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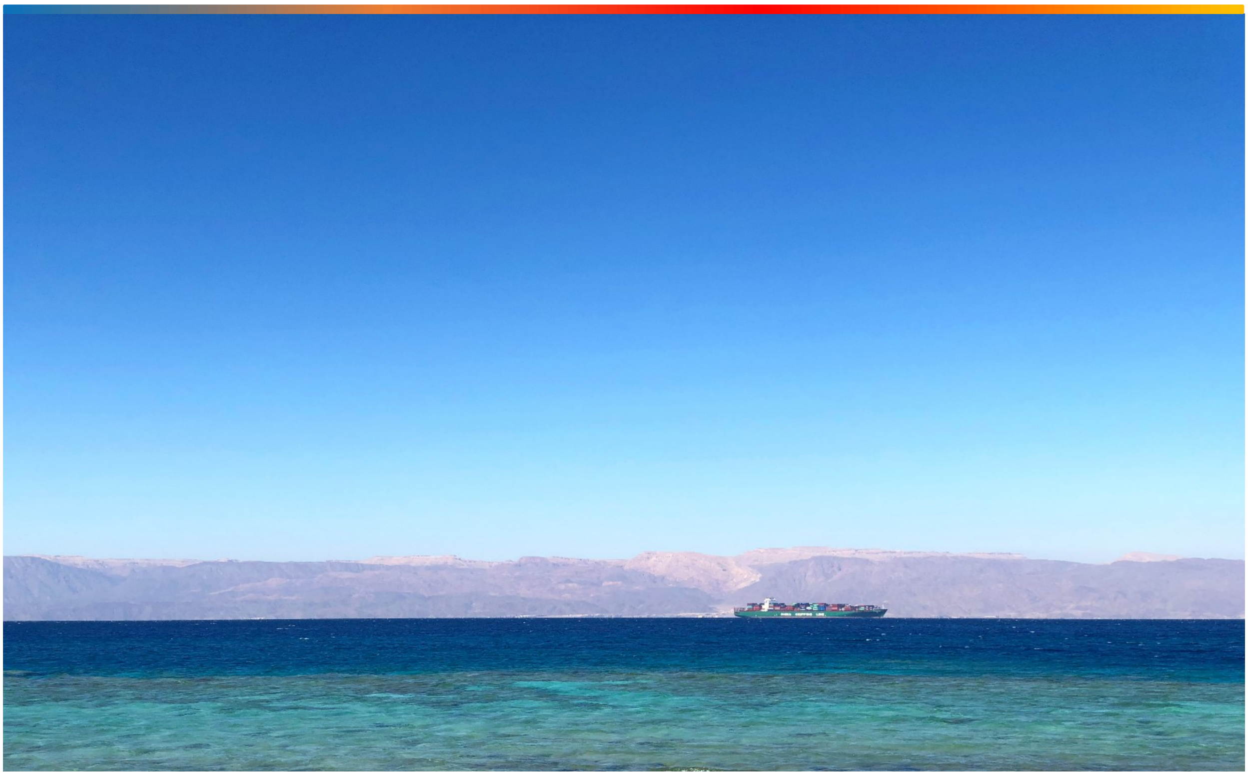

THE RISK OF CARBON LEAKAGE IN THE CONTEXT OF INCREASING THE EU GREENHOUSE GAS EMISSION REDUCTION TARGET

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List of abbreviations

BCA	Border Carbon Adjustment
BTA	Border tax adjustment
CAK	Center for Climate Analysis
CAKE	Centre for Climate nad Energy Analyses
CGE model	Computable general equilibrium model
EC	European Comission
EFTA	European Free Trade Association
ESD	Effort Sharing Decision
ESR	Effort Sharing Regulation
ETP	Version of d-PLACE model with energy technical progress
EU	European Union
EU ETS	European Union Emissions Trading Scheme
EU28	European Union of 28 Member States
GDP	Gross Domestic Product
GHG	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
KOBiZE	The National Centre for Emissions Management
MSR	Market Stability Reserve
NDC	Nationally Determined Contribution
Non-ETS	Sectors not covered by the European Union Emissions Trading Scheme
OPEC	Organization of the Petroleum Exporting Countries
PLACE	Polish Laboratory for the Analysis of Climate and Energy
PLACE model	Computable General Equilibrium Model created in Polish Laboratory for the Analysis of Climate and Energy
d-PLACE model	Dynamic version of PLACE model created in the Centre for Climate nad Energy Analyses
TNAC	Total number of allowances in circulation relevant for MSR

Abstract

Although international efforts towards GHG emission reduction to mitigate global warming seem to be increasingly ambitious, there is still no common set of binding policy measures worldwide. Accordingly, emission prices vary significantly among countries, with no price at all in some regions. This may results in distortions on industries' competitiveness in regions with more stringent climate policy measures (as European Union) and may possibly cause the carbon leakage effect, defined as "the increase in emissions outside a region as a direct result of the policy to cap emission in this region".

The purpose of this paper is to examine the possible scale of the carbon leakage, applying a set of different assumptions and policy scenarios, and to identify channels for efficient carbon leakage mitigation. The computable general equilibrium d-PLACE model has been used to analyse options. This is a recursive dynamic multi-regional and multi-commodity tool, where emissions are precisely modelled (e.g. process and each fossil fuel combustion related emissions are modelled separately). Furthermore, a very detailed modelling of the EU ETS as well as non-ETS emission targets seem to be a significant feature of the d-PLACE model. Two versions of model have been applied to run simulations presented in this paper, with and without exogenous technical change, to examine how the assumptions on technical change influence the modelling results, i.e. the carbon leakage scale.

Main factors determining the carbon leakage rates have been captured by employing the d-PLACE model. The contribution of three channels in the risk of carbon leakage has been examined, including demand, competitiveness and energy. Moreover, energy channel has been further decomposed to examine the impact of sectoral structure and emission intensity within each sector. Such decomposition enabled more accurate investigation of the main channels for carbon leakage phenomenon and identify relevant policy recommendations.

In the first two chapters a brief summary of European Union climate policy, definition of carbon leakage is provided, followed by the review of relevant literature. Third chapter includes a brief description of the model and data sources. Then, examined policy options (scenarios) are precisely described in the fourth chapter. Chapter five focuses on the examination results, while the sixth presents additional scenarios with NDCs implemented and free allocation of emission allowances in the EU ETS. These results reflecting real policy simulation were compared with the results of the main part of this paper to estimate the size of the GDP loss that can associated with the non-binding targets in the rest of the world.

Keywords: carbon leakage, climate policy, trade and the climate policy, energy, EU ETS, non-ETS, CGE, dynamic modelling, low-carbon transition, NDCs, Paris Agreement.

Executive summary

1. The purpose of this paper is to assess the possible scale of the carbon leakage using different assumptions and policy scenarios within the EU and identify channels of carbon leakage in order to prevent this phenomenon in efficient way. We determined the main channels of the carbon leakage occurrence – such as demand, competitiveness and carbon intensity.

2. In the paper, we analysed different options of climate policy implementation in the EU up to 2030. Three types of scenarios were implemented:

    1) **GHG40 (baseline)** - scenario assumes implementation of policy targets for GHG emissions reductions by 40% in 2030 relative to 1990.

    2) **GHG40/MSR** – comprises the same assumptions from GHG40 scenario plus implementation of the Market Stability Reserve in the EU ETS, which reduces the number of available emission allowances in this scheme. The EU ETS has consequently stronger impact on the sectors.

    3) **GHG45/MSR** – scenario which includes both the Market Stability Reserve operationalization and emissions reduction target for the EU equal to 45% in 2030 compared to 1990.

    Both, the GHG emissions and the economic impact in the EU result from the adopted reduction targets.

3. To examine how the assumptions on technical change affect the scale of the carbon leakage we made simulations using two versions of model – without and with technical progress. In the first version of model "*without energy technical progress*" we included only GHG emissions reduction targets in the EU without taking into account technical progress and change in energy used. In the second type of model "*with energy technical progress*" we included technical progress by decreasing the use of fossil fuel based on the projections adopted in the EU Reference Scenario 2016 for the EU Member States and in the World Energy Outlook 2016 "Current Policy Scenario" for the rest of the regions.

4. Implementation of technical progress greatly reduces the risk of carbon leakage. In the version without technical progress in all scenarios total emissions projection for the regions outside the EU rise about 70% between 2015 and 2030. If technical progress is taken into account emissions outside the EU rise about 20%. The largest increase in emissions for the regions outside the EU is in the GHG45/MSR scenarios (scenarios with the most restrictive emission reduction target for the EU analysed in this paper).

5. In both versions of the model, introduction of MSR lead to increase in total emissions due to the shifts in sectoral structure and increased use of carbon intensive fuels outside the EU. Tightening the target to 45% will lead to even higher emissions growth outside the

EU states, caused by a even higher shift in sectoral structure of production. It means that emission reduction is achieved mainly through decrease of the use of fuels in the EU countries and the production of energy intensive goods is shifted outside the EU.

