"Designing an end-user carbon account scheme as a climate policy tool in the EU context"

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ABSTRACT

Climate change threatens human societies and the ecosystems around them. Aware of the urgency, public decision-makers, experts, and other stakeholders are developing public policies aimed at reducing emissions, limiting the global warming and, already, preparing, with more or less means, adaptation to less favourable living conditions. To coordinate the actors, putting a price on carbon is a well-accepted strategy. But this is not enough. Measures that will apply at different scales need to be worked out in details. Among the tools designed, carbon account policies rely on the allocation of carbon units to individual end-users. The principle is simple: households must return carbon units during their purchases, according to the carbon footprint of the goods and services they buy. The availability of carbon units would be reduced each year to be in line with climate change mitigation targets. The design of new public policies is a difficult exercise. To increase the effectiveness of climate policies, it would be particularly useful to test their acceptability by citizens before implementing them. This study assesses the preferences of Belgian citizens for an end-user carbon account scheme and the acceptability of different designs. Its organization is as follows. First, a review of scientists' and experts' proposals is presented in order to introduce the reader to the main public policy instruments. Second, an original end-user carbon account proposal is developed, following past proposals and developments by scientists and experts. It is a policy that could be deploye...

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Faculté des bioingénieurs

Designing an End-User Carbon Account Scheme as a climate policy tool in the EU context

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Abstract

Climate change threatens human societies and the ecosystems around them. Aware of the urgency, public decision-makers, experts, and other stakeholders are developing public policies aimed at reducing emissions, limiting the global warming and, already, preparing, with more or less means, adaptation to less favourable living conditions.

To coordinate the actors, putting a price on carbon is a well-accepted strategy. But this is not enough. Measures that will apply at different scales need to be worked out in details. Among the tools designed, carbon account policies rely on the allocation of carbon units to individual end-users. The principle is simple: households must return carbon units during their purchases, according to the carbon footprint of the goods and services they buy. The availability of carbon units would be reduced each year to be in line with climate change mitigation targets.

The design of new public policies is a difficult exercise. To increase the effectiveness of climate policies, it would be particularly useful to test their acceptability by citizens before implementing them. This study assesses the preferences of Belgian citizens for an end-user carbon account scheme and the acceptability of different designs.

Its organization is as follows. First, a review of scientists' and experts' proposals is presented in order to introduce the reader to the main public policy instruments. Second, an original end-user carbon account proposal is developed, following past proposals and developments by scientists and experts. It is a policy that could be deployed on European territory. Third, to assess its acceptability by citizens, a choice experiment is designed. The characteristics of this new public policy that are selected for the experience are: the level of carbon price, the potential volatility of price, the provision of tailor-made carbon advice, and the presence of higher carbon price for people emitting beyond a certain threshold of annual emissions.

The results indicate that a majority of participants is willing to accept the end-user carbon account scheme. Among the respondents, preferences for carbon account attributes are heterogenous. Three groups of respondents can be distinguished. The first group, the smallest, was not interested to enter a carbon account policy and was composed of people that were globally older and with higher emission levels. The second and third groups were both willing to accept a carbon account scheme and expressed both interest in carbon pricing mechanisms that reduce volatility. They prefer more tailor-made carbon advices. Finally, the third group preferred to have no higher carbon price when going higher than a threshold, while the second group expressed a high interest for the concept of higher carbon price above a certain limit of annual emissions. While reminding the limits of the analysis resulting from the sample used, the conclusion stresses the interest of this innovative proposal and the first-ever choice experiment applied to an EU carbon account policy proposal and, finally, the importance of bringing together generations of citizens with different preferences as to the characteristics that will guarantee this tool a strong acceptability.

List of Abbreviations

ASC	Alternative Specific Constant
BCAM	Border Carbon Adjustment Mechanism
CO2eq	CO_2 equivalent
DCE	Discrete Choice Experiment
EEA	European Economic Area
ESR	Effort Sharing Regulation
EU APCTS	EU Aviation Personal Carbon Trading System
EU ETS	European Union Emission Trading System
EU-27	European Union with its 27 Members State
EUA	European Union Allowance
GHG	Greenhouse Gas
IIA	Independence-from-Irrelevant-Alternative axiom
IPCC	International Panel on Climate Change
LC	Latent Class
LULUCFR	Land-Use, Land-Use Change and Forestry Regulation
MBEPI	Market Based Environmental Policy Instrument
MNL	Multinomial Logit
MSR	Market Stability Reserve
MXL	Mixed Logit
NET	Negative Emission Technology
NZ ETS	New Zealand Emission Trading System
PCA	Personal Carbon Allowance
PCC	Private Carbon account
R&D	Research and Development
RAPS	Rate All Products and Services
SSP	Shared Socioeconomic Pathways
TCQ	Tradable Consumption Quota
TEQ	Tradable Energy Quota
VAT	Value Added Tax
WTA	Willingness To Accept

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1. Introduction

The relative stability of the world climate has been one of the conditions that has enabled the flourishing of human societies the past 10 000 years (Folke et al. 2020). Today, the greenhouse gas (GHG) emissions accumulated by human activities since the industrial revolution are threatening this stability by causing a climate change (IPCC 2018). Changes are already observed. If, without mitigations, global temperature continues to rise, they will become more rapid, violent, and long-lasting (IPCC 2018). It could disturb human societies for the next centuries to millennia if no mitigation and adaptations are possible (Folke et al. 2021).

To protect themselves and all the future generations to come, human societies have to reduce their GHG emissions to mitigate climate change. The Paris Agreement has united nations from all over the world around the objective of "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" (United Nations 2015). To be in line with this agreement, more and more governments have committed to reach net-zero societies for 2040, 2050 or 2060. To put an intermediary step to reach this goal, the European Union, under the Green Deal, has recently committed to a reduction of 55% of its GHG emissions for 2030 compared to the level of 1990.

However, governments do not always explain how they will be sure to achieve those targets. If they do explain how they will ensure a reduction of 25, 35, 45 or 55% they do not explain how they will achieve the 65, 75, 85, 95% reductions needed further irrespective of technological progress and economic conjuncture. All policy tools and their combinations have to be explored and studied carefully. One major challenge to implement many policies is to involve all the citizens in the emission reductions. Individuals can feel that their individual actions are helpless, but they should remind themselves that together they are the basis of the whole society emissions and that tools coordinating their actions could have the largest impacts. Changing citizens' direct and indirect carbon emissions generated by their current consumption patterns could be a crucial step to achieve the Paris Agreement. A tool motivating emissions reduction would put high pressure on the firms that would have to find solutions to provide products and services with the lowest carbon impact if they want to pursue their activities. This master thesis explores one of the possible public policy tools, an end-user carbon account policy, by conducting a thorough literature review and implementing a survey in the form of a "choice experiment" with Belgian citizens.

There is a wide family of carbon account scheme that have been proposed and studied since the 90's. Still in 2019 and 2020 new alternative proposals have been thought (Piketty 2019;

de Touzalin 2020). Between 2006 and 2008, the British government investigated two proposals but the study concluded those to be "policies ahead of their time" (Fawcett 2010). Today, no countries in the world started such policies. However, the research has been followed and some micro experiments have been set up (Hendry 2019; Kuokkanen et al. 2020). Under an end-user carbon account policy, the commonly used individual bank cards would be adapted to give access to both a monetary account and a carbon account. Access to the end-user carbon account would also be possible through computer and other devices as it is the case for classical bank accounts. Under this policy, citizens would have to surrender carbon units to buy goods and services in addition to the monetary payment. The quantity of carbon units to surrender for their purchases would be equivalent to the quantity of CO_2 directly or indirectly emitted linked to the products/services bought. One carbon unit would represent 1kg of CO_2 emissions. All or part of the carbon units available to comply with the annual target would be distributed for free to individuals to ensure a minimum access to all, the rest being to be purchased. When not all units are distributed, the governments would use the income generated by the sale of carbon units to implement energy transition and redistribution policies.

The aim of this study is to investigate the extent to which citizens would accept such policies, and if so, under which conditions. To do this, a stated preference method will be used, namely a choice experiment. This tool consists of setting up a survey in which respondents are immerged in a hypothetical scenario and are asked to make choices between different alternatives represented on cards. The choice experiment will also investigate the possible links between the various characteristics of the respondents (age, education, level of emissions, etc.) and their preferences.

A carbon account policy raises a lot of questions and the reader must be aware that all questions will not be investigated in the context of this master thesis. An example of question that could be raised by the carbon account is what would happen when people have to spend large amounts of carbon units at one moment in time, for example for the building or renovation of a house. Technical solutions can be found to answers such questions, like the possibility to spread the carbon payment in time or other creative inter-temporal solutions. Such questions are not investigated here and would be worth to explore in further works.

The thesis brings first an overview of the end-user carbon account literature (section 2), followed by the design of an EU carbon account proposal (section 3). The thesis continues with a description of the research methodology used in the choice experiment (section 4). Then, a description of the results is presented (section 5), followed by a discussion interpreting the results and translating it into policy advices (section 6). The thesis ends up with a conclusion (section 7) summarizing the research findings.

2. Literature review

2.1. Climate change and GHG emissions

2.1.1. World GHG

The International Panel on Climate Change (IPCC) estimated that GHG generated by human activities had already caused, in 2017, approximately 1.0°C of global warming above pre-industrial levels, within a likely range of 0.8° to 1.2°C. Until the publication of the IPCC 2018 report, impacts on natural and human systems had already been observed due to global warming (high confidence). Future climate-related risks are depending on the rate, peak, and duration of warming. Some future impacts may be long lasting (centuries to millennia) or even irreversible (IPCC 2018).

To tackle climate change due to global warming, both mitigation and adaptation policies are necessary. The present work focuses on the mitigation strategies and a specific mitigation policy. To mitigate climate change, the Paris Agreement has united nations from all over the world around the objective of "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" (United Nations 2015). Therefore, on the side of mitigation, drastic GHG emission reductions are needed (Fig. 1). However, present National Determined Contributions are not ambitious enough to reach the target (IPCC 2018).

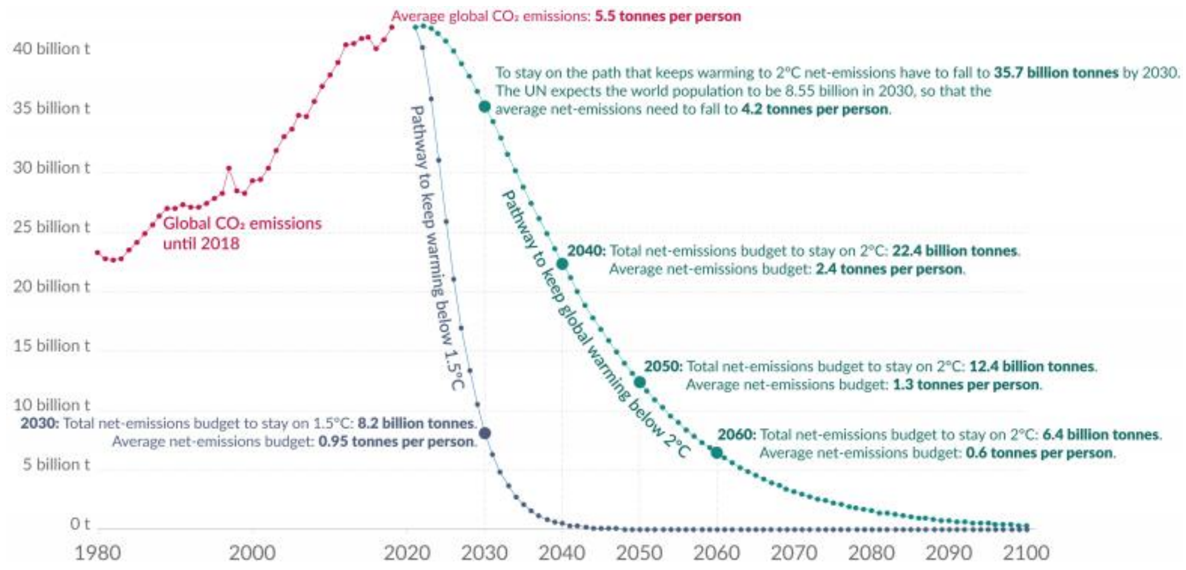


Fig. 1 – Estimations of CO_2 emission pathways compatible with the Paris Agreement (between 1.5 and 2°C of global warming) with a likelihood of 66% (Roser 2020)

Total GHG emissions in 2016 were equivalent to 49.4 $GtCO_2eq$ of which the CO_2 emissions represent 74.3 % (World Resources Institute 2016). The distribution of all GHG emissions in CO_2eq by sectors, end-use and type of gas can be found in Annex 1.

The remaining carbon budget is the remaining amount of CO_2 that can still be emitted while keeping the global average increase in temperature due to human activities below a specific temperature limit with reasonable assumptions on other non-GHG pathways of emission (Rogelj et al. 2019). Estimating this budget is not an easy task. The CO_2 emissions pathways of Fig.1 are calculated based on the IPCC remaining carbon budget estimations (IPCC 2018, p108), but the latter are subject to revisions due to current knowledge gaps and use of assumptions (IPCC 2018, pp104-108). Detailed budget estimations are available in Annex 2.

2.1.2. EU-27 GHG emissions

As this master thesis will study a climate policy proposal for the EU-27, it is important to know the distribution of GHG emissions at this level. Below, Fig.2 presents the evolution of EU-27 GHG emissions according to their origins.

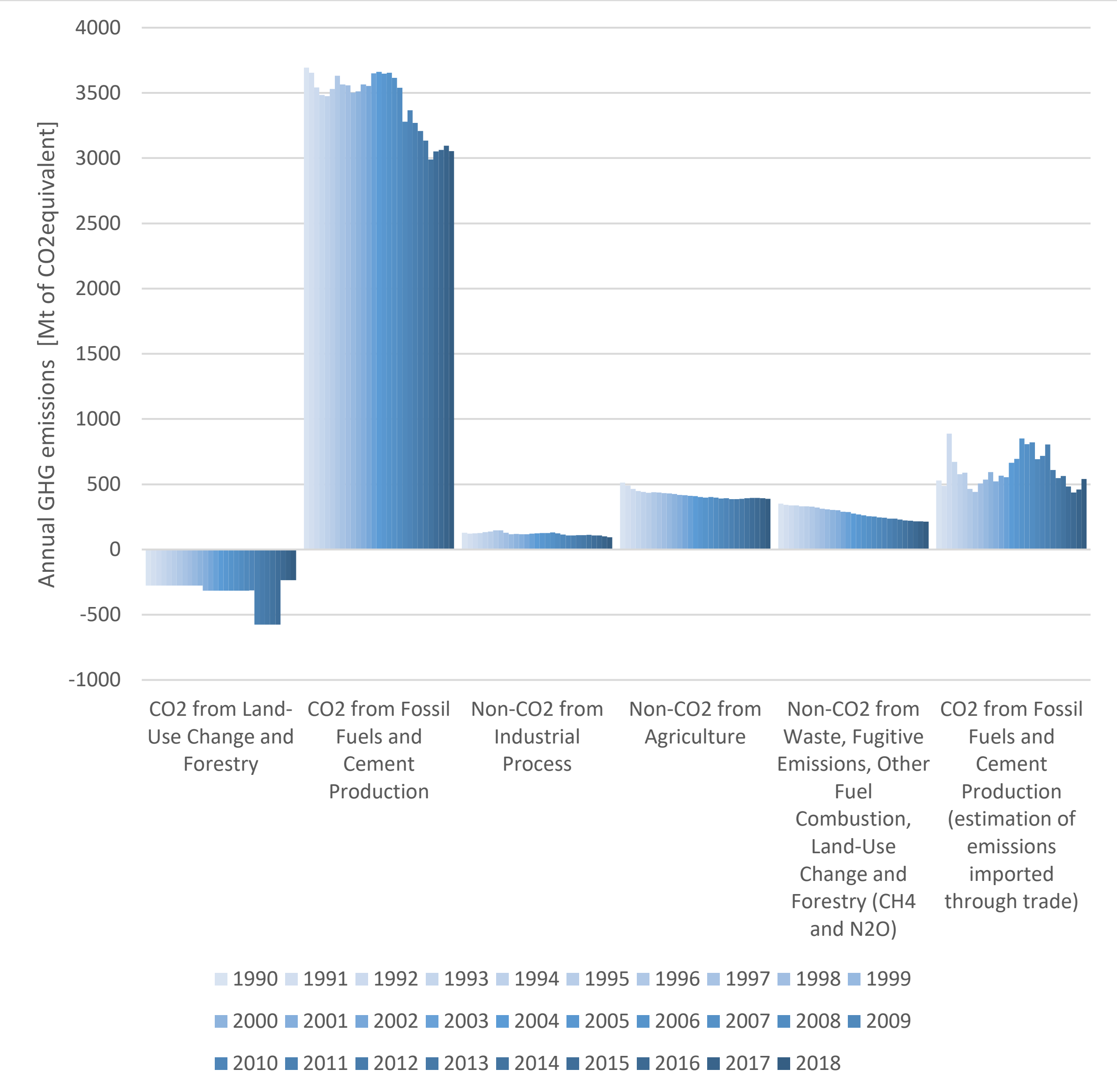


Fig. 2 – Evolution of EU-27 GHG emissions by source
(Climate Watch 2021; Friedlingstein et al. 2020)

Fig. 2 begins on the left by showing that emissions from Land-Use Change and Forestry in EU-27 are negative contrary to the world level where they are positive (6.5%).

Then the figure shows the evolution of 4 sources of EU-27 territorial positive emissions:

- CO_2 from Fossil Fuels and Cement production
- Non-CO_2 from Industrial Processes (F-gases, CH_4 and N_2O)
- Non-CO_2 from Agriculture (CH_4 and N_2O)
- Non-CO_2 from Waste, Fugitive Emissions, Other Fuel Combustion, Land-Use Change and Forestry (CH_4 and N_2O)

Finally on the right, the figure outlines an estimation of the CO_2 emissions due to the balance of trade. Sometimes called "grey emissions" those are calculated via a net balance between fossil fuels and cement CO_2 emissions emitted to produce exported goods and the fossil fuels and cement CO_2 emissions generated by the production of goods imported in EU.

Fig. 3 presents the same six sources of emissions but focuses on their distribution in 2018. CO_2 emissions from Fossil Fuels and Cement Production generate 81% of EU-27 positive GHG territorial emissions. As EU-27 Land-Use Change and Forestry emissions are negative, they compensate 6% (in green) of the positive territorial emissions. Because in the EU the importation of CO_2-emitting goods is higher than the exported ones, the EU would have to add 14% (in grey) to its actual territorial emissions. For non-CO_2 emissions imported and exported there are no precise estimations readily available.

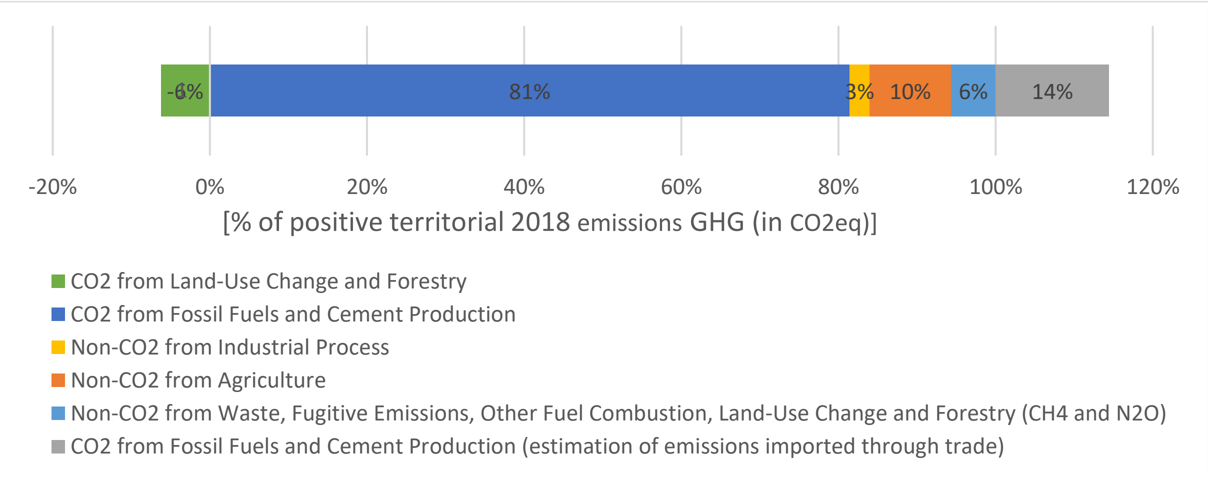


Fig. 3 – Repartition of EU-27 GHG emissions in 2018,
(Climate Watch 2021; Friedlingstein et al. 2020)

It is interesting to look further at the distribution by sector of CO_2 emissions from Fossil Fuels and Cement Production as they today represent 81% of the EU-27 territorial emissions. As shown by Fig. 4, the transportation and the bunker fuels (fuels for international shipping) are sector where emissions have risen between 1990 and 2018, therefore reducing the impacts of the efforts undertaken in the other sectors. The building sector (heating of buildings mainly) is still in 2018 the third most important emission sector. Compared to manufacturing and construction sector, the building sector have more difficulties to decrease its emissions.

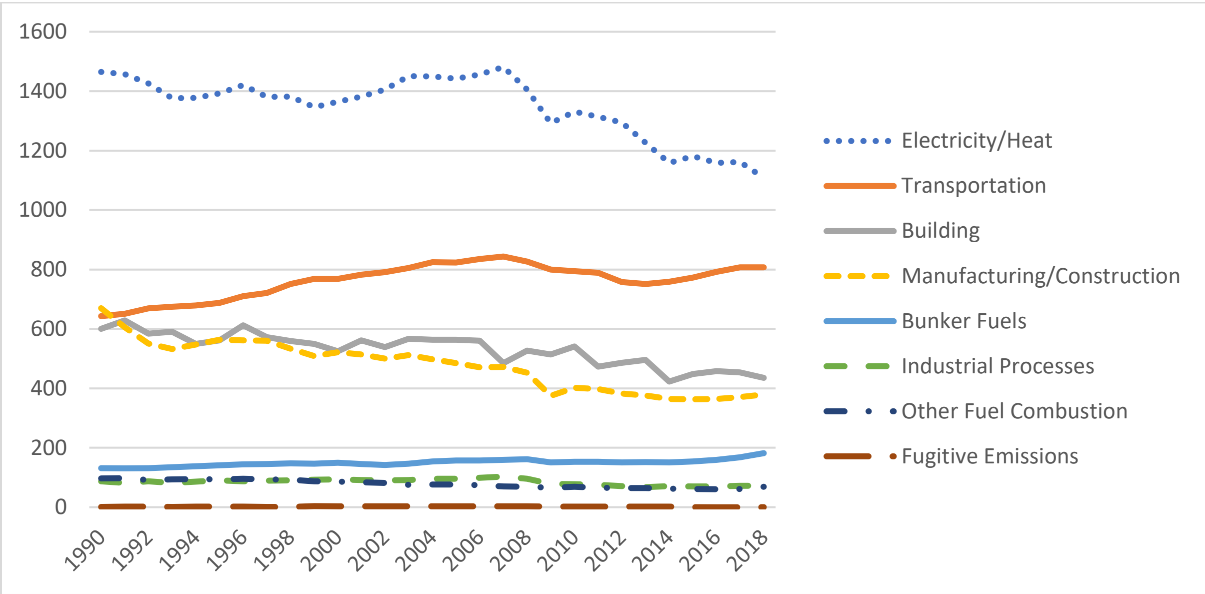


Fig. 4 – Distribution by sectors of EU-27 CO_2 emissions from fossil fuels and cement production (Climate Watch 2021)

Looking to emissions directly and indirectly generated by the consumption of individuals in the EU is another way of presenting the emissions that can highlight their distribution (Fig. 5). For example, the top 1% and top 10% emitters have a high share of air travel while other groups have almost no emissions for that category.

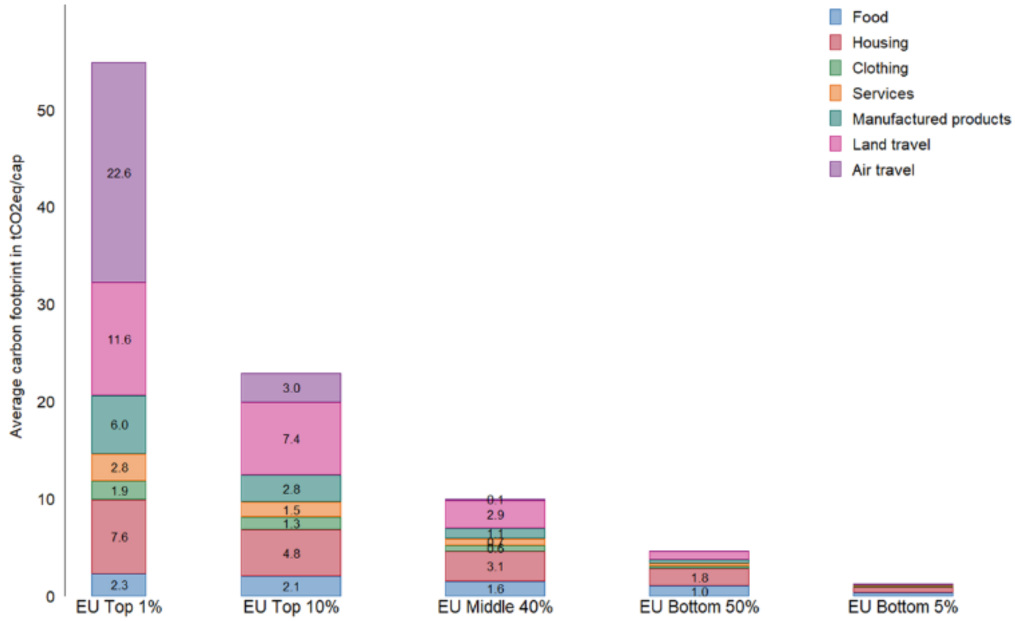


Fig. 5 – Carbon footprint distribution by consumption category in the European Union (EU). The groups are defined by emissions levels. EU household weights applied. (Ivanova and Wood 2020)

2.1.3. Belgian GHG emissions

The emissions from trade are particularly important to consider as emissions can just be displaced over time and this does not reduce the worldwide emissions. Belgium is an illustrative case of this phenomena with, in 2018, a mean of 8.53 ton of CO_2/capita[1] when only territorial emissions are counted but a mean of 15.44 ton of CO_2/capita when emissions are corrected for trade (Our World in Data 2019). Emissions corrected for trade, also called consumption-based emissions, are the territorial emissions to which emissions from imported goods are added and emissions from exported products deduced. In 1990 the Belgian territorial emissions were of 15.58 ton/capita but 12.02ton/capita when adjusting for trade; The evolution of those emission between 1990 and 2018 is presented in Annex 3.

