher financial constraints; c) are more likely to suffer job losses in carbon intensive sectors.

In this regard, the EU ETS 2 for road transport and buildings, covering emissions from fuel burning for heating and transportation, is particularly challenging due to its possible regressive effects on the most vulnerable households. Estimates suggest that ETS 2 will cost the lowest income groups approximately between 600 – 1,112 billion € (Maj et al. 2021).

The aspect of social compensation will be determinant with the ETS 2 implementation to reduce the worst effects of the rising energy bills, that could force poorest households to restrict their energy consumption below the basic needs levels (Stenning et al., 2020). Without adequate support they will struggle to afford initial energy efficient upgrade costs, leading to a potential growth of disparity in access to energy efficient homes and transport. Particular attention will have to be given to tenants. As landlords incurring in new costs due to the energy- efficiency improvements could potentially pass them the costs, increasing rents, so making adequate housing more costly (Social Platform, 2024).

Greater challenges lie ahead for municipalities with low population densities and high rates of poverty and social isolation (Strambo et al., 2022). Another challenge could be that the definition of vulnerable consumers might be insufficient to target the most vulnerable (households in the lowest income quartile, those living in the worst energy performing buildings or those with little alternative to individual transport use for their daily mobility needs. Moreover, citizens with low vulnerabilities will be likely to able to have better access to information about support schemes (Jacques Delors Institute, 2021).

The abovementioned FF55 packages including the SCF and the REPowerEU strategy represent key instruments in the EU's efforts to safeguard its most vulnerable inhabitants and achieve carbon neutrality (Borghesi & Ferrari, 2023). Different strategies aim to increase the social acceptability of higher prices and mitigate the distributional impact of climate policies through a judicious use of the auction revenues. Some studies in the literature suggest that the even limited allocation of ETS revenues to low-income households can effectively offset the negative consequences of carbon pricing in these categories (IMF, 2024).

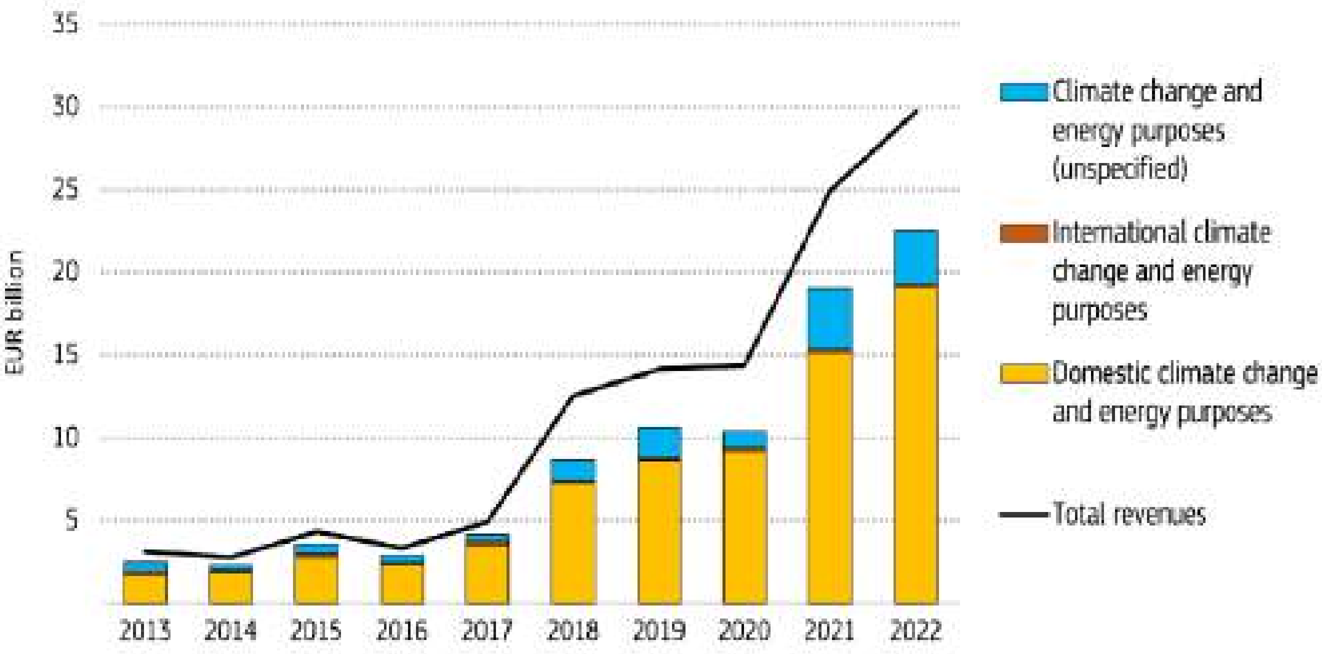
The EU ETS revenues represent a significant fund, accounting for 43 billion € in 2023, including revenue from Iceland, Liechtenstein, Norway, and Northern Ireland.