6. The highest leakage rates are observed in energy-intensive industrial sectors, such as non-metalic minerals, iron and steel and chemicals. The change in output by industry in the EU also shows that those sectors are the most exposed on carbon leakage. The size of production in these sectors is decreasing significantly after tightening of the reduction targets. It follows that these sectors are the most carbon intensive and these goods are easily tradeable. Below we presented average decrease in production in selected sectors after introduction of MSR and more stringent climate policy (in version of the model without technical progress).

Table 1. Change in output in the EU and PL in selected sectors in GHG45/MSR scenario (with MSR and -45% target) in comparison to baseline scenario in 2030. *(Without the NDCs' targets for regions outside the EU and without free allocation of allowances in the EU ETS).*

Sectors	EU	PL
Iron and steel	- 9%	- 9%
Non-metalic minerals	- 6%	- 10%
Non-ferrous metal	- 6%	- 3%
Chemicals	- 4%	- 10%

Source: CAKE/KOBiZE own study based on d-PLACE model results

7. The estimates of GDP loss in 2030 in the EU as a results of MSR and more stringent climate policy is equal to 1.3% of GDP on average in „no-technical progress" version of the model and about 1.1% of GDP in „technical progress" version of the model. The most affected countries in terms of estimated GDP loss in the EU in 2030 (in version of the model without technical progress) are:

- Bulgaria - 1,6%,
- Poland - 1,9%,
- Greece and Cypr - 0,9%,
- Adriatic countries - 0,8%,
- Benelux countries with Austria - 0,4%.

8. For an analysis of the climate policy on more realistic grounds, reflecting existing and planed GHG emission reduction measures we examined the impact of targets imposed on non-EU regions based on the NDCs submited under the Paris Agreement, assuming at the same time allocation of free emission allowances within the EU ETS (for EU States). Mechanism of free emission allocation in the EU ETS is a safeguard against the carbon

leakage and realocation of production by sectors exposed to increase of the operating costs related to climate policy.

The GDP loss in 2030 in the EU States are partially reduced due to the introduction of binding reduction targets for the rest of the world. The total GDP decrease in EU States in the scenario with MSR and more stringent climate policy in the EU is 0,6% lower for the version of the model without taking into account technical progress.

The implementation of free emission allowances allocation in the version of the model without technical progress resulted in even increase of GDP in some countries (such as the Baltic countries, Germany, Benelux and Bulgaria) as a consequence of introducing MSR and more stringent emission reduction target.

In the version of the model with technical progress, the total decrease in GDP in 2030 for the EU Member States is by approx. 0,8% with MSR and more stringent climate policy, the largest negative change in GDP were estimated for countries:

- Greece and Cyprus - 1,7%
- Poland - 1,3%
- Adriatic countries - 1,3%
- Romania - 1,1%
- Hungary - 1,1%

The estimated changes in production in 2030 (in the version of the model with technical progress), indicate that decrease of production in energy-intensive industrial sectors is in most cases lower than in scenarios without targets resulting from NDCs and without free allocation of emission allowances (table 2).

Table 2. Change in output in the EU and PL in selected sectors in GHG45/MSR scenario (with MSR and -45% target) in comparison to baseline scenario in 2030. *(including the NDCs' targets for regions outside the EU and free allocation of allowances in the EU ETS).*

Sectors	EU	PL
Iron and steel	- 6%	- 8%
Non-metalic minerals	- 6%	- 11%
Non-ferrous metal	- 3%	- 2%
Chemicals	- 3%	- 8%

Source: CAKE/KOBiZE own study based on d-PLACE model results

Key policy insights:

First, carbon leakage should be perceived as an important problem that can limit the effectiveness of EU ETS (including MSR) and overall the comprehensive EU efforts to reduce global emissions and the implementation of the Paris Agreement.

One of our base assumption of „no external emission reduction target" is used as an example to show the potential carbon leakage phenomenon scale. Adoption of more stringent policies in the EU will create incentives for other countries to relax their own emission reduction commitments. Thus not only would carbon leakage result in the loss of the EU industries by 'leaking' to places with weaker commitments, but it also means that global emissions could even increase as shown in the results of this paper.

Differences in production structure and sector carbon intensity contribute to carbon leakage to a similar extent. Therefore, we should tackle both energy mix channels (e.g. by promoting fuel efficient technologies) and sectoral structure channel (e.g. through free allocation or border tax adjustment).

Taking into account „technical progress" does not alter the main conclusions, but show how differences in technologies may affect leakage rates. Therefore, it is very important to support research on energy-efficient technologies and make them available also to rest of the world.

If we implement the assumption taking into account reduction obligations for the rest of the world and the mechanism of preventing carbon leakage in the EU ETS (free allocation of emission allowances) the decrease of GDP and production in the EU Member States is lower. It may indicate that such measures as free allocation are needed until the price for GHG emission or/and reduction targets in different regions of the world will be varied.

Carbon leakage is prevented by the defense mechanisms used by the EU, i.e. free allocation of emission allowences and compensation for indirect carbon leakage (caused by increase in electricity prices). Other potential preventing carbon leakage solutions are: linkage between ETS, as an example between California and Quebec, which is possible when jurisdictions have similar emission targets, regulatory and political systems. Due to administration burden, this mechanism is not as common as a free allocation method. Also more theoretical or sophisticated in terms of timing options might be mentioned: legal changes at the World Trade Organisation regarding options for inclusion of consumption and border tax mechanisms, or introduction of market-based climate change mitigation mechanisms under the article 6 of Paris Agreement.

1. Introduction

1.1. EU's climate policies

9. European Council in October 2014 adopted a commitment to reduce the overall greenhouse gas emissions of the European Union by at least 40% below 1990 levels by 2030. This commitment was also confirmed in the Nationally Determined Contributions (NDC's) of the European Union and its Member States and submitted to the Secretariat of the United Nations Framework Convention on Climate Change in 2015.

10. European contribution to the emission reduction target is shared among all sectors of the economy and delivered in the most cost-effective manner. To achieve this new objective the European Union has introduced reforms to its emission trading system (EU ETS) covering the most energy intensive economic sectors, jointly responsible to achieve reduction of GHG emission of 43% below 2005 levels by 2030. Remaining economic sectors not covered by the EU ETS (non-ETS) contribute to the emission reduction with a joint reduction target[1] of 30% below 2005 by 2030[2].

1.2. What is carbon leakage

11. Recently vastly emerging regional carbon emission trading schemes have been leading to a set of diverging carbon prices across the world, resulting in distortions with direct implications on competitiveness of the industries in countries with more stringent climate policies. The lack of existence of such globally binding emission reduction treaty has brought the issue of carbon leakage to the attention of policy makers.

12. Simplifying, in terms of climate protection, carbon leakage is defined as "*the increase in emissions outside a region as a direct result of the policy to cap emission in this region*"[3].

    Technically carbon leakage is measured as the ratio of emissions increase from a specific sector outside the country (as a result of a policy affecting that sector in the country) over the emission reductions in the sector (again, as a result of the environmental policy)[4].

$$CL_i = -\left(\frac{\Delta {E^{\beta}}_i}{\Delta {E^{\alpha}}_i}\right) \times 100\%$$

Where:

[1] Joint reduction target has been divided in to national emission reduction targets for 2030 for all Member States and regulated by the Effort sharing regulation adopted in 2018, see: https://ec.europa.eu/clima/policies/effort/proposal_en

[2] See Regulation (EU) 2018/842 - Binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013.

[3] See Julia Reinaud (2008)

[4] There are several channels through which carbon leakage might occur. The main focus in this study is the so-called competitiveness channel working through the loss of the market shares of the affected domestic industry.

CL_i– carbon leakage rate in sector i,

$\Delta E^{\alpha}{}_i$– change (decrease) the GHG emissions in a regions α and sector i where climate policy is present,

$\Delta E^{\beta}{}_i$– change (increase) the GHG emissions in a regions β and sector i where no climate policy is present or the activities to reduce emissions are negligible.