Emissions in Belgium, as a lot of other countries in the world, are positively correlated to income (Lévay et al. 2021). Fig. 6 shows that housing and transportation represent more than the half of the household consumption-based emissions. Figures of detailed categories of emission for Flanders per income and per age is available in Annex 4.

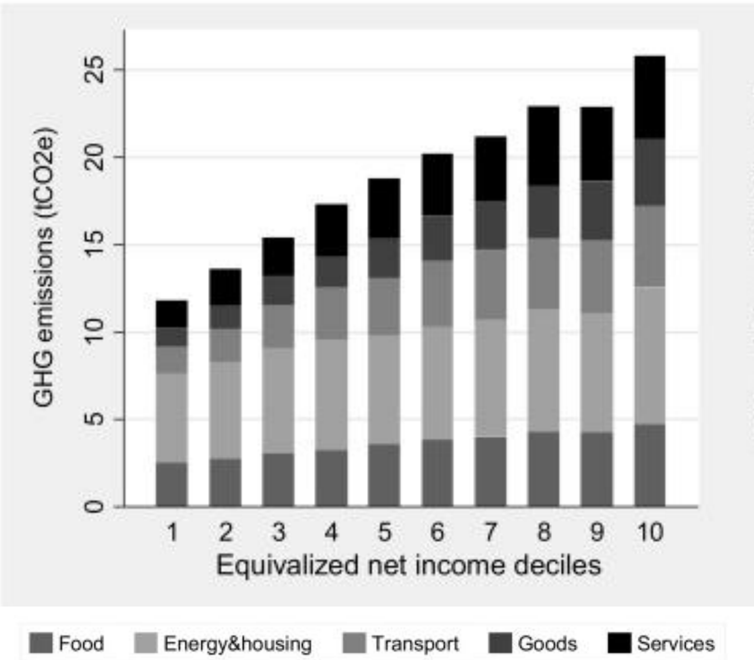


Fig. 6 – Distribution of household Belgian consumption-based GHG emissions over income deciles (Lévay et al. 2021). Note: Deciles are constructed by equivalising income using the modified OECD equivalence scale, which assigns the value of 1 to the first adult, 0.5 to each additional adult and 0.3 to each child. Those estimations of emissions are reconstructed by the use of the Household Budget Survey that does not includes expenditures such as the construction and renovations of buildings. Emissions generated by public services for which households do not directly have to pay are also not included in the emissions presented here.

[1] In the calculation of territorial vs emissions corrected for trade only CO_2 from Fossil Fuels and Cement production are included – thus CO_2 from land use change and forestry is not included.

2.2. Climate Change Mitigation Policies

2.2.1. Overview of climate mitigation policies at global level

Table 1 reports a classification of climate change mitigation polices adapted from the IPCC classification (Gupta et al. 2007). Some examples illustrate the classification in the table. The category "undirect climate change policies" regroups policies not necessarily aiming GHG reductions directly but having an impact on GHG as a policy co-product.

Table 1 – Climate change mitigation policies at global level (adapted from Gupta et al. 2007)

Climate change mitigation policy category	Policy examples already tested
Regulations and Standards	• Standards on vehicle emission levels • Green certificates mandatory for electricity suppliers
Information Instruments	• Education programs • Information campaigns
Research and Development (R&D)	• Prizes for technological advances
Carbon pricing policies	• EU ETS Carbon allowance market for large stationary companies and intra-EU aviation.
Subsidies and Incentives	• Subsidies for soft mobility in Belgium • Price reductions for public transport use • Progressive phasing out of fossil fuels subsidies (some EU policy targets)
Undirect climate change policies	• The Brussel Region's new "30 km/h Zone"

Among all those important mitigation tools, this work will focus on carbon pricing policies. The carbon price (for CO_2 or CO_2eq emissions) is a signal that passes through different actors in an economy and carbon pricing policies are an indispensable part of the strategies to reduce emissions in an effective and cost-efficient way (Stiglitz et al. 2017). For instance, a higher carbon price can be, other factors being fixed, a direct incentive to invest in renewable energies and make fossil fuels less interesting to use. Carbon pricing policies encompass several forms: taxes, tradable permits, etc. They rely on the idea of giving the right incentives to economic actors by modifying the price they pay.

In practice, climate change policies are rarely implemented in isolation and they interact with already existing national climate policies. In most cases, interactions between carbon pricing and other policies can reduce emissions further than if applied alone (Khanna et al. 2020). The combination of other effective policies with carbon pricing can induce a given emission reduction with lower carbon prices than if those other policies were absent (Stiglitz et al. 2017).

2.2.2. EU-27 current policies

The recent new EU-27 legally binding objective is to reduce GHG territorial emissions by 55% by 2030 compared to 1990 levels (European Council 2020). The GHG national inventories are territory-based, and the EU-27 Climate Action mainly focuses on territorial emissions. However, some EU policies begin to tackle also imported emissions.

Fig. 7 recalls the emissions presented in Fig. 3 and shows an overview of how EU-27 policies are organised to reduce the emissions of the different sources. First, the Land-Use, Land-use Change and Forestry Regulation (LULUCFR) (1) tackles the emissions from Land-Use Change and Forestry source. Secondly, the EU Emission Trading Scheme (EU ETS) (2) covers the GHG emissions of approximately 11 000 large stationary industry emitters and the intra-EEA flights. Most of the emissions covered are CO_2 but a short proportion are non-CO_2 emissions from Industrial Processes. Then the Effort Sharing Regulation (ESR) (3a and 3b) represents the binding engagements of Members State for the reduction of the rest of the territorial emissions. A recent proposal of the EU Commission in the context of the Green Deal also aims to target the imported emissions (in order to restore justice for EU-industries facing EU ETS price where foreign industries do not) through the mean of a Border Carbon Adjustment Mechanism (BCAM) (4). This latter could be a tax or an EU ETS extension.

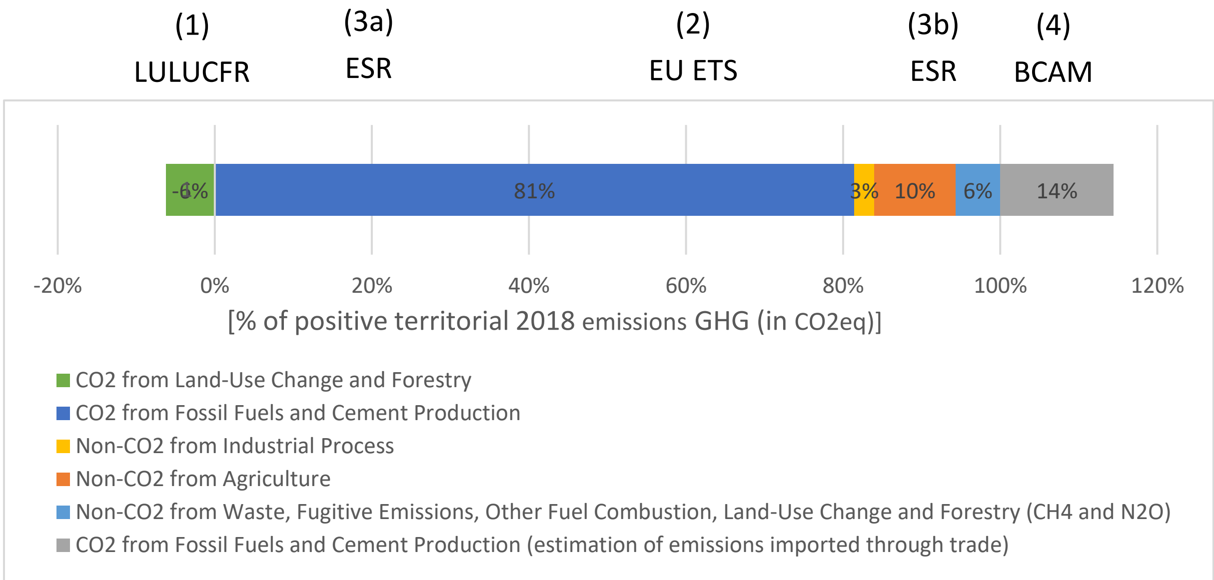


Fig. 7 – Distribution of EU-27 GHG emissions in 2018, annoted with the different EU-27 policies targeting them (Climate Watch 2021; Friedlingstein et al. 2020; European Commission 2020c; 2020a; 2020d; 2020b)
Note: LULUCFR = Land Use Change and Forestry Regulation; ESR = Effort Sharing Regulation; EU ETS = EU Emission Trading system; and BCAM = Border Carbon Adjustment Mechanism

As transport emissions are rising and building emissions are stagnating at EU level (both in 3a), the Commission also made a proposal to extend the ETS to all fossil fuels. In other words, an important part of the actual ESR (all the (3a)) could be replaced by the ETS (2).

2.2.3. Focus on carbon price policies in EU-27

In the early 1990s, when the EU started thinking about how to reduce its territorial GHG emissions, two approaches were explored: the carbon tax and the carbon cap-and-trade mechanism. There were advantages and disadvantages to both approaches. For example, a carbon tax at the EU-level has been criticized because of difficulties to implement it, due to the absence of fiscal harmonisation at this level. In addition, the Kyoto Protocol negotiation had been hugely influenced by the US proposal to build carbon cap-and-trade schemes that could then, step by step, converge into a worldwide carbon market. They defended this idea on the ground that the cap-and-trade they had built earlier to reduce SO_2 emissions had been very effective. Paradoxically, the EU decided to build the EU ETS, a cap-and-trade scheme, and the US just went out of the Kyoto Protocol.

For imported emissions the EU is now thinking about a BCAM that could be an EU-wide tax or EU-wide quota approach (European Commission 2020b). This BCAM is important to avoid the displacement of emission from EU-27 to other places of the world as this would not mitigate climate change. Annex 3 shows the magnitude of this displacement effect at Belgian level.

As the EU ETS covers only 40% of EU emissions, some EU Members States decided to keep or to implement carbon taxes on their own for the uncapped emissions. While this strategy is implemented progressively in more and more countries, it still does not allow to reduce carbon emissions significantly. The national tax strategy faces two main barriers: (i) technically - it is sometimes difficult to avoid double-accounting of emissions with the existing EU ETS and (ii) politically - carbon taxes proposals are often accompanied by citizens protests. Moreover, the inaction of some Members States can undermine the ambitions of others. It is difficult for a country to implement a credible carbon tax if its neighbours do not go into this direction.

After a long period of mistakes, trials, and adjustments, the EU ETS has, for the last three years, provided a credible carbon price to stimulate investments for the emission reductions needed. Fig. 8 shows the carbon price evolution since 2018:

Fig. 8 – Evolution of the carbon price in the EU ETS from 20018 to the 17th of May 2021 [€/ton of CO_2eq] (Ember Carbon Price Viewer 2021)

2.2.4. Focus on EU ETS functioning as a carbon pricing mechanism in EU-27

The EU ETS is the first public policy instrument to rely on a unique EU-wide carbon price. This system is based on a market for European Union Allowances (EUA). Those EUA represent the right to emit one ton of CO_2 equivalent. The EUA are first given to Members States that allocate them for free or through an auction mechanism to (around 11 000) large stationary companies. On a yearly base, companies must monitor and report their emissions, then buy or sell EUA so that they can return the number of allowances corresponding to their emission to the authorities, one EUA for each ton of CO_2 equivalent they emitted in the previous year. It is for the 30 of April that the balances are to be in order. EUA are tradable: a market allows companies to purchase allowances from other companies selling them. This implies that when a company have large emission it must purchase important amounts of EUA. Conversely, when a company perform well at reducing its emissions, it has leftover EUA to sell. This system allows to reduce emissions at the most cost-effective way and without significant government intervention. When companies do not use all their EUA, they can keep them to cover future needs. However, borrowing is not allowed (ICAP 2020). Should a company emit more than what its allowances, then it would be fined 100 € per excess emissions compared to its allowances. The noncompliant operator's name is also made public (CLEW 2018).

A. Historical overview

The ETS-directive officialized the EU ETS functioning in 2003. Since then, the system has known different phases (AWAC 2019):

- Phase I (2005-2007): a "learning by doing" phase, a preparatory one.
- Phase II (2008-2012): corresponded to the 1st period of the Kyoto protocol
- Phase III (2013-2020): corresponded to the 2nd period of the Kyoto protocol
- Phase IV (2021-2030): is implementing the Paris Agreement

B. Emission cap and firms included in the system

In the current phase (IV) the system includes so-called stationary companies (power plants and a wide range of energy-intensive industrial sectors) and intra-aviation between airports in the European Economic Area (EEA: EU + Iceland + Norway + Lichtenstein). The intra-aviation sector has been included since 2012, with preferential rules. In fact, the aviation sector has received a special emission cap reserved only to its sector. Hence, airline companies can purchase EUA both in the aviation sector and from stationary company emission cap while the other operators can only purchase EUA within the stationary company emission cap. The EU ETS include emissions of CO_2, CH_4, N_20, SF_6, perfluorocarbons, and hydrofluorocarbons. However, in practice, the CO_2 emissions are often the easiest to monitor and it is the CO_2 emissions that represents the vast majority of emissions capped under the EU ETS.

C. *Free allowances and auctions*

Each Member State has the responsibility to allocate the allowances fixed by the EU. Auction is the default method, but Member States are allowed to do some free allocation up to a legal limit depending on the phase. For the stationary companies, 90% of allowances were allocated for free in Phase II, 43% in Phase III, and this will continue to decrease in the current Phase IV (Theuer et al. 2020). The aviation sector received 82% of free allowances in Phase III and those will also be reduced in Phase IV (Theuer et al. 2020).

D. *Use of revenues and effort sharing*

Auctions are source of revenues for each Member State. At least 50% of those revenues are imposed to be used for climate and energy related purposes (European Commission 2016). As seen before, the EUA are distributed among the Members States. This distribution is done based on 2005-2007 average level of emission. However, 10% of the EUA are allocated specially to lower-income Member States to share the reduction efforts (Theuer et al. 2020).

E. *EU ETS achievements*

During the EU ETS third phase (2013-2020), a linear reduction factor of 1.74% has been applied to the annual emission cap, starting with the annual mean number of allowances emitted during 2008-2012. This linear reduction factor allowed the EU to be in line with its ETS sector specific commitment for 2020: 21% emissions reduction relative to 2005 emissions. To achieve this commitment the aviation sector included in the EU ETS (intra-EEA aviation) did not play any role as the emission cap for this sector stayed almost the same during this third phase. Recently, in 2021, the Phase IV has been started but with the objective of 40% emission reduction for 2030 compared to 1990 and therefore applying a linear reduction factor of 2.2% applied now both for stationary companies and aviation sector. However, this 2.2% linear reduction factor is not more in line with the new EU climate commitment: 55% of reduction for 2030 instead of 40%. Therefore, the Commission is now mandated to come with proposals to update the EU ETS to be in line with the new objectives (European Commission 2020a).

As seen in this short overview, the EU ETS is a cornerstone of the EU climate action and has achieved a large part of the EU emission reductions. However, this system covers only specific sectors and it is not clear how this system will achieve emission reduction further than 55%. Until now, carbon taxes have been applied to some countries, with a low rate of success stories. Overall, the carbon taxes implemented by the Member States have achieved less emission reduction than the EU ETS. The question whether those carbon pricing policies, as they are implemented today, will be able to achieve deep decarbonation is clearly to be posed (Verde et al. 2020). Therefore, all carbon pricing policies, their evolution, and their complements, must be explored.

2.3. Carbon account policies

2.3.1. Concepts and definitions

A carbon account is a policy instrument in which individuals use a "carbon account" to surrender carbon units for the purchase of goods and services (different scopes possible). The amount of carbon units to surrender are equivalent to the carbon emissions generated by the production of those goods and services purchased. Depending on the specific carbon account schemes, some or all the carbon units are routinely given for free to individuals. Different allocation mechanisms exist, with currently the equal allocation per capita of all the carbon units available being the most frequently proposed. The carbon price for the purchase or sale of extra carbon units can be defined by a pure market approach, a market with a floor and ceiling price, or defined by experts. People are given the freedom to choose between an infinity of different pathways to adapt their behaviour but, overall, those systems incentivise low carbon lifestyles (Fawcett 2010; de Touzalin 2020). It can be an efficient collective scheme respecting individual choices (de Touzalin 2020; Sconfienza 2021).

It is important to redefine well the terms to avoid confusion. There are also so-called carbon cards which are, in reality, private normal credit cards that allow consumers to track their carbon consumption. Those private credit cards are not carbon account policies. A better name to distinguish those credit cards could be "**private carbon-counting credit cards" or "private carbon cards" (PCC)**. Among those PCC, an innovative one is the recent "DO black", a credit card to be launched soon by the Swedish enterprise Doconomy with a carbon ceiling, implying that this credit card does not allow to make further payment above a certain threshold (to be decided by the user) of cumulative carbon emissions generated by the purchases under the credit card payments. Other PCC, are often linked to the possibility of offsetting emissions. Because offsetting does not treat the problem of emissions at its origin, some people judge those carbon credit cards as greenwashing (Sconfienza 2021). All those credit cards share some characteristics:

- Their adoption is voluntary,
- A card will only include the scope of emissions under credit card payments,
- The system does not consider carbon price (excluding offsets) to buy/sell carbon units,
- It uses offset mechanisms.

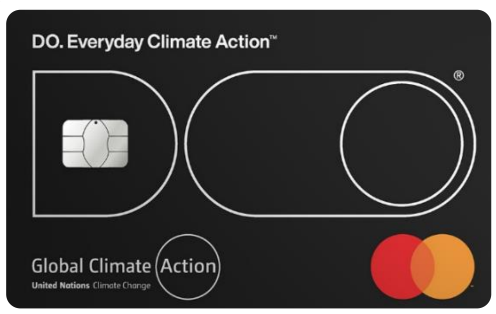


Fig. 9 – Doconomy's black "Carbon Card" (Doconomy 2021)

Complementarily with R&D on these carbon cards, some organisations and start-up companies calculate CO_2 emissions to show them to their customers. However, such data are difficult to get by one single enterprise; the cost could decrease with a scheme including all the enterprises as will be explained later.

Yet, they cannot be qualified of carbon account policies. To be recognized as such policy the carbon account must:

- Be mandatory,
- Include all the emissions of at least one sector,
- Have a price to buy and sell carbon units,
- Treat offsets (if allowed) only at the governments level to ensure long-term engagement (longer than enterprise lifetime) to maintain the offsets.

The next section will now only focus on carbon account policies.

2.3.2. Historical overview

The first ideas of carbon account policies were introduced by three researchers, each working independently, in the late 90's: David Fleming, Robert Ayres, and Mayer Hillman. After several UK climate policies failures, David Miliband, the UK Secretary of State for the Environment initiated a debate about policies to reduce the emissions linked to individual consumption and to involve individuals in climate change mitigation. In one of his speeches, he summarized the idea into one sentence: "*Imagine a country where carbon was a currency"* (Miliband 2006). The policy debate kept the attention of scholars that analysed the proposals in depth and the aspects to be researched further. A special pre-study analysis was commissioned to the Department from Environment, Food, and Rural Affairs. This study concluded that the approach was very interesting but ahead of its time (DEFRA 2008, Fawcett 2010). It is important to keep in mind that today, not enough research has been conducted in all the aspects of carbon account schemes, so knowledge gaps remain. For the moment there have been only two trials for real carbon units managed by individuals : on the Australian Norfolk island (Parag and Fawcett 2014; Chamberlin, Maxey, and Hurth 2014; Guzman and Clapp 2017; Hendry 2019) and in the Finland city of Lahiti (Kuokkanen et al. 2020). Some groups of UK citizens have also tried some systems where they make collective targets and then calculate their emissions (Howell 2012).

Most literature on carbon account schemes for individuals uses the term "Personal Carbon Trading", a term that was invented to include, among others, the proposals of the three researchers mentioned above. However, this thesis will use the term "Carbon account" as it highlights the idea of having to "pay" in carbon units to purchase goods and services and because it puts less restriction on the way of defining the carbon price. In most Personal Carbon Trading proposals, price was defined mostly through pure cap-and-trade market, rather than with a market with a floor and ceiling price or by defining the price by experts while the latter two alternatives could be interesting to explore in order to reduce volatility.

2.3.3. Carbon account mechanisms

In addition to bringing an economic incentive (via a price signal) to reduce emissions, a carbon account (i) can improve learning on the side of the citizens and their perception about what types of good and services generate carbon emissions and (ii) can contribute to build new social norms about the acceptable levels of emissions (Parag and Fawcett 2014). Fig. 10 illustrates main carbon account mechanisms:

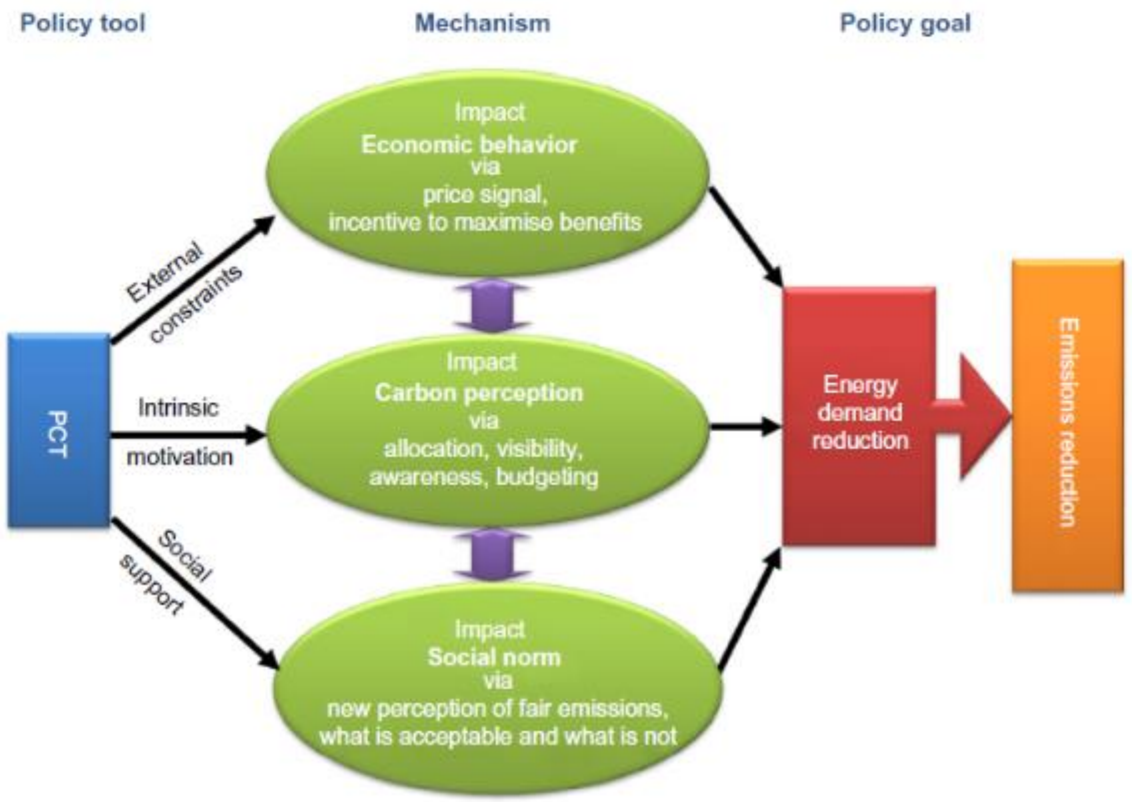


Fig. 10 – Carbon account (or PCT) mechanisms (Parag and Fawcett 2014)

A. *Economic behaviour*

Giving a price to carbon is the core principle of all market-based environmental policies instruments (MBEPI) that aim to reduce CO_2 emissions. MBEPI tackles market failures (such as environmental pollution) by incorporating the external costs of human activities through the use of tax or tradable permits. The external cost application can be enforced at different levels, but the result will always impact both the price perceived by producers and consumers. An increase of price for the producer will be translated in a higher cost of its products for the consumer. As a matter of fact, whatever the enforcement method for an MBEPI, emitting activities become more expensive and thus activities that emit less or do not emit at all become more attractive.

B. *Carbon perception*

A psychological intrinsic motivation can emerge from the combination of the individual free allowance (a benchmark to which people compare and refer), the new visibility on where carbon emissions are, and a better awareness of the existing link between emissions and individuals' actions. It is to be noted that the extent of the visibility depends on the system's scope. Experimental work has shown indication that willingness to change behaviour is affected by carbon awareness. Visibility and carbon awareness result from the fact that individuals have detailed information regarding potential emissions when they make decisions (Bristow et al. 2010; de Touzalin 2020). People are more willing to change their polluting behaviour when they become aware of their carbon habits (Parag, Capstick, and Poortinga 2011). In economic terms, the citizens' elasticities for carbon emissions change due to their behavioural changes (Lockwood 2010). In addition, people often rely on past habits when making decisions, so any reminder of the carbon content and a rapid comparison with the alternatives, could be beneficial for the citizen (Parag and Strickland 2009). People may also be inclined to respond to a carbon indicative level (being higher or lower than a benchmark) rather than responding with pure economic rationality (Capstick and Lewis 2010).

C. *Social norms*

The social support mechanism is based on the notion that the initial allocation of carbon units is not neutral because that level of allocation emphasizes or clearly signals what is a fair and acceptable level of carbon emissions for the cardholder. In other words, he or she is given a reference level. Such a guideline is supposed to act as a social force that helps people find solutions for themselves and with others. Today several barriers to the reduction of personal carbon emissions are social barriers, e.g. the symbol of having a bigger house than neighbours or the way people commute to their job. Developing a new shared perception of fair carbon thresholds could progressively inverse this negative social force. The social mechanism implicated here would influence individual behaviour by changing social discourses and habits (Parag and Strickland 2010).