In 2022, rising carbon prices increased ETS auction revenues to 38.8 billion €, up 7.7 billion € from 2021. Of this total, 29.7 billion € went to the 27 Member States (European Commission, 2023c). By 2050, the expected amount of ETS revenues could be between 800 and 1,500 billion € (Fuest & Pisani-Ferry, 2020). Thus, it is important to look at how revenues are spent. According to the

European Commission (2023b), most of the auction proceeds in the EU ETS still go toward funding the budgets of the participating MS. These profits should be allocated to energy and climate-related projects. In 2022, for instance, MS allocated around 76% of their total revenues, both domestically and internationally, to energy and climate-related initiatives; 25% of the funds were dedicated to climate and energy initiatives, 27% went to environmental funds, and 48% was added to their national budgets (European Commission, 2023).

The allocation to the jurisdiction's budget is a fiscally preferred mechanism for the flexibility in spending it provides (Figure 8). However, it does not help to increase the acceptability of climate policies since it is not visible.

Figure 8: Auctioning revenues received by EU MS and report usage (2013-2022)



Source: European Commission (2023).

An alternative way is to earmark carbon revenues spending them for a predetermined action; this is the case of the Innovation and Modernisation Funds, shaped in Phase 4 (2021–2030) to encourage decarbonization in the EU ETS sectors, which are fully financed by the auction of allowances. Another example is the SCF, established through the Regulation (EU) 2023/955. The SCF aims to assist vulnerable households, small businesses, and transportation users to mitigate the potential financial burden of implementing the EU ETS 2. Even if the ambition of SCF was watered down from a €144 billion budget to €86,7 billion, the plan remains an elaborate scheme to address the twofold need to mitigate their distributional impact and promote the acceptability of ETSs at the European level. To do so, €65 billion from the EU ETS 2 auction revenues are expected to be allocated to the SCF over the period 2026-2032, with an additional 25% covered by national resources plus a further €4 billion from the auctioning of 50 million allowances under EU ETS. The costs of measures financed by the SCF that provide temporary direct income support shall not represent more than 37,5 % of the estimated total costs (i.e., the majority of the funds should have a structural impact).

6. The socio-economic impact of carbon prices in three EU Countries

The Paris Agreement (Article 4, paragraph 2) mandates that every country must draft, communicate, and uphold a series of nationally determined contributions (NDCs) to address climate change. These NDCs outline each nation's strategies for cutting down greenhouse gas emissions and adjusting to climate impacts. Countries are required to submit their NDCs to the UNFCCC secretariat every five years. Additionally, countries can revise their NDCs to increase their ambitions (Article 4, paragraph 11). The EU did just that in November 2023, updating its NDCs.

By 2030, each European MS will achieve specific percentage reductions from their 2005 emission levels. Regulation (EU) 2023/857, emending the previous Effort Sharing Regulation (ESR), sets an EU-level GHG emission reduction target of 40% by 2030, compared to 2005. For the sectors covered by the EU ETS and EU ETS 2 the goal is to reach a total reduction of emissions by 62% by 2030 compared to the baseline year 2005.

The ambitious targets are presented on a continent-wide level, but each country has its own quota of emission reductions to meet[3].

In this section of the report, we will focus on the impact of European climate policies, especially ETSs, on three MS. The three countries analysed are France, Italy and Hungary. The first two represent Western Europe, the third is from Eastern Europe. These three countries, despite their profound differences, are experiencing a similar political trajectory, with very conservative parties opposed to climate policies increasing their influence and obtaining parliamentary majorities.

France, led by Emmanuel Macron, a leading supporter of the Von der Leyen Commission, is amid a political storm following the rise of the far-right Rassemblement National party and the debacle of the governing parties at the last parliamentary elections in July 2024, and the consequent political gridlock. Italy and Hungary fulfil important responsibilities, respectively the coordination of the G7 and the presidency of the European semester (July-December 2024), led by leaders openly hostile to EU initiatives to combat climate change.

In all three cases, the opponents of the EGD rely on a widespread fear that European climate policies may lead to very negative socio-economic and distributional impacts.