13. The carbon leakage does not have one precise definition. There are many possible interpretations of carbon leakage phenomenon. Carbon leakage is defined as a displacement of economic activity or investment directly or indirectly causing GHG emissions out of the jurisdiction with more stringent emission abatement policies into other jurisdiction with less stringent policies, see *CEPS (2013)*. IPCC has defined[5] carbon leakage as "*the increase in CO_2 emissions outside the countries taking domestic mitigation action divided by the reduction in the emissions of these countries*". Their definition is limited to relocation of energy intensive production, but also pays attention to leakage induced by decline in world prices of fossil fuels and potential demand due to the improvements of some countries. EC Directive on EU ETS[6] confirmed that carbon leakage "*could put certain energy-intensive sectors and subsectors in the Community which are subject to international competition at an economic disadvantage. This could undermine the environmental integrity and benefit of actions by the Community*" and introduced specific technical conditions under which a sector or subsector is deemed to be at risk of carbon leakage[7]. Similar reasoning also applies for the foreign direct investments[8].
14. Carbon leakage represents both, a major environmental concern effectively undermining the overall effectiveness of any meaningful global environmental agreement as well as economic concern of a loss of competitiveness on the global markets due to the incremental costs represented by the carbon price for the incumbent companies. The available evidence collected by the ex-post studies seems to suggest, that due to the continuous free allocation of emission allowances[9] to energy intensive and trade exposed sectors and generally low carbon prices have resulted in a very low risk of carbon leakage at present[10]. Concerns however still prevail in particular among the Central and Eastern

[5] For IPCC see: Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ed. O.R.D. B. Metz, P.R. Bosch, R. Dave, L.A. Meyer. 2007, Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. https://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch11s11-7-2.html,

[6] See recital 24 of the Directive 2009/29/EC amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0029&from=EN

[7] See Directive 2009/29/EC, paragraphs 15-17, more details are also provided here: https://ec.europa.eu/clima/policies/ets/allowances/leakage_en.

[8] In case of foreign direct investments the key parameter is the degree of international mobility of capital.

[9] According to the Directive 2003/87/EC, sectors in the EU ETS which are exposed at the risk of carbon leakage get a part of the emission allowances free of charge. Carbon lists were established to identify sectors with high risk of carbon leakage. The first carbon leakage list was valid for 2013–2014. The second carbon leakage list covers the period 2015–2019. As a part of the post 2020 architecture sectors proven being exposed to carbon leakage continued receiving emission allowances free of charge.

[10] See Carbon Leakage Evidence Project: Factsheets for selected sectors, *Ecorys (2013)*,

European economies which remain more energy and carbon intensive and trade exposed unless far reaching structural reforms are implemented. Such concerns might act as to prevent or slow down adoption of structural reforms and implementation of climate and energy policies.

15. The initial regulatory framework of the EU ETS has recently undergone substantial adjustments (i.a. by introduction of Market Stability Reserve[11]) addressing the pressing structural imbalances on the allowance market. Moreover at the same time the political discussion has been questioning the environmental integrity of the EU ETS. In this context we believe that further analysis on how variation of the key measures will affect the carbon leakage and competitiveness of the European industry and how this impact differs among the EU Member States is needed. In line with the 2030 climate and energy policy framework free allocation will continue beyond 2020 until other major economies undertake similar climate policies and measures. The strategic decision of the European Commission and the proposed carbon leakage measures[12] attempt to strike the right balance at this point in time, but should be kept under review in the coming decade, in light of the Paris Agreement. Carbon leakage will however remain as one of the major concern even beyond 2020[13].

1.3. Purpose of the publication

16. Some earlier analysis of the risks of carbon leakage specifically for Polish economy pointed at an absence of empirical research sufficiently documenting the potential of carbon leakage risks and identify the key economic sectors under the risk of carbon leakage. An earlier study offered a comparison of macroeconomic and sector specific impacts of different allocation rules for distribution of emission allowances among polluters and concluded that without any free allocation competitiveness of the European industry would be heavily undermined[14]. This study is based on the new baseline and available macroeconomic and energy projections. More specifically the objective of this paper is to review the potential for carbon leakage driven by the adoption of the most recent GHG emission reduction targets within the EU and operationalization of the Market Stability Reserve. Our analysis also attempts to identify main channels driving the carbon leakage.

https://ec.europa.eu/clima/sites/clima/files/ets/allowances/leakage/docs/cl_evidence_factsheets_en.pdf

[11] Detailed information about MSR can be found on the European Commission website (link: https://ec.europa.eu/clima/policies/ets/reform_en).

[12] See Commission Decision of 27 October 2014 determining, pursuant to Directive 2003/87/EC of the European Parliament and of the Council, a list of sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage, for the period 2015 to 2020.

[13] See Article 10b Directive (EU) 2018/410 of the European Parliament and of the Council of 14 March 2018 amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, and Decision (EU) 2015/1814 and Commission Notice on the Preliminary Carbon Leakage List for the EU Emissions Trading System for Phase 4 (2021-2030).

[14] See Maciej Cygler et. all (2016).

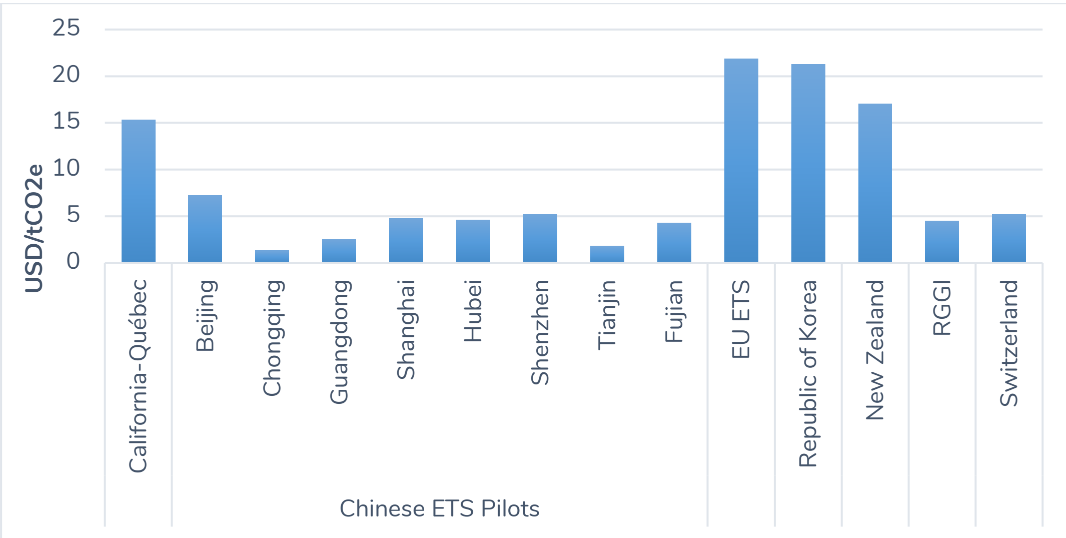
The objective of the analysis is also to present the different economic impacts of carbon leakage on particular sectors and Member States.

2. Literature review and legislative background

2.1. Carbon leakage

17. According to the economic theory a global emission reduction agreement would be the best solution to address "international externalities" and first best response to the global environmental problems such as climate change, see e.g. *Markusen (1975)*. Global efforts in the emission abatement would imply existence of a single carbon world price equalizing marginal abatement costs among all polluting firms across the regions. Despite all efforts of recent negotiations including increasing participation of the developing countries, the emerging carbon markets world-wide remain fragmented. The progress occurs at a rather slow pace maintaining carbon price differentials, which remain a challenge for policy makers and in particular for business exposed to the international competition[15]. Figure 1 shows the differences between the prices of emission allowances in various ETS established in the different parts of the world.

Figure 1. Carbon prices from ETS around the world (based on data from November 2018)



Source: "Raport z rynku CO2", KOBiZE, no. 80, November 2018 (based on the International Carbon Action Partnership)

17. Additional challenge according to European Commission and some experts is a low price of emission allowances (EUA) in the EU ETS due to the surplus of allowances on the market. The European Commission, after the attempt to address the remaining imbalance

[15] See Das, et.all (2018), for overview of the options for international trade from the clmate policy point of view.

by backloading of allowances on the EU carbon market, addressed it by the adoption of the Market Stability Reserve, however there are many uncertainties remained around the potential impact of this flexibility mechanism.

18. The introduced to EU ETS mechanism of the Market Stability Reserve functions as a selfregulatory instrument managing the supply of emission allowances to ensure a carbon price which is credible for low emission investments by regulating the amount of emission allowances in circulation through withdrawals and injections under a set of pre-defined rules. Existing analysis (see e.g. *ECOFYS 2014*) suggest that the set up of the MSR has the potential "*to increase prices and stimulate abatement*".
19. Unilateral adoption of climate policies by a small group of polluters committed to reduce their emissions might fail to reach the global objective due to the potential carbon leakage i.e. shift of the emissions beyond their jurisdictions. The resulting effect of such action could be very modest if emissions in the non-abating countries would increase. Moreover, remaining high variability in the abatement costs across the countries do not warrant an equal level playing field and therefore provide justification for further policy intervention preventing the loss of industrial competitiveness.

20. Broad range of measures stand ready to protect industrial competitiveness undermined by carbon costs. Many of them are well described and analysed in the literature, see e.g. Fischer and Fox (2012). The most known measures include e.g. distribution of the emission allowances for free or allowing output based rebates to refund producers. In several cases e.g. such as strategic decisions and investment projects direct cost compensations (e.g. cuts in other type of taxes) or targeted trade measures might work better. Alternatively subsidies for installations with significant energy cost impacts can be considered. Possibility for border adjustments also received substantial attention, see e.g. *Böhringer et all (2012)*. Proposals to tax the carbon emissions embodied in the imports and rebate the tax paid for carbon emission generated by producing the country exports might have appealing efficiency properties, but potentially incentivise artificial improvements of countries terms of trade through strategic manipulation of tariffs. Estimates reported in the empirical literature seem to suggest that BCA or BTA[16] can be effective in reducing the potential leakage rates.