D. *Interactions*

The carbon perception mechanisms can interact positively with the social norm's mechanism. It is sometimes difficult to distinguish the two, e.g. the allocation might influence both carbon budgeting (carbon perception) and social norms.

All the mechanisms could also interact positively with existing schemes such as energy labels, products and buildings standards, regulations and low carbon transportation infrastructure (Fawcett 2010; Parag and Fawcett 2014). Those complementary policies, if they do not already exist are likely to be asked by citizens if a carbon account is implemented. One can imagine low carbon alternatives that government could stimulate, such as night trains, and that could then be developed with even more social support than today.

E. Other potential advantages

There could be other advantages that have been less explored by the literature. The first one is that because a carbon account system involves directly the individuals, those have less resource to game the system compared to large companies that are more prone to do lobby in order to orient the scheme (Sconfienza 2021). As an example, the past EU ETS negotiation for free allowances today still undermines the efficiency of the system even though this level of free allowances is currently decreasing each year.

A second advantage besides the carbon emission reduction goal is that the carbon account system would leave a trace of the level of emissions that a certain individual emits. Because the level of emissions is largely correlated with the income level, carbon account information of the total emissions of an individual could be used as a tool to detect fraud like tax avoidance. There would still be other ways to continue gaming the system, but the double accounting that a carbon account introduces (classical currency accounting supplemented by carbon accounting) would make tax evasion more difficult (Sconfienza 2021).

2.3.5. Main idea: individual freedom in a limited world

One of the underlying ideas of the carbon account proposal is to maintain the freedom of choice of individuals within a scheme that would limit the negative impacts on the climate system. The following passage expresses why a carbon scheme would maintain the most freedom of individuals within a limited world:

"*[…] without yet-untested NETs [Negative Emission Technologies], carbon mitigation capable of reaching net-zero by mid-century will affect economic activities by changing how we move, where we live, what we eat, and what we buy. If these changes are imposed from the top via the placement of a strict cap on energy-intensive industries or via other regulations, citizens and consumers might feel that their preferences for products and services are being guessed or, worse, paternalistically dictated from above, instead of being taken into consideration. Such a system could even bring individuals to reconsider effective environmental regulation in the ballot box. While this system cannot be equated to a command [and control] economy because consumers, through their demands for goods and services on the market, would still be able to inform the producers' supply, for those who have recollection of what was available on the market before environmental regulation became effective, the difference would nonetheless be stark, and the experience discomforting. For example, flights for a given destination might become few and far between, maybe requiring advance planning, long waiting-lists, or a lottery system to get on board, and a system of formal verification for those* *who advance urgent reasons to jump the queue. This might frustrate anyone who experienced the days in which boarding a plane could be done effortlessly by arriving at the check-in counter and swiping a credit card. An individual cap and an individual carbon card [/account] would make visible to everyone the difficult trade-offs involved in protecting the environment while allowing them to claim ownership of, and ultimately embrace, environmental regulation*." (Sconfienza 2021, p11)

It can be added that, at the humanity level, the scheme let the destiny of individual to be chosen by themselves rather than imposed by climatic catastrophes.

2.3.6. Carbon account schemes overview

This section presents an overview of the carbon account schemes that have been proposed in the past. The different schemes are presented in Table 2 and Table 3 below.

Fig. 2 and Fig. 3 highlighted the predominance CO_2 emissions from fossil fuels and cement production in the global EU-27 GHG emissions. That is the reason why carbon account schemes have always focused on fossil fuels emission (to which CO_2 emissions from cement production could easily be added). Moreover, CO_2 emissions from fossil fuels and cement production are generally easier to measure and have less uncertainties than emissions of other origins.

In both tables, it is observed that most schemes are based on the idea of equal per capita adult allocation, while some schemes would allow extra allocations for individuals with children or with other specific needs ("adjusted allocation"). Note that this extra allocation could be given either in "carbon allowance" or in "monetary compensation from the government". Because rights can be traded, compensation from the government could be simpler put in place with the same final result. Research shows that the system has to stay the simplest possible to be publicly acceptable (Szuba 2014). Research in the UK also shows that people would prefer an adjusted per capita allocation, but they do not want the government to assess their needs (Bristow et al. 2010). Staying with the equal per capita basis and adapting with extra money from the government could therefore be a realistic alternative.

Table 2 – Early pioneers' schemes

Scheme	Scope	Carbon price evolution	Carbon visibility and how individuals surrender units	Allocation method
Tradable Energy Quota's (TEQs) *(Fleming 1997)*	All fossil fuels	Market price (cap-and-trade)	Fossil fuels and electricity would be carbon labelled. In addition, there would be a "pay as you go" option for individuals that do not want to use carbon units but prefer directly paying the carbon price to their retailers rather than transferring them carbon units	40% given as free to individuals on an equal per capita basis (representing the share of domestic and personal transport fossil fuel use in UK) 60% for organisations, auctioned on the market. The revenues made by this last sale would go to the government for energy transition
Tradable Consumption Quotas *(Ayres 1997)*	All fossil fuels	Market price (cap-and-trade)	All products and services would be carbon labelled via an "in-out carbon accounting" in each organisation (VAT-like system)	100% given as free to individuals on a per capita basis
Personal Carbon Allowance (Hillman 1998)	Domestic use and personal transport fossil fuels	Market price (cap-and-trade)	Fossil fuels and electricity would be carbon labelled, possibility of "pay as you go"	100% given as free to individuals on a per capita basis or other adjusted allocation rules (not fixed)

Table 3 – Later schemes

Scheme	Scope	Carbon price evolution	Carbon visibility and how individuals surrender units	Allocation
Rate All Products and Services (RAPS) (*Starkey and Anderson 2005)*	All fossil fuels + potentially other GHG if precise calculations are possible	Not described	All products and services would be carbon labelled	100% to individuals on a per capita basis
Household carbon trading (Niemeier et al. 2008)	Domestic fossil fuels	Market price (cap-and-trade)	Fossil fuels and electricity would be carbon labelled, possibility of "pay as you go"	100% to individuals on a per capita basis or other more adjusted allocation rules (not fixed)
Tradable transport carbon permits (Raux and Marlot 2005)	Personal transport fossil fuels	Market price (cap-and-trade)	Fossil fuels and electricity would be carbon labelled, possibility of "pay as you go"	100% to individuals on a per capita basis or other more adjusted allocation rules (not fixed)
EU Aviation Personal Carbon Trading System (de Touzalin 2020)	Commercial aviation (flight for both personal and professional reasons). Other flight submitted to a carbon tax.	Market with a floor and ceiling price	Online platform where individuals can manage their carbon budget. People would have to give their identification number at each purchase of flight (like passport are needed to fly in some other countries)	100% to individuals on a per capita basis
Progressive taxation carbon account (Piketty 2019)	"Carbon emissions" but not described further	Price defined by experts (like classic taxes)	Not described. The minimum being an annual or monthly summary of the emissions, so that the individual knows the total tax he/she has to pay	First tranche of CO_2 emissions is for free (precise amount not given, to be defined in the context). Later tranches of emissions are submitted to an increasing carbon price

2.3.7. Early pioneers' schemes

A. Tradable Energy Quota's (TEQ)

Tradable Energy Quota's (initially named Domestic Tradable Quota's in 1997) is a scheme designed for the two sides of the energy problem : climate change and the depletion of fossil fuels (Fleming and Chamberlin 2011). In the event of shortages, this scheme would guarantee access to fuel for all especially as scarcity develop. Scarcity could come both from the side of the climate change mitigation objectives and the fossil fuel supply (Fleming 1997)[2].

This scheme has been proposed for the UK economy. Each year, the Committee on Climate Change (already existing in the UK) would determine the national carbon budget available for the year and make a prediction for the coming years compatible with the climate targets. A quantity of carbon units (equal to the annual carbon budget targeted) is then made available by the government to individuals and organizations. A proportion of those carbon units are directly allocated to individuals on an equal per capita rule. This operation is named the Entitlement. The proportion allocated to individual represent the total energy emissions (domestic and personal transport) made by individual direct fossil fuel and electricity use in the period prior to TEQ's implementation. In the UK, the current proportion is around 40%. For the 60% carbon units remaining, organizations must purchase them at an auction, named the Tender, organized by the government on a weekly basis (Starkey 2012). This Tender provides revenues for the government with which it can reduce the overall dependence on fossil fuels (Fleming and Chamberlin 2011). Fig. 11 illustrates how the scheme works.

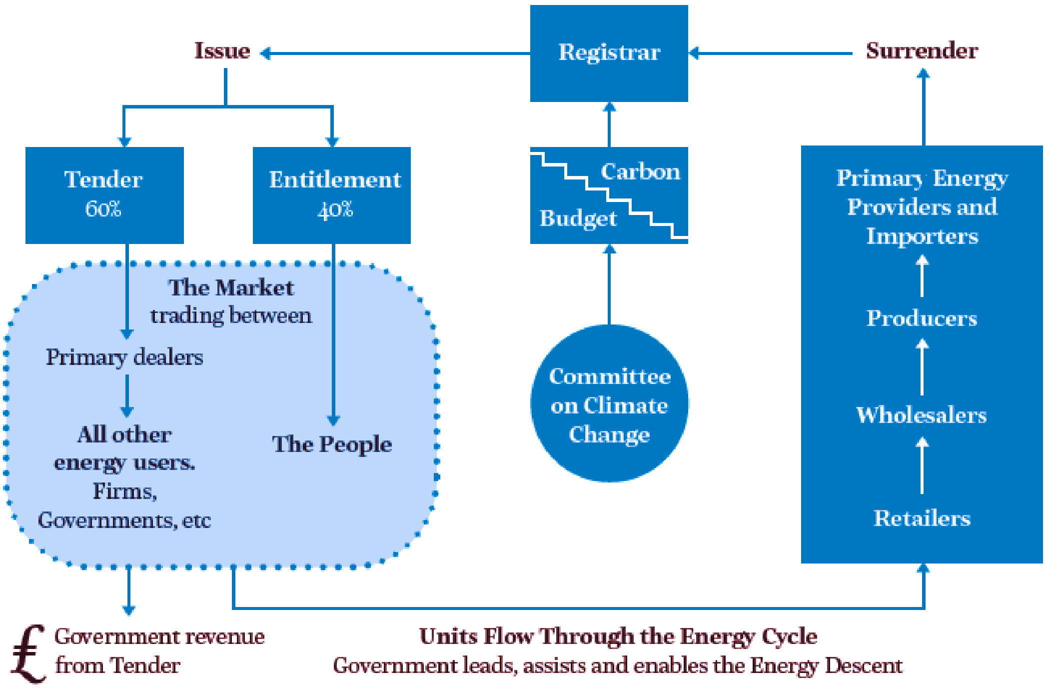


Fig. 11 – The market for Tradable Energy Quotas (TEQs) (Fleming and Chamberlin, p13)

[2] Fleming defended the TEQs until his death in 2010.

For all fuel or electricity purchase, buyers (citizens and organizations) would pay it as usual with money, but they would also have to surrender carbon units corresponding to the carbon content of their purchase. In this system carbon units are electronic and transferable using an electronic carbon account. All the following carbon account proposals are using electronical devices, but some researchers opened the debate of having also or only a paper version like during the UK rationing in and after the World War II (Szuba 2014).

In the TEQ scheme, if people make efforts to emit less than their Entitlement, they will have the possibility to sell their surplus carbon units on the market. In case people emit more than their allowance they would have to buy extra units on the market (Fleming and Chamberlin 2011).

To know the amount of carbon units to be purchased, a simple rating system evaluates the carbon content of fuel and electricity. In this system, 1 TEQs unit or carbon unit represent the quantity of fuel or electricity that produce 1 kg of CO_2. This includes both the combustion of the fuel but also the other fuels used to bring that fuel in the economy (extraction and transport of fuels). Citizens surrender TEQs units to energy retailers whenever they buy fuels or electricity. Energy retailers then surrender those units when buying carbonated energy from the wholesaler who, in turn, surrenders them to the primary provider or importer. To close the loop, primary providers or importers surrender back TEQs units to the Registrar when pumping, mining, or importing fuels. This latter point of obligation ensures that the system functions and is easy to check as there are few actors (Fleming and Chamberlin 2011).

All other energy users (firms, government, etc.) have to buy carbon units on the market for their purchase. They surrender their units to their suppliers for every purchase of carbonated energy. (Fleming and Chamberlin 2011).

The TEQ defender highlight a feature specific to the scheme: "*TEQs provides perhaps the only viable alternative to that price-based approach of trying to reduce emissions by making them more expensive. Instead, TEQs simply sets a firm – and declining – limit on the quantity of carbon coming into the economy (and explicitly guarantees fair entitlements to the energy that is available within that cap). Society as a whole can then collectively focus on adapting within this limit, and thus keeping the price of energy as low as possible, which is a simply-understood task that everyone can buy into with enthusiasm*" (Chamberlin 2021).

An important feature proposed for this scheme is the "pay as you go" option. The author states that individuals could leave the charge of getting carbon units to the energy retailers directly at the point of purchase of fuels and energy and so not being confronted to manage carbon units in advance if they do not want to. Fig. 12 shows the two purchase options for an individual in the system. The first option (Fig. 12, Box 1) is the conventional way of surrendering the carbon units. At the bottom of this Box 1, Fig. 12 shows that an above allocation individual (needing to purchase extra unit) would purchase carbon units (CU) on the carbon market (with Market maker) before purchasing fuels and having to surrender their carbon units to their energy retailer. The second option (Fig. 12, Box 2) is the "pay as you go" option. Now, at the bottom of the Box 2, Fig. 12 shows that an "above allocations" individual can also choose to leave the task of purchasing carbon unit (CU) to its fuel retailer by transferring him the money necessary to purchase by himself the carbon units he otherwise would have surrendered to him. This last convenience would certainly interest visitors without carbon accounts (e.g. visitors coming from abroad) or some people that often lose their bank card (Starkey 2012).

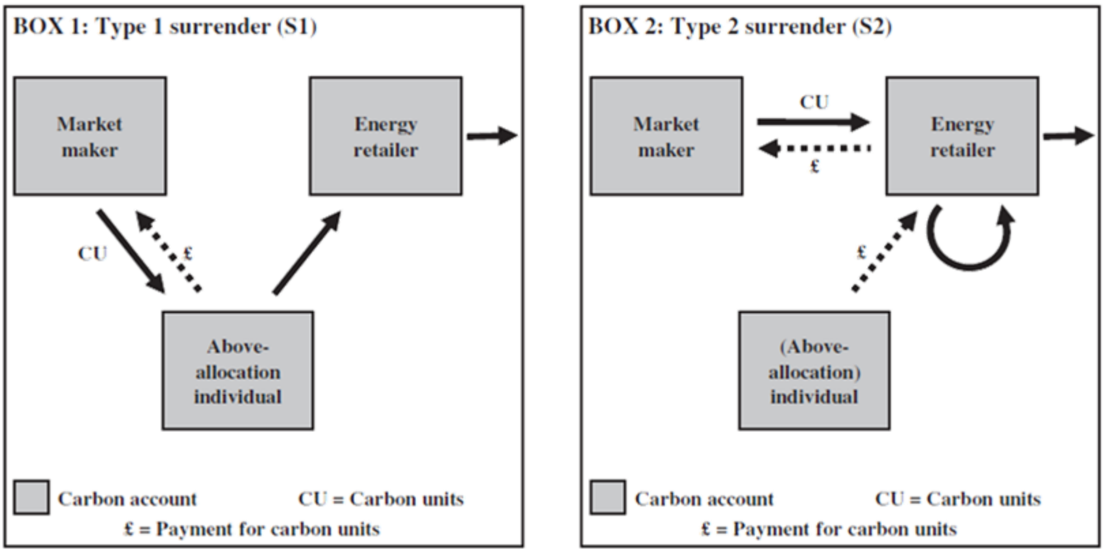


Fig. 12 – The two possible options to surrender carbon units in a TEQs system (Starkey 2012).

The author also proposes that in some circumstances some organizations could get carbon units for free. This would be similar to free allocation scheme still occurring today in the EU ETS (Member States can decide to allocate some of the allowance for free, but this part is now diminishing year after year). However, the authors argue that free allocation for some organisations should be an exception only used for energy demanded by essential services for instance (Fleming and Chamberlin 2011).

The author explains why such a system would be urgent to implement: "*If energy scarcity were to develop before tried and tested rationing systems were in place, profound hardship would follow – that is, actual energy famine for the losers in the competition for fuel. All too clearly, this would be unjust. Indeed, the distribution of scarce fuel would involve some form of auction or contest which, in the case of severe scarcity, could be violent. TEQs are designed to sustain orderly access to energy in these conditions. And the instrument is designed, too, to prevent an even greater injustice, in that it represents a realistic response to climate change*." (Fleming and Chamberlin 2011)

B. *Tradable Consumption Quota's (TCQ)*

This scheme, like Fleming's one, would cover a whole economy but has not been designed for a precise country or group of countries (Ayres 1997).

In this system, unlike Fleming's, 100% of carbon units would be allocated as free for individuals on a per capita basis. Ayres proposes that unused quotas of individuals could be traded in regulated (but untaxed) auction markets. He imagined the system working with an electronic credit cards with a code to eliminate virtually all theft and fraud possibilities (Ayres 1997).

What is interesting in Ayres' scheme is that it could also be applied for other environmental indicators, such as SO_2 emissions because the sulphur content of fuels is easy to measure, or even a better general measure of fuels, the "exergy content", could be used, provided that the measurement techniques would make it feasible (Ayres 1997).

To launch such a scheme, the government should first determine the total quantity of a harmful substance for the environment that can be emitted for the next year (and prevision would be made for next years (Ayres 1997).

Secondly, following the substance or indicator targeted (e.g. carbon, sulphur or exergy), an accurate way of measuring should be found (e.g. the carbon content of fossil fuels). Subsequently the detailed implementation could largely be delegated to manufacturers subject to occasional government audits given a standardized methodology (Ayres 1997).

The third step is to label *each* product in terms of its X-equivalence. To do so, each firm would be obligated to specify both the **indirect-X-content** ('X' being carbon, sulphur of exergy) and the **direct-X-content** of all of its products. The indirect X-content is considering the X used in previous process before the firm action (e.g. the carbon emissions to extract 1 barrel of oil). The direct-X-content considers the X-content of the product itself (the carbon content of 1 barrel of oil). All the products would be labelled with both those numbers.

If a firm does not use the direct-X-content of a product, it simply labels the products it sells with the same indirect-X-content and direct-X-content. However, if the firm uses a part of the direct-X-content, then it has to purchase quotas for the used part. In addition, the firm has also to put on its marketed products a new updated indirect-X-content (the previous indirect-X-content added to the quantity of the direct-X content used) and a new updated direct-X-content (the previous direct-X-content subtracted by the quantity of the direct-X content used). All the processors along the supply chains would have to respect this same rule. As a result, at each use of direct-X-content the product would be increased in price as the firm has to buy quotas. In addition, the information of the indirect-X-content passes through all the economy to go to the final end-users (Ayres 1997).

As a consequence of this scheme if applied to track the carbon of fossil fuels, all products would then be carbon labelled (Parag and Fawcett 2014). To be more precise, all products would be direct and indirect-carbon-content labelled. However, it is obvious that if there remains no direct-carbon-content in a given product, its direct-carbon-content would be of 0 and so the final end-user would not have to surrender any quotas to purchase this product. In this case, all the carbon quotas would already have been surrendered by firms in the supply chain and so resulting in a higher price of the product (Ayres 1997).

The final step is to be sure that for any purchase of any product (by a firm or an individual) an appropriate purchase of "X-quota" is deduced from the customer's quota account. For the domestic firms to be treated on a fair basis, the imported goods would be subjected to border carbon adjustment that would assess the direct- and indirect-X-content. Importers not willing or unable to provide such information would be indirect-X-content assessed at a rate equal to the one of the worst-case domestic producer (Ayres 1997).

Ayres explains further the technical enforcement questions: *"The problems of implementation are essentially technical. The use of credit cards is already widespread. The administrative mechanisms for auditing already exist (having been put in place throughout Europe to implement the VAT). To check whether a particular firm is reporting correctly, the auditor needs only to compare the X-content of inputs, as reported by the firm in question with the X-content of the same commodities as reported by the sellers. In the event of a discrepancy, the auditor would have several optional ways to proceed, depending on whether the discrepancy were indicative of fraud or merely error. Given the large and growing capacity for information processing in our society, solutions to these problems should not be beyond the realm of feasibility."* (1997, p304)

C. Personal Carbon Allowance (PCA)

Personal Carbon Allowance scheme has first been proposed by Mayer Hillman in 1998 and has been further developed by Hillman and Fawcett in 2004 (Fawcett 2010; Hendry 2019).

The philosophy of the Personal Carbon Allowance is to cover only emissions under "direct personal control" such as household energy use (electricity and gas), personal transport (not including public transport because of difficulties to implement it) and personal air travel (Parag, Capstick, and Poortinga 2011).

Since this scheme has also been proposed for the UK context it would represent 40% of the total emissions as the scope focus on domestic and personal transport energy. The idea has been examined further, alongside the TEQ proposal of Fleming, in the pre-feasibility report on Personal Carbon Trading for the British government (DEFRA 2008).

To conclude, this scheme is very similar to the TEQ proposal but without including the auction market for all other energy users (firms, government, etc.) that accounts for the remaining 60% of UK fossil fuel emissions.

2.3.8. Critics on early pioneers' proposals

- <u>Tradable Energy Quota (TEQ)</u>

Defenders of this proposal argue that: "*The flow of units round the loop is routinely accounted-for in companies' existing stock-control systems, so the system is self-monitoring, requiring no routine public sector intervention*." (Fleming and Chamberlin 2011, p14). However, this assumption has been challenged. There is a high probability that, without control systems, companies that are not involved in domestic or personal transport fuels would by-pass the principle of carbon units flows through all the supply chains. In fact, companies would be more interested in directly buying carbon units on the market rather than asking them to their customers as this increases the transactions costs (Eyre 2010). The same remark can be applied to the "pay as you go" option. Therefore, it can be expected that the citizens would not have the choice for using carbon units or money for his carbonated purchases. The "pay as you go" option is just an alternative that is not specific to the TEQ proposal. However, if this option could be interesting for visitors and people who have lost their bank card, this option could undermine the effectiveness of the carbon account mechanisms. With a "pay ay as you go" option people using it will have less carbon visibility and this will not guarantee civil implication, what could undermine the whole system (Eyre 2010).

This TEQ system would replace the EU ETS but this was not thinkable at that time in UK (Brohé 2010). Now because of the Brexit such a scheme could be tested with more freedom in regard to the EU ETS.

- <u>Tradable Consumption Quota (TCQ)</u>

The Ayres proposal has remained a theory proposal as it has not been adapted to a specific context like TEQ and PCA for the UK. No pre-feasibility analysis has been done contrary to the other proposals.

- <u>Personal Carbon Allowance (PCA)</u>

In PCA literature, authors explain that the PCA scheme could complement the EU ETS. However other researchers show that the PCA would be complicated to put in place in the context of the EU ETS because of double-counting problems such as for the electricity sector that would be included in both schemes (Brohé 2010).

The argument for the restriction of the scope to the personal transport and domestic energy sector as being the only actions that are in "direct personal control" is poor. In fact, a lot of other consumption decisions are also in "direct personal control". In addition, giving people the information that benzine, gas and electricity are a source of CO_2 is not a so value-added information as most people are now aware of it. The only help that people get would be a system where conversion and addition are made automatically. It does not give people any indication on emissions more complex to see: indirect emissions generated by consumption.

2.3.9. Later proposals

A. *Rate All Products and Services (RAPS)*

This idea has been put forward by Starkey and Anderson (2005) in a paper where they analysed the feasibility of TEQ in the context of UK. They proposed the idea as a benchmark idea to compare it with the TEQs proposal. The concept is to calculate the carbon content of all products and services. All products and services would have to be rated by this mechanism. In practice, the rating has to be done everywhere, from the filling of a car to the purchase of an ice cream and from the stay in a hotel to a haircut. Individuals would have to surrender carbon units for any of their consumption of goods and services (Starkey and Anderson 2005).

In this scheme 100% of emissions rights are allocated to individuals. The idea remains that each adult would receive an equal amount of carbon unit. If the individual needs more unit, then he could purchase extra units from individuals who have too much as in the TEQ proposal (Starkey and Anderson 2005).

The authors argue that such a system would be really nice but that we do not have the technology to do so today. Rating all products and services just before they are consumed remains an unaffordable idea today. The authors finally conclude that a RAPS scheme (where all product and services would be rated at the final point) was not technically possible at that time (Starkey and Anderson 2005). The Ayres approach could be a way to overcome this difficulty (see 2.3.7 B above).

B. *Household Carbon Trading*

The Household Carbon Trading scheme was proposed in California and covers only the domestic energy consumption (Niemeier et al. 2008). The details of this scheme are not particularly well developed by the authors.

The idea is to allocate carbon units to each household on an equal per capita basis via utility service providers who place the allowances in each user's account. The carbon units are tradable. Carbon units are deducted periodically by the utility according to energy use, and additional carbon units must be purchased if the account is in deficit. At the end of a compliance period, the state collects the carbon units from the utilities and determines compliance with the cap (Parag and Fawcett 2014).

C. Tradable Transport Carbon Permits

Tradable Transport Carbon Permits were originally suggested in France and the scheme was examined for emissions generated by French private transport (Raux and Marlot 2005; Raux, Croissant, and Pons 2015). It has also been applied to the UK personal transport and recent papers focus also on the China context (Li et al. 2019).

In this system all carbon units would be allocated for free to individuals but not necessarily on an equal per capita basis. The units are surrendered for every purchase of fuel for the personal transport. Like in the TEQ scheme people could get carbon units on the market, via intermediate like banks or buy it directly at the petrol station (Parag and Fawcett 2014).

This scheme seems to be the most explored today in recent papers. Maybe because transport is the sector where emissions continue to grow since 1990 and that until now, policies seems to have difficulties to reduce the transport impacts.

