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Ex-ante evaluation of EU ETS during 2013–2030: EU-internal abatement

Jing Hu [a,*], Wina Crijns-Graus [a], Long Lam [b], Alyssa Gilbert [b]

[a] Copernicus Institute of Sustainable Development, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands
[b] Ecofys, Kanaalweg 16 G, 3526 KL, The Netherlands

HIGHLIGHTS

- Quantification of CO_2 emission abatement in the EU resulting from the ETS up to 2030.
- The impact of policy interventions and the inclusion of aviation is quantified.
- The effectiveness of EU ETS in EU-internal abatement is limited until 2023.

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ABSTRACT

This study investigates CO_2 emission reduction within the EU resulting from the Emissions Trading Scheme (ETS) up to 2030. This is performed by constructing a baseline scenario without the ETS and assessing the impacts of the ETS, as currently designed. The results indicate that the ETS will start to impact emissions primarily after 2025 due to the prevalence of a sizable allowance surplus. The impact of approved (i.e. back-loading and 2.2% linear reduction factor (LRF)) and proposed (i.e. market stability reserve (MSR)) policy interventions and the inclusion of aviation, could accelerate the exhaustion of surplus and increase emission reductions during the investigated period. However, these measures would be insufficient to restore the scarcity of allowances and the corresponding carbon price before the start of ETS Phase IV, and the effectiveness of EU-internal abatement cannot be guaranteed until 2023. The effectiveness could be further reduced in the case of the economic shocks or the exclusion of international aviation.

To restore the scarcity of allowances, other reform options are necessary. This paper extends the reasoning for the early removal of the back-loaded 900 Mtonne allowances by 2020 and broadening the scope of ETS to other sectors with potential high demand for allowances.

1. Introduction

The European Union (EU) has set targets to reduce EU-wide GHG emissions by 20% in 2020 and by 80–95% by 2050, against 1990 levels, to mitigate climate change and facilitate its transition towards a competitive low carbon economy. To hit these targets, the EU launched the European Emissions Trading System (EU ETS) in 2005 as a central-pillar climate policy. The EU ETS covers sectors that account for approximately 45% of Europe's total GHG emissions[1], with a stated policy objective to "promote reductions of GHG emissions in a cost-effective and economically efficient manner" (European Parliament and Council, 2003, Article 1).

The EU ETS is a cap-and-trade system. Its expected overall abatement can be visualized by the gap between the cap and baseline emissions that would have occurred with the absence of the ETS (De Perthuis, 2012). Due to the linkage with the Kyoto flexible mechanisms, overall abatement can be achieved via offsets that reduce emissions outside of Europe (Graus et al., 2009). In accordance with the *supplementarity principle* of the Kyoto Protocol, "[the use of offsets] should be supplemental to domestic action and domestic action will thus constitute a significant element of the effort made" (European Parliament and Council, 2003, page 4). While enhancing the cost-effectiveness of the overall abatement and engaging non-ETS participating countries in climate mitigation actions (Ellsworth et al., 2012), offsets have drawn many criticisms. For instance, the additionality of emissions reduction in

* Corresponding author.
E-mail address: j.hu@uu.com (J. Hu).

[1] A detailed category of activities covered by the EU ETS can be found in DIRECTIVE 2009/29/EC (European Parliament and Council, 2009)

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many offset projects (e.g. industrial gas offsets) cannot be guaranteed, meaning that offset is *per se* a zero-sum game, at best (Methmann et al., 2013). Furthermore, offsets may discourage and delay domestic activities and risk locking the EU into carbon-intensive infrastructure, rendering its ambitious long-term emissions target too expensive to achieve (Bows et al., 2009). In other words, only with a strong focus on domestic activities can the EU ETS stimulate low-carbon investments in the sectors covered, avoiding the risk of technological lock-in and facilitating decarbonization in the EU. As emphasized by the European Commission (EC, 2011a, page 4), "The transition towards a competitive low carbon economy means that the EU should prepare for reductions in its *domestic* emissions by 80% by 2050 compared to 1990. Domestic emission reduction, meaning real internal reductions [within the EU] and not offsetting through the carbon market" (hereafter referred to as "EU-internal abatement"). This raises an interesting question for policy-makers: To what extent will the EU ETS, as currently implemented, drive EU-internal abatement?

Several ex-post studies (Ellerman et al., 2010, Anderson and Di Maria, 2010, Deutsche Bank, 2010) have quantified the EU ETS's EU-internal abatement for its Phase I&II. Most studies estimated an impact of between 2.5% and 5% (or 150–300 Mtonne CO_{2eq}) emissions reduction within Europe against baseline emissions during Phase I (Brown et al., 2012). For Phase II, it was estimated that the EU ETS accounted for at least an EU-wide emissions reduction of 6.3% (or 260 Mtonne CO_{2eq}) during 2008–2009, against baseline emissions (Brown et al., 2012). Egenhofer et al. (2011) calculated that emissions abatement and emissions intensity improvement in Phase II were even larger than the extrapolated trend from Phase I, exhibiting that the EU ETS is accelerating the trend of decoupling economic growth from emissions in Europe (Kettner et al., 2011).

The EU ETS has entered into Phase III since 2013. As a joint result of the economic recession, sizeable influx of offset credits and overlapping energy policies (Taschini et al., 2014), the current performance of the EU ETS is characterized by a large allowance surplus, banked from Phase II and a weak carbon price (EC, 2012a). This surplus "is expected to continue to erode [the EU ETS's] role as a technology neutral, cost-effective and EU-wide driver for low carbon investment" (EC, 2014f, page 8). Some literature and reports have discussed the potential impact of this and different options that may restore the scarcity of allowances (Sandbag, 2012; Grubb, 2012; EC, 2012a). However, only a few ex-ante studies providing a quantitative analysis on the ETS's EU-internal abatement during the post 2012 period are available. Graus et al. (2009) calculated the volume and structure of the EU ETS's cumulative abatement between 2008 and 2020, but the result is no longer timely because of the unexpected Phase II allowance surplus. Moreover, the EC (2014a and 2014b) has approved back-loading (i.e. the postponement of auctioning 900 Mtonne allowances until 2019–2020) as a temporary solution, and proposed to establish a market stability reserve (MSR) in 2021 as a sustainable solution to address the sizable allowance surplus. The EC (2014c) also plans to increase the annual linear reduction factor (LRF) of the cap on the EU ETS to 2.2% after 2020 to fall in line with the 2030 emissions reduction target recently approved by the European Council (2014) on October 23rd, 2014. However, the impacts of these policy interventions on EU-internal abatement still need further investigation. In addition, the newly inclusion of the aviation sector into the EU ETS in 2012 could also affect the EU-internal abatement through creating further demand for emissions allowances (Alberola and Solier, 2012). Thus, the aim of this paper is to provide a quantitative assessment of the EU-internal abatement of the EU ETS, during the post-2012 period in an ex-ante manner. With aims to analyze the evolution of allowance surplus over time in terms of volume, structure, duration, and its impact on the EU-internal abatement and emissions trajectory of the ETS sectors. The temporal scope for this analysis is set as the period 2013–2030, which is beyond the current Phase III. As 2030 is the intermediate year of Europe's decarbonization trajectory, not only can this study deliver insights to improve the performance of EU ETS, but also the produced policy implications may contribute to the on-going discussion of the 2030 EU emissions reduction target and beyond.