21. Adoption of all such measures comes at cost of distorted carbon price and reduced incentives for emission abatement. The available empirical evidence on carbon leakage has not been unambiguous. According to different studies e.g. by Carbon Market Watch (2015), Ecofys (2014) no compelling evidence that the EU climate policies were forcing companies moving outside the EU, could have been presented. In addition distribution of emission allowances for free also bears the risk of leading to windfall profits[17] at the

[16] BCA – Border Carbon Adjustment; BTA – Border Tax Adjustment

[17] Windfall profits is defined as unexpected profit arising from a circumstance not controlled by a firm or an individual. These profits constitute transitory income and can give rise to unusual consumer behaviour (see: Rutherford 2002). In the EU ETS

expense of the taxpayers. On the other hand simulations based on structural CGE models estimates of the carbon leakage seem to range between 2% and 130% with a mean value of 20%[18]. Major candidates for carbon price offsetting measures include heavy industries such as cement and clinker, iron and steel or aluminium production. Energy intensive sectors such as basic chemicals, pulp and paper and refineries might also warrant some compensation measures.

22. Understanding the mechanism how the carbon leakage occurs is a key to design appropriate (efficient) policy response. A majority of papers addressing carbon leakage mechanism employed a general equilibrium framework. This framework can well capture the main factors, which determined the carbon leakage rates such as market structure, market regime on emission trading, transportation costs, elasticity parameters[19], different policy instruments[20]. Combination of these parameters also determine the ability of companies to pass through the additional carbon related costs downstream or towards customers.

2.2. Different channels of carbon leakage

23. Other strand of the literature attempts to decompose the carbon leakage into channels distinguished by a specific driving factor. Three main channels have been identified:

    I. The first - **energy channel** refers to the increase of the consumption of fossil fuels in the non-abating countries. This is due to the decrease of international fossil fuel prices induced by the constrained demand in the GHG abating countries. However, this can be also achieved through technology changes, shifts in the fossil fuel mix and even the change in production structure. **Therefore, we will refer to that channel also as to carbon intensity channel**, because not only change in fuel consumption is involved.

    II. The second - the **competitiveness channel** refers to the induced changes in comparative advantage of the emission-intensive and trade-exposed industries vis-à-vis their competitors in the non-abating regions. Industries comparative advantage is driven by the relative cost patterns, which are affected by the carbon mitigation policies raising production costs of the energy intensive industries. Higher production costs lead to loss of competition and international market

windfall profits may occur when installations past through the cost of emission allowances (necessary to cover all its emissions) on the final consumers despite the fact that it receive part of allowances free of charge. Windfall profits may also occur if installations receive too many free emission allowances that can be sold for a profit in the market.

[18] See *Parousso et all (2015)* page 206. Note that such estimates are largely determined by the type of estimate procedure i.e. the model employed for estimation and particularly assumptions on the values of the key elasticities.

[19] See Oliveira Martins (1996) and Bollen et *al.* (1999)

[20] See Paroussos et all (2015)

shares. As a consequence competitive position of the industries in countries mitigating their greenhouse gas emissions might deteriorate.

III. The third - **demand channel** refers to the changes in the demand for energy intensive products. Climate policies in general affect the relative prices of goods and incomes. Rising prices of energy intensive goods will induce a shift of demand from abating into the non-abating regions.

24. Competitiveness channel has so far received the most attention in the literature. Through this channel the competitiveness of the energy intensive industries would be weakened due to more stringent carbon mitigation policies. This can induce the potential relocation of the affected industries into the non-abating regions. Impact on industrial competitiveness will be visible through changes in the trade patterns[21] and capital flows. For example *Böhringer (2012)* in his comparative analysis concluded that the competitive chanel is more important than energy channel.

25. Carbon intensity channel refers to decline of the world fossil fuel prices induced by the fall in demand for fossil fuels in the abating countries. Lower fossil fuel prices might induce an increase of the fossil fuel based energy demand in the non-abating regions. Literature does not appear conclusive on the strength of this channel as also strategic interactions might play an important role such as decisions of the fossil fuel supplying countries, see e.g. *Böhringer (2012b), Criqui and Mima (2012)*.

26. Using an index number decomposition[22] of the total carbon emissions, different specific channels through which the carbon leakage might occur. Literature refers to competitiveness, demand, and carbon intensity channels[23]. To show, how different channels affect the changes in emissions, we will use framework that decompose the changes in emissions to:

$$\Delta C_i = \frac{(\Delta EX_i - \Delta IM_i + \Delta DD_i)(CI_i^{sc} + CI_i^b)}{2} + \frac{\Delta CI_i(Q_i^{sc} + Q_i^b)}{2}$$

Where:
ΔC_i - change in carbon emissions,
ΔEX_i - changes in exports,
ΔIM_i - changes in imports,
ΔDD_i - changes in domestic demand,
CI_i^{sc} – carbon intensity in analysed scenario,
CI_i^b – baseline carbon intenstity in analysed scenario,
Q_i^{sc} – GDP in analysed scenario,
Q_i^b – baseline GDP,

[21] Analysis by *Babiker (2001)* highlights the importance of the trade channels over capital mobility.
[22] There is a broad literature considering suitability of several index number forms for decomposition, for an overview see e.g. *Agn et al (2003)*. Our decomposition is based on *Tan et al (2018)*.
[23] Our exposition draws on *Tan et al. (2018)*.

$\frac{(\Delta EX_i - \Delta IM_i)(CI_i^{sc} + CI_i^b)}{2}$ - competitiveness channel,
$\frac{\Delta DD_i(CI_i^{sc} + CI_i^b)}{2}$ - domestic demand channel,
$\frac{\Delta CI_i(Q_i^{sc} + Q_i^b)}{2}$ - carbon intensity channel.

Moreover, carbon instensity channel may be further decomposed into changes in energy demand and changes in the structure of the economy. Therefore, changes in internal production structure (such as shifts between different domestic commodities) are also included, as well as changes in the structure of use of fossil fuels or changes in emission intensity of fuels as such.

27. Consequently, the carbon intensity component of change in emissions can be further decomposed to changes in sectoral structure and energy intensity, using additive logarithmic mean divisia index decomposition, see *Ang et al. (2013)*:

$$\Delta CI_i = CI_i^{sc} - CI_i^b$$

$$\Delta CI_i = \sum_s \frac{L(\frac{C_{s,i}^{sc}}{C_i^{sc}}, \frac{C_{s,i}^b}{C_i^b}) L(CI_i^{sc}, CI_i^b)}{\sum_{ss} L(\frac{C_{ss,i}^{sc}}{C_i^{sc}}, \frac{C_{ss,i}^b}{C_i^b})} \ln\left(\frac{sh_{s,i}^{sc}}{sh_{s,i}^b}\right) + \sum_s \frac{L(\frac{C_{s,i}^{sc}}{C_i^{sc}}, \frac{C_{s,i}^b}{C_i^b}) L(CI_i^{sc}, CI_i^b)}{\sum_{ss} L(\frac{C_{ss,i}^{sc}}{C_i^{sc}}, \frac{C_{ss,i}^b}{C_i^b})} \ln\left(\frac{CI_{s,i}^{sc}}{CI_{s,i}^b}\right)$$

$C_{s,i}^b$ and $C_{s,i}^{sc}$- sectoral carbon emissions in baseline and scenarios,
$CI_{s,i}^b$ and $CI_{s,i}^{sc}$ - carbon intensities in baseline and scenarios,
$sh_{s,i}^b$ and $sh_{s,i}^{sc}$ - shares of sector in output (GDP) in baseline and scenarios,
$L(x,y) = \frac{x-y}{\ln x - \ln y}$ is the logarithmic average.

The first component of the sum is the part of the change in carbon intensity that is due to the changes in share of given sector in output and the second is contribution of changes within sector carbon intensity. Such decomposition will allow to say whether the changes in aggregate carbon intensity are achieved due to the changes in sectoral structure of the economy or due to efforts of enterprises either to reduce energy use or change in the internal use of fuels.