D. EU Aviation Personal Carbon Trading System (EU APCTS)

This scheme would specially focus on aviation at the EU level both for intra-EU and outside-EU flights. To our knowledge, this scheme has been proposed for the first time in 2020 by Loic de Touzalin. The proposed scheme is quite original and goes through hitherto unexplored carbon account design possibilities. His proposal has inspired a recent law proposal in France to instore individual quota on flights of French people (Novethic 2020).

The focus on this scope has the advantage of putting less pressure on the fairness debate. In fact, even if progressive for most of the population, a carbon account scheme focusing on all transport or domestic energy could still affect more deeply some minor part of the lowest income quartile while it is not the case for a carbon account focusing only on the aviation sector (de Touzalin 2020).

As mentioned earlier, an equal per capita allocation does not guarantee to satisfy basic needs in an equal way. However, flying is not a basic need and is also a sector that is consumed more by high income people. So focusing only on the aviation could be a source of revenues for low-income people that normally don't use a lot of flights and could be an extra cost for high income people (de Touzalin 2020).

However, some inequalities at the geographical scale could still result from this scheme. The southern countries of EU are more dependent on tourism revenues and so the reduction of the airlines activities would be more difficult for them in general (de Touzalin 2020). However, this difficulty could be surpassed by previous arrangements or by accepting displacement or disappearing of activities that would have sooner or later been impacted by climate policies.

A first important exploration of the design possibilities made with the scheme is the mechanisms to define exchange price of carbon units. In all the previous schemes, the idea was that the price had to be defined by a pure cap-and-trade system. This means that until the moment where the emissions cap is fixed, a price would emerge on the market for carbon units. However, most authors do not explain if citizens would accept this price that could have a lot of volatility. It is in the idea of protecting citizens against extreme carbon price variation that this EU Aviation Personal Carbon Trading System proposed a price floor and ceiling.

A second very interesting exploration is about the monitoring of the system. The proposition is inspired by Christian de Perthuis, who studied the functioning of the EU ETS and made a call for the creation of an EU ETS central bank that could manage the supply of carbon allowances and intervene on the carbon market in order to reduce short-term and long-term emissions as efficiently as possible. Following de Perthuis, the EU ETS has the weakness of working without an independent regulatory agency and this makes it inefficient to adapt to shocks, as it relies on the European Parliament and the Council regulation. With a precise mandate from the European Parliament and the Council, this EU ETS central bank could, like the European Central Bank, be independent of short term political waves so that it can have the long-term vision needed for the climate objectives (de Perthuis 2011; 2012).

In the case of the EU Aviation Personal Carbon Trading System, this central authority would be named the EU Personal Carbon Trading Agency and would have the mandate to *"define allowance budgets and to distribute the allowances to individuals, to collect data from commercial airlines, to develop and manage the personal carbon trading platform, to compute the fines and collect them, to define floor and ceiling prices, to intervene in the market to maintain these limits and to inform and help citizens understand the system. Besides, it will also report to the European regulatory bodies on the market dynamics and the effectiveness of the system and be accountable to the European Parliament"* (de Touzalin 2020).

E. Progressive Taxation Carbon account

In his book "Capital et Idéologie", Thomas Piketty explains that carbon accounts schemes could be improved and serve as a tool to implement progressive carbon taxation. He argues that classical carbon account schemes are not putting any limit on the emissions of the richest as they would have enough money to pay all the carbon taxes even at the highest proposed carbon prices (Piketty 2019, pp1156-1159).

Piketty is in favour of a progressive taxation scheme of emissions. However, he knows that for a progressive tax to be implemented it would need a carbon account-like system that could sum up all the carbon-purchases of individuals by using the payments information. His scheme can be seen as an adaptation of other scheme proposals. In his improved carbon account scheme, the first annual emissions would not been taxed. Then above the threshold of free emissions, individuals would have to pay for extra emissions. From this threshold begins the progressive taxation implementation. The higher the total of emissions of a citizen, the higher the extra carbon unit would cost for him. In addition to the exponential carbon price that normally would discourage excessive personal carbon emission, a final carbon limit for individuals with very high carbon footprint could also be imposed with sanction like confiscatory taxation of income or wealth (Piketty 2019; L'Obs 2019; Paris School of Economics 2019; L'Obs 2020).

The revenues generated by this progressive carbon tax scheme would be used by governments to help the households the most affected by the carbon price and to finance the energy transition (Piketty 2019).

Piketty does not give further details on the scope of emissions to include. He mentions the "carbon emissions" in general. For the ease of implementation, he proposes to start the progressive taxation carbon scheme with the aviation kerosene as this fuel is mostly used by richer people and will not affect significantly the poorest as they generally do not need aviation services (Piketty 2019).

Piketty is afraid of the volatility that could be generated by a carbon market for individuals and it is why he prefers a system where the price is defined by experts rather than a cap-and-trade scheme (Piketty 2019). This point differs from previous scheme proposals and is worth the exploration as volatility could be an important factor of distaste for citizens.

2.3.10. Critics on later proposals

The scope is limited in the Household Carbon trading, Tradable Transport Carbon Permits and EU Aviation Personal Carbon Trading System proposals. However, the authors often recognize themselves that a larger scope could be more interesting. The larger the scope, the better people can make trade-offs within the scope and the best it is for them and for the efficiency (Wadud and Chintakayala 2019).

For the technical feasibility it is the Rate All Products and Services that receives the most critics as the carbon footprint rating calculated when products are already in the stores would be very expensive. Today, companies trying to implement it on their own have huge costs to dedicate to calculation (ADEME 2021). However, there could be alternatives, such as Ayres approach, to reduce those information cost, e.g. if an accounting scheme were used for all companies of a whole economy with an in-out accounting, some reporting rules and auditors. To our best knowledge, the recent Piketty's proposal has not been yet analysed.

3. Conceptual framework of converting the current EU ETS to an EU carbon account: possible steps and potential benefits of each step

Could a carbon account system covering all the emissions from fossil fuels be imaginable at the EU-27 level? Most of previous schemes proposed carbon account systems at a national level but here the case will be made for an EU-wide carbon account system starting from the current EU ETS as it is the current most credible EU-wide carbon price mechanism. The following EU Carbon account system proposal can be built as a progressive addition of 3 extensions to the current EU ETS. Each step presented here would have its own benefits so that each step in the direction of this scheme is already interesting. The following proposal is imagined as a scheme that would cover fossil carbon emissions of all the goods and services as it has been defended as the most desirable scheme by many authors (Ayres 1997; Fleming 1997; Starkey and Anderson 2005; Fleming and Lean Economy Connection 2006; Fleming and Chamberlin 2011; Roy and Woerdman 2012; Woerdman and Bolderdijk 2017; Wadud and Chintakayala 2019; de Touzalin 2020; Sconfienza 2021)

3.1. Step 1: EU ETS extension to upstream monitoring and BCAM

As seen in the section 2.2.3. the current EU ETS covers only 40% of the GHG of the EU-27. The reason for that limited cap is the way the EU ETS has been thought in the beginning. In fact, this policy has been first designed to target the points of emissions (locations where emissions take place). To minimize costs to measure emissions, the ideal way to implement the scheme was to start by big, concentrated points of emissions. It is why the ETS started with large stationary industries. In 2012 the scheme was enlarged to the intra-EU aviation sector. The idea at the start was to enlarge the scheme further progressively to other sectors. However, keeping the emissions approach makes it impossible to monitor more dispersed emitters such as cars, trucks, heating systems, small factories, etc., even if they account for an aggregate 60% of the emissions.

To include more emissions in the EU ETS scheme, the approach has to be changed. Some other ETS schemes have succeeded in including more sectors. The New Zealand ETS is a good example as it has included fossil fuels sectors by an upstream approach. What was successful in this scheme is the control for the carbon content at the point of entry of fossil fuels in the scheme while still checking the point of emissions on industries for other gases. In fact, the point of obligation (the actor in the chain to which carbon permits are asked) has no impact as the price is supposed to express itself across all the supply chain (Leining 2017; Leining, Kerr, and Bruce-Brand 2020).

It is this idea of carbon content of fossil fuels monitoring that will be used for this first EU ETS extension. Some points of obligation should be moved from points of emission to points of entry of fossil fuels (points where fossil fuels are imported or extracted). Factories that pump, mine, or import fossil fuels would have to surrender carbon allowances when bringing fossil fuels into the EU economy. This idea translates the implementation of a recent EU commission proposed plan to extend the EU ETS to be in line with the current EU Green Deal (European Commission 2020e).

For the imported emissions from trade, there is also a Commission proposal to implement a Border Carbon Adjustment Mechanism. There are suggestions to do it as a simple tax equivalent to the carbon price paid by EU enterprises, but also suggestions to do it on a cap-and-trade principle, with a specific quota on imported goods and services or with a direct linking with the EU ETS quotas (European Commission 2020f; European Parliament 2020). The EU ETS carbon market would of course be enlarged to allow this importers inclusion.

A. *The benefits of reaching this first point*

From an economic point of view, achieving this extension would be already interesting because pricing the carbon amounts gives the right incentives to invest in less polluting activities and to disinvest from fossil fuels industries. Furthermore, maintaining the fossil fuels subsidies that exist today would become impossible because of the cap fixed for emissions. Whatever happens, total fossil emissions would be obligated to reduce years after years.

The EU ETS generates revenues from the sale of allowances that are reversed to government. Today governments are obligated to spend this money for a minimum of 50% in energy transition. The extended scheme would stay in the same idea. To be in line with the Green Deal's « Just Transition » philosophy it could be imagined that 50% would obligatory be used for energy transition investments and the other 50% to help households in energy poverty.

B. *Is it still a good idea to maintain a price volatility? Could it be otherwise?*

Price volatility is something that is hard to avoid in a market such as the current ETS. No one could have predicted what would happen on the carbon allowance market some years ago. If the system would later be extended to a carbon account for citizens, the question if volatility is still acceptable for them is an important question. However, this question can already be posed for organizations yet included in the system. Some companies prefer in fact to be in schemes with price floor and ceiling to avoid situations that would lead them to bankruptcy. Interventions on markets is an example to achieve a carbon price floor and ceiling.

Some economists even go further in arguing that without any idea of the future carbon prices, companies are not able to do any investment plans for the future. In this situation, long-term investments needed for energy transition are more difficult to find. It is especially an idea that Christian Gollier, Jacques Delpla and Christian de Pertuis put forward as one of the basis for their call for a EU Carbon Bank (de Perthuis 2011; Gollier and Delpla 2019).

The idea of an EU Carbon Central Bank has already been presented in the explanation of the EU Aviation Personal Carbon Trading System. Fig. 13 summarizes all the ideas presented here about the ways to define carbon price:

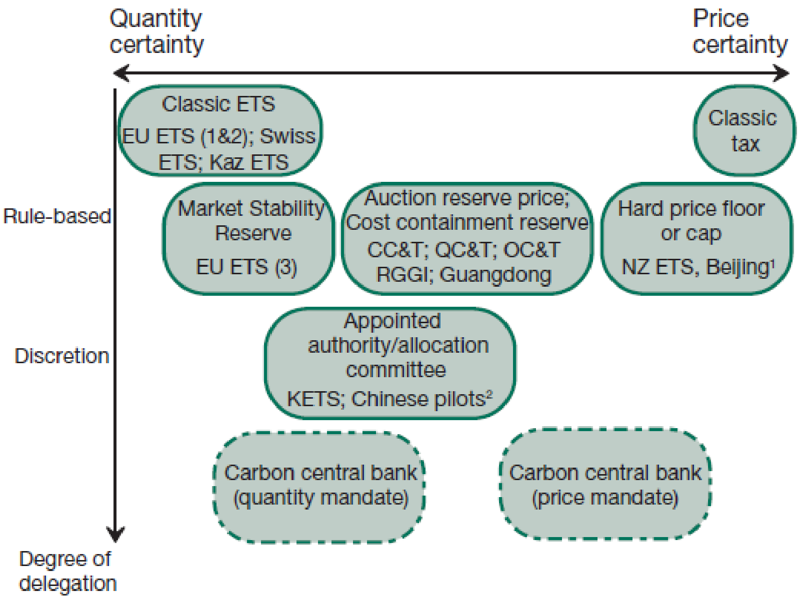


Fig. 13 – ETS governance space – an empirical mapping of tools to adjust the allowance market (Knopf et al. 2018)

This question of the mechanisms that could be put in place in order to reduce price volatility for actors remains interesting within or without a carbon account policy.

3.2. Step 2: EU ETS extension towards fossil carbon accounting

When the first step would be well implemented, there is the possibility for the EU-27 to obligate each enterprise to have a fossil carbon accounting that would be based on a VAT-like system. The idea is that because primary energy providers have to surrender carbon units when they pump, mine or import fossil fuels (or produce cement), it is feasible to ask them to inform all their firm-customers of the carbon content of the fuels (or cement products) they sold them, so that those can record it as an input in a carbon accountancy. In the same carbon accountancy, the firm will allocate the carbon content to all its outputs and pass that information to their own customers. The information would go through all the supply chain to the final products and services that citizens consume. A fossil carbon unit tag (perhaps complemented with a code bar) would then figure besides conventional prices to show all the fossil carbon needed to supply the goods or service to the final customer. Those tags would enhance citizen's perception of carbon content related to the products and services they buy.

Because foreign enterprises have also to be evaluated on the fossil carbon content of their products at the point of entry in the EU economy, they should transmit the fossil carbon information to the enterprises to which they sell their products. To do so the EU could create third-body auditing that verifies the calculated embedded carbon emissions. The carbon content could be determined using benchmark values for the products imported based on conventional production process unless the exporter certifies a lower carbon content due to another way of producing it (European Commission 2020b).

For the enforcement of the system, controllers would be engaged to regularly verify that "in-account" of enterprises are equal to "out-account". Each enterprise would have to hold an in-out accounting to be checked routinely, like VAT checks exist today. Some good accounting practices would serve as rules when it is difficult for a firm to distribute its carbon inputs on a large range of different output products. This sort of idea has already been proposed at the Commission level seriously, but the goal at that moment was to do a whole Life Cycle Analysis on products based on a wide range of environmental indicators. The scheme failed because it was deemed too large. For a scheme more focused, here only on fossil carbon content, it could be more realistic.

Fossil carbon content accountancy may be the most evident to put in place, but other emissions could be included if easy to do so. Using the same argument of simplicity, in this first proposal only CO_2 from fossil carbon emissions will be counted (fossil fuels and cement) as they are easier to count on territorial and imported emissions basis. In order not to abandon the non-CO_2 emissions regulation in the EU ETS (even if it concerns a small part), the non-CO_2 emissions would be subjected to a small EU ETS-like scheme with specific targets. The target would be made so that prices in both schemes are quite similar. The emissions still outside of the EU-ETS extended and the EU ETS for non-CO_2 emissions would be subject to other policies within the actual Effort Sharing Regulation.

A. *The benefits of reaching this second step*

The benefits that could derive from the increased carbon perception could be a greater individual awareness of all the direct and indirect carbon emissions linked with the goods and services they buy. Knowing their precise impact and making more reflections when purchasing a good or service because the exact amount of emissions is known, could already have a significant impact on citizens. This level is thus interesting to reach with or without carbon account policies.

B. *Could the visibility be pushed further? Visibility on emissions reduction possibilities?*

Today there is more and more fatigue about conventional polluters-pays policies. People may want to get more than those policies. They certainly do not want to feel helpless to make changes in their habits when facing increasing prices for products and services they are used to consume. For those reasons, it is proposed that the carbon account scheme could be accompanied by emissions reductions tips for citizens. In reality, those tips or advices could be showed on a dashboard where the user can see reduction tips near his location. The dashboard could already be made accessible without carbon account, but then users would have to record their consumptions manually or with a system that automatically records the products and services purchased. This scheme would be easier with a carbon account but could still be tested without.

3.3. Step 3: EU ETS extension to downstream level: carbon units in hands of citizens

For this last step, the idea is that fossil carbon units circulation would start at the level of citizens. Because carbon units would be asked for each product or service, and that regular checks would control the good implementation of the carbon units circulation, the fossil carbon units would pass through all the enterprises of the supply chains to finish in the hands of primary fossil fuels providers (or cement producers for a little part of the carbon units). To make it clearer Fig. 14 shows the final result of implementing all the EU ETS extensions to achieve the carbon account policy aimed.

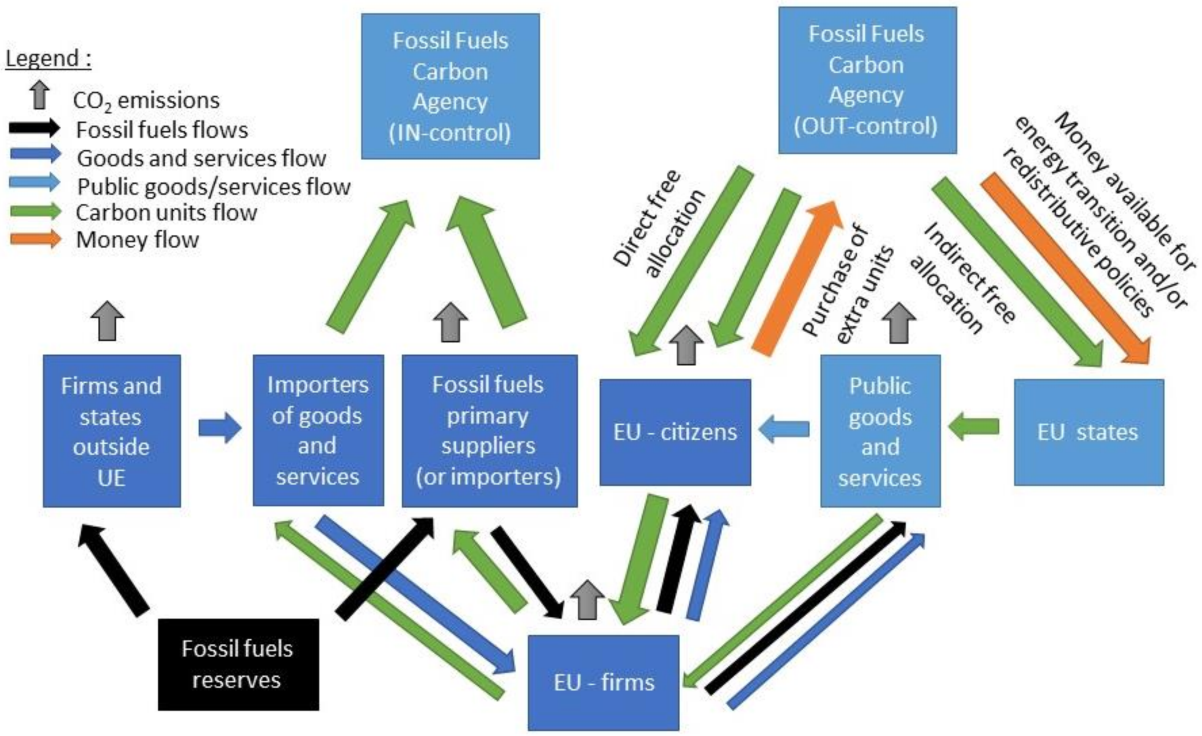


Fig. 14 – Functioning of the EU Carbon account System proposal

The right-hand side of Fig. 14 shows that an EU agency, which could be named the Fossil Fuels Carbon Agency, could be responsible to regularly distribute a free allocation of carbon units to the EU citizens. In addition, this agency would also distribute a share of the carbon units for the different governments based on their population size (and potential commonly agreed other criteria) so that each government can provide the public goods and services to its citizens. This feature is important because it would be very strange that citizens would have to pay also in carbon units for public goods and services where today a lot of them are free or subsidized in monetary terms. To illustrate this, if someone has to call the police for whatever the reason, the expenditure linked to the arrival of the police should be paid by the government, be it in money or carbon units. At the EU level there would be arrangement between countries for the share that governments can use for public goods and services. It is not impossible to have different countries having different scope of public goods and services paid in carbon units by the different countries. Today all countries have public management preferences. It could stay like this without hurting the scheme's effectiveness.

As explained, the agency would regularly distribute carbon units to citizens and government, but a part of the annual carbon units would not be distributed and rather put on a common reserve. Citizens and governments would then be the only entities allowed to buy carbon units on this common reserve. The interest of the common reserve is that it would generate revenues to be used by governments for investments in energy transitions and/or redistributive policies like help to households in energy poverty.

The presentation of the TEQ system showed that it is possible to have some free allocation to citizens and the rest to be put in a reserve that people would have to pay for (indirectly in the TEQ scheme, but it does not change a lot if it is paid directly). The minimum for a carbon account scheme is that carbon units have a price, that goods and services purchased in the scope are carbon-labelled, and that citizens receive some initial allocation and have to surrender carbon units when purchasing a good or service within the scope**.**

To determine the part of free carbon units to allocate each year, the idea is that citizens would get a free equal allocation representing the target to reach for 2050. For all their emissions above that level they would have to buy carbon units from the common reserve.

The literature is mostly unclear about this target: some speak about 2t/person, others speak about 1 or even about 0 ton/person. Therefore, the free allocated amount could be included within those values.

This freely allocated amount could be decreased if the rest of the world does less efforts for climate or if more ecosystems feedbacks loops start increasing more rapidly (permafrost thawing, long term icesheet disappearing, big forest fires). On the contrary, the value of the freely allocated amount could be increased if forests are replanted faster, agricultural practices begin to stock more carbon that it emits at world level, if a lot of new houses or isolations are built in wood, straw and other carbon containing materials or if technologies of Bio-Energy Carbon Capture and Storage develop more rapidly than expected. Potentially, the freely allocated amount per person could be adapted to the worldwide population size evolution. When being near the 2050, for example in 2040, a new further target would be interesting to be set, for example for 2075 until the scheme would not be necessary anymore. To imagine different pathways Fig. 15 gives an overview of different IPCC 1.5°C scenarios.

Here a limitation on positive emissions approach has been presented but the "net-zero date communication" approach seems to be more and more claimed. It could be argued here that both approaches are complementary and that the best would be that countries both declare a date of reaching net-zero emissions but also their level of emissions at that date so that people can directly see the negative level of emissions in which a country engages itself. The negative emissions are just the equivalent of the positive emissions at the date of net zero emissions. And it is important to remind that to date, negative emissions are very difficult to implement at large scale.

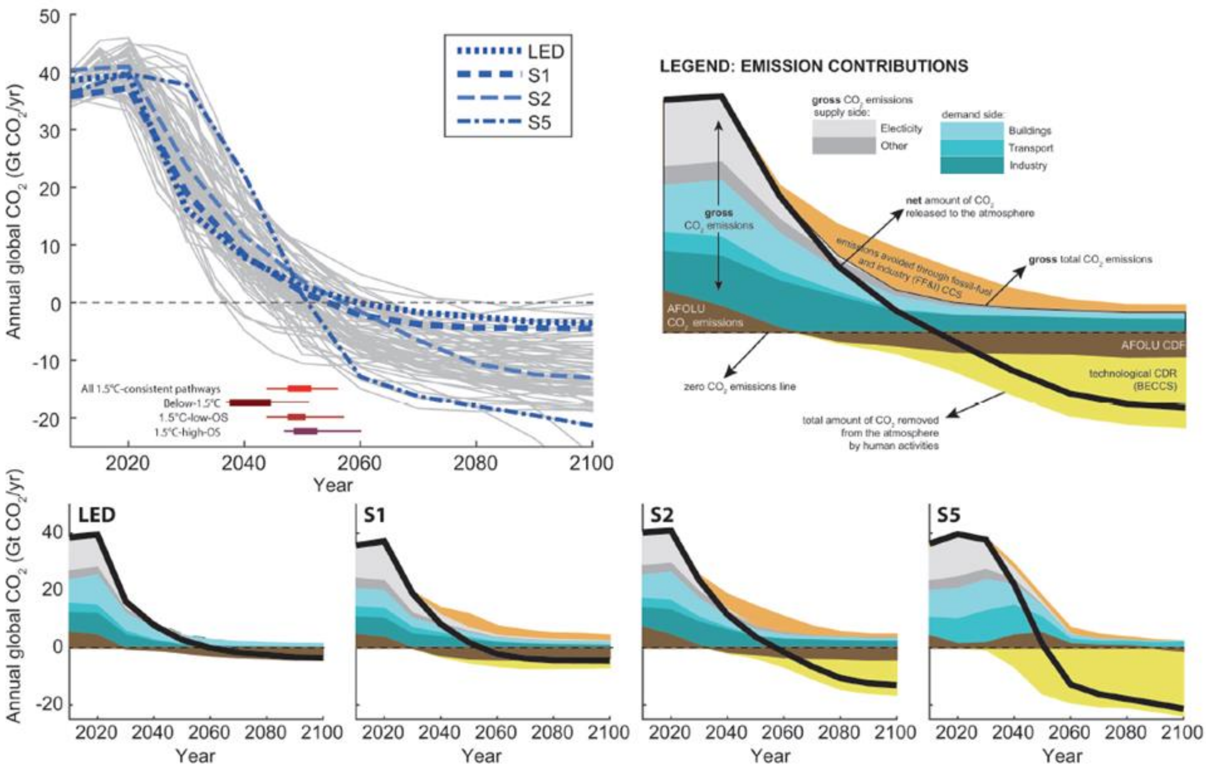


Fig. 15 – Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development (IPCC 2018) p113. *The LED scenario stands for Low Energy Demand, S1 = Sustainable development, S2 = middle of the road, S5 = fossil fuel development. For further information see IPCC 2018.*

A. The benefits of reaching this third point

By achieving this step, only citizens and governments[3] could buy and sell units to the Fossil Fuels Carbon Agency. As a result, citizens would get the information of their own total emissions and other information such as the mean emissions of their locality and their country. Following carbon account literature, the expected effect here would be that new social norms would appear around the levels of emissions that are acceptable.

Another interesting thing is that the amount of revenues for governments to invest in energy transition and help to citizens in energy poverty would not be reduced a lot because a lot of emissions would still remain to be bought by citizens. The freely allocated amount per person would certainly help already a lot of citizens to escape energy poverty. Some recent papers insist on this point: “Besides, it can also be argued that a personal carbon trading system would be fair if everyone is granted enough allowances to cover at least their basic needs.” (de Touzalin 2020).