2. Method

To quantify the ex-ante internal abatement of the EU ETS in the EU-27[2], a baseline scenario without the implementation of the EU ETS during the investigated period is constructed. The baseline emissions represent the level of emissions if a cap and associated carbon price were not to be present. In a prototypical cap-and-trade system without offsetting linkage and allowance surplus from the previous phases, the required abatement effort (i.e. the gap between the cap and baseline emissions) represents the scarcity of allowances. Correspondingly, a carbon price is generated through the market. At individual level, each rational ETS participant will abate along its marginal abatement cost curve (MACC) until the marginal abatement cost equals the carbon price. The overall EU-internal abatement (i.e. the sum of abatement at individual level) in principle should be equal to the required abatement effort of the EU ETS. Although, admittedly, according to economic theory the realized EU-internal abatement may exceed the required abatement effort due to hedging[3] and banking behavior, this impact is deeply uncertain because of the heterogeneous hedging and banking behaviors and assumed risk premiums of different ETS participants. Thus, for simplification purposes this study only aims to quantify the required abatement effort of the ETS, which could be deemed as a *conservative and minimum* value of EU-internal abatement (see also Section 4). Given the fact that the large allowance surplus banked from Phase II and the influx of offset credits raise the *de facto* cap of the ETS, they should be taken out from the gap to determine the EU-internal abatement. This formulates a stepwise approach: Firstly, we determine the EU-internal abatement of the EU ETS in stationary sectors during the investigated period without policy interventions (i.e. back-loading, MSR and 2.2% LRF). Secondly, the impacts of the aforementioned policy intervention measures on the EU-internal abatement are further investigated through a comparative analysis. Then we determine the impact of the EU ETS on the aviation sector separately, given that the rules applied are different. Finally, the impact on the aviation sector is integrated through an aggregation approach to determine the overall internal abatement of the EU ETS.

[2] Croatia, the 28th member state who joined in 2013 is not included in this study. Note that the inclusion of Croatia would have very low impact on results since it accounts only for 0.5% of primary energy use in EU27 in 2011 (IEA, 2013).

[3] Hedging refers to the behavior of ETS participants to hold more allowances beyond their annual need for emissions compliance to hedge against uncertain future carbon prices. Therefore, hedging creates an additional market demand for emissions allowances and increases the carbon price, incentivizing ETS participants to abate more so as to bank more allowances if the carbon price is expected to increase in the future. In the case of hedging, theoretically a rational ETS participant would make abatement decisions along its marginal abatement cost curve until the marginal abatement cost equals the market carbon price plus a risk premium for hedging. A detailed discussion on hedging in power sector can be found in Schopp and Neuhoff (2013).

2.1. Stationary ETS sectors without policy interventions

2.1.1. Determine the cap

According to the revised EU ETS Directive (European Parliament and Council, 2009), to achieve the 20% overall reduction target below 1990 emission levels by 2020[4], the emissions cap for stationary ETS sectors from 2013 onwards should be determined by an annual LRF of 1.74% that started in 2010 on the average cap over Phase II. This implies that the average Phase II emissions cap (2081 Monne CO_{2eq}[5]) has been decreased over time since 2010 to generate the annual emission cap for 2013 and beyond.

2.1.2. Develop baseline emissions scenario

The baseline emissions scenario can be constructed based on decomposing emissions of stationary ETS sectors into activity volume (GDP) and emissions intensity (against GDP), assuming GDP is the primary driver for ETS emissions. Through extrapolating the historical trend of emissions intensity improvements into the investigated period, the annual baseline emissions can be calculated. This approach has been applied in Ellerman et al. (2010)'s ex-post study in estimating the abatement impact for the EU-25 throughout Phase I (2005–2007). It is still applicable to this ex-ante study for the EU-27 after appropriate modifications, using the historical trend of emissions intensity improvement immediately before the implementation of the EU ETS (Ellerman et al., 2010), the most up-to-date GDP projection and the latest verified 2012 ETS emissions.

2.1.2.1. Identify the historical trend of emissions intensity improvement. To obtain a holistic view, a time period of the past two decades (1990–2012) has been investigated, which should be long enough to fully reflect the historical trend of the emissions intensity of stationary ETS sectors before and after the implementation of the EU ETS. To calculate the emission intensity, the annual GDP ($Euro_{2005}$) and verified ETS emissions data are needed. These are provided in Eurostat (2014) and EU ETS data viewer (EEA, 2014), respectively. However, there is no aggregate emissions data available specifically for the ETS sectors before the implementation of EU ETS in 2005. This problem can be solved through matching ETS sectors with the relevant source categories of the GHG inventory in the UNFCCC common report format (CRF), based on Herold (2007)'s finding of a high consistency between CRF emissions and verified ETS emissions for 2005, through an extensive comparison (Ellerman et al., 2010). Considering the consistency between ETS sectors and relevant CRF sectors, it is possible to generate a data series for the pre-2005 ETS emissions in the EU-27 if the share of ETS emissions relative to relevant CRF emissions is known. Although an average ~85% share of verified ETS emissions out of relevant CRF emissions at aggregate EU level (EU-8, EU-15, EU-23) is given in Herold (2007)'s study, it only holds true for the year 2005. To justify the accuracy of this approach, the share of verified ETS emissions relative to relevant CRF emissions is calculated for the EU-27 from 2005 to 2011[6] in Table 1.

The share is steady at ~80.8% during 2005–2006. It then increases to ~85.9% in 2007 and remains constant at ~87.5% during 2008–2011. This can be explained by the fact that the verified

Table 1
Share of verified ETS emissions relative to relevant CRF emissions for EU-27 from 2005 to 2011.

Year	$\frac{\text{Verified ETS emissions}}{\text{Relevant CRF emissions}}$ (%)	Verified ETS emissions (MTonne)	Relevant CRF emissions (MTonne)
2005	80.7	2014	2498
2006	80.9	2035	2513
2007	85.9	2165	2520
2008	87.5	2100	2400
2009	87.6	1860	2124
2010	87.3	1919	2197
2011	87.4	1885	2156

Sources: Data compiled from EU ETS data viewer (EEA, 2014) and Greenhouse Gas Inventory Data (UNFCCC, 2014).

emissions did not include Bulgaria and Romania until they joined the EU in 2007, and the scope expansion of the EU ETS in its transition from Phase I (2005–2007) to Phase II (2008–2012) (DECC, 2013). The constant share of verified ETS emissions out of relevant CRF emissions accurately reflects and verifies the consistency between ETS emissions and relevant CRF emissions over time. Thus, a data series of pre-2005 ETS emissions under the scope of Phase II for the EU-27 can be calculated via formula (1)

$$ETS\ emissions_{pre-2005} = 87.5\% \times\ Relevant\ CRF\ emissions_{pre-2005} \quad (1)$$

Bearing in mind that verified ETS emissions data for 2005–2007 needs to be adjusted to maintain the consistency of the scope, Fig. 1 shows the trend of ETS emissions in the EU-27 from 1990 to 2012 (with scope adjustment).

A general decreasing trend of emissions can be observed for the period 1990–2000, followed by a steadily rising trend during 2000–2004. After the implementation of the EU ETS, ETS emissions remain at almost the same level in Phase I (2005–2007), in spite of a relatively robust economic growth of ~2.9%/year (Eurostat, 2014). The downward trend of emissions still continues in Phase II (2008–2012) due to the joint impact of ETS and the economic crisis. Therefore, the period 1990–2012 can be divided into four distinguishable sub-periods. Their corresponding average annual emissions intensity improvement rates are calculated in Table 2.

Strong annual reductions in emissions intensity can be observed respectively for the period 1990–2000, and Phase I&II. To a very large extent the former intensity improvement in 1990 s was under the external influence of drastic politico-economic changes in member states in Eastern Europe following the collapse of the Soviet Union. Shut-down of inefficient coal-fired power plants and energy-intensive installations due to economic restructuring in these countries, coupled with the rehabilitation in former East Germany, directly lead to the decrease in emission intensity (Rootzén, 2012; EEA, 2011). Emissions intensity improvement during this period was also accelerated by the increasing penetration of renewable energy sources in the EU-27 and the significant fuel-switch from coal to gas in the UK. In the EU-27 the penetration of renewable energy in final energy consumption increased by 16% during 1990–1999 (IEA, 2013), while in the UK the shares of coal and gas for electricity generation changed respectively from 65% to 38% and from 1% to 28% (Gummer and Moreland, 2000). As for the emissions intensity improvement during Phase I&II, it should be primarily ascribed to the policy effectiveness of the EU ETS (Laing et al., 2013), whose carbon price spurred substantial abatement actions among both power and industrial installations.