3. Model and data

28. d-PLACE model[24] was employed to run the scenarios described below. d-PLACE is a recursive dynamic multi-regional and multi-commodity (20 sectors) model developed in the neoclassic tradition of CGE models. For the purpose of the analysis we aggregated the world into 26 regions. In the context of carbon leakage analysis, this model have several advantages over its competitors. First of all, emissions are modelled in a great detail. Process and fossil fuel combustion related emissions are modelled separately. Moreover, each fossil fuel is modelled explicitly. This allows to analyse where carbon leakage occurs and what policies can be introduced to counteract carbon leakage. Second advantage is a very detailed modelling of EU ETS market. Even though, in the baseline scenario, we do not include free allowances for industries under risk of carbon leakage, there is a possibility to do so and results of such scenarios are presented in the appendix. Inclusion of non-CO_2 emissions in d-PLACE model allows for modelling also leakage of other GHG's. As the model includes the labour-leisure choice, it allows for the analysis of impact of climate policies on households welfare including calculation of compensation mechanisms to offset the increased costs of products for consumers.

29. In line with earlier analysis we further investigate the heavy and energy intensive and trade exposed industries such as refined oil products and coke, chemical production, non-metallic minerals (e.g. cement, lime, gypsum and glass), paper–pulp, iron and steel, aluminium production, reportedly to be expected as the key candidates for carbon leakage. One of the key driving factors behind carbon leakage is the ability of the firms to pass-through the additional climate policy related costs further towards final consumer. In turn the cost pass-through is a result of several factors, including the underlying market structure, magnitude of the carbon penalty, product substitutability and market demand patterns.

[24] d-PLACE is a recursive dynamic model developed on the basis of the static CGE model called PLACE, which was created in cooperation with IOŚ-PIB in 2013-2016 at the Climate Analysis Center set up in the KOBiZE. More detailed description of the PLACE model is available: https://www.mf.gov.pl/documents/764034/5005995/mf_wp_22.pdf

4. Analysed policy options (scenarios)

4.1. Types of scenarios

30. Table 1 shows the different scenarios analysed together with the respective emission reduction targets assuming for the EU States.

Table 3. Types of scenarios and models used for analysis

Scenario	GHG emission reduction target for EU-28			Market Stability Reserve in EU ETS
	Total GHG emission reduction in 2030 compared to 1990	EU ETS in 2030 compared to 2005	non-ETS in 2030 compared to 2005	
Type I – *"without energy technical progress"* Version of model without exogenous change in energy use *(based on conservative assumptions)*				
GHG40	40%	43%	30%	Not included
GHG40/MSR	40%	43%	30%	Included
GHG45/MSR	45%	48%	36%	Included
Type II – *"with energy technical progress (ETP)"* Version of model in which exogenous change in energy use (motivated by energy-saving technical progress) is taken into account *(based on EU Reference Scenario 2016* [25] *and World Energy Outlook*[26]*)*				
GHG40/ETP	40%	43%	30%	Not included
GHG40/MSR/ETP	40%	43%	30%	Included
GHG45/MSR/ETP	45%	48%	36%	Included

Source: CAKE/KOBiZE

31. The basic calculation in our analysis does not include emission reduction targets of regions outside the EU and implemented measure to prevent carbon leakage in the EU Member States, ie. free allocation of emission allowances in the EU ETS.

To better reflect current climate policy in the additional scenarios (in section 6) we assume:

- Paris Agreement and adopted objectives resulting from NDCs for the rest of the world regions.
- Free allocation of emission allowences in the EU ETS.

[25] European Commission, EU Reference Scenario 2016 – Energy, transport and GHG emissions Trends to 2050, 20th of July 2016.
[26] International Energy Agency, *World Energy Outlook 2016 – Current Policy Scenario*, 16th of November 2016.

4.2. Differentiation of the models due to implementation of technical progress

32. The analysed policy options (scenarios) were prepared on two versions of the model:

- **Type I – "*without energy technical progress*"** – model including only GHG emissions reduction targets in 2030, without taking into the account technical progress reflecting, e.g. increase of energy efficiency or decrease the use of fossil fuels.
- **Type II – "*with energy technical progress*"** – assumptions used in the model based on the projections of energy consumption adopted in the EU Reference Scenario 2016 for the EU Member States and in the World Energy Outlook 2016 "*Current Policy Scenario*" for the rest of the regions. Scenarios generated by this kind of model are marked with the ETP abbreviation in the tables and content. Implementation of these projections lead to decrease the use of fossil fuel (compared to previous types of scenarios) which partly contributes to the achievement of the climate policy targets. This change corresponds to the increase of the energy efficiency and decrease demand for fossil fuels. Scenarios were generated in two steps. In the first step assumptions concerning energy consumption were introduced to the d-PLACE model through the changes of the parameters of the production structure. In the second step, the constraint reflecting the additional emission reduction targets was added (for details see the description below).

4.3. Differentiation of the scenarios due to the EU climate policy implementation

4.3.1. GHG40 and GHG40/ETP (the baseline scenarios)

33. Scenarios assume implementation of the EU's climate policy targets for GHG emission reductions by 20% in 2020 and by 40% in 2030 relative to 1990. These targets concern emissions from all sectors of the economy. Total GHG emissions reductions were split between sectors covered by EU ETS and non-ETS.

34. Emissions will be reduced in the EU ETS sectors by 21% in 2020[27] and by 43% in 2030 respectively relative to 2005. The non-ETS sectors would need to cut emissions by 10% in 2020 and by 30% in 2030, relative to 2005.

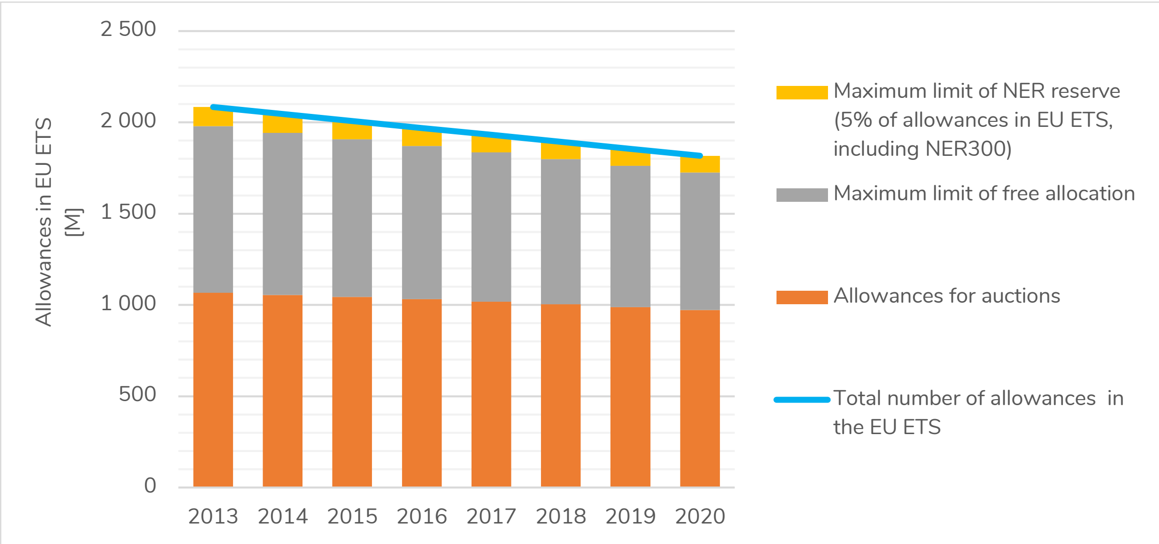
[27] The number of allowances corresponding to the target 21% in the EU ETS in 2020 has been modified by assumption that allowances removed from the market due to backloading and not distributed free of charge pursuant to art. 10a EU ETS directive will never come back on the market.

A. Emission reduction targets in the EU ETS sectors adopted for the periods 2013-2020 and 2021-2030 (with linear reduction factors: 1,74% for 2013-2020 and 2,2% for 2021-2030)

35. The total number of allowances in 2013 for installations covered by the EU ETS in 28 EU Member States and three EFTA countries was set at 2 084 million[28]. A linear reduction factor of 1.74% (of the average number of allowances issued to the installations in the years 2008-2012) was applied on the total number of allowances for the period 2013-2020. In absolute terms, this means that the number of allowances is reduced annually by approx. 38 million. [29]

36. Figure 2 presents the total number of allowances issued in the EU ETS in the period 2013-2020 with the splitting of those allowances into free allocation, auction and reserve for new installations - New Entrant Reserve (NER)[30] (for additional information see Annex I).