The construction of transition scenarios is a useful approach to assess the extent of these undesired consequences under different policy scenarios. The International Institute for Applied Systems

[3] Each EU Member State will reduce its emissions from 2005 levels by 2030 in accordance with the following percentage: Belgium 47%, Bulgaria 10%, Czechia 26%, Denmark 50%, Germany 50%, Estonia 24%, Ireland 42%, Greece 22.7%, Spain 37.7%, France 47,5%, Croatia 16,7%, Italy 43,7%, Cyprus 32%, Latvia 17%, Lithuania 21%, Luxembourg 50%, Hungary 18,7%, Malta 19%, Netherlands 48%, Austria 48%, Poland 17,7%, Portugal 28,7%, Romania 12,7%, Slovenia 27%, Slovakia 22,7%, Finland 50%, Sweden 50% (UNFCCC, 2023).

Analysis (IIASA) established the Shared Socioeconomic Pathways (SSP) database, which was updated in 2024, to investigate the feedback between socioeconomic issues and climate change. It offers a vast array of simulations built upon various scenarios. Through the database, we studied the impact of sustainability on economic development on France, Italy, and Hungary.

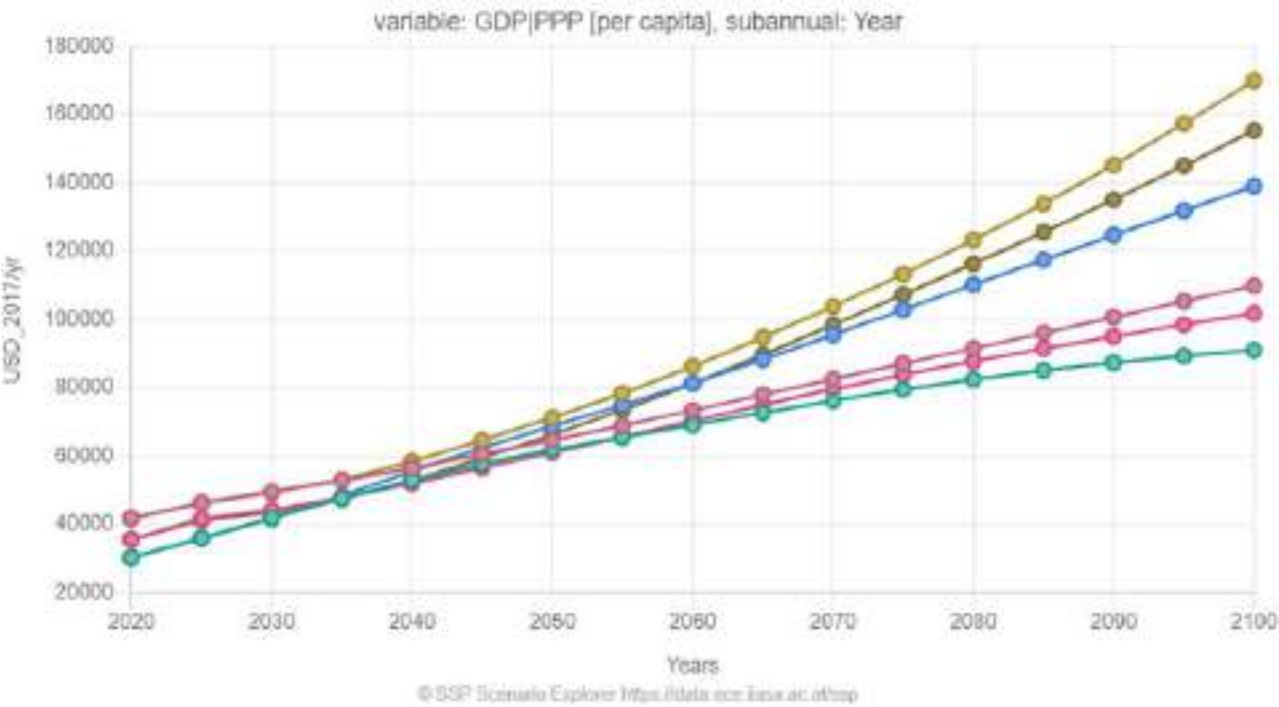
The two scenarios considered were:

the SSP1 (Sustainability), in which the world is moving toward sustainability through faster technical advancement, less reliance on fossil fuels and resources, and increased economic growth in low-income nations. Lower population growth is the result of high education investments, with an emphasis on eco-friendly technologies.