Thereby, neither average annual emissions intensity improvement throughout 1990–2000 nor that during Phase I&II would be suitable for developing a baseline emissions scenario; they are far beyond the level that autonomous emissions intensity

[4] The 20% overall emissions reduction target by 2020 can be translated into 21% and 10% emissions reductions for (stationary) ETS and non-ETS sectors in 2020 (against their 2005 emission levels), respectively (EC, 2014d). The LRF of 1.74% ensures the 2020 emissions for stationary ETS sectors to be capped at 21% below 2005 emission levels.

[5] Data for EU-27, derived from EU ETS data viewer (EEA, 2014)

[6] Because UNFCCC (2014) only provides CRF emissions data up-to 2011, this calculation is only conducted for 2007 to 2011.

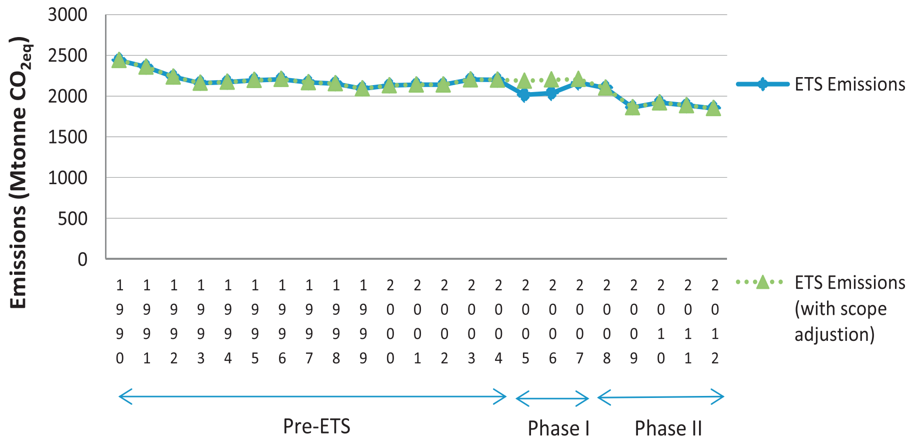

Fig. 1. (Stationary) ETS emissions for EU-27 (with adjustment to Phase II scope) during 1990–2012.

Table 2
Average annual ETS emissions intensity improvement rate in EU-27 for different time period.

Time period		Average annual ETS emission intensity $\left(\frac{\text{ETS emissions}}{\text{Real GDP}}\right)$ improvement rate (%)
Pre-ETS implementation	1990–2000	3.48
	2000–2004	1.19
With ETS implementation	2004–2007 (Phase I)	3.12
	2007–2012 (Phase II)	3.17

improvement could reach under baseline conditions in the absence of external influences or a carbon price. As a result, the moderate average annual emissions intensity improvement rate of 1.19% during 2000–2004 seems to be the most appropriate one to use. It not only corresponds to the historical trend occurring immediately before the implementation of the EU ETS (Ellerman et al., 2010), but it is also hard to find any major external influence other than autonomous improvement that had an impact on emissions intensity, during the period.

2.1.2.2. Determine the annual GDP of the EU-27 for the period 2013–2030. GDP projections for 2013–2030 can be derived from the AUGUR scenarios, which are the most up-to-date economic scenarios for Europe (Cripps, 2013). They are based on a macroeconomic model, officially developed by the EU AUGUR program (EC, 2013). The "multi-speed" scenario is selected in this study because of the moderate GDP growth projection. It assumes that while "the EU continues to play a central role in infrastructure, energy and trade, greater internal flexibility for fiscal and monetary policies are given to each member state to support economic growth at a national level" (adapted from EC, 2013, pp. 11–12). Fig. 2 shows the multi-speed Europe scenario together with the other two AUGUR scenarios; "struggling on" and "towards federal Europe". Compared to the multi-speed Europe scenario, they are more extreme cases. The struggling on scenario "maintains the Eurozone intact without addressing long-term problems of government finance, regional depression and unemployment"; while the towards federal Europe scenario "envisages a big-government solution to unequal development in the Eurozone" (EC, 2013, p. 26).

2.1.2.3. Calculating the baseline ETS emissions. The baseline emissions of stationary ETS sectors for year i during the investigated period can be calculated from formula (2)

$$E_{BAU,i(s)} = GDP_{i*}EI_{2012(s)} \times \left(1 - \bar{r}_{2000-2004(s)}\right)^{i-2012}, \quad 2013 \le i \le 2030$$

$$EI_{2012(s)} = \frac{E_{verified,2012(s)}}{GDP_{2012}} \qquad (2)$$

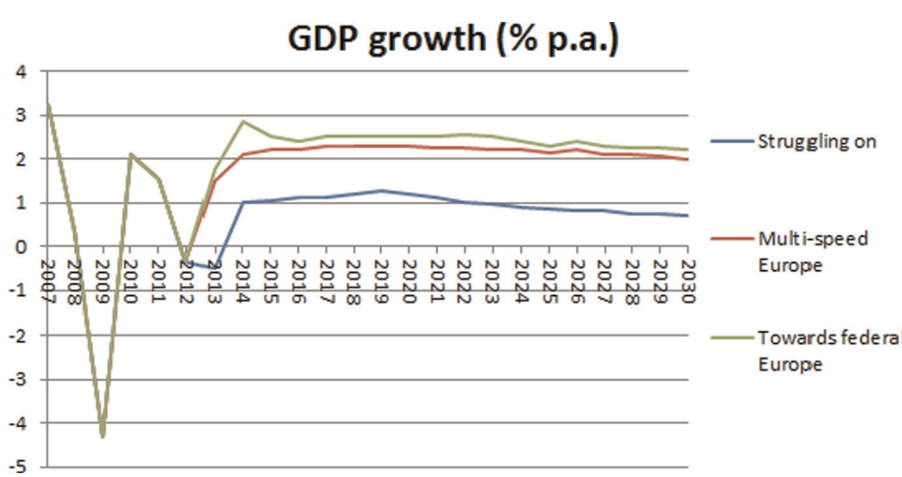

Fig. 2. AUGUR Macro-model scenarios.
Source: Cripps (2013).

where

$E_{BAU,i(s)}$ = Annual baseline emissions of stationary ETS sectors in year i (Mtonne CO_{2eq})
GDP_i = Annual GDP in year i (Billion $Euro_{2005}$)
$EI_{2012(s)}$ = Emissions intensity of stationary ETS sectors in 2012 (0.158 Mtonne CO_{2eq}/Billion $Euro_{2005}$)
$E_{verified,2012(s)}$ = Verified emissions of stationary ETS sectors in 2012 (1848 MtonneCO_{2eq}[7])
GDP_{2012} = GDP in 2012 (11720 Billion $Euro_{2005}$)
$\overline{r_{2000-2004(s)}}$ = average annual emissions intensity improvement of stationary ETS sectors during 2000–2004 (1.19%)

2.1.3. Determining allowance surplus and offset credits

The surplus of allowances, in principle, mainly comes from two sources: over-supply of allowances and the usage of offset credits (Carbon market watch, 2012). Over-supply is the phenomenon that the ex-ante determined cap is greater than the ETS emissions (Venmans, 2012). It results either from too low of a cap-setting, or over-estimated baseline emissions in the case of unexpected economic shocks. Offset credits also contribute to the formation of allowance surplus, as the surrender of a number of offset credits for compliance purpose will simply free up the same quantity of allowances in the EU ETS (Ellsworth et al., 2012). Therefore, using data provided in the EU ETS data viewer (EEA, 2014), formula (3) and (4) can be respectively applied to quantify annual and cumulative allowance surplus for a given year i starting from 2008. As inter-phase allowances banking is allowed from 2008 onwards, 2008 is chosen as the starting year for quantifying allowance surplus

$$AS_{i(s)} = (EC_{i(s)} - E_{i(s)}) + OC_{i(s)}, \quad i \geq 2008 \tag{3}$$

$$CS_{i(s)} = \sum_{2008}^{i} AS_{i(s)}, \; i \geq 2008 \tag{4}$$

where

$AS_{i(s)}$ = Annual allowance surplus in year i (Mtonne CO_{2eq})
$EC_{i(s)}$ = Annual emissions cap in year i (Mtonne CO_{2eq})
$E_{i(s)}$ = Annual emissions in year i (Mtonne CO_{2eq})
$OC_{i(s)}$ = Annual usage of offset credits in year i (Mtonne CO_{2eq})
$CS_{i(s)}$ = Cumulative allowance surplus in year i (Mtonne CO_{2eq})

For convenience, the surplus already banked from Phase II and the continuous build-up of surplus over the post-2012 period are analyzed separately:

2.1.3.1. Surplus banked from Phase II (2008–2012). Fig. 3 shows the allowance surplus built up in Phase II from stationary ETS sectors.