Of course, in such a system, there would be some need for time arrangement for the enterprises to be able to surrender units before they get the final units from their customers (Fig. 14). To arrange this delay, it is easy to imagine implementing small carbon banks that could be the actor giving (pre) carbon units in advance before being themselves reimbursed in those (pre) carbon units. There would be rules so that the non-pay back enterprises would have to pay high taxes (or doing long term good public carbon storage activities) as a punishment. The functioning of this carbon delay scheme should be detailed in further works but can be already smoothly tested and implemented in step 2. For the ease of implementation, it could be interesting for the years before the step 3 to use “test” carbon units that would not really count and would just be a step for people to get the habits.

B. Do people want restrictions on personal emission levels? How to do it?

Today, there is no limits on the amount of CO_2 that someone can emit directly and indirectly. Very high-income people of the 1% richest have levels of emissions that others could never imagine. Fig. 16 from an Oxfam study represents the mean of this group in comparison to others. When seeing such disparities, could citizens be interested in a sort of annual limitation of emissions? In the survey, this question will be explored by proposing some schemes with an annual limit that if people go beyond, their extra units have to be subject to high levels of fines. It can be argued that first emissions are there to satisfy important basic needs and that following emissions are less and less important to sustain someone’s happiness.

[3] The non-profit organizations could potentially also be an actor allowed to buy units if they do not receive it through the government. The debate is left open in the context of this master thesis.

Thomas Piketty defends such an idea of a carbon account that would enable to measure the individual carbon consumption so that a system of progressive carbon taxation can be in place as explained previously.

The idea of an annual limitation that if people go beyond it, they must pay large fines is like a first gross introduction towards Piketty's idea. The initial freely allocated amount of carbon units can be seen as a non-taxed level of emissions.

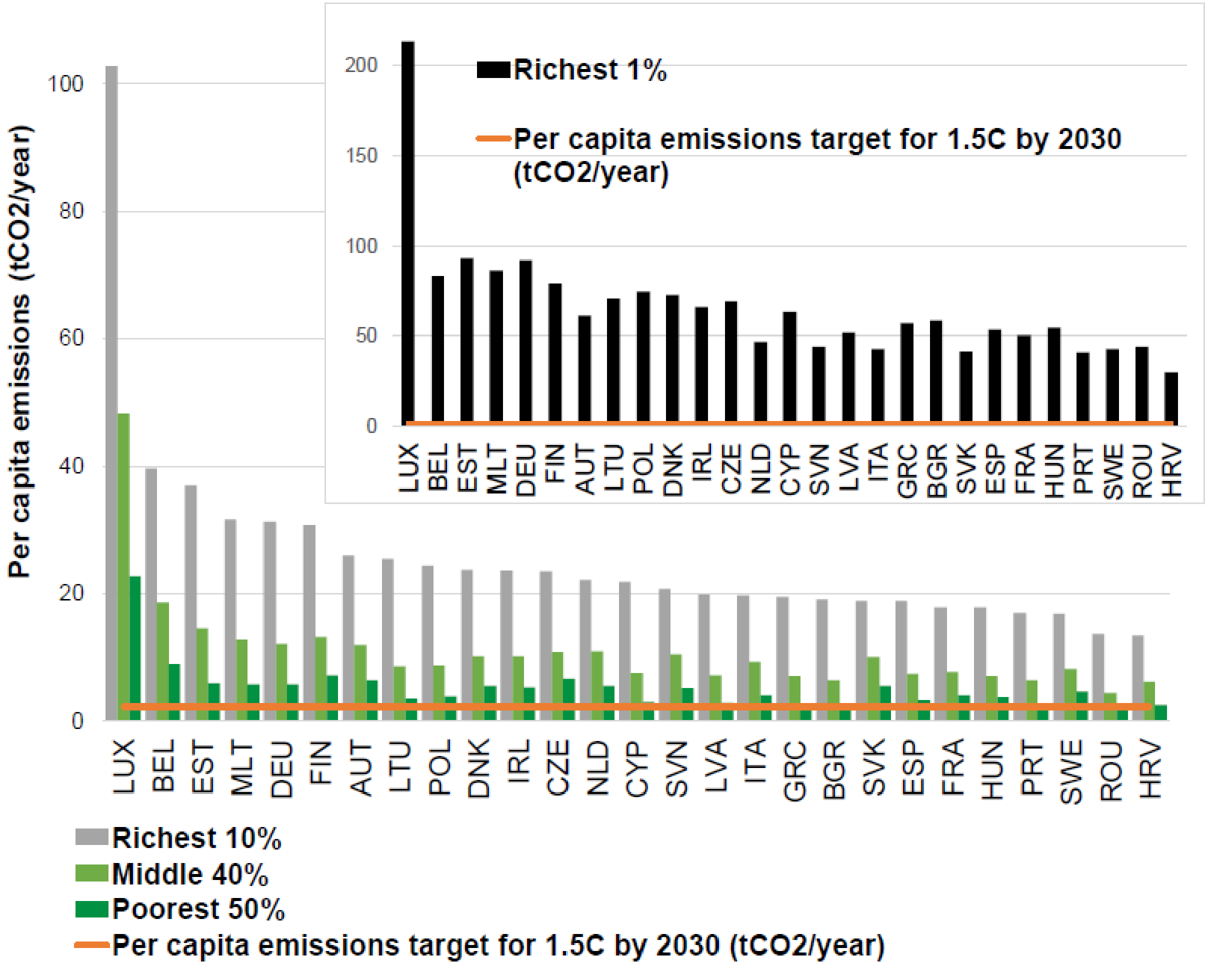


Fig. 16 – Estimation of per capita consumption emissions (tCO2/year) in EU-27 Member States by national income groups (Gore and Alestig 2020)

3.4. Barriers and potential solutions

To the introduction of a carbon account policy, many barriers can appear. Those barriers can be both technical questions as more ideological obstacles.

A. *Preference to deny the emission reductions to be made*

It can be a major temptation for some people to deny the climate change problem and, if not the climate change itself, then a deny of the emissions reductions and action needed to mitigate climate change under acceptable level of global warming. Whatever the carbon price policies implemented to incentivise good environmental behaviour, it is sure that people trying to deny would not be able to conserve the same way of living eternally. The increase in price over their consumption habits would force them to change. However, if all prices of consumption increase for those denying people, they will become very angry without understanding or taking part of what happens to them if the carbon price is fixed by a simple cap-and-trade or carbon tax system. On the contrary, people trying to deny in a carbon account scheme will have more difficulties as they will have regular reminder of the level to reach in terms of carbon units to which a lot of people will pay attention around them.

The percentage of EU citizens completely denying climate change should be limited. In June 2019, the Eurobarometer showed that 93% of EU citizens consider climate change as a serious problem and 92% want the GHG emissions to be reduced to achieve the 2050 carbon neutrality objective (European Commission 2019a)

B. *Political trust and acceptability*

Acceptability of a carbon account system will depend on its design but also on the trust that citizens have in European politics. The difficulty is that in the EU the trust in politics varies between and within countries and so the acceptability could be heterogeneous among countries (European Commission 2019a).

The fact that beyond the level of the freely allocated carbon units the extra units are to be bought could make the proposal unpopular. However, as the collected revenues would finance the energy transition and support households in energy poverty, the scheme could receive important support.

C. *Present and future narratives*

Some persistent discourses in the society could make this carbon account proposal today difficult to implement. From the viewpoint of those that claim that the large enterprises are responsible for climate change it will be very difficult to imagine a carbon account policy where the climate mitigation burden seems to be placed on individuals and their governments. However, the unpopularity of the proposal if this vision is used could be overcome by explaining the true rationale behind the policy: **that whether a carbon price is asked to enterprises or citizens, it is always the citizen consumption that will have to change at the end**. No one pollutes for the pleasure of polluting. It is thus more interesting to start at the point of citizens and having a system that asks them for their whole consumption what is the most important to keep and what can be diminished. Of course, enterprises would also be involved in finding the best solutions as they would be incentivised to propose products or services with less fossil carbon utilisation to provide goods. The enterprises polluting too much to provide goods and services and not adopting alternatives would have to adapt or go bankrupt.

To conclude it is understandable that today if a citizen tries to change his consumption patterns, he could have the impression that his actions are like a drop in an ocean, but this would be radically different in a carbon account scheme that would act on the whole ocean of drops. The narrative that lots of other policies failed could also be used (Sconfienza 2021).

What is interesting with the carbon account proposal is that it does not judge the growth and degrowth narratives. What is important for the scheme is to reach a reduction of carbon emissions (Sconfienza 2021).

D. Migrants, undocumented, EU-visitors and EU neighbours

Some could argue that the scheme is too complicated to put in place because there always are migrants, undocumented people, EU visitors and EU neighbours. If it is certainly challenging, solutions can be found.

Concerning the participants included in the scheme, it could be good to include all EU citizen adults and long-term residents (people above 18 years old and living in the EU for more than 5 years) as they represent 4.4% of the EU population in 2018 (European Commission 2019b).

For migrants, undocumented and EU-visitors, temporary carbon accounts could be imagined. For the EU neighbours (Lichtenstein, Switzerland, Iceland, Norway, UK, etc.) special arrangements like carbon taxes for the importation of EU products could also be imagined.

E. Commodity/currency approach

A last question that can emerge for a carbon account implementation is whether carbon units would be rather a commodity or a currency. If they are considered as commodity, then those allowance would be recognized as financial instruments, implying that they would be subject to financial regulation (de Touzalin 2020). But carbon units could also be seen as currency because their value entirely relies on their use to meet an obligation. This latter option could help foster transparency, temper price volatility and implement a central supervisory authority (Button 2008; de Touzalin 2020).

4. Materials and method

4.1. Carbon account design possibilities and citizens' preferences

As seen in section 2, there are a lot of carbon account design possibilities and as no EU-wide carbon account scheme proposals already existed, the master thesis made a proposal for this scale. In the EU proposal three important questions were highlighted for the acceptability:

1) Is it still a good idea to maintain a price volatility? Could it be done otherwise?
2) Could the visibility effect be increased? What about emission reduction advices?
3) Do people want more restrictions on personal emissions levels? How to do it?

4.1.1. Method used to assess citizens acceptable level of carbon price and citizens preferences

The higher the public acceptability of a public policy, the higher are the chances for this policy to be successfully implemented. A lot of carbon pricing policies have failed due to public reluctance in many countries. A detailed understanding of the public acceptability for climate mitigation policies is therefore of crucial importance to be able to improve their design (Ščasný et al. 2017).

To assess citizens' acceptability of carbon pricing policies and/or obtain information on citizens' preferences over scheme possibilities, three different methods could be used. First, the acceptability could be assessed by analysing public opinion and referenda studies. Secondly, social or psychological theories of behaviour and cultural theories could be used. Finally, from an economic perspective, the utility theory approach can also be useful to assess the acceptability (Zverinova, Ščasný, and Richter 2014). This last economic approach is the one that has been adopted in the frame of this master thesis. To assess the public acceptability with the economic approach, two families of tools can be used: the revealed preferences method and the stated preferences method.

A. *Revealed preferences method*

This method is based on data analysis from market decisions. The method consists of analysing the behaviour of choices based on the purchase of goods and services subject to a carbon price. This method is interesting to overcome the hypothetical bias. However, in this case there is no real situations where individuals would have the choice between two carbon account scheme design in their everyday life so this revealed preferences method cannot be used.

B. *Stated preferences method*

With this method, the actual behaviour is not observed like a revealed preference method would do. Here, preferences are evaluated by introducing a hypothetical situation to respondents and asking them to state their preference among different possible alternatives or scenarios.

One of the ways to do it could be by directly asking each citizen of a survey how much they agree to pay for a given carbon account scenario. This method is called the contingent valuation and is a direct method to assess the willingness to accept (WTA). An alternative method is the choice experiment method and consists of asking respondents to make choices in an hypothetical situation between 2 or 3 scenarios with specific attributes characterised by levels (Kjær 2005). Choice experiments allow to simulate spending decisions to obtain consumer preferences for product or scheme alternatives characterized by attributes and levels (De Marchi et al. 2020).

The choice experiment tool was originally used to evaluate consumer preferences in marketing and transport sector. The method has then been applied more and more widely for other purposes. As an example, the method has been used in environmental economics to investigate willingness to pay of citizens for environmental services. In 2010, the choice experiment tool has also been first used to evaluate citizen preferences and willingness to accept carbon prices for different carbon account schemes and scenarios. Some studies have kept a large overview on carbon account design questions (Bristow et al. 2010). Their study has been conducted in two parts: (i) one on a carbon account scheme vs another and (ii) a second part on a carbon account scheme *vs* different carbon tax designs. The present document will only focus on a comparison of a carbon account scheme *vs* another. Other papers have focused on the willingness to pay in a carbon account system *vs* another but for the personal transport fossil emissions (Raux, Croissant, and Pons 2015).

4.2. Choice experiment

The goal of this choice experiment is to investigate citizens’ preferences for a carbon account policy. Both preferences for different characteristics and preference heterogeneity among citizens will be studied. To convert preferences in a comparable unit, the calculation of willingness to accept (WTA) will translate preference coefficients into monetary terms. WTA values express individual’s willingness to accept a certain value of carbon price in different carbon account scheme situations.

4.2.1. Conceptual framework

Stated preferences (SP) methods consist of a family of techniques to estimate utility functions of individuals by using their statements about their preferences when presenting them a set of options in a hypothetical context (Kroes and Sheldon 1988).

Discrete Choice Experiment (DCE) is a type of stated preference method. They are called choice experiments because respondents are asked to choose between different hypothetical scenarios or alternatives, consisting of a set of attributes with different levels (Kjær 2005). They are qualified as discrete because respondents can only choose one option. The concept underlying choice experiments is the Lancaster's economic theory of value. His theory states that consumers' utility or satisfaction from one good is derived from the attributes or properties of the good, rather than from the good itself (Lancaster 1966). In addition, the decision maker is supposed to maximize his/her utility. This assumption means that the decision maker will chose the alternative that gives him the highest utility given his budget constraint (Train 2002).

DCE theory assumes that utility has both a deterministic and a random component. This implies that the utility derived from the choice of each decision maker will always be characterized by some uncertainty. This random utility theory is based on probabilistic choice theory (McFadden 1973; Manski 1977). The utility derived from alternative *i* by decision maker *n* can be described as follows:

(1) $$U_{in} = V_{in}(X_i, S_n) + \epsilon_{in}$$

In equation 1, the U_{in} represents the total utility of decision maker *n* when he chooses alternative *i*. $V_{in}$is the deterministic part of utility and ϵ_{in} the error term. The deterministic part of utility depends usually on the attributes of alternative *i* (X_i) and on characteristics of the decision maker (S_n). When respondent characteristics are observed (asked in a survey), the function V_{in} can be statistically estimated. The utility contained in the ϵ_{in} error term, such as taste variation, cannot be observed by the researcher. Because of this impossibility, this term will be assumed to be random (Train 2002).

To model the choice made by the respondents in a DCE, it is usually assumed that the deterministic part of the utility U_{in} (equation 2) depends on the attributes selected for the experiment. Attributes are weighted following the respondent preferences. A main-effects additive model is usually giving the following formulation:

(2) $$U_{in} = \beta_{in}\chi_{in} + \epsilon_{in}$$

Where β_{in} represents the vector containing the weighting coefficients and χ_{in} the vector containing the attributes (Kjær 2005).

The uncertainty associated to the utility function makes it impossible to determine which alternative will be preferred by the decision maker. However, probabilities to be chosen can be assigned to each of the alternatives. Still assuming utility maximizing behaviour, the probability that an alternative *i* is preferred over *j* among *J* alternatives, is equal to the probability that the utility of the first is larger than the second. This can be expressed as:

(3) $$P_{in} = P(U_{in} \geq U_{jn}) = P(V_{in} + \epsilon_{in} \geq V_{jn} + \epsilon_{jn}) \; \forall \, j \, \in [1, \ldots, J] \; and \; i \neq j$$

Because there is no information about the random component of utility, one needs to make assumptions to develop operational choice models (Louviere, Hensher, and Swait 2000). The models used for this study and their assumptions are discussed in section 4.3.

4.2.2. Selected attributes and levels

To start a choice experiment, the attributes of the studied object and their levels have to be selected by the researchers. The studied object to evaluate in this master thesis is the price that respondents would agree to pay in different carbon account policy scenarios. There are many alternatives for carbon account design as shown by the literature.

The attributes are derived from the literature and from discussions within the master thesis supervising team. It is important to keep in mind that a large number of attributes exists because there are many alternative schemes. However, for the respondents, a too large number of attributes would make the choice task too complex. In addition, some attributes have interactions with others or even can make other attributes not applicable. For those reasons, a careful selection of the most important attributes was conducted for our case study. Table 4 presents the final selected attributes and their levels. Annex 5 proposes a description of the attributes that could have been included but that were not added in order to reduce the choice experiment complexity.

Table 4 – Selected attributes and levels of attributes

Attribute	Explanation	Attribute levels
Price level	Price that people would pay (or receive) to get (or to sell) extra carbon units per ton (or kilo) of CO_2 emissions	• 10 € / ton • 20 € / ton • 50 € / ton • 100 € / ton • 200 € / ton • 500 € / ton
Price evolution	Mechanism to determine the carbon price. The way to determine the price would affect its volatility.	• Market price resulting from supply and demand • Bordered carbon price evolution (floor and ceiling price) • Price defined by experts with regular revisions
Reduction advice	The carbon account scheme could give access to a dashboard giving personalised advices to reduce carbon emissions and initiatives accessible locally to the account holder	• No advice • Advice
Purchase limit	The carbon account scheme could be implemented with an annual purchase limit. Should an individual exceed the limit, then he would be fined (it can be seen as a gross progressive taxation)	• No limit • Light limit (equal to 2x the actual Belgian individual CO_2 emissions mean) • Strong limit (equal to the actual Belgian individual CO_2 emissions mean)

A. Price level

The price level is an important attribute that will allow to estimate the WTA for different attributes and scenarios. The levels of this attribute are derived from carbon prices estimations from different sources, and ranges from 10 €/ton to 500 €/ton.

Fig. 17 presents global carbon prices trajectories limiting global warming to 2°C with a likely (greater than 66%) probability under different Shared Socioeconomic Pathways (SSP) scenarios (Guivarch and Rogelj 2017). The SSP are scenarios that have been built by the climate change research community. Those are based one five narratives of future possible socio-economic development each including different degrees of sustainability, inequality, fossil fuel, regional rivalry, etc. The SSP have been set up to facilitate the integrated analysis of climate impacts, vulnerabilities, mitigation, and adaptation (Riahi et al. 2017).

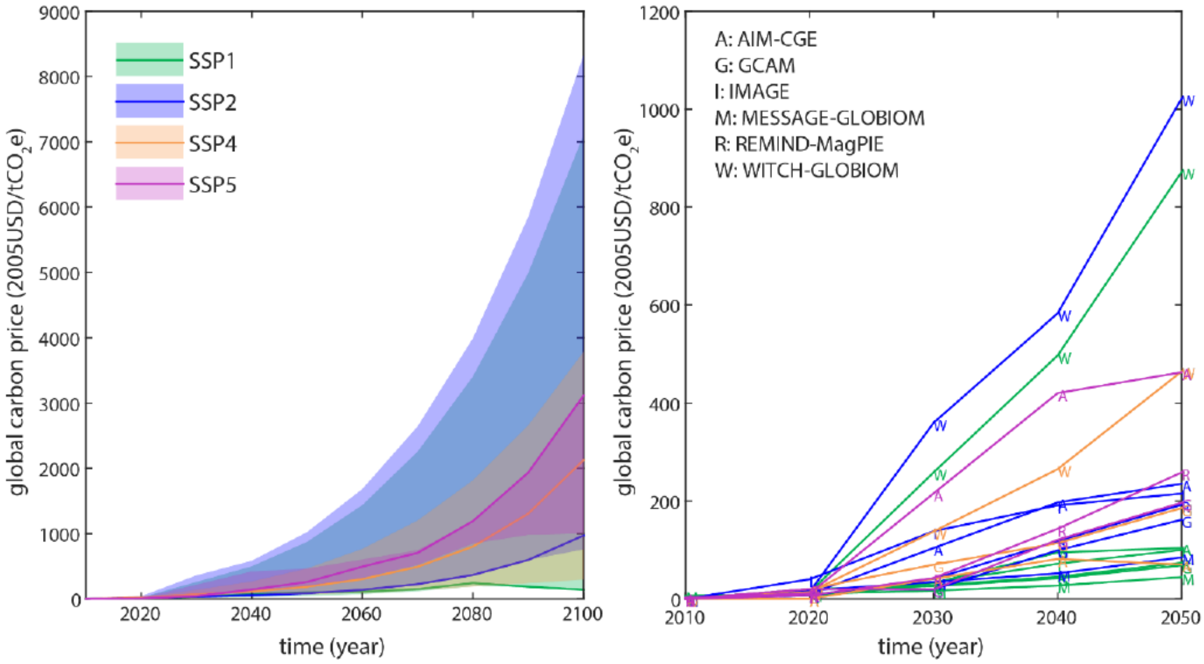


Fig. 17 – Carbon price trajectories from RCP2.6 scenarios limiting warming during the 21st century to below 2°C with a likely (greater than 66%) probability. The left panel shows carbon price trajectories over the entire century per SSP (Shared Socioeconomic Pathways). Shaded areas show the range per SSP and solid lines indicate the carbon price trajectory for the marker implementation of each SSP. The panel on the right shows detailed estimations of six different Integrated Assessment Models (IAMs) represented with capital letters (Guivarch and Rogelj 2017). Note: 100 US $ in 2005 are to be converted as 112,34 € in 2021.

The carbon price presented by Guivarch and Rogelj (2017) range from 15 to 360 USD_{2005}/tCO_2eq[4] in 2030. Four out of the six price level selected for the choice experiment are included within those values. The lowest price level presented in the choice experiment is

[4] In euros of 2021 this represent 17 € to 404 €

10€/ton to be able to capture preferences for price that would be lower than those recommended for climate mitigation, leading therefore to ineffective carbon account policy. The highest carbon price selected for the choice experiment is 500 €/ton. This level of price can reflect the abatement costs or subsidies used for adoption of low-carbon technologies. Those where estimated at 550 €/ton in Germany during 2006-2010 (Marcantonini and Ellerman 2014).

B. Price evolution

Because atmospheric temperature is correlated with carbon concentration of emissions, the goal of 2°C agreed by the states in Paris, is de facto, a carbon cap (Sconfienza 2021). However, the pure cap-and-trade approach is not the only carbon pricing policies that could ensure staying under that cap.

The price evolution attribute is related to whether individuals would dislike a carbon price determined by a pure market mechanism because they fear volatility such as the one that can be observed on the current EU ETS (Fig. 18). When there is volatility, price become less predictable for citizens. Even if some abrupt decreases of price may be appreciated by some citizens in the short run, the unpredictable steep increases on other moments could harm a lot of citizens. In addition to the volatility disagreement, individuals could also fear that there would be no limit to the carbon price with a pure cap-and-trade mechanism. If extreme high carbon price occurs, people may fear not to be able of ending the month with enough money. Other economic actors can also be affected by volatility for their long-term planning activities and investments.

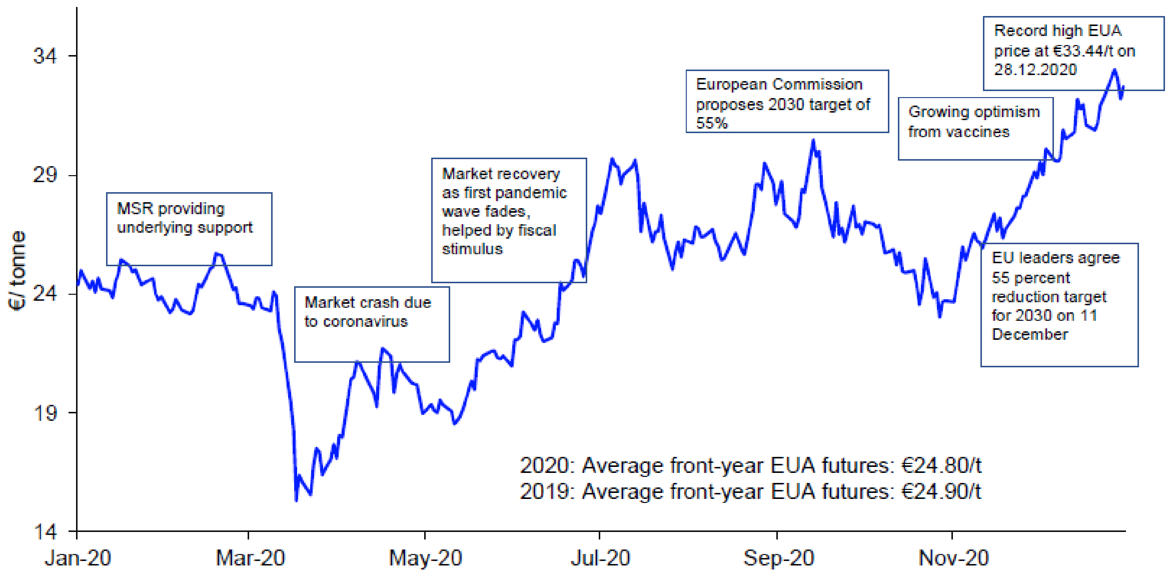


Fig. 18 – Evolution of EUA and effect of external events (Maet and Goossens 2021).

Three attributes have been proposed to investigate the preference of citizens. The first level consists of a price determined by demand and supply on the market. The amounts of units supplied each period would be decided in advance by the political representants, but the carbon demand would result of the carbon unit demand of individuals. An EU market scheme covering all CO_2 emissions would add some uncertainty for goods, services, and energy prices for individuals if they would have to pay it directly[5]. Because the carbon demand is likely to differs from day to day, the price would also consequently vary. This would consequently lead to somewhat more (instead of less) uncertainty in prices for goods, services, and energy (Woerdman and Bolderdijk 2017).

Therefore, preference for a regulated price can be expected to avoid this possibility of very high prices, especially for low-income groups (Bristow et al. 2010). These citizens might be the most affected and the most averse to price uncertainty as they are likely the most risk averse (Bristow et al. 2010).