The SSP5 (Conventional Development), that places a strong emphasis on using fossil fuels to drive economic growth, which raises emissions. However, robust economic activity and well-designed infrastructure minimize adaptation issues and help achieve human development goals.

Using the GDP per capita (USD_2017/year) as a proxy of economic development, the database outlined economic growth from 2020 to 2100 for the three countries, based on the two possible designed scenarios. The upper three lines in the Figure 9 represent economic growth in the case of the SSP5 scenario for, starting from the top, France (yellow), Italy (brown) and Hungary (blue); the lower lines draw the GDP growth trend in the case of the more SSP1-sustainable scenario, in the same order as above with France (pink), Italy (light red), and Hungary (green).

Figure 9: Sustainability and Conventional Development scenarios in the three EU countries



Source: International Institute for Applied Systems Analysis (2024)

The simulation is in line with other studies that use GDP as an indicator of economic development, and which emphasise that a more decarbonised approach could lead to slower growth in the long run (Claeys et al., 2024).

However, it is not clear from the scenarios how growth trajectories can lead to irreversible damage to the ecosystem (Waidelich et al., 2024); in other words, the scenarios do not account for the irreversible damages that may derive from economic growth. In addition, they use GDP as a metric of development, which is questionable (Biggeri et al., 2023); in fact, it is quite clear that new measurement systems are needed to measure sustainable human development (Gábos et al., 2023). Moreover, the simulations consider a climate policy mix rather than a specific carbon pricing measure.

To understand the potential distributional impact of EU ETS and its expansion to new sectors with the EU ETS 2 for each country, it is possible to rely on previous studies.

According to Berghmans (2022), the introduction of the EU ETS 2 is expected to have varying distributional impacts on French households. The analysis indicates that the overall effect on household disposable income is relatively limited, with an estimated negative impact of less than €0.35 per year on average without redistribution measures. However, the distributional effects are more pronounced across different income deciles and regions. The most significant negative impacts are observed among middle-income households (deciles 4 to 8), which could experience a reduction in disposable income of 1%, equating to a monetary loss of €323 to €510 per year. Redistribution of auction revenues, particularly through the SCF, mitigates these impacts significantly. For the 30% of the lowest-income households, the redistribution can turn the impact positive. Yet, the SCF alone is insufficient to fully offset the income reductions, necessitating additional national auction revenue allocations. Furthermore, the geographic analysis shows that households in densely populated areas are more adversely affected. Thus, targeted redistribution strategies are essential to alleviate the negative effects on vulnerable households (Berghmans, 2022).

In Italy, things may not be different. Costantini et al. (2023) focuses on the implementation of EU ETS 2 as part of FF55 package. Its distributional impact in Italy was assessed using a dynamic Computable General Equilibrium (CGE) model and a consumer demand system estimation. The study evaluated three policy scenarios: the removal of fossil fuel subsidies, the introduction of a carbon tax, and a combination of both. Results indicated a nationwide annual welfare loss exceeding EUR 10 billion across all scenarios, an average loss of € 166 per capita.

It also highlighted an overall welfare loss, with low-income households disproportionately affected by rising food prices, signifying a regressive impact in this area. To mitigate adverse effects, redistributive interventions were recommended. Additionally, the potential to offset household welfare losses through policy measures funded by revenues from these interventions was identified.

The extension of carbon pricing under EU ETS 2 has more significant distributional impacts in Hungary (Energy Policy Group, 2023). On the one hand, the introduction of a carbon tax in Hungary is projected to reduce natural gas imports by up to 35% by 2032, decreasing dependency on fossil fuel imports and enhancing energy and climate security. On the other hand, household welfare losses exhibit regressive tendencies, disproportionately affecting lower-income households. By

2032, the poorest 10% of households will experience welfare losses 1.6 times higher than those of the wealthiest 10%.

Not surprisingly, the willingness to pay for a carbon tax among Hungarian citizens is low: Muth et al. (2024) study's results show low public acceptance of such measure, with just a slight rise from 20.3% to 27.3% because of revenue recycling. Indeed, the negative impact on poorer households underscores the need for targeted revenue redistribution strategies. Effective redistribution, such as lump-sum transfers or price subsidies, could mitigate these adverse effects and potentially enhance welfare for lower-income households.

Overall, assuming an average carbon price of 48 €/tonne CO2 (lower than the current value), the European Commission (2021) assessed the impact of EU ETS 2 heating oil and natural gas consumer price for each European country. The imposition of carbon pricing would significantly affect consumer prices for heating oil and natural gas across France, Italy, and Hungary. In France, heating oil prices could rise by 17% and natural gas by 12%. Italy might see heating oil prices increase by 11% and natural gas by 12%. In Hungary, heating oil prices could go up by 12%, with natural gas experiencing a substantial 31% hike.