The cumulative surplus accumulated in Phase II amounted to 1776 Mtonne, of which 41.5% and 58.5% resulted from over-supply and offset credits, respectively. The overall Phase II surplus was even closer to the verified ETS emissions in 2012, and all of it was banked into the post-2012 period.

2.1.3.2. Surplus build-up during 2013–2030. Besides surplus banked from Phase II, the allowance surplus during the post-2012 period consists of three components: over-supply of allowances, offset credits and the unused Phase II New Entrants Reserve (NER) auctioned in 2013 (EC, 2012b).

2.1.3.3. Over-supply of allowances. Through comparing the annual emissions cap and projected baseline emissions, the over-supply of allowances during the investigated period can be quantified in an ex-ante manner. Over-supply will emerge only if the pre-determined cap exceeds baseline emissions.

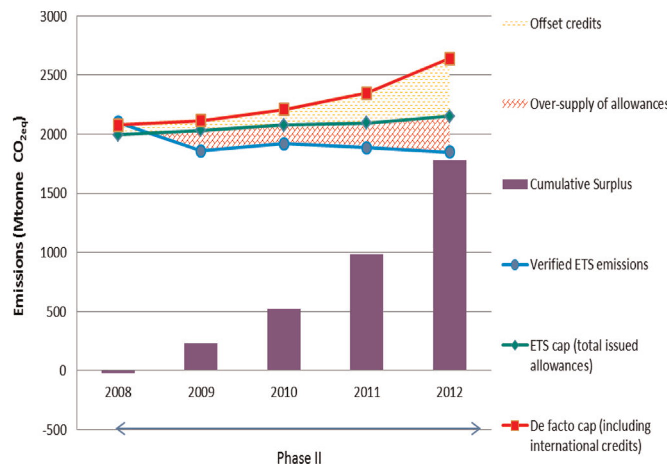

Fig. 3. Surplus build-up of stationary ETS sectors during Phase II.

2.1.3.4. Offset credits. The (EC 2014e) estimated that the maximum access of offset credits is limited to ~1600 Mtonne between 2008 and 2020 for stationary ETS sectors. Since in total 1039 Mtonne offset credits have been surrendered in Phase II (EEA, 2014), the remaining quota for 2013–2020 is only 561 Mtonne. For simplicity this influx of credits is treated as evenly distributed throughout Phase III, resulting in an annual usage of 70.1 Mtonne. For Phase IV (2021–2027) and beyond, it is assumed that the use of offset credits would be banned, given the expiration of the Kyoto Protocol in 2021.

2.1.3.5. Phase II NER leftover. The Phase II NER is a pool of grandfathered allowances set aside to enable eligible new installations to enter into the EU ETS in Phase II. It is also supposed to recycle allowances from closed installations, preventing excessive allowances entering into the market directly (Gilbert, Phylipsen, 2006). As an impact of the economic crisis, less than 16% of allowances from the NER were issued in Phase II (Pearson and Worthington, 2009). Although France, Ireland and Portugal have committed to cancel their unissued allowances in the Phase II NER, other ETS participant countries would still bring their NER leftover into Phase III (ICIS, 2013 and Ellsworth, 2010). This results in an additional 125 Mtonne allowances auctioned in 2013 (EC, 2012b).

Thus, cumulative surplus for stationary ETS sectors in a given year i during 2013–2030 can be expressed through formula (5)

$$CS_{i(s)} = CS_{phase\ II(s)} + NERL_{Phase\ II(s)} + \sum_{2013}^{i} \left[\left(EC_{i(s)} - E_{BAU,i(s)} \right) + OC_{i(s)} \right], \; 2013 \leq i \leq 2030 \tag{5}$$

$$OC_i = \begin{cases} 70.1 \text{ Mtonne}, & if\ i \leq 2020 \\ 0, & if\ 2021 \leq i \leq 2030 \end{cases}$$

where

$CS_{i(s)}$ = Cumulative allowance surplus in year i (Mtonne CO_{2eq})
$CS_{phase\ II(s)}$ = Allowance surplus banked from ETS Phase II (1776 Mtonne CO_{2eq})
$NERL_{Phase\ II(s)}$ = Phase II NER leftover (125 Mtonne CO_{2eq})
$EC_{i(s)}$ = Annual emissions cap in year i during 2013–2030

[7] Derived from EU ETS data viewer (EEA, 2014)

($Mtonne\ CO_{2eq}$)
$E_{BAU,i(s)}$ = Annual baseline emissions in year i ($Mtonne\ CO_{2eq}$)
$OC_{i(s)}$ = Annual offset credits usage in year i ($Mtonne\ CO_{2eq}$)

2.1.4. Quantifying internal abatement

In theory, at individual level rational firms will abate along their MACCs until the point equal to the market carbon price plus a risk premium, even if they hold an allowance surplus. However, because of the large surplus at EU-aggregate level and the limited foresight of firms, the carbon price would be depressed and prolonged, thus, insufficient to stimulate investment in most abatement measures (CCAP-Europe, 2012). In addition, the surplus loosens the *de facto* cap of the EU ETS, reducing the required emissions reduction (i.e. the *minimum* value of EU-internal abatement). In others words, internal abatement cannot be guaranteed as long as the cumulative allowance surplus is not fully absorbed as this surplus can be surrendered to avoid abatement. It is therefore assumed that the allowance surplus at an EU-aggregate level is used at a maximum speed, meaning that the impact of hedging/banking is not taken into account in the calculation (see Section 4). If the year where internal abatement first starts to occur is denoted as *x*, the cumulative internal abatement for stationary ETS sectors in any given year *i*, and the total internal abatement for 2013–2030 can be calculated respectively via formula (6) and (7)

$$CIA_{\,i(S)} = \begin{cases} 0, & if\ 2013 \le i \le x-1 \\ \sum_{x}^{i} (E_{BAU,i(S)} - EC_{i(S)}) - CS_{x-1(S)}, & if\ x \le i \le 2030 \end{cases} \tag{6}$$

$$IA_{\,2013-2030(S)} = \sum_{x}^{2030} (E_{BAU,i(S)} - EC_{i(S)}) - CS_{x-1(S)} \tag{7}$$

where

$CIA_{\,i(S)}$ = Cumulative internal abatement in year i ($Mtonne\ CO_{2eq}$)
$E_{BAU,i(S)}$ = Annual baseline emissions in year i ($Mtonne\ CO_{2eq}$)
$EC_{i(S)}$ = Annual emissions cap in year i ($Mtonne\ CO_{2eq}$)
$CS_{x-1(S)}$ = Cumulative allowance surplus in the year before internal abatement first occur ($Mtonne\ CO_{2eq}$)
$IA_{\,2013-2030(S)}$ = Total internal abatement during 2013–2030 ($Mtonne\ CO_{2eq}$).

2.2. Stationary ETS sectors with policy interventions

This section gives the assumptions used to investigate the impact of approved (i.e. back-loading and 2.2% LRF) and proposed (i.e. MSR) policy interventions, on the EU-internal abatement impact of the EU ETS.

2.2.1. Back-loading of 900 Mtonne allowances

Back-loading is the postponement of the auction of 900 Mtonne allowances until 2019–2020. The allowances to be auctioned are reduced by 400, 300 and 200 Mtonne during 2014–2016, and increased by 300 and 600 Mtonne in 2019 and 2020 (EC, 2014a). This is modeled by adjusting the cap-setting for stationary ETS sectors.