The second level entails a market price but with a floor and ceiling price that may reduce the aversion of volatility for citizens. This suggestion is based on the practical application of such policies in many markets where a government tries to introduce some security for players. For example, Belgium has a green electricity production market in which individuals receive "green certificates" for electricity produced by their solar PV panels. This market is more controlled and ensures a price floor and ceiling for those certificates (Gravez 2018).

The third level proposes a price fixed by a group of experts. This proposition is less heard in the media but may be interesting to focus on. The idea has been put back recently on the table by the economist Christian Gollier. The idea consists of having an independent group of experts – like the independent experts of the European Central Bank – to determine a stable and progressive carbon price (de Perthuis 2011; 2012; Gollier and Delpla 2019). This central bank could have "the potential to better shield the market from political uncertainty while maintaining flexibility with respect to economic shocks" (Perino and Willner 2017).

C. Reduction advice

In addition to a dashboard the carbon account policy could provide, it can offer advices about how to reduce the footprint of consumption baskets such as substitute goods with lower emission footprints or maps where people can find less impacting products in nearby shops and other local initiatives managed by citizens. The dashboard would also show the mean level of emissions of the region, national and European mean emissions. This comparability is inspired from the Lahiti city carbon unit app where a summary of your own emissions and those of the city was shown (Kuokkanen et al. 2020).

[5] It is to be noted that if citizens would pay it indirectly, for example if only firms would have to pay it (e.g. with the current EU ETS), individuals would be charged of the average price increase but they would be less impacted by the volatility because this latter would be attenuated at the firm level. In fact, intermediate economic actors do not always change their price tag everyday so they can smooth a daily volatility for example.

D. *Purchase limit*

Some individuals might prefer having a limitation on carbon units purchases in order to avoid excessive personal carbon emissions. Other individuals would rather regard a purchase limitation as an excessive constraint on their freedom or access to luxury (Bristow et al. 2010). This attribute and its levels reflect the ideal of some people who want a more equal emission pattern and more expensive excess emissions. In the same vein, Thomas Piketty (2019) proposed a progressive evolution of the cost per emission depending on the level of emissions an individual generates. The more an individual emits, the more it would cost per carbon units (Paris School of Economics 2019). He defends an "individual and progressive carbon tax made possible through the use of a "carbon card" to measure individual consumption" (L'Obs 2019).

This attribute is important to check if people care about carbon emissions inequalities and if they want to do something about it. Today the level of emissions of an individual or an household is positively correlated with its income (Sommer and Kratena 2017; Christis et al. 2019; Lévay et al. 2021). This result holds both at Belgian (Fig. 6) and EU-27 level, but also at regional level as shown by Annex 4 presenting the level of emissions by income deciles in Flanders.

4.2.3. Experimental design

The choice cards faced by respondents includes a pair of options that describe different carbon option policy designs in order to keep the choice task manageable. An opt-out option, representing the status quo scenario, is always presented as the third option for participants. This third option makes the choice situation more realistic to the respondents.

With all the attributes and their different levels, many different carbon account scenarios can be compiled. There is one attribute with six levels, two attributes with three levels and one attribute with two levels. Therefore, it results in 108 (=6*3*3*2) possible carbon account scenarios. If a full factorial design were used, all possible cards would have to be included, and doing this would make it possible to estimate all main and interaction effects between levels of attributes. However, such an experiment would be very long to implement, and cognitively demanding for the respondents: there would be then too many cards.

In order to have the most cards possible we decided to have three blocks of cards presented to their corresponding group of respondents. The number of cards per block of respondents should not be too high because this can provoke respondent fatigue. It is advised to stay between 3 and 12 choices cards per block for this type of survey. As this survey is taking place online, we decided to make 3 blocks with 6 cards in each block, resulting in 18 cards to select among all the combinations possible of the 4 attributes and their levels.

To select optimally the choices cards situations the D-efficiency criterion was used to find an efficient design using the Ngene software (ChoiceMetrics 2018). An efficient design, as an orthogonal design does, tries to minimize the correlation in the data but also works on the minimization of the standard errors of the parameters used in the data. To reach this second property, the efficient design needs to use prior information. With this information, the design can be optimized in a way that the most knowledge is gained from each choice situation and too evident dominance of one alternative over the other can be avoided.

The design results in choice situation where probabilities to choose one of the 3 options (A, B or C) are the most similar possible so that the respondents are obligated to make trade-offs. Without this design, respondent could face cards where a combination of some attribute level dominates each other proposition. No information is gained from such evident choice situation (ChoiceMetrics 2018).

Prior estimates can usually be found from similar past studies or from pilot tests (if sufficiently large). Because this is the first choice experiment about carbon account with Belgian respondents, there were no such precise prior values. However, based on the literature and a choice experiment in the UK context, we were able to make assumptions on the sign of the parameters. The estimates we used were close to zero and with the expected sign. If the price evolution attribute proposed a higher control of price volatility or if advice were given with the carbon account, a positive sign is expected. Conversely, when a restriction on purchase or when a higher carbon price was proposed the sign is expected to be negative as people do not face those constraints today (or without perception if we think about the carbon price in the EU ETS). Finally, it has been hypothesized that people would in general not prefer to adopt a carbon account policy. Using dummy coding, this gave us the following utility function:

$$(4) \qquad \begin{aligned} V(alt1) = \ & b_1(-0.001) * Plevel + b_2(0.01) * Pevolution\_BOR \\ & + b_3(0.02) * Pevolution\_EXP \ + b_4(0.01) * Radvices \\ & + b_5(-0.01) * Plimit\_LIGHT + b_6(-0.02) * Plimit\_STRONG \end{aligned}$$

$$(5) \qquad \begin{aligned} V(alt2) = \ & b_1(-0.001) * Plevel + b_2(0.01) * Pevolution\_BOR \\ & + b_3(0.02) * Pevolution\_EXP \ + b_4(0.01) * Radvices \\ & + b_5(-0.01) * Plimit\_LIGHT \ + b_6(-0.02) * Plimit\_STRONG \end{aligned}$$

$$(6) \qquad V(alt3) = \ b_0(0.01)$$

The efficient design was calculated using the Ngene software (ChoiceMetrics 2018). It was specified that the design should be made to estimate a multinomial logit model.

4.2.4. Implementation and content of the survey

The survey was designed to be conducted online. Therefore, a Google Forms online survey was used because this software is user-friendly for respondents and can be both suitable for laptop and mobile online survey. The idea of the survey was to involve as many different people as possible among the French-speaking habitants of Belgium. There was in advance a greater probability that the majority of respondents would be students and researchers and their relatives, even if respondents were asked to disseminate the survey around them.

The first questions in the survey were collecting general socio-economic information about respondents. Other information such as their EU climate policy knowledge and carbon account knowledge was also collected. All those data can be used as explanatory variables to investigate preference heterogeneity. For the respondents to be able to make reasonable choices latter in the questionnaire, an estimation of the current level of emission of respondents was realised based on Fig. 19.

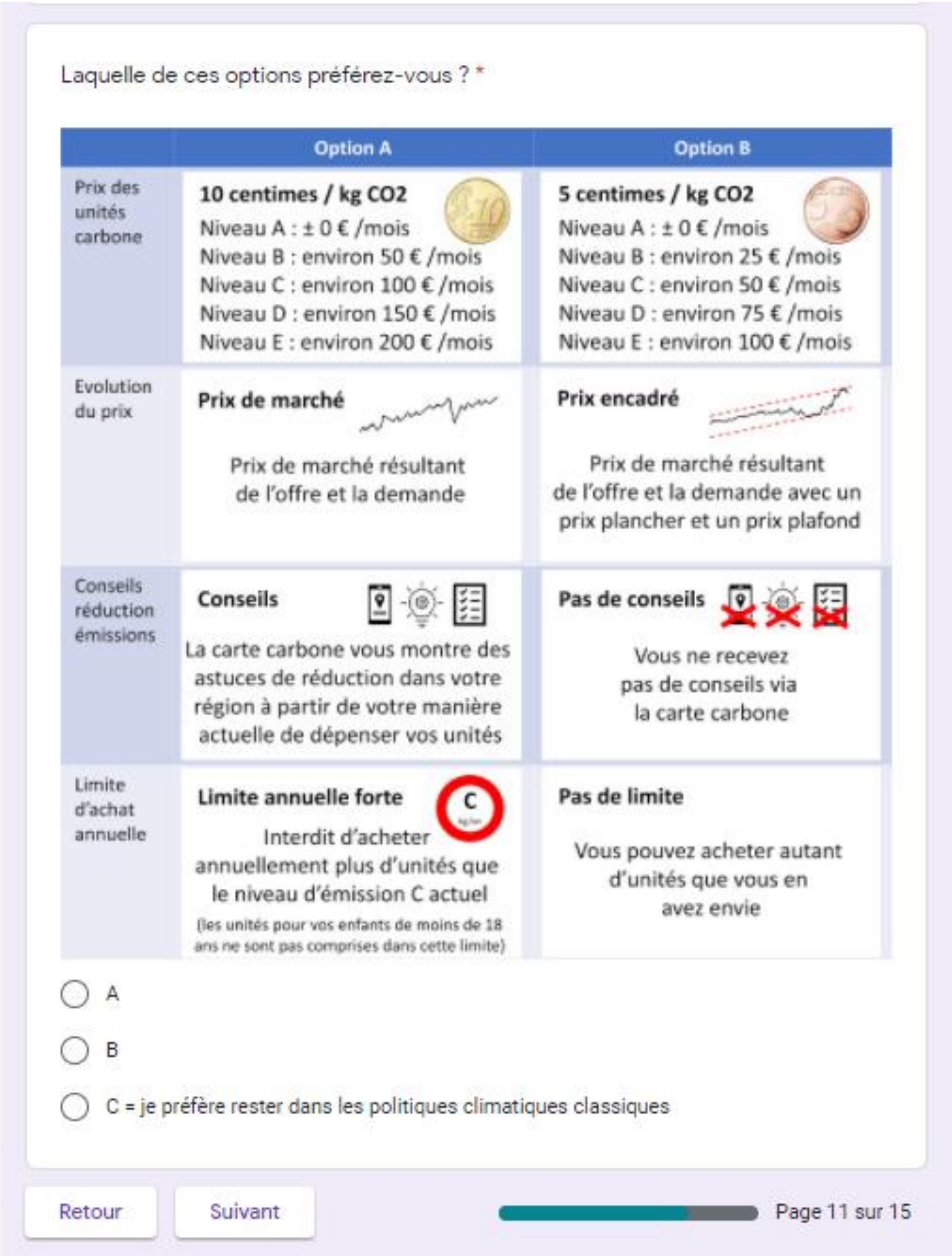
With this table, the respondents were first asked to select in each line all the cases that corresponded to their actual lifestyle. Then, a latter question asked them to only choose 1 level of emission (A, B, C, D or E) that would represent their level of emission. Of course, this procedure can only make a gross estimation, but this survey design was chosen because of its user-friendliness. There are a lot of online website to make more detailed and precise emissions footprint available, but our choice experiment did not necessitate such a precision.

	A	B	C	D	E
Vacances (votre type de mobilité)	Vélo, train, bus, tram, métro	Covoiturage (à plus de 2)	Avion/voiture 1x/an, en Europe	Avion/voiture + de 1x/an, en Europe	Avion/voiture 1x/an ou +, hors Europe
Semaine (mobilité job, loisir, achats)	Vélo, train, bus, tram, métro	Covoiturage (à plus de 2)	Voiture moyenne	Voiture type berline	Voiture type SUV
Logement (bâti et type de chauffage)	Totalement passif et pas de chauffage	Quasi passif avec pompe à chaleur	Bâti récent, chaudière au gaz ou fioul	Peu isolé et chaudière au gaz	Vieux bâti et chaudière au fioul
Surface (m^2 habitable dispo/pers)	Très petit ou très partagé [±20m²/pers]	Petit ou partagé [±30m²/pers]	Moyen [±40m²/pers]	Spacieux [±60m²/pers]	Très spacieux (ou 2$^{\text{ème}}$ résid) [±80m²/pers]
Dépenses (estimées par vos revenus)	Très basses (très bas revenus)	Basses (bas revenus)	Moyennes (revenus moyens)	Hautes (hauts revenus)	Très hautes (très hauts revenus)

Fig. 19 – Gross estimation of respondent's emissions level

After a summary of the carbon account system (Annex 6), the respondents receive an overview of all the attributes and levels of attributes that could appear in the choice cards (Annex 7). The core choice experiment was then introduced with the presentation of the six choice cards. The order of apparition of the choice cards was random so that no card would be subject to more fatigue from the respondents.

Moreover, respondents were told to make their choice as if the carbon account would be their everyday live reality. To facilitate their choice a calculation of their monthly expected expenditure in carbon units was presented depending on their lifestyle. The 18 situations were transformed in 18 choice cards with text and illustration of the level of attributes to make the choices more pleasant and understandable to participants (Fig. 20). Finally, respondents were asked if they ignored some attributes for the choices they made.



Laquelle de ces options préférez-vous ? *

	Option A	Option B
Prix des unités carbone	**10 centimes / kg CO2** Niveau A : ± 0 € /mois Niveau B : environ 50 € /mois Niveau C : environ 100 € /mois Niveau D : environ 150 € /mois Niveau E : environ 200 € /mois	**5 centimes / kg CO2** Niveau A : ± 0 € /mois Niveau B : environ 25 € /mois Niveau C : environ 50 € /mois Niveau D : environ 75 € /mois Niveau E : environ 100 € /mois
Evolution du prix	**Prix de marché** Prix de marché résultant de l'offre et la demande	**Prix encadré** Prix de marché résultant de l'offre et la demande avec un prix plancher et un prix plafond
Conseils réduction émissions	**Conseils** La carte carbone vous montre des astuces de réduction dans votre région à partir de votre manière actuelle de dépenser vos unités	**Pas de conseils** Vous ne recevez pas de conseils via la carte carbone
Limite d'achat annuelle	**Limite annuelle forte** Interdit d'acheter annuellement plus d'unités que le niveau d'émission C actuel (les unités pour vos enfants de moins de 18 ans ne sont pas comprises dans cette limite)	**Pas de limite** Vous pouvez acheter autant d'unités que vous en avez envie

◯ A

◯ B

◯ C = je préfère rester dans les politiques climatiques classiques

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Fig. 20 – Example of a choice card used in the choice experiment.

4.3. Econometric approach

The goals of the following statistical analysis are (i) to estimate the utility function of French-speaking inhabitants of Belgium for key characteristics of a carbon account policy (these characteristics being level of attributes), (ii) to identify preference heterogeneity and sources thereof, (iii) to estimate the willingness to accept carbon prices in a carbon account scheme. Among all the statistical models that have been developed to estimate the parameters of a utility function, the simplest is the conditional logit or multinomial logit (MNL) model, which can be written as follow:

(7) $$P_i = \frac{1}{\sum_{j=1}^{J} \exp\, -(V_i - V_j)}$$

In equation 7, P_i is the probability that alternative *i* is selected out of *J* alternatives. V_i and V_j are the deterministic parts of the utility associated with the alternatives *i* and *j*. This model relies on the Independence-from-Irrelevant-Alternatives (IIA) axiom. This axiom states that the ratio of the probabilities of selecting one alternative over another is not influenced by the presence or absence of additional alternatives in the choice set. For an MNL model, this means that it is assumed that the random components of utility are independent and identically distributed across alternatives. If those two assumptions are not valid, results might be biased (Louviere, Hensher, and Swait 2000). It is important to keep in mind that a MNL model is well able to represent heterogeneity linked to the observed characteristics but cannot capture random variation in preferences (Train 2002). Because of this limitation, it can be interesting to use more complex model such as the Mixed Logit (MXL) model and the Latent Class (LC) model. The statistical software Stata 16 was used for all the model estimations.

4.3.1. Mixed Logit model

The MNL model has thus three limitations but the Mixed Logit (MXL) model, also named the Random Parameters Logit, can overcome them. First, the MXL can relax the IIA assumption by allowing for unrestricted substitution patterns. Second, this model is not restricted to situations where unobserved factors are independent, and the model allows for random taste variation. Finally, the coefficient β of the utility function are allowed to vary aver decision makers with a density f(β) and this can be very useful for our situation. MXL models are the integrals of standards logit probabilities over the density of the parameters (Train 2002).

(8) $$P_i = \int L_i(\beta) f(\beta) d\beta$$

Where $L_i(\beta)$ is the logit probability evaluated at the parameters β:

(9) $$L_i = \frac{\exp\,(V_i(\beta))}{\sum_{j=1}^{J} \exp\,(V_j(\beta))}$$

All the attributes' parameters are included in the model. The alternative specific constant (ASC), an additional parameter, is also added. The use of an ASC can be interesting to capture the (dis)utility associated with the status quo option (here: staying with classical EU and Belgian climate policies). When a decision maker chooses to opt out, the ASC is set to one but when he rather chooses one of the two carbon account proposals, the value is then fixed to zero.

The qualitative attributes (all the attributes except the price level) are coded using dummy coding. This method makes it easier to interpret the estimations. The estimates of the parameters and their standard deviation over the decision makers in the sample are the output that will be the most relevant for the analysis. An indication of the presence of heterogeneity in the sample will be given by the significance levels of the standard deviations. Because the MXL model cannot capture where the sources of heterogeneity are, an approach with a latent class model will also be used after.

4.3.2. Latent Class model

Latent class models (LC) are relying on the idea that a population of decision makers can be described as a compilation of different classes or segments, each one being characterised by a unique preference pattern (Louviere, Hensher, and Swait 2000; Birol, Karousakis, and Koundouri 2006). Therefore, this model states that respondents' characteristics indirectly affect choice trough the impact on segment membership (Birol, Karousakis, and Koundouri 2006). Some researchers argue that such LC are more interpretable than MXL models (Sagebiel 2017).

The LC can be seen as a sort of mixed logit model where the mixing distribution would be simplified by a discrete distribution that takes as many values as there are classes in the population (Train 2002). This approach gives a final number of classes, with each one having their own utility function and choice probabilities. Homogenous preferences but also independent and identically distributed error terms can be assumed within each of this classes (Louviere, Hensher, and Swait 2000). In such model individuals can be assigned into different classes, based on an unobserved membership likelihood function. This function will depend on variables related to latent general attitude and perceptions, potentially combined with socio-economic data about the decision maker (Boxall and Adamowicz 2002).

4.4. Willingness to accept

The modelling results will finally be used to estimate the willingness to accept (WTA) different carbon account schemes. WTA is expressed in monetary terms. Those monetary values are derived from the marginal rate of substitution between the price level attribute and another attribute, holding all else constant, and they are calculated as the ratio between the two parameters (Louviere, Hensher, and Swait 2000; De Marchi et al. 2020).

(10) $$Marginal\ WTA = -\frac{\beta_{attribute}}{\beta_{price}}$$

With $\beta_{attribute}$ corresponding to the estimated coefficients of the non-price attribute in the utility function and β_{price} representing the estimated coefficient of price.

The calculation of the WTA directly with the estimates of the MXL model, could lead to bias. This is because distributional assumptions are made on the distribution of coefficient and these distributions are used to derive the distribution of the WTAs. When this estimation is done, this is called an estimation in preference space. This estimation generally leads to a very large variance of WTA distributions. To solve this problem, WTA is here estimated in WTA space, meaning that the distributional assumptions are placed directly on the WTAs and the price coefficient (Train and Weeks 2005). It is also possible to calculate WTA with latent class model. The advantage with this method is that WTA can directly be estimated with the formula presented above as coefficient are assumed to not vary among respondents.

WTAs indicates at which level of carbon price a Belgian citizen could accept to enter a specific carbon account scheme compared to his actual situation. If people are accepting a high price, it is because they state that they are more willing to change behaviour to reduce emissions under a carbon account scheme than with current climate policies.

5. Results

5.1. Sample description

Table 5 summarizes the respondents' characteristics in our sample. The average respondent is 31 years old, which is younger than the 41 years Belgian mean. Nearly half of the respondents choose to identify their gender as female. The respondents were at 18.35% living in the Brussels-Capital Region. The level of education is here summarized by the 3 main groups: 25.54% of respondents with a secondary school certificate, 29.50% with a bachelor's degree and 42.09% holding a master's degree. The proportion of respondents reporting there were student is 46.40%. Globally, the sample is not representative of the Belgian population, as respondents tend to be younger, higher educated or still enrolled as student, and are more likely to live in Brussels.

Table 5 – Socio-economic characteristics of respondents

	Belgium	Sample			
	Mean[1]	Mean	St. Dev.[2]	Min	Max
Individual characteristics					
Age	40,84	31,20	13,42	17	86
Female (%)	50,75	48,92			
Habitant of Brussels-Capital Region (%)	10,60	18,35			
Primary school certificate[3] (%)	10,80	2,88			
Secondary school certificate (%)	55,10	25,54			
Bachelor's degree (%)	16,60	29,50			
Master's degree (%)	17,50	42,09			
Student (%)	-	46,40			
Household's characteristics					
Less than 2000 €/month[4] (%)	-	14,75			
Between 2000 and 5000 €/month (%)	-	53,24			
More than 5000€/month (%)	-	15,83			
Household income not reported (%)	-	16,19			
Number of adults in the household	-	2,94	1,70	1	11
Number of children in the household	-	0,53	0,93	0	5

The sample consists of 278 observations.

[1] If not specified, data are coming from Statbel database (Statbel 2020b)

[2] Abbreviation for Standard Deviation

[3] Instruction of population (% of population aged more than 15 years) (Statbel 2020a)

[4] In Belgium, the net income per habitant is of 1564 (€/month) (Statbel 2018)

The net total household income was less than 2000 €/month for 14.75% of the respondents, between 2000 and 5000 € for 53.24% and superior to 5000 €/month for 15.83%. A share of 16.19% did not report their household income because they did not know it or did not want to report it in the survey. On average the household had 2.94 adults and 0.53 children.

The survey also explored the self-reported current knowledge of respondents about current EU climate policies (Fig. 21). A large majority of respondents (68.35%) stated to know EU climate policies a little while 7.91% claimed to know them well. Only 2 respondents (0.72%)

stated to know the EU climate policies very well. Finally, 23.02% claimed that they did not know them at all. Another binary question showed that 34.53% of respondents previously heard about carbon account policy systems.

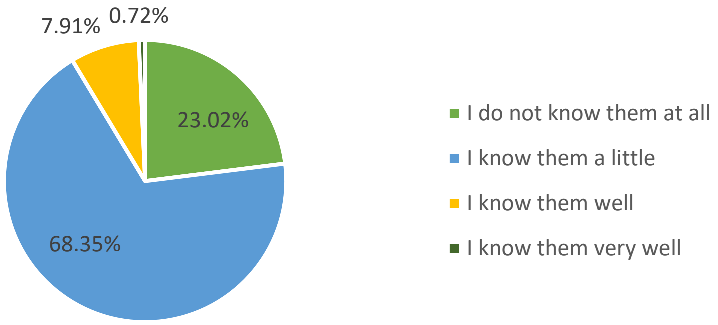

Fig. 21 – Answers to the question “Do you know the actual climate policies of the EU?”

Based on the table presented in Fig. 19, the respondents reported the actual levels of emission that corresponded the best to their actual lifestyle. Results show (Fig. 22) that the majority of respondents (61.15%) identified themselves in the mean category (C). For other categories, there were 3.6% in A, 21.58% in B, 12.23% in D and 1.44% in E. This indicates a larger proportion of respondents with comparatively lower emissions than the Belgian mean (C).

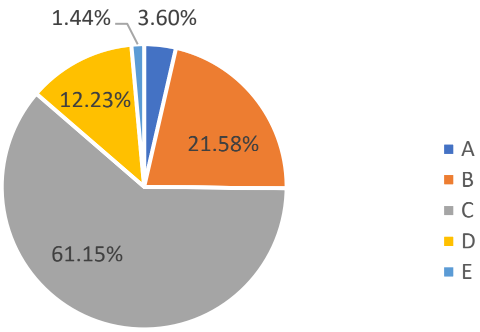

Fig. 22 – Estimation of emissions levels of respondents
based on the table presented in the survey

5.2. Choice experiment: sample preferences and preference heterogeneity analysis

The choice experiment, presenting three alternatives on six different cards presented to 278 respondents results in 5004 observations to be analysed (3*6*278). The number of choice situations is 1668 (6*278) because respondents could only choose one of the three alternatives for each card. 18 respondents selected the opt-out option for all their six cards presented. It is impossible to derive whether they genuinely do not want to adopt a carbon account, or they were simply not interested in the CE. As a robustness check, the models were analysed with and without these respondents, but results were similar - hence their inclusion in all the models.

Respondents could state in the survey the attribute that helped them the most to make their choices (whatever the direction). The results show that the annual limit attribute and the price were the most important (25% and 24%), while the reduction advice and the price evolution where less often presented as the most important for their choices (17% and 7%). Finally, 27% stated they cared about the global combinations and they did not want to highlight a particular attribute.

5.2.1. Mixed logit (MXL) model

Table 6 shows the MXL estimation and the WTA estimations in WTA space related to this model. The ASC estimate is significant and negative, meaning that the utility associated with the selection of the *status quo* alternative is negative. This indicates that the respondents preferred in general to enter a carbon account policy with the selected attribute than choosing the *status quo* scenario. The negative WTA estimate of the ASC shows also that respondent generally lose utility by not entering into the presented carbon account scheme.

Results shows that respondents prefer a carbon account scheme with a lower carbon unit price that is regulated either by a floor and ceiling price or determined by experts instead of a free-market price, that offers advice on emission behaviour, and that contains annual purchase limitations.

All the attribute and their levels are significant for the mean estimates. For the standard deviation, only the estimates for the price floor and ceiling and the price defined by expert attribute levels are not significant; it means that those are not subjected to different preferences among the respondents. For the advice and the annual limit attribute, the MXL model shows that respondents had preference difference, even if they are not the priority of most of the respondents. This indicates that an analysis with a Latent Class model (LC) could also be useful to see the different responses among the different classes (see below 4.2.2).