Further analysis on the impacts of carbon price changes, and specifically the EU-ETS 2, at the country level would be highly insightful. However, empirical academic literature on country-specific impacts of carbon pricing mechanisms is still not broad. Given its novelty, exploring the EU ETS 2 is so far possible only through scenario analysis, but scenario databases usually do not consider the country level directly and instead work on more coarse regional levels like the EU-12 (corresponding to Eastern European countries) and the EU-15 (corresponding to Western European countries).

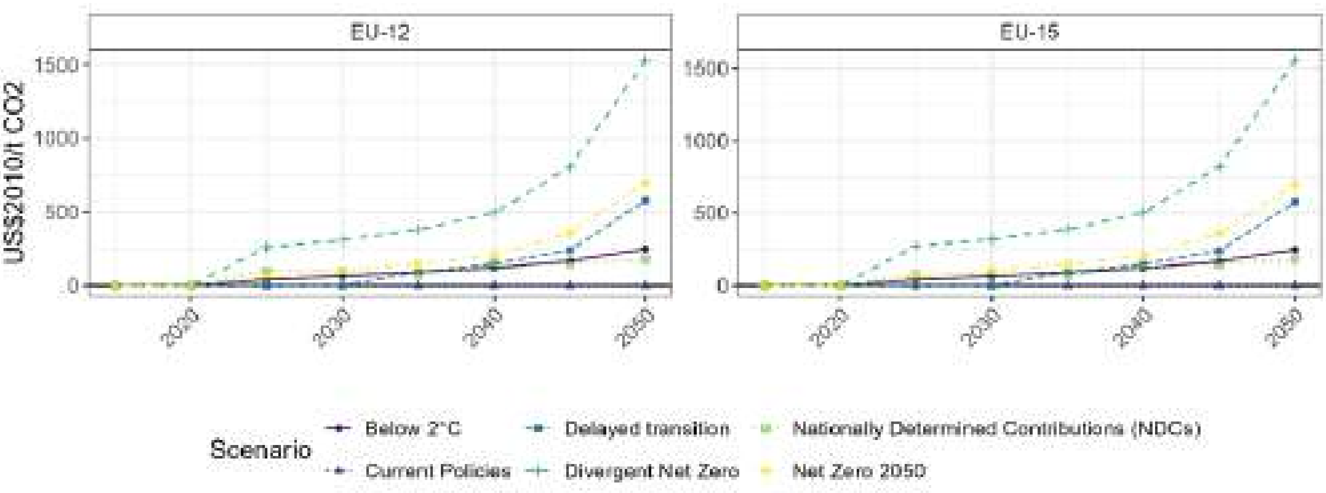
The transition to a low-carbon economy in the EU hinges on significant reductions in CO2 emissions. Scenario pathways provide a useful strategic tool to comparatively analyse likely future emission trajectories. These pathways are structured, model-based narratives that describe possible futures based on a set of defined assumptions. They offer plausible projections grounded in models that replicate the intricate and non-linear dynamics of energy, economic, and climate systems. This is achieved through a combination of theoretical models and empirical calibration (Wiek et al., 2006), providing tangible strategic narratives for policymakers and related stakeholders.

Most available scenario pathways emphasise the significant role that carbon pricing mechanisms play in this transition. Economic incentives are projected to actively discourage the production of emissions and reduce emission intensity per capita. For illustration, we consider six exemplary regional scenario pathways for carbon price developments and emissions from the Network for Greening the Financial System (NGFS). While these scenario pathways serve as specific examples, their insights and narratives generally overlap with those of other major scenario databases. The six presented NGFS scenario pathways encompass various plausible narratives for the future energy transition process.

For example, the scenarios include projections under currently implemented policies, under systematic, strong and immediate mitigation efforts, and under more disorderly, disruptive transition processes. The Net Zero 2050 scenario envisions reaching net zero CO_2 emissions by 2050 through rigorous climate policies and advancements. The Below 2°C scenario involves a gradual tightening of climate policies to keep global temperature rise below 2°C. Under the Delayed Transition scenario, global emissions remain steady until 2030, requiring robust policies thereafter to keep warming under 2°C. The Nationally Determined Contributions (NDCs) scenario incorporates all climate pledges, regardless of their current implementation status. The Current Policies scenario maintains only existing climate policies. Detailed information is available on the NGFS website and in their materials [https://www.ngfs.net/ngfs-scenarios-portal/].