2.2.2. Annual LRF at 2.2% after 2020

The 2030 overall emissions reduction target within the 2030 framework for climate and energy policies proposed by the EC (2014c) has been approved by the European Council (2014). It aims to reduce domestic EU emissions by 40% against 1990 levels. For stationary ETS sectors this would deliver an emissions reduction of 43% against 2005 emission levels in 2030, meaning that the current annual LRF of 1.74% for cap-setting has to be increased to 2.2% from 2021 onwards (EC, 2014c).

2.2.3. MSR starting in 2021

The EC (2014b) has also proposed to establish a MSR starting in 2021 to address the sizable allowance surplus among stationary ETS sectors and strengthen the system's resilience in case of future demand shocks. The proposed rules for the MSR can be summarized as follows: “In each year i starting in 2021, a quantity of allowances equal to 12% of the cumulative surplus in year i-2 shall be put in the reserve, unless this quantity is less than 100 Mtonne. In any year i, if the cumulative surplus is less than 400 Mtonne, 100 Mtonne allowances shall be released from the reserve; In case less than 100 million allowances are in the reserve, all allowances in the reserve shall be released” (adapted from EC, 2014b, Article 1). Therefore, formula (8) and (9) can be applied respectively to determine the annual number of allowances to be injected in the reserve and the corresponding cumulative surplus excluding allowances in the reserve for a given year i from 2021 onwards[8].

$$AR_{i(s)} = \begin{cases} 12\% \times CSER_{i-2(s)}, & \text{if } CSER_{i-2(s)} \ge 833 \text{ Mtonne and } CSER_{i-1(s)} \ge 400 \text{ Mtonne} \\ 0, & \text{if } CSER_{i-2(s)} < 833 \text{ Mtonne and } CSER_{i-1(s)} \ge 400 \text{ Mtonne} \\ -100 \text{ Mtonne}, & \text{if } CSER_{i-1(s)} < 400 \text{ Mtonne} \\ -\sum_{2021}^{i} AR_{i(s)}, & \text{if } 0 \le_{i} \sum_{2021}^{i-1} AR_{i(s)} < 100 \text{ Mtonne} \end{cases} \tag{8}$$

$$CSER_{i(s)} = CS_{2021(s)} - \sum_{2021}^{i} AR_{i(s)} \tag{9}$$

where

$AR_{\,i(S)}$ = Annual number of allowances to be injected in the reserve in year i ($Mtonne\ CO_{2eq}$).
$CSER_{\,i(S)}$ = Cumulative allowance surplus excluding allowances in the reserve in year i ($Mtonne\ CO_{2eq}$).
$CS_{i(s)}$ = Cumulative allowance surplus in year i ($Mtonne\ CO_{2eq}$).

2.3. Incorporation of aviation sector

The aviation sector has been integrated into the EU ETS since 2012, including both intra-Europe and international flights to or from Europe (European Parliament and Council, 2008). It accounts for 11% of emissions covered by the EU ETS, with most coming from international aviation (Leggett et al., 2012). As the unilateral integration of international aviation has triggered strong dissatisfaction from many other international actors, the (EC, 2014f) decided to postpone the enforcement of including international flights. It aims to provide negotiation time for reaching a global market-based mechanism (GMBM) through the International Civil

[8] Note that the our calculation does not take account of the provisions in the MSR proposal (EC, 2014b) that are “aimed at smoothening auctioning supply in the years around transitions between trading phases”, as no explicit rules are available for the operation of these provisions.

Aviation Organization (ICAO) assembly that could deliver aviation emissions reduction at least equivalent to what the EU ETS is going to deliver. Such a GMBM is still pending and uncertain, although ICAO, without a binding commitment, called for appropriate measures to be finalized and voted on in 2016, and implemented in 2020 (Rock et al., 2014). Therefore, it is assumed in this study that the scope of aviation ETS only includes intra-EU flights between 2012 and 2019, and from 2020 onwards international aviation would be integrated into the EU ETS.

2.3.1. Determining the cap

The cap for the aviation sector shall be equivalent to 97% of the historical aviation emissions[9] in 2012, and it shall be reduced to 95% from 2013 onwards (European Parliament and Council, 2008). As such, the annual aviation cap for 2012, 2013–2019 and the post-2019 period can be determined as 71.1, 69.6 and 208.5 Mtonne CO_{2eq}, respectively. The first two periods include only intra-EU aviation.

2.3.2. Constructing the baseline emissions scenario

Alike stationary ETS sectors, baseline emissions of the aviation sector can be projected based on decomposing the annual aviation emissions into air traffic volume and emissions intensity factors, namely *Revenue Tonne Kilometer* (RTK)[10] and Emissions per RTK (EI). Using a combination of top-down and bottom-up approaches, Boeing (2013) provided a projection of the annual air traffic volume growth rate at 4.15%[11] for Europe over the period 2013–2032. Meanwhile, an annual emissions intensity (of air traffic) improvement target of 1.9% for the post-2010 period was stated by IATA (Macintosh and Wallace, 2008; IATA, 2007). As such, an annual aviation emissions growth rate of 2.17% is assumed. Given the historical aviation emissions (i.e. average annual emissions for 2004–2006), a series of aviation emissions for the EU-27 during the investigated period can be generated, applying formula (8)

$$E_{BAU,\ i(A)} = \overline{E_{2004-2006(A)}} \times (1 + 2.17\%)^{i-2006} \quad 2013 \le i \le 2030 \qquad (10)$$

where

$E_{BAU,\ i(A)}$=Annual baseline emissions of aviation sector in year i (Mtonne CO_{2eq})
$\overline{E_{2004-2006(A)}}$=Historical average aviation emissions during 2004–2006 (Mtonne CO_{2eq})

2.3.3. Determining offset credits

In addition to emissions allowances, additional offset credits can be used by the aviation sector. A volume of offset credits up to 15% of the annual aviation emissions can be used in 2012, while for 2013–2020 a usage limit equivalent to 1.5% of the annual emissions has been set (European Parliament and Council, 2008). Just as for stationary sectors, it is assumed that the use of offset credits in the aviation sector would be banned beyond 2020.

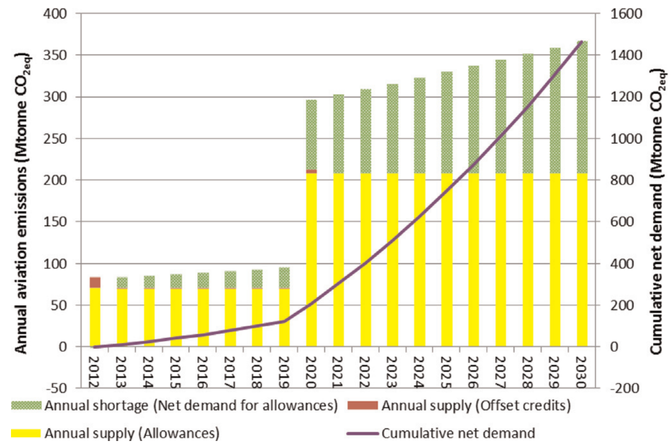

Fig. 4. Supply/demand balance of allowance for the aviation sector included in the EU ETS.

To observe the supply-demand balance of emissions allowances for the aviation sector, annual allowances supply, offset credits and demand for allowances (i.e. emissions) from 2012 to 2030 are shown in Fig. 4.

As the demand for allowances (i.e. emissions) increases each year, the annual shortage of allowance among the aviation sector would increase steadily for the entire period 2013–2030. This results in an overall net demand for allowances of 1465 Mtonne by 2030.

3. Results

3.1. EU-internal abatement of the EU ETS (excluding aviation) without policy interventions

The EU-internal emissions abatement by the EU ETS (excluding aviation) without policy interventions is shown in Fig. 5.