In the MXL, the WTA estimates (5th column in Table 6) are to be translated as the amount of money (in €) that people are willing to pay for 1t CO_2 in a scheme where the attribute level chosen is present compared to a scheme where this attribute is at the reference level. This reference is a scenario where (i) there is no carbon pricing for all CO_2 emissions (ii) if there is a carbon market it is planned to be a pure cap-and-trade (iii) there is no advice offered (iv) and finally there are no fines applied if some people would go beyond an emissions limit.

Table 6 – Results of the Mixed Logit model and estimation of the WTA[1] in WTA space

	Mean Coef. [2]	**Std. err.** [3]		**SD**[4] **Coef.**	**Std. err.**		**WTA**	**WTA (95% interval)**	
ASC[5]	-4.337	(0.755)	***	5.342	(0.729)	***	-1710.71	-2518.04	-1073.35
Carbon unit price (€/ton)	-0.003	(0.000)	***						
Price floor and ceiling	0.591	(0.110)	***	-0.039	(0.276)		233.10	149.62	332.28
Price defined by experts	0.553	(0.110)	***	0.004	(0.392)		218.26	134.16	312.69
Advice offered	1.019	(0.111)	***	0.948	(0.140)	***	401.77	313.51	518.44
Annual limit: 27t	0.661	(0.115)	***	0.714	(0.219)	***	260.69	171.70	369.62
Annual limit: 15t	0.375	(0.134)	***	1.361	(0.193)	***	147.92	47.44	257.02
Observations	5004								
Log likelihood	-1203.51								

*p<0.1, **p<0.05, ***p<0.01

[1] Willingness to Accept; [2] Coefficient; [3] Standard error; [4] Standard Deviation ; [5] Alternative Specific Constant

Because the per capita Belgian CO_2 emission mean is 15 tons and that the carbon account scheme ensured free access to 3 tons of CO_2 per year in the first years, the mean emitter would have to pay for 12 tons of emissions, or in other words approximately 1t per month. WTA results can here therefore approximate the price that the mean emitters would accept to pay per month to get his carbon units of the month to cover his emissions. Results shows that the mean respondents are willing to pay around 233€/t CO_2 more for a scheme where he/she is sure that there is a carbon price floor and ceiling rather than a pure market mechanism. The estimates show also that respondents would generally accept to pay more for the carbon units if they receive advice about how to reduce emissions or if an annual limit with fines is applied. Main results of this first stage analysis are summarized in the box below.

Box 1. Summary findings from the MXL model

1) Globally respondents are interested in the carbon account scheme proposed
2) Having a price floor and ceiling or a price defined by expert increases the utility for respondents
3) Respondents are largely interested by advice to reduce emissions
4) Respondents show interest for fines applied when going beyond some limits
5) All attributes are significantly heterogenous among respondents except the price evolution attributes

5.2.2 Latent Class model

Determining the optimal number of classes for the analysis requires a balanced assessment of the statistics presented in Table 7. The presence of multiple classes in our sample is supported by the log likelihood improvement when more classes are added. The model with three classes fits the best to the sample since, although AIC and BIC decrease when more classes are added, the change is much smaller from three to four classes.

Table 7 – Criteria for determining the optimal number of classes

No. of classes	Log likelihood	Parameters	AIC[1]	BIC[2]
2	-1247.288	15	2593.99	2578.99
3	-1194.449	23	2541.334	2518.334
4	-1167.679	31	2540.814	2509.814

[1] Akaike Information Criterion; [2] Bayesian Information Criterion

A. *Comparison of the probabilities to belonging to a certain class*

The socio-economic characteristics of the three classes are compared in Table 8, using a one-sided t-test. Looking to individual socio-economic characteristics, this table shows that respondents are older in class 1. This class has also a lower student share as it can be expected from the older age of the members of this class. The class 2 is a class that has a higher probability to live in Brussels.

Regarding household characteristics, the results show that class 3 has a lower probability to be composed of respondents living in household with lower income. The class 1 is composed of a larger share of household with high income compared to the class 2.

Knowledge of EU climate policies is not significantly correlated with the probability to belong to one class rather than another. Conversely, the fact that people already heard about carbon account policies, whatever the type of proposal, increases the probability to belong to class 2 and, decreases the probability to belong to class 1. Following the same type of distribution, the lower emitters (emissions level of A, B, or C regrouped together) are less represented in Class 1 and 3.

Finally, the age variable can be transformed in age categories to decompose the inter-generational variation of opinions about the carbon account presented in the survey. Results shows that the group aged 15-29 is the most represent in class 2, near followed by class 3. The group aged 45-59 is however more represented in class 1, underlying a generational variation of opinion in the sample.

Table 8 – Comparison of the latent classes using one-sided t-test and proportion test

	Class 1 Class share = 16.1%		Test 1-2[2]		Class 2 Class share = 38.9%		Test 2-3		Class 3 Class share = 45.0%		Test 3-1	
	Mean	se[1]	t[3]	pr[4]	Mean	se	t	pr	Mean	se	t	pr
Individual characteristics												
Age	**36,17**	16,62	***		**29,43**	12,05			**30,86**	12,92	**	
Female (%)	**58,70**	49,78			**44,76**	49,96			**48,82**	50,18		
Living in Brussels (%)	**17,39**	38,32			**24,76**	43,37		**	**13,39**	34,18		
Primary certificate (%)	**0,00**	0,00			**3,81**	19,23			**3,15**	17,53		
Secondary certificate (%)	**23,91**	43,13			**24,76**	43,37			**26,77**	44,45		
Bachelor's degree (%)	**28,26**	45,52			**29,52**	45,83			**29,92**	45,97		
Master's degree (%)	**47,83**	50,50			**41,90**	49,58			**40,16**	49,22		
Student (%)	**32,61**	47,40		*	**47,62**	50,18			**50,39**	50,20		**
Household characteristics												
Income less than 2000 €/month (%)	**23,91**	43,13			**18,10**	38,68		**	**8,66**	28,24		***
Income between 2000 and 5000 €/month (%)	**45,65**	50,36			**50,48**	50,24			**58,27**	49,51		
Income higher than 5000€/month (%)	**21,74**	41,70		*	**11,43**	31,97			**17,32**	37,99		
Number of adults in the household	**2,67**	1,45			**2,99**	1,98			**3,01**	1,54		
Number of children in the household	**0,52**	1,01			**0,45**	0,85			**0,59**	0,97		
Individual climate policy knowledge												
Knowing min a little of EU climate policies (%)	**73,91**	44,40			**81,90**	38,68			**74,02**	44,03		
Already heard about carbon account policies (%)	**17,39**	38,32		***	**47,62**	50,18		***	**29,92**	45,97		*
Individual emission level												
Low emitters (A, B, and C emission level together) (%)	**80,43**	40,11		*	**91,43**	28,13		*	**84,25**	36,57		
Individual's category of age												
Aged between 15-29 (%)	**50,00**	50,55		***	**73,33**	44,43			**68,50**	46,63		**
Aged between 30-44 (%)	**19,57**	40,11			**14,29**	35,16			**14,17**	35,02		
Aged between 45-69 (%)	**19,57**	40,11		*	**8,57**	28,13			**12,60**	33,31		
Aged between 60-74 (%)	**8,70**	28,49			**2,86**	16,74			**3,94**	19,52		
Aged between 75-89 (%)	**2,17**	14,74			**0,95**	9,76			**0,79**	8,87		

One sided t-test with *p<0.1, **p<0.05, ***p<0.01

[1] Standard error; [2] Here tests are comparing whether the means of Class 1 and Class 2 are significantly different or not; [3] T-test; [4] Proportion-test

Box 2. Reading of Table 8

1) Stars indicate where there is a significant statistical difference between two classes for a particular characteristic presented in each row
2) Then, comparing the means indicates whether the level of a characteristic is higher or lower than in the other classes

B. Description of attribute preference heterogeneity

Table 9 summarizes the results of the latent class analysis with three classes and the WTA related to the coefficients. Respondents have the lowest likelihood to belong to class 1 (16.1%) but higher likelihood to be member of class 2 (38.9%) or class 3 (45%). The coefficients of the table show that the preferences vary a lot between the different classes.

The first class ('Latent Class 1' in the table below) regroups respondents that have a positive ASC coefficient. This means that those respondents do not perceive the carbon account as interesting for them because their utility globally decreases by entering the carbon account proposal they encountered. If respondents of this class would enter into a carbon account scheme, they prefer a price floor and ceiling rather than an uncontrolled market price. The estimate shows that they also prefer a price defined by experts compared to an uncontrolled market price. This class is finally also sensible to the advice offered but less than the other classes that have similar level of interest for this attribute. For the annual limit, no WTA could be calculated because of the non-significance of those attributes.

Table 9 – Results of the Latent Class model with related WTA[1]

	Latent Class 1				**Latent Class 2**				**Latent Class 3**			
	Class share = 16.1%				**Class share = 38.9%**				**Class share = 45.0%**			
	Coef. [2]	**Std. err.** [3]		**WTA**	**Coef.**	**Std. err.**		**WTA**	**Coef.**	**Std. err.**		**WTA**
ASC[4]	2.270	(0.500)	***	568	-1.783	(0.544)	***	-1783	-2.779	(0.484)	***	-926
Carbon unit price	-0.004	(0.001)	***	n.a.	-0.001	(0.000)	*	n.a.	-0.003	(0.000)	***	n.a.
Price floor and ceiling	0.699	(0.348)	**	175	0.467	(0.173)	***	467	0.422	(0.185)	**	141
Price defined by experts	0.797	(0.367)	**	199	0.516	(0.172)	***	516	0.434	(0.164)	***	145
Advice offered	1.073	(0.304)	***	268	0.405	(0.166)	**	405	1.286	(0.197)	***	429
Annual limit: 27t	0.117	(0.344)		0	1.539	(0.300)	***	1539	-0.382	(0.229)	*	-127
Annual limit: 15t	-0.720	(0.438)		0	1.737	(0.323)	***	1737	-1.068	(0.363)	***	-356
Observations	5004											
Log likelihood	-1194.4											
AIC	2541.3											
BIC	2518.3											

* p<0.1 ** p<0.05 *** p<0.01

[1] Willingness to Accept; [2] Coefficient; [3] Standard error; [4] Alternative Specific Constant

The second class ('Latent Class 2' in the table above) has the highest WTA a carbon account proposal. They are the class that is willing to pay higher prices than the other class, as shown by the small price coefficient and the high WTA in general. Those respondents have increased utility for carbon account schemes with a price defined by experts. Their WTA for advice is higher than the first class. Surprisingly, their utility for the limitation attribute increases if there is a light annual limit proposed and even more if the annual limit is stronger.

The last class has (as the class 2) a negative ASC meaning that on average they also prefer to enter a carbon account scheme (see ‘Latent Class 3’ in the table above). Their preference for the carbon price evolution attributes is lower than the class 2, while still positive. They have however a higher WTA for advice offered compared to class 1. This class is finally significantly very different from the class 2 for the negative WTA of its respondents for annual limits. This means that those respondents prefer to reject the idea of having fines if they go beyond an annual limit of emissions. Estimates shows that the stronger the limit, the more they dislike.

To summarize, class 1 comprises respondents who generally prefer to reject the carbon account policy presented in the survey, class 2 as the class of respondents preferring the carbon account and even more when there are limits and the class 3 as the class where respondents also prefer the carbon account policy but less when there are limits.

6. Discussion

6.1. Interpretation of the choice experiment models

6.1.1. Preferences for carbon account in general

The results show first that a large proportion of the sample (84%) is favourable to a carbon account policy. This level is higher than a previous study on a wide range of attributes that showed that the acceptability of a carbon account policy could range, in the UK context in 2010, from 17% to 80% depending on the level of attribute presented (Bristow et al. 2010).

The different types of our respondents have heterogenous preferences. Generally, people in favour of such a policy seems to be younger, students, more aware of carbon account policies and emitting less CO_2. This may reflect a difference between younger generations more aware of the climate crisis and the emission reduction to be made and older generations.

6.1.2. Preferences for price evolution

Results show that respondents prefer having a policy designed to control for carbon price volatility. This result holds for all the three classes. The difference between the preference for the price floor and ceiling attribute and the price fixed by experts is small. Whether this difference is insignificant or not, is not straightforward. Hence another model has been used with price defined by experts being the reference level. This model showed not significant difference between the price floor and ceiling compared to the price defined by experts.

It seems that the most important criterion of choice for the respondents is that there is a mechanism containing the price volatility whatever the nature of this tool. This supports the intuition that people are guided more by the aversion of a non-controlled price rather than a strict preference for one of the three alternatives. A study in the UK context showed however a significant preference for price annually fixed by the government compared to a free market mechanism. The same study found no significant difference between a scheme with a free market and a market on which the government would set a ceiling (Bristow et al. 2010). The authors explain that the preference for the price fixed by the government may be preferred because citizens expect lower carbon prices if it is the responsibility of the government to define it. However, this explanation is not relevant for our case as the third level of attribute represented a less volatile carbon price defined by experts but not by governments.

6.1.3. Preferences for emission reduction advice

This attribute is preferred by all respondents. This means that people are willing to accept carbon unit cost if they receive advice to reduce their emissions. This preference can be explained by the difficulty of some respondents to find ways to adapt their everyday ways of live. Even if a lot of information is now available on the internet and with advice firms, it seems that respondents prefer to have advice directly presented to them rather than to have to do research on the internet or to have to call or to ask for some advice. A carbon account could help them to have more personalised advices as those can be built on the expenditure compared to advice services in firms and on internet where you would first have to give a lot of information before receiving advices. As an example, the simple exercise of calculating the precise carbon footprint of an individual alone can take a lot of time and energy. In fact, an advisor is typically asking people a lot of information. This can ask a lot of time or even be impossible when people do not remember their expenditures (e.g. their total annual expenditure in clothing and what percentage of each clothes).

6.1.4. Preferences for annual emission limit

In the UK context, a limit corresponding to the double of the mean emissions was preferred compared to a situation where there would be no limit on emissions associated with the carbon account (Bristow et al. 2010). Our results show however a large heterogeneity of preferences for the attribute capturing the limitation on the individual annual emissions. Some respondents are highly interested in personal annual limitations of carbon emissions with a principle of fines if you overpass a certain threshold. But others truly reject this idea when it is presented to them.

Among the respondents not rejecting the carbon account idea, people in favour of limits are more likely to live in Brussels, to have heard about carbon account policies, and have a lower net household income and emission level. The fact that people from Brussels are more interested by limits is probably because there are more opportunities in cities such as Brussels to reduce its personal emissions. There are much more transport facilities in the Brussels region than in the rest of Belgium. There are also a lot of jointed houses and opportunities to do cohousing. The impact of cohousing can be significant, as at the EU-27 level, an average household of five person reaches the half of carbon emissions/capita compared to a household of one person (Ivanova and Büchs 2020). It is important to recall that transport and housing are two sectors where emissions are consequent both at EU-27 (Fig. 4) and Belgian level (Fig. 6). In the EU-27, transportation is a sector that increased its emissions while the building sector is decreasing its emissions but could go faster (Fig. 4).

Having lower household income and choosing limits could be explained by the fact that this could globally ask more efforts for the richer people. People choosing the limit option certainly see in this limit a guarantee that richer people will not be able of emitting a lot while just paying a relative low share of their income to buy carbon units. Some people are in fact afraid with all carbon price policies that richer people will just buy more carbon units or pay carbon taxes but emit the same quantity of emissions, letting the burden of the reductions to the poor (Bristow et al. 2010; Chamberlin 2021). The lower income preference for individual limitation is in line with the results of the previous study in the UK context (Bristow et al. 2010).

For the previous knowledge of carbon account scheme, the respondent's preference can come from the fact that personal limitations on carbon emissions can be very strange and abrupt if people hear this idea for the first time. If people have previously had the time to think twice about it they may consider this as a still interesting solution.

Finally, having lower emissions than the actual Belgian mean can motivate respondents to ask others to have limits. People with lower emissions experience lifestyles that they do not see as impossible to be adopted by others to live well. On the other hand, the dislike of limitations can be explained as it entails restrictions in consumption behaviour.

6.2. Research implications

6.2.1. Limitations

The sample size was sufficient to get statistically significant results but not large and diverse enough to be representative of the Belgian population. Half of the sample was composed of students. This is of course not representative of the Belgian mean. Other characteristics deviate also from the Belgian mean and even further from the EU-27 statistics.

Choice experiments are always based on stated preferences so hypothetical bias might be present. For example, it is possible that some young people are so motivated by climate questions that they selected the highest carbon price possible in order to express the fact that they are ready to pay every kind of price level as long as the Paris Agreement climate targets or even more ambitious targets are met. In choice experiments people do not pay for real and as a consequence they might state that they are willing to pay more than what they would do in reality. The results in this choice experiment show higher carbon prices than the mean carbon prices recommended by economists to mitigate climate change. The results are thus certainly subject to stated preference bias. To go beyond this limitation real experiments could be implemented. Other choice experiments should evaluate the other specific aspects that are impossible to be tested without a real carbon account policy implementation.

6.2.2. Further research perspectives

Reducing the emissions requires changes in the consumption patterns that may be experienced by many as restrictive and can therefore only be accepted if the public is convinced that these changes are necessary to maintain the conditions for a good quality of human life on earth. Therefore, the question of public acceptability is crucial for any emission reduction policy and should be pushed further. It would be interesting to conduct a choice experiment at European level and study the acceptability and the preference heterogeneity of people across countries. The acceptability of a carbon account should be also compared with other taxes and quotas policies with different attributes. Besides, the costs of all the technical implementation of the policy for the different scenarios should also be assessed.

Globally the design of a choice experiment for samples representative of the EU-27 countries could be inspired by the one presented in this master thesis. Attributes presented in this study but not selected or even other attributes could be tested in such experiments. Different more detailed rates of progressivity (from slow and smooth to rapid and abrupt) should also be explored.

The visibility and social norm mechanisms could be examined further with different interdisciplinary approaches to evaluate the magnitude of their potential to help people reduce their emissions. The political coalition/party able to defend a carbon account could also be studied even as the potential law barriers and accelerators.

6.3. Public policy implications

6.3.1. Adopting the EU carbon account proposal?

The experiment shows a high interest of some part of the population in the carbon account tool as a public policy to mitigate climate change. Therefore, the EU Parliament, the Commission and the Members states should consider the possibility of implementing a carbon account system at the EU level. As shown in section 3, some steps can already be implemented without any obligation to go to a final carbon account scheme. The two first steps can already have impacts on the reduction of emission and should therefore be seriously considered by the EU.

6.3.2. Under which conditions will acceptability increase?

There are many ways to implement carbon account public policies. Our analysis shows that some are more supported by citizens.

- Reducing price volatility

Giving a price to carbon is key for the future. But in order to increase the acceptability of a carbon account policy, policy makers should consider that citizens fear market volatility. A price signal can trigger change in citizens' behaviours. Previous carbon account policies proposals did not really pay attention to how prices are defined and how potential volatility is linked to the system. The results show that respondents are more likely to accept a carbon account if there are specific mechanisms to control the carbon price volatility. Policy-makers should also investigate the benefits of achieving a progressive carbon pricing system as it seems to please a non-negligible part of the population, particularly among young people.

- Going further than carbon price signal

For carbon pricing policies, a price signal is not enough. If citizens do not know what to change, carbon pricing policies will not be as effective as possible. Developing personalised emission reduction advices is another key feature of carbon account public policies. Our analysis stresses the importance for policy-makers to understand that many citizens seem to be interested by obtaining more information on ways to reduce their carbon emissions. The carbon account policy presented here is a tool to (i) give the right incentives to citizens to change their behaviours to reduce their carbon footprint achieve and, at the same time, (ii) present them some tips and existing solutions to change as fast as possible. To be short: incentives for behavioural changes with useful information into one single instrument. In the absence of carbon account policy, governments will have to respond to this demand by increasing or supporting services for personalised advices. For students, governments should coordinate with the educational sector to improve the information of reductions possible within the teaching sessions. For non-student and specifically baby-boomers, other creative information campaigns have to be developed. A likely consequence is the uncoordinated multiplication of supports and initiatives. Conversely, a carbon account is also a unique communication channel that can be used for the dissemination of personalized information based on the observation of consumption behaviour. This obviously raises questions that the analysis does not address here such as respect for privacy, the use of big data, etc.

- Intergenerational difference

Climate policies without a generalized coordination between generations will lack effectiveness. The survey showed heterogeneity of preferences among generations. This implies that policy-makers should gather around the table a more diverse intergenerational panel when designing further a carbon account policy and anticipating on its acceptability and effectiveness.

- Paying attention to the distribution of individual emissions

The ensured minimum free allocation seems to have pleased the respondents because a majority of respondents were willing to enter the carbon account scheme they were proposed and that the framing always included a free allocation. This allocation could have been appreciated by respondents because it can be seen as protecting the essential needs of individuals. Therefore, policies should think about the distribution of efforts to be made within the society. Guaranteeing that everybody can emit a part of the collective emission budget without having to do efforts for those because they would be freely allocated can be one of the policies envisaged.

Globally, the sample was willing to pay for annual limits on emissions. However, a careful look at the preference heterogeneity for the limitation attribute (by the use of extra fines) shows that a share of 45.0% of the respondents where quite reluctant to this principle while a share of 38.9% was highly willing to pay for system with higher carbon price when going beyond some limits. Those groups have radically different opinions about this question. Policy makers and researchers should think about and design systems that could make compromises between those two visions. This thesis presented only the option of no limitations at all *vs* abrupt carbon price increase (by the use of fines) beyond a unique threshold of individual carbon emissions. The compromise could be a progressively increasing carbon price: the higher the annual individual level of emissions, the higher the price per carbon unit for this individual.

Therefore, a carbon account policy could be one of the few tools to achieve a progressive pricing depending on individual level of emissions so governments should take it into account. If a progressive pricing carbon account is not implementable directly, governments can consider implementing alternative policies that have the same target: putting more pressure on the high emitters. As example, government can think about putting higher carbon price for activities mainly considered as non-essential such as: small distance aviation, spatial vacation, indoor ski, quad, etc. However, this list is not so long, and more and more people would argue that the targeted activities are essential to them. A carbon account may therefore be the least intrusive/interfering on personal preferences while achieving progressive carbon pricing.

- What about a carbon account for an EU-subgroup or other countries of the world?

The proposal as presented here applies directly to the EU-27 context, as it would be senseless to propose such a scheme at the Belgian level, a very small country with a lot of open borders. However, a group of EU countries could also try to implement it if they can make their group scheme in line with the EU treaties. Of course, countries outside EU could also think about such a system to be implemented nationally or within a group of countries. Today big emitters such as US and China should certainly put this idea on their agenda for a nationally implemented scheme. Finally, the UK, having now realized its Brexit can think about transforming its UK ETS progressively into a carbon account policy.

If some countries want to be added later to an existing carbon account scheme, the carbon account proposal presented here would make it possible because the free emissions allocation (same emission target for all humans in 2050) could easily be done at the same level with the added country and a new (merged) common annual quantity of emission.

7. Conclusion

Climate change threatens human societies and the ecosystems around them. To mitigate climate change, several types of public policies have been designed. Carbon account policies are climate mitigation policies through which carbon units are allocated to individual end-users who must return them whenever they purchase some or all types of goods and services involving carbon emissions. Starting from the 1990s, several types of schemes have been proposed by various authors.

In this thesis, an end-user carbon account policy proposal has been designed for the EU-27 level starting from its current cornerstone tool, namely the EU Emission Trading System (EU ETS). The proposal has been designed to be implemented in three steps, each of which bringing its own potential benefits: (i) EU ETS shift to all fossil fuels points of entry (importation and extraction); (ii) setting up a carbon accounting in each enterprise in order to be able to make the carbon impact of each product or service visible to end-users; and (iii) setting up end user carbon accounts for citizens.

The implementation of this proposal up to the third step is subject to several conditions among which public acceptance is of crucial importance. In addition, several important issues to be considered have been identified among which: (i) the demand for price volatility control mechanisms; (ii) the demand for targeted reduction advice; and (iii) the demand for emissions limit in the form of high fines for emitters above a certain threshold. Hence, a choice experiment has been constructed to address these issues. The findings of the choice experiment conducted in the context of this master thesis are summarized below.

Firstly, a large majority of the sample is willing to accept the carbon account scheme presented in this master thesis. However, this sample is likely not representative for the whole EU-27 or Belgian population, as it was composed of younger people with a large share of students.

Secondly, respondents of the choice experiment expressed a clear preference for mechanisms that would reduce price volatility. This issue is important because if the carbon price is expressed directly to citizens, they could feel more the volatility compared to a situation where they would be exposed to it indirectly via carbon prices at firms' level.

Thirdly, all respondents declared high interest for tailor-made carbon advices. The carbon account policy is in fact a public tool that could easily introduce advices to help citizens reduce their carbon emissions. Generalisation of carbon account is expected to make tailor-made carbon advices much cheaper than the same advices offered in the present context where experts have to spend a lot of time asking each citizen about their expenditure. With a carbon account policy, the carbon emissions of each product and services would be collected and citizens could themselves choose the information on which they want to get advices.

Fourthly, respondents were divided on whether limits should be set on emissions trough high fines for individual emissions above a threshold. The carbon account, with this latter option, may be one of the few public policy tools able to ensure a basic access to energy services for all while imposing progressively higher carbon price on higher emitters. Therefore, further research should continue to investigate this progressive carbon pricing possibility with different degrees of progressivity.

Finally, the analysis of the variation of preferences showed that younger generations tend to have preferences that differ from those of older generations, highlighting inter-generational divergence of opinion on climate policies attributes, especially on the issue of progressive carbon pricing. These differences are important to consider. Gathering around the same table people of different ages when building policies may be a good idea to find creative solutions for all sort of climate policies.

Not all issues raised by a carbon account policy have been addressed in this master thesis. Here are some questions to explore in complementary researches. The question of the free initial allocation is something that remains unanswered in the context of this master thesis and the debate should be pursued. Therefore, research should not stay confined to carbon account proposals where all carbon units are directly allocated to individuals with no units left to generate revenues for government to be actor of the transition. Researchers should feel free to think and present systems where only a part of the emissions are given free to citizens so that progressive carbon pricing can be put in place if demanded. Such designs allow also that some revenues can be collected by the governments in order to be able to take the place of a key actor in the energetic transition and a more targeted help for households in energy poverty. In fact, the choice experiment conducted in the frame of this master thesis suggests that a large majority of respondents were willing to enter such kind of policy.