In terms of regional focus, the two regions used for illustration are the EU-12 (corresponding to Eastern European countries) and the EU-15 (corresponding to Western European countries), aligning with the geographical focus of the remainder of this report on the EU.

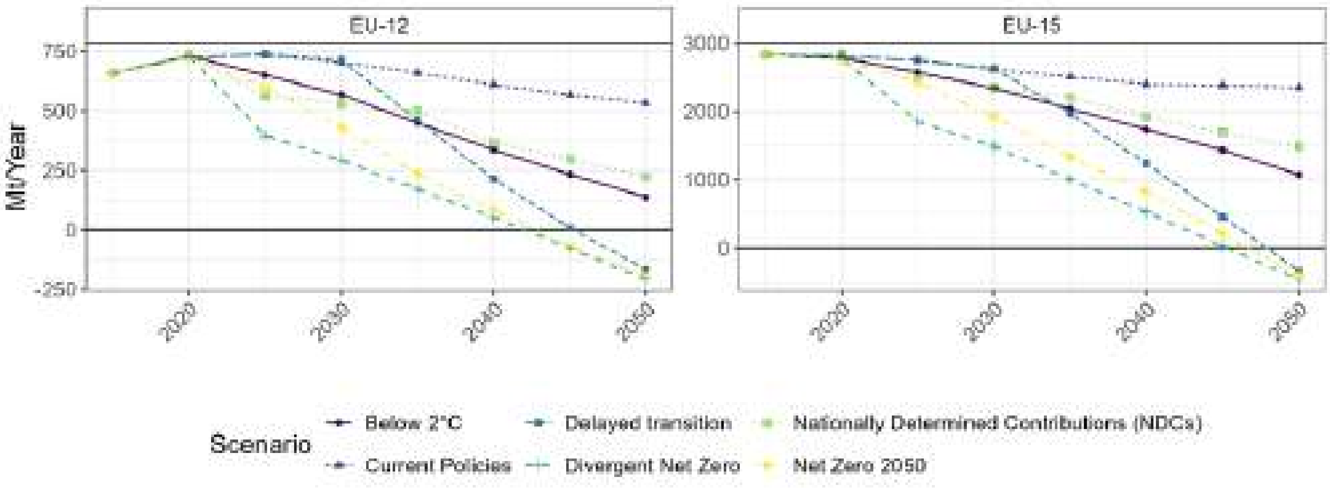
Figure 10: NGFS Carbon Shadow Price Scenario Pathways for Selected Regions



Source: Authors' visualisation based on Network for Greening the Financial System (2024) scenario pathways

Figure 10 showcases projected carbon prices corresponding to the NGFS scenarios. In the NGFS scenarios, the carbon price represents a shadow emissions rate that reflects not only any actual price or tax related to carbon emissions, but a combination of all policies that indirectly and directly influence the price of emissions. A higher shadow price of emissions hence implies a generally more stringent policy approach. All scenario pathways, except for the projections under current policies, are characterized by a significant rise in carbon shadow prices, underscoring that higher direct and indirect emission costs are essential to driving down emissions, irrespective of the specific scenario narrative and the detailed assumptions regarding the transition process.

Figure 11: NGFS Carbon Dioxide Emissions Scenario Pathways for Selected Regions



Source: Authors' visualisation based on Network for Greening the Financial System (2024) scenario pathways

Figure 11 shows the corresponding trajectories of CO2 emissions in million tons per year. The chart illustrates the projected CO2 emissions under six different scenarios, each presenting a distinct pathway. All scenarios imply emission reductions by 2050, with some trajectories reaching net zero emissions in the considered regions. A key driver behind these reductions is the increasing financial incentive to reduce emissions via carbon pricing mechanisms. Other factors include technological progress, among others.

In summary, the NGFS scenario database, similar to most other scenario pathways focusing on energy and sustainability transition processes, highlights the necessity of substantial increases in carbon (shadow) prices (more than $500 per CO2 tonnes) to achieve emission reductions. However, in line with most scenario databases with a broad focus, it does not provide details regarding specific policies that can influence the direct and indirect cost of emissions to accomplish these reductions. Carbon trading mechanisms, as discussed in this report, emerge as a key candidate, especially in large economic conglomerates like the European Union. Hence, the EU Emissions Trading System (EU-ETS) emerges as a potentially crucial mechanism, with a vital role in the future carbon policy landscape.