The allowance surplus would continue to build up in an incremental fashion over 2013–2016, due to the combined impact of surplus banked from Phase II, Phase II NER leftover, over-supply of allowance and the usage of offset credits. After reaching its peak in 2016, the allowance surplus would begin to decrease because it is being continuously absorbed by the enlarging gap between baseline emissions and the cap. However, no internal abatement could be guaranteed before the surplus is fully absorbed; the portion of baseline emissions above the cap that should have been abated could still be emitted through surrendering an equal amount of excessive allowances held by ETS participants. This may lead to a deviation from the EU's emissions reduction trajectory and create uncertainty in achieving the 2020 emissions reduction target[12]. It is not until 2025 that the total volume of surplus (2622 Mtonne CO_{2eq}) prevalent throughout most of the investigated period would be fully exhausted, and since then internal abatement would certainly begin to emerge. As demonstrated by the negative bar[13], the cumulative internal abatement would increase from

[9] The historical aviation emissions represent "the mean of the annual emissions in the calendar years 2004, 2005 and 2006" from all flights to and from EU airports, amounting to 219.5 Mtonne CO_{2eq} (EC, 2011b). However, as only intra-EU flights emissions are covered under the EU ETS between 2012 and 2019, accordingly the aviation cap for this period should also be determined based on average historical intra-EU aviation emissions. According to Preston et al. (2012), intra-EU aviation emissions account for 33.4% of total aviation emissions that would be covered by the EU ETS. As such, historical intra-EU aviation emissions should be equal to 73.3 Mtonne CO_{2eq}.

[10] Revenue Tonne Kilometer (RTK) is the standard activity unit for air transport. One RTK denotes one Tonne of load (passenger or cargo) traveled for one kilometer (ICAO, 2010).

[11] This value has been adjusted to the difference of the projected GDP growth rates between Boeing (2013) and Augur multi-speed Europe scenario used in this study. The former assumes an annual GDP growth rate of 1.8% for Europe, while a value of 2.15% is implied in the latter. A projection of air traffic volume growth rate at 3.8% is reported by Boeing under its GDP growth projection, based on the assumption that the growth of air traffic volume is the sum of GDP growth and an independent time-varying function (Boeing, 2013). This leads to an air traffic volume growth rate of 4.15% under the projected GDP growth used in this study.

[12] For ETS sectors, the 2020 emissions reduction target is reflected in the 2020 emissions cap

[13] The negative bar (i.e. the negative cumulative allowance surplus) starting from 2025 is equivalent to the cumulative shortage of allowances, whose absolute value per se actually represents the cumulative internal abatement of ETS.

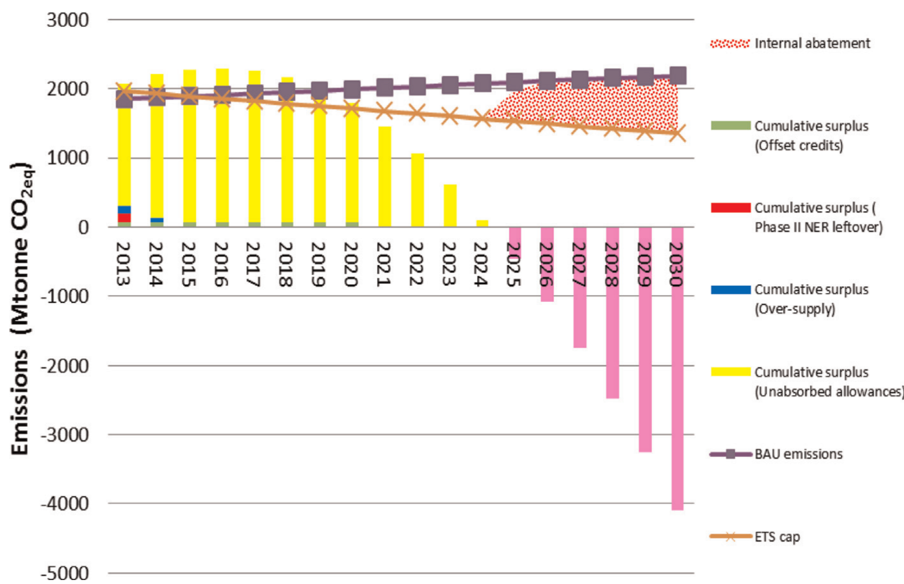

Fig. 5. EU-internal abatement (excluding aviation) without policy interventions and cumulative surplus build-up of the EU ETS under baseline emissions during 2013–2030.

2025 onwards, reaching 4095 Mtonne by 2030. This value also represents the total EU-internal abatement of the EU ETS during 2013–2030, which can be illustrated by the spotted area. As the EU-internal abatement would only be concentrated over the last six years of the investigated period, the relevance of the EU ETS as an emissions reduction instrument would be limited for many years to come.

3.2. EU-internal abatement of the EU ETS (excluding aviation) with policy interventions

Fig. 6 shows the EU-internal abatement of the EU ETS (excluding aviation) with the incorporation of policy intervention measures (i.e. back-loading, 2.2% LRF and MSR) that aim to restore the scarcity of allowances. Although back-loading would substantially alleviate the build-up of surplus over the initial three years of Phase III, it would also contribute to the rapid surge of surplus in the last two years of the same phase. As a result, in 2020 the cumulative surplus of 1794 Mtonne remains at the same level as the case without back-loading. Compared to the case with unchanged LRF at 1.74%, the LRF of 2.2% starting in 2021 would accelerate the absorption of allowance surplus, but in an incremental manner through increasing the downward slope of the cap. In this way, it would contribute to an additional EU-internal abatement of 524 Mtonne during the investigated period. The establishment of MSR after 2020 would substantially reduce the amount of surplus, with 537 Mtonne allowances being put into the reserve by 2023. However, as the cumulative surplus declines to less than 100 Mtonne in 2023, the reserve would begin to withdraw allowances from 2024 until all stored allowances are released. Consequently, under the baseline emissions the MSR would have a zero net impact on the total internal abatement during the investigated period.

As a combined impact of these measures, the allowance surplus would be fully exhausted in 2024, which is only one year ahead of that without policy interventions. The total internal abatement during the investigated period would be increased to 4619 Mtonne, compared with 4095 Mtonne in the case without policy inventions. Despite a duration of 18 years for the investigated period, the occurrence of EU-internal abatement could only be guaranteed in its last seven years because of the sizable total allowance surplus of 2966 Mtonne.

3.3. EU-internal abatement of the EU ETS (including aviation) with policy interventions

With the inclusion of the aviation sector (see Fig. 7), the allowance surplus would be fully absorbed in 2023. Hence, the cumulative internal abatement would increase steadily from 2023 onwards, reaching 6084 Mtonne by 2030. However, including the aviation sector would not be sufficient to restore the scarcity of allowance until the last eight years of the investigated period. It would, to some extent, lessen the impact of excessive allowances, by accelerating the process of surplus being absorbed. The full exhaustion of the surplus would be one year ahead of that excluding aviation, and the duration of EU-internal abatement of the EU ETS would increase by one year. This can be explained by the general shortage of allowances and the relatively high abatement cost within the aviation sector (IPCC, 2007). Airline companies have to purchase additional allowances to cover their increasing emissions each year, which would create an additional net demand for allowances from stationary ETS sectors with a significant surplus. Furthermore, the inclusion of the aviation would strengthen the EU-internal abatement during the investigated period. The net shortage of allowances from aviation would increase the total internal abatement by 31.7% (or 1465 Mtonne), compared with the situation excluding aviation.

4. Discussion of uncertainties

The determination of the future EU-internal abatement resulting from the EU ETS involves many data sources and assumptions. This section discusses the main uncertainties that may induce a significant impact on calculated results.