Preferences of the population regarding the areas and magnitude of action of the government should also be studied further. Other unanswered questions such as the governance of an end-user carbon account policy should be studied further. The questions to progressively include other GHG, if measures are sufficiently accurate and scalable, is also to be raised. Impacts on different types of socio-economic indicators could be interesting to analyse. Whether classical tax and cap-trade policies would be able to achieve emission reduction further than 50 or 60% should also be analysed considering that massive social contestations can occur with even small price increases. Questions on how to correctly communicate over carbon account policies are also to be raised.

Reduction of carbon emissions, a global public problem, is difficult to grasp on the citizen's side. It is a recurrent difficulty to sustain efforts to change their ways of life. A diminishing carbon credit is a simple way to translate the climate boundaries and their evolution into personal boundaries within which the maximum possible personal freedom of choice is kept. So far, for citizens, the carbon account policy is the only public tool that can bring our societies a decisive step further. The results and the unexplored intuitions of this thesis are paths to future exciting research.

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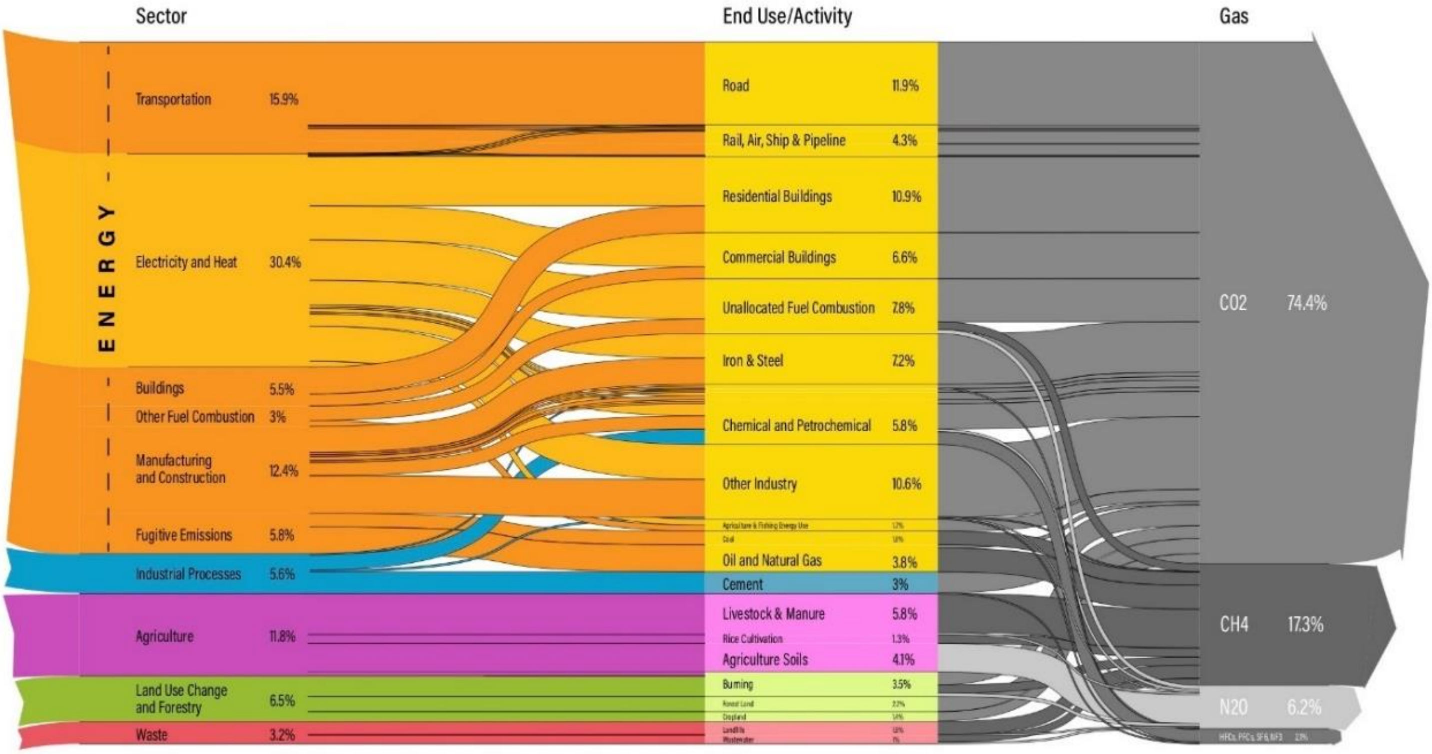
Annexes

Annex 1 – World greenhouse gas emissions



Annex 1. World greenhouse gas emissions in 2016 by sector, end-use and gas (World Resources Institute 2016). The energy sector represents 73,2% of the GHG emissions in CO2eq and is the major responsible of CO2 emissions.

Annex 2 – Remaining carbon budget

Additional Warming since 2006–2015 [°C]*(1)	Approximate Warming since 1850–1900 [°C]*(1)	Remaining Carbon Budget (Excluding Additional Earth System Feedbacks*(5)) [$GtCO_2$ from 1.1.2018]*(2)			Key Uncertainties and Variations*(4)					
		Percentiles of TCRE *(3)			Earth System Feedbacks *(5)	Non-CO_2 scenario variation *(6)	Non-CO_2 forcing and response uncertainty	TCRE distribution uncertainty *(7)	Historical temperature uncertainty *(1)	Recent emissions uncertainty *(8)
		33rd	*50th*	*67th*	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*
0.3		290	160	80						
0.4		530	350	230						
0.5		770	530	380						
0.53	**~1.5°C**	**840**	**580**	**420**	Budgets on the left are reduced by about –100 on centennial time scales	±250	–400 to +200	+100 to +200	±250	±20
0.6		1010	710	530						
0.63		1080	770	570						
0.7		1240	900	680						
0.78		1440	1040	800						
0.8		1480	1080	830						
0.9		1720	1260	980						
1		1960	1450	1130						
1.03	**~2°C**	2030	1500	1170						
1.1		2200	1630	1280						
1.13		2270	1690	1320						
1.2		2440	1820	1430						

Annex 2. The assessed remaining carbon budget and its uncertainties (IPCC 2018a, p108.)

Shaded blue horizontal bands illustrate the uncertainty in historical temperature increase from the 1850–1900 base period until the 2006–2015 period as estimated from global near-surface air temperatures, which impacts the additional warming until a specific temperature limit like 1.5°C or 2°C relative to the 1850–1900 period. Shaded grey cells indicate values for when historical temperature increase is estimated from a blend of near-surface air temperatures over land and sea ice regions and sea-surface temperatures over oceans.

*(1) Chapter 1 has assessed historical warming between the 1850–1900 and 2006–2015 periods to be 0.87°C with a ±0.12°C likely (1-standard deviation) range, and global near-surface air temperature to be 0.97°C. The temperature changes from the 2006–2015 period are expressed in changes of global near-surface air temperature.

*(2) Historical CO2 emissions since the middle of the 1850–1900 historical base period (mid-1875) are estimated at 1940 GtCO2 (1640–2240 GtCO2, one standard deviation range) until end 2010. Since 1 January 2011, an additional 290 GtCO2 (270–310 GtCO2, one sigma range) has been emitted until the end of 2017 (Le Quéré et al., 2018).

*(3) TCRE: transient climate response to cumulative emissions of carbon, assessed by AR5 to fall likely between 0.8–2.5°C/1000 PgC (Collins et al., 2013), considering a normal distribution consistent with AR5 (Stocker et al., 2013). Values are rounded to the nearest 10 GtCO2.

*(4) Focussing on the impact of various key uncertainties on median budgets for 0.53°C of additional warming.

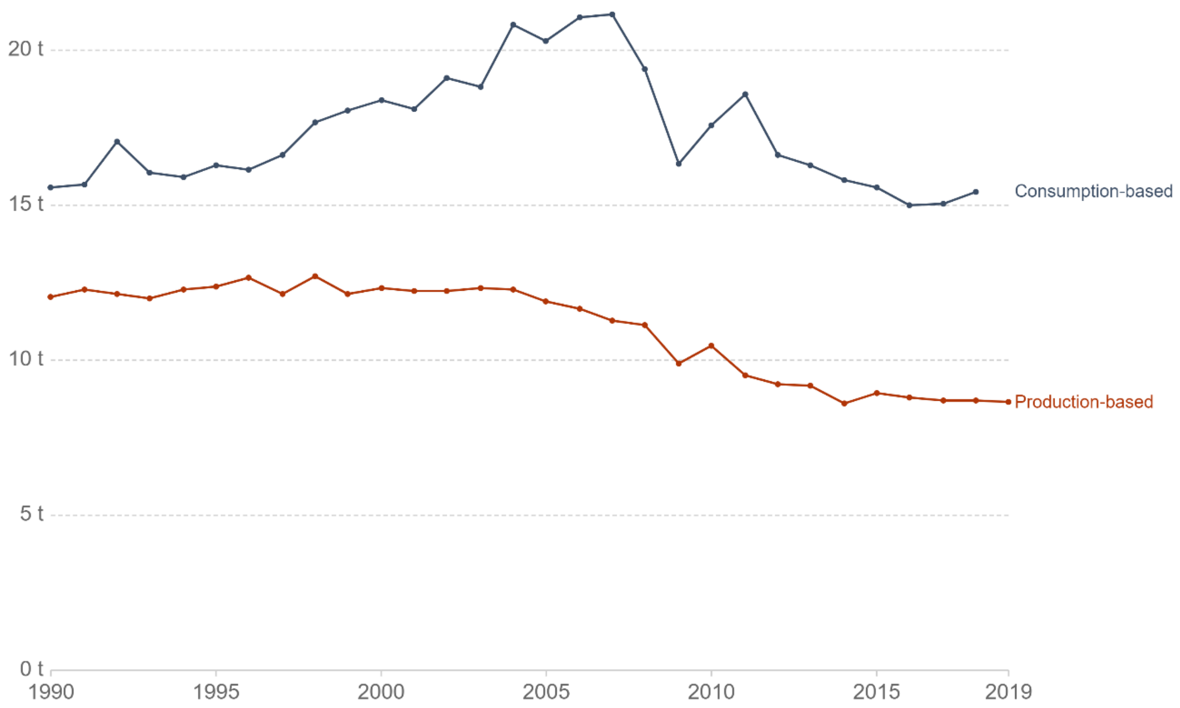
*(5) Earth system feedbacks include CO2 released by permafrost thawing or methane released by wetlands, see main text.

*(6) Variations due to different scenario assumptions related to the future evolution of non-CO2 emissions.

*(7) The distribution of TCRE is not precisely defined. Here the influence of assuming a lognormal instead of a normal distribution shown.

*(8) Historical emissions uncertainty reflects the uncertainty in historical emissions since 1 January 2011.

Annex 3 – Production vs consumption CO_2 emissions in Belgium



Annex 3. Evolution of production vs. consumption-based CO_2 emissions, Belgium [ton of CO_2 per capita] (Our World in Data 2019). Note: This measures CO_2 emissions from fossil fuels and cement production only.

Annex 4 – Detailed household carbon footprint in Flanders

Annex 4. Summary of the results of the household carbon footprint per COICOP-domain for Flanders (2010). The average household carbon footprint (a) is further detailed across household characteristics (b-h). Note that panels (a), and (b) provide footprints per household, while panels (g) and (h) provide footprints per person (Christis et al. 2019)

Annex 5 – Rejected attributes

This annex proposes a description of the attributes that could have been included but that were not added in order to reduce the choice experiment complexity.

A. *Use of data*

As many citizens are concerned with privacy questions, this attribute would have been interesting how far they fear that the scheme would threatens their privacy (Ogden 2001). However, in the choice experiment it was clearly explained that all private data policies rules would be respected. This respect of privacy is completely possible and the fact that nobody can know what an individual bought in a supermarket is a good example. There is, for current carbon account policies proposals, no impossibility to protect and secure personal data with effective and transparent safeguards (Woerdman and Bolderdijk 2017).

B. *Sale limit*

Some authors suggest that a sale limit could be a safeguard for a carbon account policy. The idea is that a person able to sell units would be limited to not sell all his/her unit in order to avoid carbon inequality or carbon poverty (Sconfienza 2021).

C. *Excess units*

Qualitative studies previous to the study of Bristow in 2010 indicate that some low emitters would prefer rather to keep or retire units than letting high emitters have access to them(Prescott 2007; Harwatt 2008). More generally, it could be expected that individuals with excess units would prefer having the choice on the use of units rather than to be forced to sell them (Bristow et al. 2010). The PhD thesis of Harwatt about carbon units systems shows that some individuals prefer to give their excess carbon units to friends and/or relatives (Harwatt 2008).

Personal carbon units may be perceived as giving individuals more choices than a carbon tax, as personal units could be decided to be destroyed to stop the use of them by others (Wadud, Noland, and Graham 2008).

The introduction of personal carbon units can transform carbon into a visible resource that can be managed by individuals (Capstick and Lewis 2010; Zanni, Bristow, and Wardman 2013). Capstick and Lewis call this the "endowment effect", an established tendency to place relatively higher value on resources already owned by an individual. In psychological terms, the introduction of personal carbon units could increase the individual "engagement" in the goal of achieving emissions reductions because individual would feel the scheme as an "immediate" and more direct way to "exercise responsibility" (Fleming 1997; Starkey and Anderson 2005).

D. *Carbon unit lifetime*

This attribute could be seen as interesting for people to be allowed to keep personal unused carbon units for the years when they would face unexpected personal needs. However, allowing to have level for this attribute would have had implications on other attributes and would have complexified the choice task.

In addition, some authors show that carbon units that people could save for later use would simply destroy all the effectiveness of the scheme because the carbon units would increase in value more rapidly than other assets in the economy because of the speed at with emissions have to be reduced. This would result in a situation of everybody wants to buy units at the start of the scheme and then always wanting to sell them after the longest time period possible (Gollier and Delpla 2019). This explains why a too long period would destroy the effectiveness of the scheme for carbon units. It is important to notice that this remark does not necessarily apply to other tradable permits for other environmental goods services. For the choice experiment the lifetime has been fixed to 1 month.

E. *Governance of objectives and future modifications*

Policies that last and that are validated by the public are policy that have in themselves mechanisms to evolve to adapt to new unplanned circumstances. An attribute capturing the preference of the public for the determination of some important goals of the system and the evolution of it could be interesting to include in further research.

F. *Account management and technology*

Another concern about a carbon account scheme could be the question of which entities are responsible to manage carbon units. Even if in all options it would be logic to have regular audits from a mandated EU Agency, there are different possibilities to implement the carbon account. A first option could be to ask banks to do this work alongside the classical account with different specific rules. Another solution is to mandate a national or European agency. Finally, it is also thinkable to have new specialized actor using new technologies such as blockchains. Further research could evaluate public preferences related to this attribute.

G. *Initial allocation*

For a matter of simplicity, the carbon account scheme presented in the choice experiment proposes an equal per capita allocation per capita at the level to be reached in 2050. However, this is one of the possibilities among a large variety of ways to do initial allocation.

This attribute is highly correlated to the perception of fairness. There are different criteria to assess whether a policy can be considered as fair, and many attributes could be proposed to evaluate citizens preferences. For example, people may perceive a policy as fair if everyone is affected equally (equality principle, e.g. interdiction of single use plastics in the EU), but also if policy affect individuals relative to their share in the problem (polluter-pays principle) (Woerdman and Bolderdijk 2017).

Whatever the proposed scheme, there is no way to avoid that some groups of individuals will claim unfair treatment, because they feel more impacted that others. If some people feel that they are not able to reduce their consumption patterns, they could see the obligation to buy extra allowances as unfair. In some case people react only because they do not like changes.

The idea of equal per capita allocation can come from the idea of protecting the low-income people that are in majority the lowest emitters (Starkey and Anderson 2005). Many studies show that the higher the mean income of a group the higher are the mean emissions of this group (Sommer and Kratena 2017; Christis et al. 2019). The gross effect of the equal per capita carbon unit allocation has the potential to distribute wealth among income group in a way that would reduce gross income inequalities. This reduction of inequalities can be seen as fairer than the current system (Woerdman and Bolderdijk 2017). The principle that the individuals that emit more will be affected more negatively than those who emit less, can be considered as fair from an equity point of view (Woerdman and Bolderdijk 2017).

However, it is important to check the distribution of the impact on more vulnerable groups and find solutions for them. A study in the UK highlighted that it is essential to pay attention on low-income household, people living in the countryside, or with poorly insulated homes (Thumim and White 2008). This is because of this little group of vulnerable low-income people with important emissions that some researchers have proposed that governments could held back some allowances to be distributed to those who submit successful applications for additional allowances based on unchosen exceptional circumstances (Hyams 2009). However, to achieve the concrete realization of the latter proposal this would require agreements on the eligibility criteria with can consume a lot of time. This could also reduce the acceptability because of increased complexity (Szuba 2014). In addition, this could favour counter-effective behaviours, e.g. if individuals increasing voluntarily their emissions to receive more allowances (de Touzalin 2020). Finally, conventional money help could be sufficient to help them.

A last point about fairness concerns the inter-generational fairness. A system that puts a price on carbon can be seen as a policy that protect the interest of future generation. Previous research has found that policies that protect next generations are considered as fairer and more acceptable by the public (Schuitema, Steg, and van Kruining 2011).

H. Use of revenues

Not all carbon account schemes would generate revenues by the sale of carbon units as this depends on the initial allocation option chosen. A lot of attributes could be tested here but for the simplicity, the choice experiment was framed with a rule of 50% of revenues used for energy transition and 50% to help household in energy poverty. However, in reality there could be a larger range of possibilities.

Annex 6 – The carbon account summary presented to respondents

Pourquoi une carte carbone ?

Pour respecter l'Accord de Paris, les émissions fossiles mondiales doivent au moins descendre à 1200kg de CO2/personne avant 2050, autrement dit une moyenne de 100kg/mois par personne.

Imaginez que pour y arriver, l'UE lance une "carte carbone" c'est-à-dire l'équivalent d'une carte bancaire mais avec des unités carbone à débourser pour tout achat de bien ou service générant des émissions de CO2 (par l'utilisation directe et indirecte de combustibles fossiles).

La carte carbone serait utilisée pour toutes les dépenses carbone privées. Les Etats assumeraient les autres émissions, c'est à-dire celles qui relèvent des biens et services publics (enseignement, santé, défense, déchets, infrastructures publiques, etc).

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Mise en contexte

1) La carte carbone indique le niveau à atteindre et donne une base à tous

- Chaque mois, l'UE distribuerait gratuitement 100kg de CO2 (en unités carbone) à chaque adulte. Ces 100kg représentent le niveau à atteindre avant 2050 et garantissent un minimum pour toute personne.

- Chaque mois, selon que vous utilisiez plus ou moins que ces 100kg, vous devriez soit acheter soit revendre des unités. Au niveau d'émissions A vous n'auriez en moyenne pas d'unités à acheter.

2) La carte vous offre une visibilité sur vos émissions et des conseils pour les réduire

- L'UE imposerait à toute entreprise d'indiquer le montant d'émissions de CO2 direct et indirect, sur tous les biens et services. Ce système forcerait les entreprises à réduire leurs émissions.

- Votre carte carbone vous permettrait de voir quels étaient vos achats qui vous ont demandés le plus d'unités carbone et elle pourrait aussi vous offrir des conseils pour réduire vos émissions.

3) La carte carbone garantit une réduction des émissions

- Pour le bon fonctionnement du système, il a été fixé que les unités ne sont valides que durant le mois auquel elles ont été reçues ou achetées.

- Les Etats seraient obligés de dépenser l'argent perçu par les achats des unités carbone à raison de 50% dans la transition énergétique et 50% dans l'aide aux ménages dans la précarité énergétique.

Annex 6. The carbon account summary presented to respondents.

Annex 7 – Attribute and level of attribute explanations presented to respondents

Vous êtes arrivés aux 6 cartes de choix !

Comment fonctionnent les cartes de choix ?

Les cartes de choix sont caractérisées par 4 critères avec différentes possibilités. Avant d'utiliser les cartes de choix (en bleu) veuillez prendre connaissance des différentes possibilités au sein des 4 critères

Critère 1 : Prix des unités (6 possibilités) :

Regardez la ligne de votre niveau d'émission (A,B,C,D ou E) et observez le cout du total de vos unités carbone du mois. Nous avons déjà déduit les 100 kg offerts chaque mois, cela explique que le niveau A aurait un cout moyen de 0 euros/mois. Les niveaux sont à titre indicatif.

1 centime / kg CO2

Niveau A : ± 0 € /mois
Niveau B : environ 5 € /mois
Niveau C : environ 10 € /mois
Niveau D : environ 15 € /mois
Niveau E : environ 20 € /mois

2 centimes / kg CO2

Niveau A : ± 0 € /mois
Niveau B : environ 10 € /mois
Niveau C : environ 20 € /mois
Niveau D : environ 30 € /mois
Niveau E : environ 40 € /mois

5 centimes / kg CO2

Niveau A : ± 0 € /mois
Niveau B : environ 25 € /mois
Niveau C : environ 50 € /mois
Niveau D : environ 75 € /mois
Niveau E : environ 100 € /mois

10 centimes / kg CO2

Niveau A : ± 0 € /mois
Niveau B : environ 50 € /mois
Niveau C : environ 100 € /mois
Niveau D : environ 150 € /mois
Niveau E : environ 200 € /mois

20 centimes / kg CO2

Niveau A : ± 0 € /mois
Niveau B : environ 100 € /mois
Niveau C : environ 200 € /mois
Niveau D : environ 300 € /mois
Niveau E : environ 400 € /mois

50 centimes / kg CO2

Niveau A : ± 0 € /mois
Niveau B : environ 250 € /mois
Niveau C : environ 500 € /mois
Niveau D : environ 750 € /mois
Niveau E : environ 1000 € /mois

Critère 2 : Evolution du prix (3 possibilités) :

Prix de marché

Prix de marché résultant
de l'offre et la demande

Prix encadré

Prix de marché résultant
de l'offre et la demande avec un
prix plancher et un prix plafond

Prix des experts

Prix défini à l'avance
par des experts
avec révisions régulières

Critère 3 : Conseils de réduction pour vos émissions (2 possibilités) :

Conseils

La carte carbone vous montre des astuces de réduction dans votre région à partir de votre manière actuelle de dépenser vos unités

Pas de conseils

Vous ne recevez pas de conseils via la carte carbone

Critère 4 : Limite d'achat annuelle (3 possibilités) :

Pour la limite annuelle légère et forte, la sanction pour qui dépasserait la limite d'achat est de devoir payer des amendes sévères. Plus une personne serait au delà de la limite, plus les kg supplémentaires de CO2 seraient chers en amendes.

Pas de limite

Vous pouvez acheter autant d'unités que vous en avez envie

Limite annuelle légère E

Interdit d'acheter annuellement plus d'unités que le niveau d'émission E actuel

(les unités pour vos enfants de moins de 18 ans ne sont pas comprises dans cette limite)

Limite annuelle forte C

Interdit d'acheter annuellement plus d'unités que le niveau d'émission C actuel

(les unités pour vos enfants de moins de 18 ans ne sont pas comprises dans cette limite)

A vous de jouer !

Sur les 6 cartes suivantes, veuillez faire votre choix entre les 3 options proposés (A, B ou C). Assurez-vous de choisir tel que vous le feriez si l'option choisie devenait réelle pour vous.

Pour en savoir plus sur l'option C :

Cochez l'option C quand vous préférez les politiques climatiques classiques en Belgique et Union Européenne qui visent à donner un prix au carbone (quotas et taxes classiques).

Annex 7. Attribute and level of attribute explanations presented to respondents.

Designing an End-User Carbon Account Scheme as a climate policy tool in the EU context

Arnaud Van Der Cam

Climate change threatens human societies and the ecosystems around them. Aware of the urgency, public decision-makers, experts, and other stakeholders are developing public policies aimed at reducing emissions, limiting the global warming and, already, preparing, with more or less means, adaptation to less favourable living conditions.

To coordinate the actors, putting a price on carbon is a well-accepted strategy. But this is not enough. Measures that will apply at different scales need to be worked out in details. Among the tools designed, carbon account policies rely on the allocation of carbon units to individual end-users. The principle is simple: households must return carbon units during their purchases, according to the carbon footprint of the goods and services they buy. The availability of carbon units would be reduced each year to be in line with climate change mitigation targets.

The design of new public policies is a difficult exercise. To increase the effectiveness of climate policies, it would be particularly useful to test their acceptability by citizens before implementing them. This study assesses the preferences of Belgian citizens for an end-user carbon account scheme and the acceptability of different designs.

Its organization is as follows. First, a review of scientists' and experts' proposals is presented in order to introduce the reader to the main public policy instruments. Second, an original end-user carbon account proposal is developed, following past proposals and developments by scientists and experts. It is a policy that could be deployed on European territory. Third, to assess its acceptability by citizens, a choice experiment is designed. The characteristics of this new public policy that are selected for the experience are: the level of carbon price, the potential volatility of price, the provision of tailor-made carbon advice, and the presence of higher carbon price for people emitting beyond a certain threshold of annual emissions.

The results indicate that a majority of participants is willing to accept the end-user carbon account scheme. Among the respondents, preferences for carbon account attributes are heterogenous. Three groups of respondents can be distinguished. The first group, the smallest, was not interested to enter a carbon account policy and was composed of people that were globally older and with higher emission levels. The second and third groups were both willing to accept a carbon account scheme and expressed both interest in carbon pricing mechanisms that reduce volatility. They prefer more tailor-made carbon advices. Finally, the third group preferred to have no higher carbon price when going higher than a threshold, while the second group expressed a high interest for the concept of higher carbon price above a certain limit of annual emissions. While reminding the limits of the analysis resulting from the sample used, the conclusion stresses the interest of this innovative proposal and the first-ever choice experiment applied to an EU carbon account policy proposal and, finally, the importance of bringing together generations of citizens with different preferences as to the characteristics that will guarantee this tool a strong acceptability.

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