7.Policy recommendations on the next steps

So far, we examined how ETSs clearly contribute to decarbonisation, but also how these mechanisms, if not appropriately designed, can lead to distributional effects. This last aspect is one of the main issues to consider.

According to the European Commission Impact Assessment Report (2021), the ETS extension could raise fuel costs for the lowest-income households by about 2%, leading to more energy poverty. Up to 25% of these households might struggle to meet basic energy needs without help. However, the policy generates revenues that can be used to offset these costs. The report suggests that using these revenues to provide subsidies, direct financial assistance, and support for public transport can reduce up to 80% of the additional expenses for the poorest families (European Commission, 2021).

Funke et al. (2024) assessed the average support to the EU ETS by interviewed individuals in three main countries (France, Germany, Spain), through a survey submitted to a sample of 2,251 citizens. The results showed that the percentage of “somewhat support” or “strongly support” of the system depends on the revenue recycling mechanism which is in place. The support is lower in case of equal cash transfers to vulnerable households, both at national and European level (28,1%; 42%), than in case of revenues recycling to low-carbon investments (66,5%).

Distributing EU ETS 2 revenues equally as cash transfers can have mixed effects. On the one hand, equal transfers can promote social equity by giving direct financial support to everyone, potentially helping those struggling with energy costs and the higher cost of living due to carbon pricing. On the other hand, this approach might miss the mark for the most vulnerable populations and ignore regional differences in income and energy expenses. It also may not encourage energy efficiency and emission reductions as effectively as investments specifically aimed at green technologies and infrastructures.

Alternatively, using EU ETS 2 revenues to invest in low-carbon technologies can bring substantial benefits. These investments can drive innovation and increase the use of renewable energy, significantly cutting GHG emissions. Eco-innovation plays a crucial role in achieving a low-carbon transition by fostering sustainable economic growth through technological, organizational, and behavioural changes (Borghesi et al., 2015). Investments in eco-innovations drive the development of new products and processes that reduce environmental impacts and resource use, aligning with long-term climate goals. These innovations not only mitigate greenhouse gas emissions but also enhance energy efficiency and stimulate economic growth by creating green jobs and fostering new industries.

Together with eco-innovations and renewable energy, recycling revenues to low-carbon investments could push carbon removals. Furthermore, to achieve net-zero targets, the EU must integrate novel carbon dioxide removal (CDR) techniques into its climate policies. Technologies like Bioenergy with Carbon Capture and Storage (BECCS) and Direct Air Carbon Capture and Storage (DACCS) offer promising long-term solutions for CO2 storage, especially for sectors that are hard to decarbonise (Fridahl et al., 2023).

Similarly to what happened with carbon offsets from afforestation or reforestation activities (LULUCF), the EU ETS would become an internationally renowned system with a carbon central bank (CCB) that converts carbon removals into allowances.

In our view, both revenue recycling mechanisms are acceptable. However, the key word is flexibility. To make the EU ETS 2 fair and effective, we need to carefully manage its impacts on different countries and communities within the EU.

The governance of the SCF, whether it is managed at the EU level or by individual member states, is essential to its success.

Increasing the financial resources to support the SCF (as initially planned before its downsizing), including channelling the revenues of the main EU ETS, is necessary.

Communicating the revenue recycling system transparently and effectively is another indispensable task, by "earmarking revenues" (Borghesi & Ferrari, 2023).

The SCF can effectively adjust for price volatility by adopting dynamic and responsive mechanisms. Implementing flexible allocation strategies ensures that disbursements vary in response to carbon price fluctuations, providing greater support during high-price periods and conserving resources when prices drop. Additionally, financial hedging through futures and options can stabilize the fund's purchasing power, mitigating the impact of unpredictable market shifts. Learning from the MSR, the SCF can incorporate automatic adjustments and transparent criteria to enhance predictability and market confidence. Regular market assessments and stakeholder engagement will ensure that the SCF remains attuned to evolving market conditions, allowing for timely and informed adjustments. By integrating these approaches, the SCF can effectively manage price volatility, ensuring stable and adequate support for vulnerable populations while maintaining the fund's overall sustainability and effectiveness.

In a world characterised by an increasing number of ETSs, a viable way to enhance market stability by reducing price volatility is by linking the different ETSs. When two or more ETS systems are linked, the supply and demand for emissions allowances from different regions are combined, leading to price equalisation. In addition, a larger market with several participants can absorb fluctuations in supply and demand more effectively, helping to stabilize carbon prices. A further concrete solution to this issue could be a price collar that sets both an upper limit (ceiling) and a lower limit (floor) for the allowance value, providing a range within which the price is allowed to fluctuate and mitigating volatility (Doda et al., 2022).