4.1. Banking of allowance surplus

In this paper, the ex-ante *minimum* EU-internal abatement (i.e. the required abatement effort) of the EU ETS is quantified, based on the assumption that firms would use allowance surplus at a maximum speed so as to avoid early emissions abatement. This assumption is supported by the time-discounting effect that the perceived abatement cost associated with early reduction actions tends to be higher than those with later actions (Nordhaus, 2008), which, to some extent, reflects the bounded rationality of firms. In addition, the "wait-and-see" strategy aimed at exploiting the

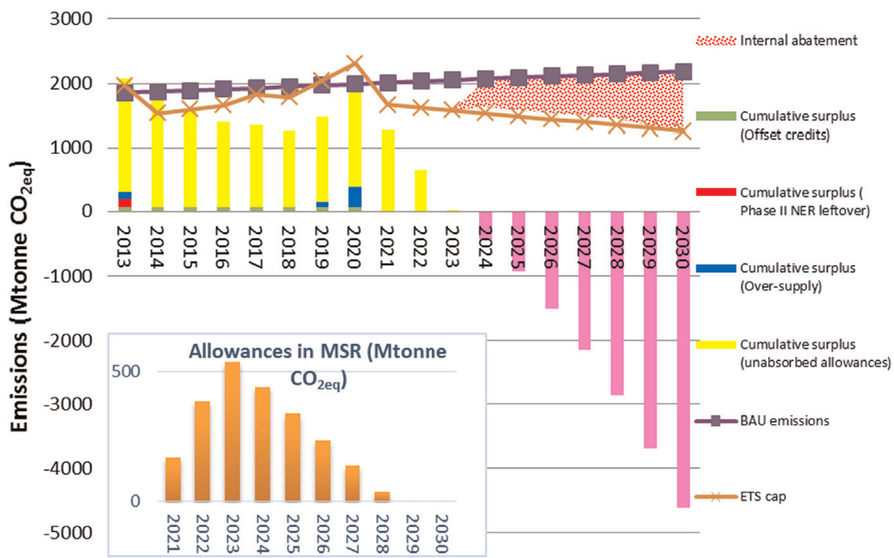

Fig. 6. EU-internal abatement (excluding aviation) with policy interventions and cumulative surplus build-up of EU ETS under baseline emissions during 2013–2030.

reduction of abatement cost due to future technological breakthrough may also favor the postponement of reduction actions (Wigley et al., 1996). However, allowance surplus may also be banked for future usages depending on hedging, arbitrating or speculating purposes (Neuhoff et al., 2012), especially when the abatement investment itself is profitable. In theory, a rational firm will abate emissions along its MACC until its marginal abatement cost equals the market carbon price plus a risk premium. The aggregated risk premium at EU-level would determine the speed at which allowance surplus is used or banked, and correspondingly, how much additional EU-internal abatement would be realized on top of the minimum EU-internal abatement. However, as the heterogeneous hedging strategies, and risk premiums used differs by firm, the realized EU-internal abatement resulting from hedging/banking is intrinsically too uncertain to rely upon.

4.2. Emissions intensity improvement and GDP growth rate

In the baseline emissions scenario, a moderate value of the emissions intensity improvement rate (1.19%) and GDP growth rate (2.15%, derived from AUGUR multi-speed Europe scenario) is used. To identify the impact of these assumptions, a sensitivity analysis is conducted, with a high and low value for both intensity improvement rate and GDP growth rate.

Considering the general difference in economic structure, mitigation cost and abatement potential between developed western European countries (EU-15) and transitional eastern European countries (Buchan, 2010), the annual intensity improvement rates during 2000–2004 for EU-15 (0.91%) and Czech Republic (1.98%), were chosen as the low and high value. These respectively represent two typical values for western and eastern European countries. The high and low values (i.e. 0.89% and 2.40%) for the GDP growth rate come from the AUGUR “towards federal Europe” scenario and “struggling on” scenario, respectively (see Fig. 2).

The EU-internal abatement for the different GDP growth and intensity improvement rates are presented in Fig. 8. The EU-internal emissions abatement is *ceteris paribus* larger under either higher GDP growth or lower intensity improvement rate, and *vice versa*, because either higher GDP growth or lower intensity

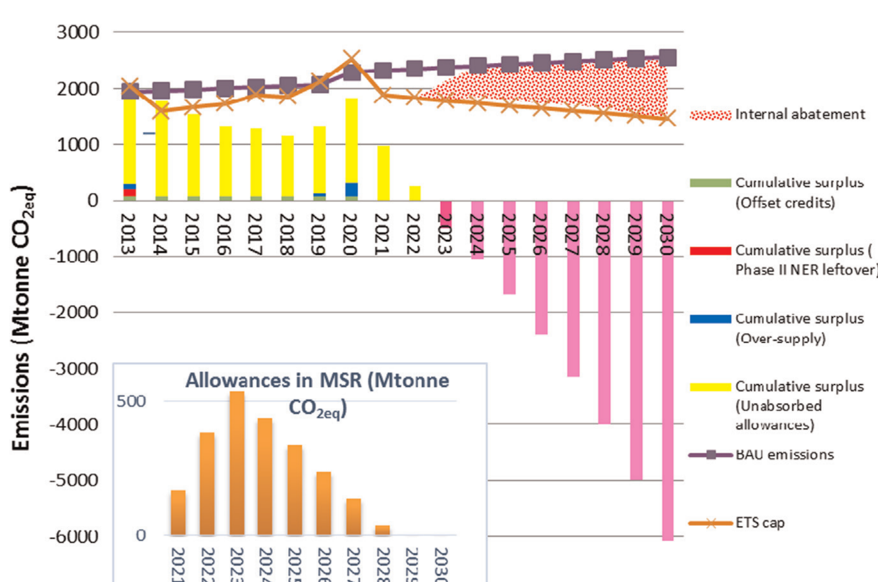

Fig. 7. EU-internal abatement (including aviation) with policy interventions and cumulative surplus build-up of the EU ETS under baseline emissions during 2013–2030.

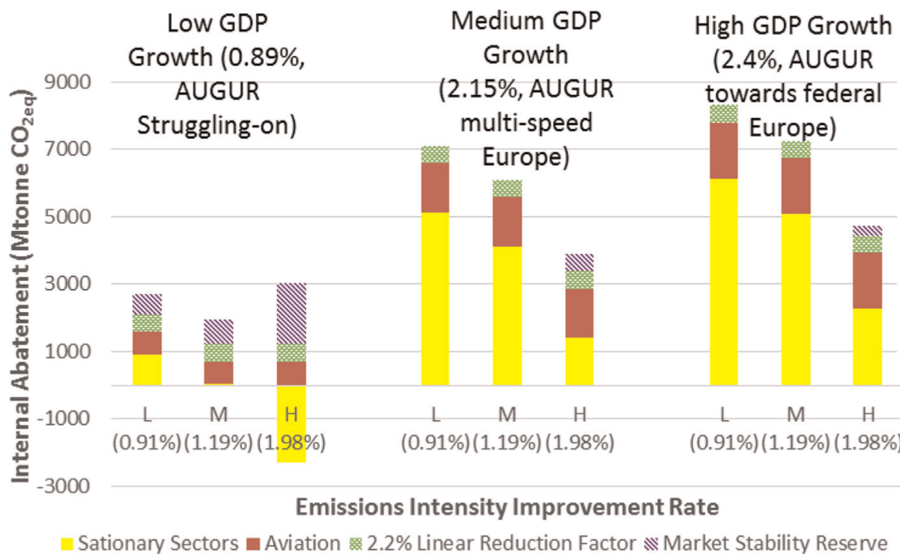

Fig. 8. Sensitivity analysis of EU-internal abatement of the EU ETS (including aviation) with policy interventions for different annual GDP growth and emissions intensity improvement rates.

improvement increase baseline emissions. The observed largest EU-internal abatement (8299 Mtonne) is under both low intensity improvement and high GDP growth, while the smallest (702 Mtonne) is under the combination of high intensity improvement and low GDP growth. For all scenarios, the contribution of the LRF of 2.2% after 2021 to the EU-internal abatement is fixed at 524 Mtonne, which is insensitive to GDP growth and intensity improvement. However, the impact of the MSR is highly dependent on baseline emission levels. The MSR would not affect the internal abatement under the high baseline emission scenarios (i.e. medium GDP plus low/high intensity improvement, high GDP plus low/high intensity improvement), as the net stock of allowances stored in the reserve is zero by the end of 2030. Interestingly, under the low baseline emissions scenarios (i.e. either low GDP or high intensity improvement), the MSR would increase internal abatement through storing a number of allowances at the end of 2030, ranging from 286 to 1818 Mtonne. The number of allowances stored in the MSR is particularly high (1818 Mtonne) under the lowest baseline emissions (i.e. the combination of low and high intensity improvement), suggesting its ability to strengthen the resilience of the EU ETS in case of uncertain future demand shock. The internal abatement would be otherwise a negative value of −1116 Mtonne without MSR in that case. This represents in essence a sizable volume of unused cumulative allowance surplus by the end of 2030. It would be banked into the post-2030 period of the EU ETS, further depressing the carbon price and undermining the effectiveness of the EU ETS to induce EU-internal abatement.