Figure 2. Total available number of emission allowances for EU ETS sectors in the period 2013-2020*



* *Without taking into account backloading and the Market Stability Reserve.*

Source: CAKE/KOBiZE own calculations based on the Directive 2003/87/EC

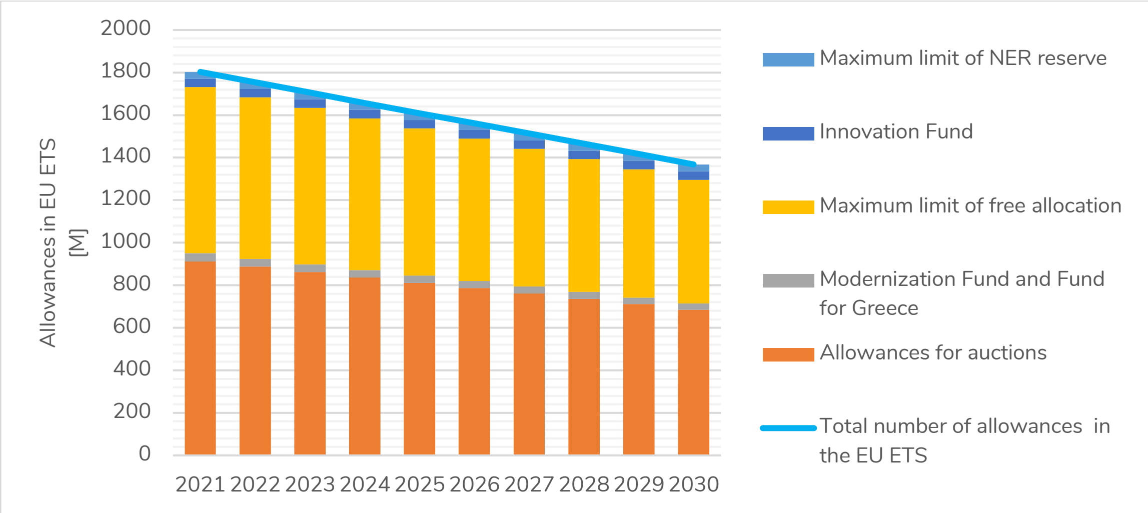
37. From the total number of emission allowances in the period 2013-2020 (see Figure 2. above) we withdrawn 900 million emission allowances from the auction due to the backloading[31] and remaining emission allowances which will not be allocated free of charge (on the basis of 2015 – the first year of the projection)[32].

[28] See Commission Decision 2013/448/EU.
[29] https://ec.europa.eu/clima/policies/ets/ETPp_en
[30] Allowances set aside for new installations and installations that increase capacity, which allows for additional free allocation in the EU ETS.
[31] See Regulation (EU) No 176/2014.
[32] From New Entrants Reserve (NER) and pursuant to art. 10a EU ETS Directive.

38. In 2030, emissions from sectors covered by the EU ETS will be 43% lower than in 2005. In order to achieve the 43% target by 2030, the total number of emission allowances in the period 2021-2030 will be reduced annually by 2.2% of the average number of emission allowances issued to the installations in the years 2008-2012. This means an annual reduction of emission allowances from 2021 by approx. 48 million[33].

39. Figure 3 presents the allocation of emission allowances in the EU ETS in the period 2021-2030 (for additional information see Annex I).

Figure 3. Total available number of allowances for EU ETS sectors in the period 2021-2030*



** Without taking into account the Market Stability Reserve.*

Source: CAKE/KOBiZE own calculations based on the Directive (EU) 2018/410

40. It was assumed that sectors included in EU ETS (in EU-28, and three EFTA countries) have to surrender enough emission allowances to cover all its emissions. Emissions allowances are generally divided into three categories:

- allocated free of charge,
- auctioned,
- available in the funds in the EU ETS (these allowances are auctioned) i.e.:
  - ✓ in the period 2013-2020: Innovation Fund (NER300),
  - ✓ in the period 2021-2030: Innovation Fund, Modernization Fund and Fund for Greece.

[33] https://ec.europa.eu/clima/policies/ets/ETPp_en

41. In the EU ETS sectors exposed to a risk of carbon leakage receive part of emission allowances free of charge[34] (the list of industrial sectors with free allocation in d-PLACE model: "*Refined oil products, coke*", "*Paper–pulp–print*", "*Non-metallic minerals*", "*Food industry*", "*Chemical industry*", "*Iron and steel industry*", "*Non-ferrous metals*"). Industries are granted with free emission allowances on the basis of activity level (production) and their emission benchmark.

42. Amount of auctioned emission allowances has been distributed among Member States according to the following rules[35]:

   - in the period 2013-2020: **88% / 10% / 2%** (share of Poland in auctioned emission allowances 12,11%),
   - in the period 2021-2030: **90% / 10%** (share of Poland in auctioned emission allowances 11,92%).

B. Emission reduction targets in the non-ETS sectors adopted for the periods 2013-2020 and 2021-2030

43. In 2020, the EU GHG emission reduction target for the non-ETS sectors was set to 10% relative to 2005. Distribution of GHG emission reduction efforts for the years 2020 was calculated taking into the account gross domestic product (GDP) per capita and country specific non-ETS targets ranges which from -20% to +20%. For Poland, the target is set to +14% in 2020[36].

44. According to the Effort Sharing Regulation[37], in the non-ETS sectors the emission reduction target in 2030 is equal to 30% relative to 2005. This target is converted into national emission reduction targets in 2030 for all Member States, ranging from 0% to -40% (for Poland the target is -7%). The way of distribution of the emission reduction targets among the EU Member States was based on the same principles as for the year 2020.

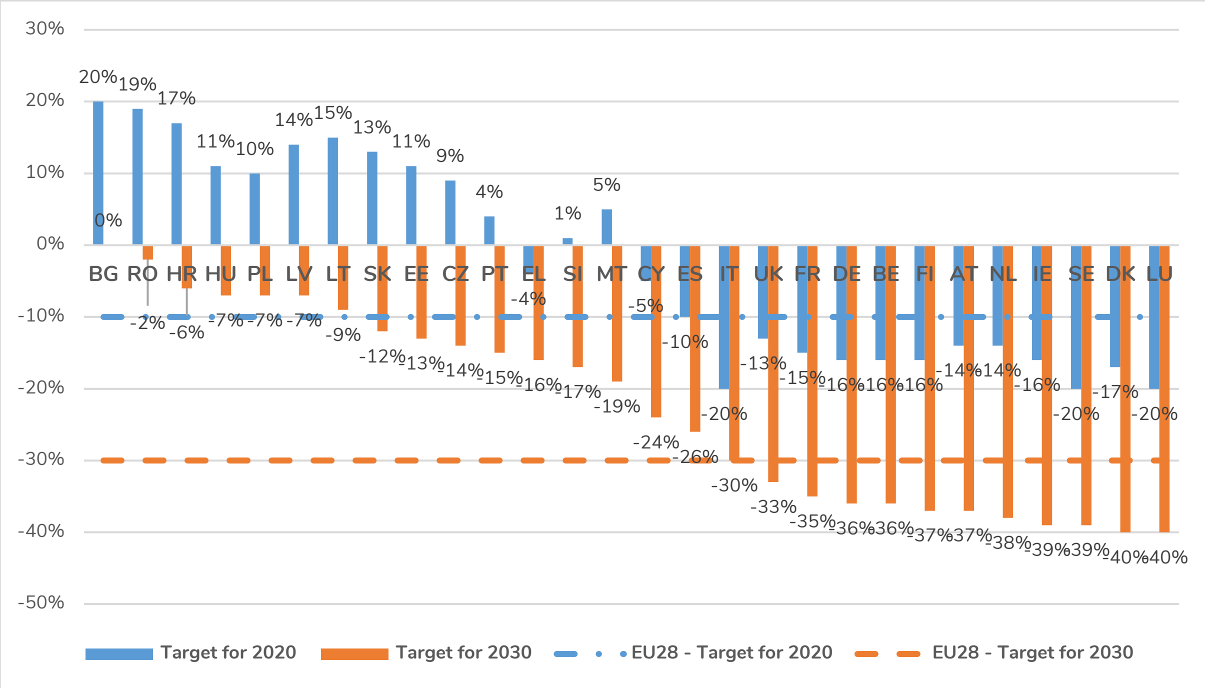
[34] A detailed description of the allocation rules adopted in PLACE and d-PLACE models (called "historical allocation") includes the CAK analysis on the issue of carbon leakage in the context of EU climate and energy policy CAK (2015), „*Dynamiczna alokacja bezpłatnych uprawnień w systemie EU ETS a zjawisko carbon leakage w perspektywie 2030 roku*" presentation of the Center for Climate Analysis, 10/07/2015. The description of allocation of emission allowances in the PLACE model is also included in the paper "*Allocation rules of free allowances in the EU ETS system. A CGE analysis*", Michał Antoszewski, Krzysztof Wójtowicz, 2016.

[35] See Article 10 (2) of the Directive 2003/87/EC.

[36] For details see EC Decision 2009/406 /EC.

[37] See Regulation (EU) 2018/842.

Figure 4. Emission reduction targets in the non-ETS sectors for each EU Member State in 2020 and 2030 relative to 2005



Source: Based on Decision 2009/406 /EC[38] and Regulation (EU) 2018/842 (Effort Sharing Regulation)

45. Annual emission limits were set for GHG emissions for each EU Member State[39] for the period 2013–2020. The annual limits for GHG emissions were calculated on the basis of adopted GHG emission reduction targets for 2020.