Linking ETSs could determine positive effects on price dynamics but present obstacles. Conflicting policy goals and objectives among different jurisdictions and the difficulties in aligning rules and regulations can complicate harmonization. Countries or regions may not be willing to surrender autonomy over carbon pricing and strategies. We believe that by implementing coordination and collaboration projects between the various jurisdictions, it is possible, indeed desirable, to provide for a linkage between ETSs that will ensure less volatility in allowance prices, with all that this implies regarding the efficiency of carbon markets.

The international coordination is also a relevant feature when discussing fairness of climate policies.

EU ETS and EU ETS 2 that we have reviewed in this paper also have some implications outside the EU, mainly related to potential emulation or linking with other systems. There are also other measures in the same policy framework that directly affect third countries.

This is the case of the Carbon Border Adjustment Mechanism (CBAM), which levies a carbon tax on imports from five sectors (iron and steel, aluminium, cement, fertilisers, electricity and hydrogen) based on their embedded carbon emissions. This mechanism became operational on October 1, 2023, with a transitional phase lasting until January 31, 2024. It aims to avoid the risk of carbon leakage by ensuring that specific imported goods meet similar emissions standards as those produced within the EU.

The permanent system, starting on January 1, 2026, will require annual declarations of imported goods and their embedded emissions, with corresponding CBAM certificates, priced based on EU ETS allowances. The CBAM will coincide with the gradual phasing-out of free allocation under the EU ETS from 2026 to 2034. A review during the transitional phase will precede the definitive system's entry into force, and the scope may expand to include additional sectors by 2030 (EC, 2023).

The CBAM has been challenged for its potential incompatibility with World Trade Organisation (WTO) rules, for not being fully effective in limiting carbon leakage, and for its implicit contrast with the CBDR-RC principle. We will discuss whether the mechanism is non-discriminatory and fully compatible with the existent international regulation in the next paper of this SPES work package 7.

8. Conclusions

Climate change is an urgent reality, making environmental sustainability central to both Sustainable Human Development and the SPES (Sustainable, Performances, Evidence, and Scenarios) framework. Global warming extends beyond environmental pollution; it also perpetuates social inequities by disproportionately impacting vulnerable communities.

Therefore, robust climate policies are essential. Europe is making commendable progress towards achieving climate neutrality by 2050, as outlined in the FF55 package. The European climate policy framework is complex, with the EU ETS as a cornerstone. For such reason, we have decided to focus this work on the functioning and impacts of EU ETS, designed as a market-based mechanism to incentivise industries to reduce emissions.

The EU ETS has been effective in lowering emissions within the sectors it covers. So, there is now a need for a complementary system, the EU ETS 2, which targets emissions from further sectors such as buildings, transportation, and small businesses. While promising, this new system poses socio-economic and distributional challenges.

A brief overview of the political landscapes in three European countries reveals a lack of robust support for decarbonisation efforts at the national level. The regressive economic impacts of measures like the EU ETS 2, particularly in Eastern European nations, contribute to low public willingness to bear the additional costs.

To mitigate the negative impacts of carbon pricing, several policy recommendations are proposed. Chief among these is revenue recycling, which involves redirecting the revenue from carbon pricing to support vulnerable households and fund low-carbon investments. These investments should focus also on carbon removal technologies and include CO2 capture within the European carbon offset schemes.

Furthermore, international cooperation is crucial for managing carbon price volatility, which affects potential revenue. Linking the EU ETS reduces extreme price fluctuations, leading to more predictable revenue streams and enabling the SCF to allocate resources more efficiently.

A coordinated global effort can create a more stable and equitable system, ensuring fair distribution of costs and benefits.

ETSs should therefore serve to achieve net-zero targets faster, according to a logic of temporary use of market instruments to tackle existing negative externalities, until it is no longer necessary to apply such measures.

This work focused on the EU ETS, providing insights into its key aspects. However, given the broad nature of climate policies, there are several areas that future research could address.

Future developments in the analysis could benefit from extending the case studies to other European countries. In terms of policy design, increasing the involvement of relevant stakeholders (e.g., business, civil society) in the decision-making process through a bottom-up approach could be an alternative. This comprehensive approach aims to mitigate protests and proactively implement subsidies to facilitate policy adoption and effectiveness.

As Claeys et al. (2024) emphasise, decarbonisation is necessary and achievable. With strategic institutional management, it can be pursued without severe socio-economic consequences or exacerbating inequalities.

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