4.3. Linear reduction factor (LRF)

Another parameter that may have a large impact on the EU-internal abatement is the LRF used to determine the ETS cap. This study analyses two cases: the continuation of the current LRF of 1.74% and the increase of LRF to 2.2% starting in 2021. The latter case would deliver a 43% emissions reduction for stationary ETS sectors by 2030 against 2005 emission levels. This is consistent with the 40% EU overall emissions reduction target (against 1990 levels) by 2030 (EC, 2014c). Although this target will ensure the achievement of the lower bound of the EU's long-term 80–95% overall emissions reduction target by 2050, it is insufficient to fulfill the ambitious higher bound target. To be in line with 95% overall emissions reduction target, the LRF from 2021 onwards should be increased to 2.55%[14]. In that case, it would further increase the EU-internal abatement impact by 399 Mtonne during the investigated period. This also implies that the 2030 emissions reduction target (i.e. the cap) for ETS sectors should have been set at 46% below 2005 levels.

4.4. Inclusion of international aviation

In this study it is assumed that international aviation is incorporated into the EU ETS from 2020 onwards due to the implementation of a GMBM through the ICAO that is equivalent to the EU inclusion of international aviation under the EU ETS. However, it is still unclear whether such a GMBM could be reached due to the conflicted political interests of different actors. As international aviation roughly accounts for 2/3 of the total aviation emissions under the scope of EU ETS (Preston et al., 2012), the exclusion of international aviation would reduce the EU-internal abatement by 853 Mtonne (under the moderate GDP growth rate of 2.15%) during the investigated period.

5. Conclusion and policy implications

This study aims to investigate the EU-internal emissions abatement resulting from the EU ETS during the period 2013–2030, in a quantitative ex-ante manner. It is identified that the EU ETS (including aviation) would lead to an EU-internal abatement of 5560 Mtonne CO_{2eq} during the investigated period under the most plausible baseline emissions scenario, of which 1465 Mtonne is contributed by the net shortage of allowances in the aviation sector. Under the same baseline emissions, the combined impact of the policy intervention measures approved (i.e. back-loading and 2.2% LRF) or proposed (i.e. MSR) by the EC would lead to an additional internal abatement of 524 Mtonne. However, these measures would be insufficient to restore the scarcity of allowances and the corresponding carbon price before the start of ETS Phase IV in 2021. Due to the prevalence of a sizable allowance surplus (2855 Mtonne), the occurrence of EU-internal abatement could not be guaranteed until 2023. The EU-internal abatement

[14] Calculated based on the EU 1990 emission levels of 5583 Mtonne CO_{2eq} (UNFCCC, 2014) and the 45% share of ETS emissions in overall EU emissions.

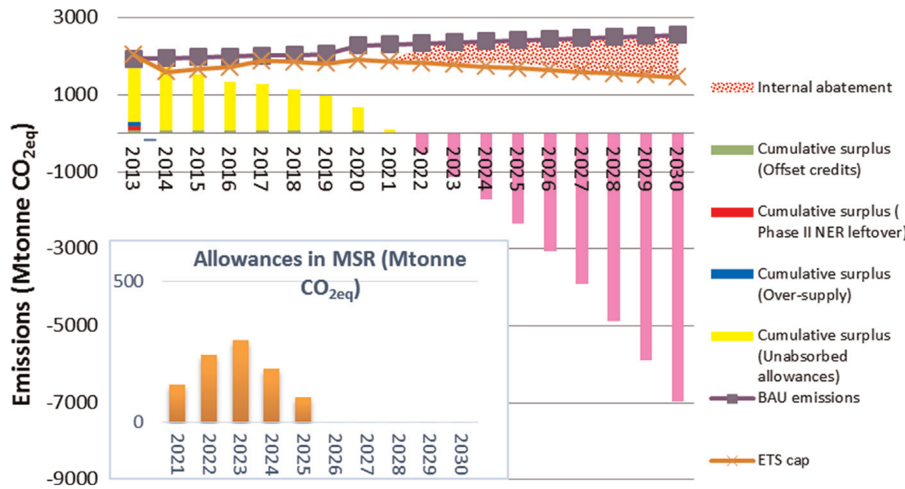

Fig. 9. EU-internal abatement (including aviation) with early-removal of 900 Mtonne allowance surplus under baseline emissions.

impact and policy effectiveness of the EU ETS could be further undermined, in the case of the over-estimation of future baseline emissions or the exclusion of international aviation. Insufficient and deferred EU-internal abatement efforts could reduce the implementation levels of low-carbon technologies. As a result, technological lock-in may occur, rendering the EU's ambitious decarbonization transition too expensive to realize under much more stringent environmental regulations foreseeable in the future. This is particularly a concern, considering even the annual LRF of 2.2% for the cap-setting after 2020 is insufficient to deliver the higher end of the EU's long-term 80%-95% emissions reduction target by 2050. Not to mention the large allowance surplus that raises the *de facto* cap of the current ETS. A more in depth understanding of where this lock-in would occur and its impact on the transition cost would be a valuable further piece of analysis to understand the scale of this risk.

The large allowance surplus banked from Phase II, due to the overwhelming use of offset credits and the unexpected economic recession, can largely be blamed for the limited EU-internal abatement impact of the EU ETS. However, this can also be traced back to the fundamental design of the EU ETS: the inability of the ETS to adjust its absolute inelastic supply of allowances (the ex-ante determined cap) to the uncertain demand (related to baseline emissions).

The authors here strongly advise policy-makers to allow the EU ETS to respond to unexpected changes in demand through adjustment of the cap in a predictable and transparent manner. The EC (2014b)s proposal of establishing a MSR seems to be a sensible starting point for this. This paper shows that the MSR is able to significantly reduce the supply of allowances by storing a number of allowances under the low baseline emissions scenarios where there is a demand shock. This may strengthen the resilience of the ETS in the long run. However, further research on the design and operation of the MSR are required to provide more conclusive evidence. The percentage of annual surplus to be put into the reserve could be higher, to better tackle the current persistent surplus and incentivise EU-internal abatement earlier.

As the combined impact of policy interventions that is currently approved or proposed by the EC is insufficient to restore the scarcity of allowances before ETS Phase IV, other reform options are necessary. These options are identified in the EC (EC, 2012a)s Report "*The state of the European carbon market in 2012*", such as retiring a number of allowances in Phase III and extending the scope of the EU ETS. This paper also supports the reasoning for the early removal of the back-loaded amount of 900 Mtonne allowances by the end of Phase III (2019 and 2020). If that were going to happen (see Fig. 9), allowance surplus would be reduced to less than 115 Mtonne in 2021, and the cumulative internal abatement would reach 6984 Mtonne by 2030. This would certainly strengthen the abatement performance of the EU ETS in Phase IV.

Furthermore, based on results regarding the impact of incorporating aviation into the EU ETS, a solution would be to broaden the scope of the ETS to other sectors with potential high demand for emissions rights (e.g. the transport sector). This may create additional demand for allowance surplus under the current scope of the ETS, accelerating the process of allowance surplus being absorbed and increasing the EU-internal abatement.

Last but not least, considering the EU ETS´ central-pillar role in the EU´s transition towards a competitive low-carbon economy, the EU ETS should be able to deliver the EU´s long-term 80–95% emissions reduction target by 2050 through its cap. Should the EU wants to remain consistent with the higher end of the 2050 target, the LRF would have to be increased to at least 2.55%. This means that the 2030 EU target for emissions reduction should have been set at 53% below 1990 levels, rather than the 40% in the 2030 framework for energy and climate policies (EC, 2014c; European Council, 2014). A more stringent 2030 target with long-term certainty will in turn bolster ETS participants' confidence in the carbon market, ensuring a stable environment for low-carbon investments essential for the EU's decarbonization ambition.

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