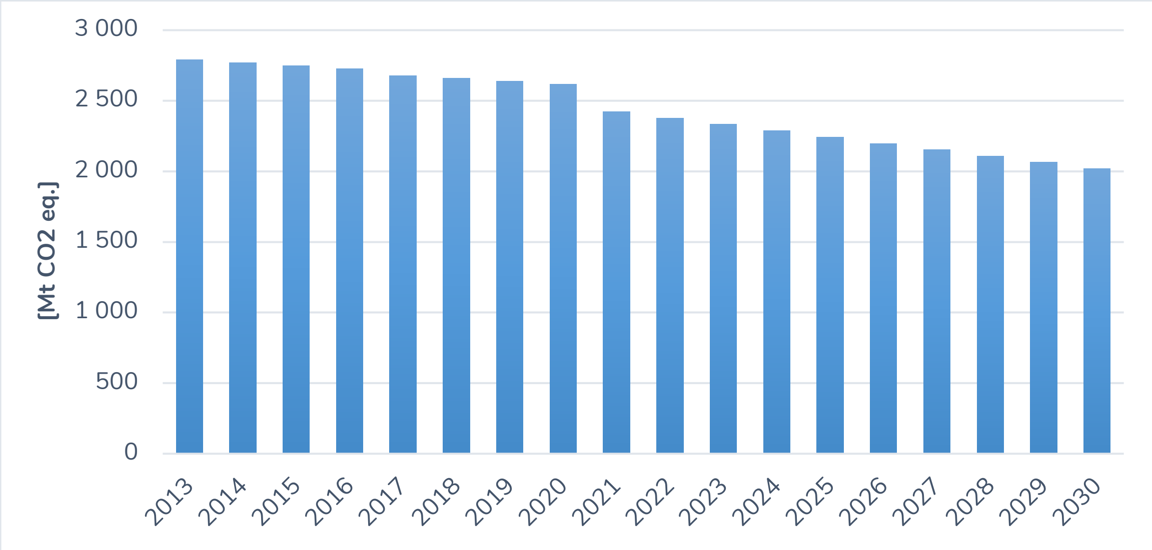
46. For the period 2021–2030 the limits for GHG emissions were also calculated on the basis of the adopted GHG emission reduction targets for each EU Member State. Annual emission reductions for the years 2021-2030 for each EU Member State is formulated by the line which connects starting and final points[40]:

- starting point - average emissions between 2016-2018[41] placed in the timeline within five twelfth distances from 2019 to 2020 (or at 2020 if this results in further reductions for specific Member State),
- final point - set on the basis of the 2030 target compared to 2005.

The values of annual emission limits enter our modeling simulations as exogenous parameters.

[38] See Decision No 406/2009/EC.
[39] See Decision 2013/162/EU. Note that these limits were changed in 2013 by Decision 2013/634/EU and in 2017 by the Decision (EU) 2017/1471.
[40] Based on information avalabble on the EC webside (link: https://ec.europa.eu/clima/policies/effort/proposal_en).
[41] Emission projection based on EU Reference Scenario 2016 – Energy, transport and GHG emissions Trends to 2050.

Figure 5. Total annual emission limits in the non-ETS sectors for EU Member States in the period 2013-2030 for 40% target



Source: CAKE/KOBiZE own calculations based on: Decision 2013/162/EU, Decision 2013/634/EU and Regulation (EU) 2018/842 (Effort Sharing Regulation)

4.3.2. GHG40/MSR and GHG40/MSR/ETP

47. The EU ETS has stronger impact on the sectors due to the implementation of the Market Stability Reserve (MSR)[42] which reduces the number of available allowances in auctions. Implementation of MSR generates stronger price signal to reduce emissions in the sectors covered by the EU ETS.

48. MSR is a mechanism designed to automatically adjust the number of emission allowances available for auctioning on the primary market, depending on the number of emission allowances in circulation[43]. If there is a significant surplus of allowances, a part of allowances starting from 2019 is deducted from auction volumes and added to the reserve (thus reduces auction supply of allowances)[44].

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[42] Detailed information about MSR can be found on the European Commission website (link: https://ec.europa.eu/clima/policies/ets/reform_en).

[43] See Decision (EU) 2015/1814.

[44] If there are more than 833 million allowances on the market, the auction pool designated for sale by Member States will be reduced by 24% from the number of allowances in circulation (from 2024 the rate is reduced to 12%) . However, if the number of allowances in circulation reaches a value of less than 400 million, 100 million allowances will be transferred from the MSR to the auction pool.

The transfer of emission allowances from MSR to the auction is a problematic issue. According to analysis made by Carbon Tracker the emission allowances will never came back to the auction due to the way how the surplus of allowances is calculated. Definition of surplus does not take into account deficit of emission allowances caused by aviation. Carbon Tracker said: "*we are still projecting a cumulative deficit for aviation of 600Mt by 2030 – this means that the cumulative surplus for fixed installations (otherwise known as the TNAC) cannot fall below 600m by 2030*" (page 16, "Carbon Countdown", Mark C. Lewis, August 2018). According to the definition of surplus (TNAC) adopted in MSR Decision lower threshold 400 million will never be reached. We take into account this issue in our calculations of surplus in the EU ETS.

49. Based on the emission projections from the *EU Reference Scenario 2016* we estimated that **by 2020, around 760 million** of emission allowances will be transferred from auction and put into the MSR. In the next period, the MSR will have a slightly less effect on the market - **during the period 2021-2030 690 million allowances will be transferred to the reserve**[45].

    The number of allowances withdrawn from the market is enormous and roughly equal to the number of allowances which will be sold during two-year period in the EU ETS. The transfer from auctions to the MSR such a large number of emission allowances will correspond to an annual reduction of the auction on average 95 million in the period 2013-2020 and 69 million in the period 2021-2030.

50. Emission allowances withdrawn from the auctions due to the backloading and emission allowances which were not allocated free of charge to the installations in the period 2013-2020 at the amount of 900 million will be transferred to the MSR[46]. In addition, from 2024 all emission allowances exceeding the amount of emission allowances auctioned in the previous year will be canceled.

51. MSR **does not affect** the volume of emission allowances allocated free of charge to industrial sectors, as well as the volume of 2% reserve of emission allowances for Modernization Fund and volume of emission allowances dedicated to the Innovation Fund.

4.3.3. GHG45/MSR and GHG45/MSR/ETP

52. In this section we describe scenarios with emission reduction target of 45% for the EU in 2030 compared to 1990. **For the EU ETS sectors, the new emission reduction target in 2030 was set at the level of 48% compared to 2005 and for the non-ETS sectors at the level of 36% compared to 2005**[47].

A. Emission reduction target in the EU ETS sectors adopted for the period 2021-2030 (with linear reduction factor 2,7%)

53. To reduce emissions in EU ETS sectors by 48% in 2030 (compared to 2005) the linear reduction factor was set equal to 2.7% of average number of emission allowances issued to the installations in the years 2008-2012. This corresponds to an annual reduction in the number of emission allowances in the EU ETS by approx. 59 million in the period 2021-2030.

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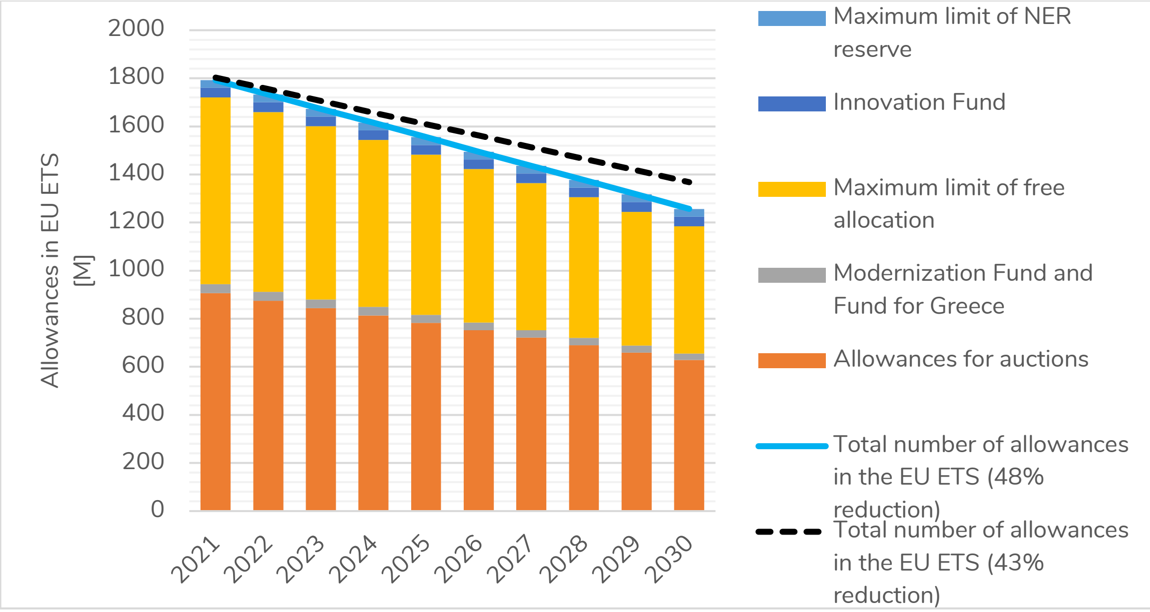
[45] There is a very small difference (less than 1%) between the scenarios with a different targets in EU ETS (-43% and -48% in 2030 compared to 1990) in the number of allowances transferred to the MSR.

[46] Part of the unallocated allowences from the period 2013-2020 will be used to create Innovation Fund, NER and Fund for Greece.

[47] See Ingvild Sorhus (2018).

Figure 6 presents the allocation of emission allowances in the EU ETS in the period 2021-2030 (for additional information see Annex I).

Figure 6. Total available number of emission allowances for sectors covered by the EU ETS in the period 2021-2030*



** Without taking into account the Market Stability Reserve.*

Source: CAKE/KOBiZE own study

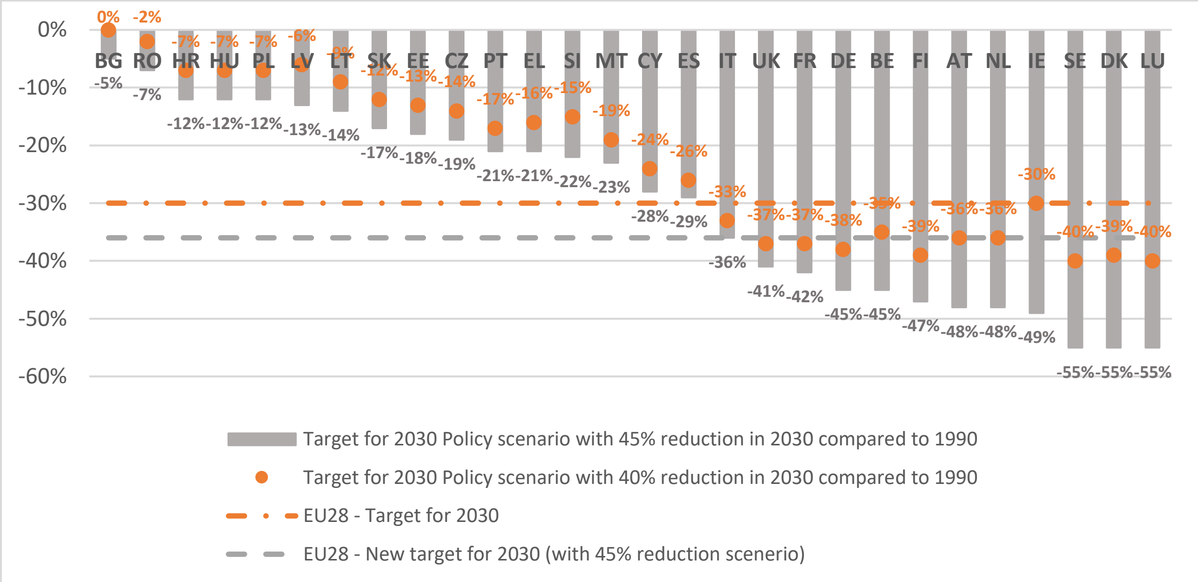
54. In addition, the total number of emission allowances foreseen for the auctions is reduced by approx. 9%[48] in the period 2021-2030 as a result of operation of the MSR.

B. Emission reduction target in non-ETS sectors adopted for the period 2021-2030

55. After the increase of the emission reduction target, the non-ETS sectors in 2030 would need to reduce their emissions by 36% compared to 2005. To achieve the overall target in the non-ETS we determined individual binding targets for each EU Member State. The distribution of the reduction effort under non-ETS was estimated on the basis of GDP per capita for 2013. It was assumed that the EU Member States will achieve targets ranging from -5% to -55% (for Poland is -12%) (for additional information see Annex I).

[48] Transfer of allowances from auctions to the MSR decreases compared to the GHG40/MSR and GHG40/MSR/ETP scenarios because there is a change in the number of emission allowances mainly due to a change in the emission reduction target. The projection of the number of emission allowances transferred to the MSR from the auctions is very similar for both types of scenarios.

Figure 7. Emission reduction targets in the non-ETS sectors for each EU Member State for 2030



Source: CAKE/KOBiZE own study

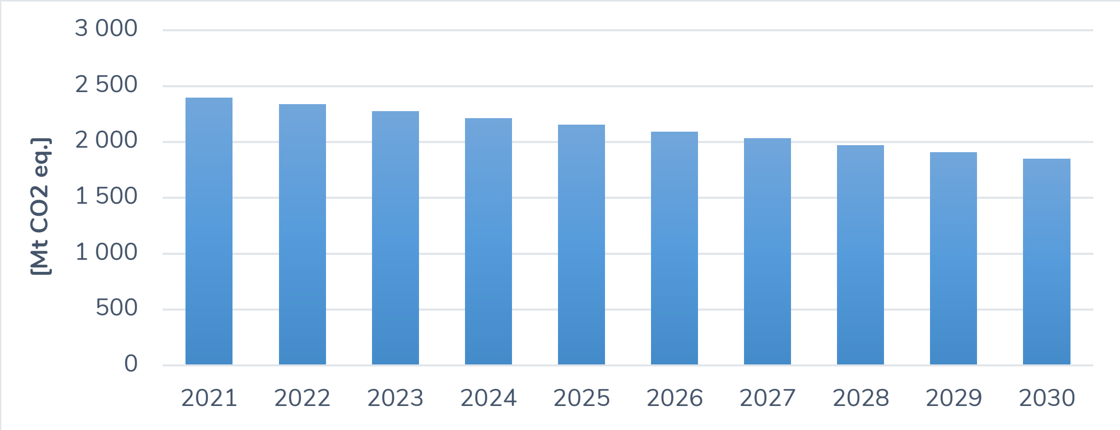
56. The new limits of annual emission reduction for each EU Member State for the period 2021-2030 are formulated by the same method as it was used for the baseline scenarios (GHG40 and GHG40/ETP). The limits are determined by two points:

- starting point - average emissions from each EU Member State within 2016-2018[49] placed in the timeline within five twelfth distances from 2019 to 2020 (or at 2020 if this results in further reductions for specific Member State),
- final point - set on the basis of the new emission reduction targets in 2030 compared to 2005.

The new annual emission limits for 2021-2030 were used in our modeling simulations as exogenous parameters.

[49] Emission projection based on EU Reference Scenario 2016 – Energy, transport and GHG emissions Trends to 2050.

Figure 8. Total annual emission limits in the non-ETS sectors for EU Member States in 2013-2030 for 45% target



Source: CAKE/KOBiZE own study

4.4. GHG emisssion reduction targets for the rest of the world

57. **To analyse the theoretical impact of carbon leakage we assume that all world regions outside the EU considered in the modelling scenarios would not adopt any binding emission limitation/reduction targets.** The implementation of reduction targets included in the NDCs submitted under the Paris Agreement, especially by developing countries Parties, may be threatened for several important reasons:

- Lack of legal consequences for failure to meet the reduction targets submitted in the NDCs under the Paris Agreement.
- Developing country Parties in many cases do not have much experience and legal mechanisms in place to implement incentives dedicated to GHG emission reduction. They need to develop capacity, skills and instruments in this regard.
- The implementation of reduction targets in many developing regions rely on external financial support provided by developed countries (Paris Agreement, point 5 of Article 4). As a consequence, it may lead to a situation in which failure to comply with achieving reduction targets will be justified by not receiving adequate financial support and/or capacity building.
- Flexibility in setting reduction targets in the NDCs made them difficult to compare. As regards developing countries, their targets may for example cover selected sectors of the economy and selected greenhouse gases. In addition, developing country Parties may still have limited reduction targets[50] in the light of different national circumstances. In many cases targets set in NDCs do not directly concern GHG emission reduction,

[50] For example, not including all GHG or sectors.

but they refer to developing renewable energy sources or increasing the efficiency of the economy. At the same time when it comes to the developed country Parties they are encouraged to undertake economy-wide absolute emission reduction targets (Paris Agreement, point 4 of Article 4).

Not including emission reduction targets (NDCs) in the first part of analysed scenarios for other countries (outside the EU) is important limitation and should be borne in mind while analysing the results.

58. **In second part of analyzed scenarios (scenarios with NDCs implemented and free allocation of emission allowances in the EU ETS) to identify the economic aspects of realistically implemented climate policies in the world, in line with the Paris Agreement, we adopted the objectives for NDCs.** Implemented GHG reduction targets for regions outside the EU in this scenario resulting from NDCs (based on CARBON BRIEF'S I / NDC TRACKER.) NDCs submitted in other form than GHG reduction target were transformed into a GHG reduction targets using emission forecasts prepared by PBL Netherlands Environmental Assessment Agency.[51]

5. Results

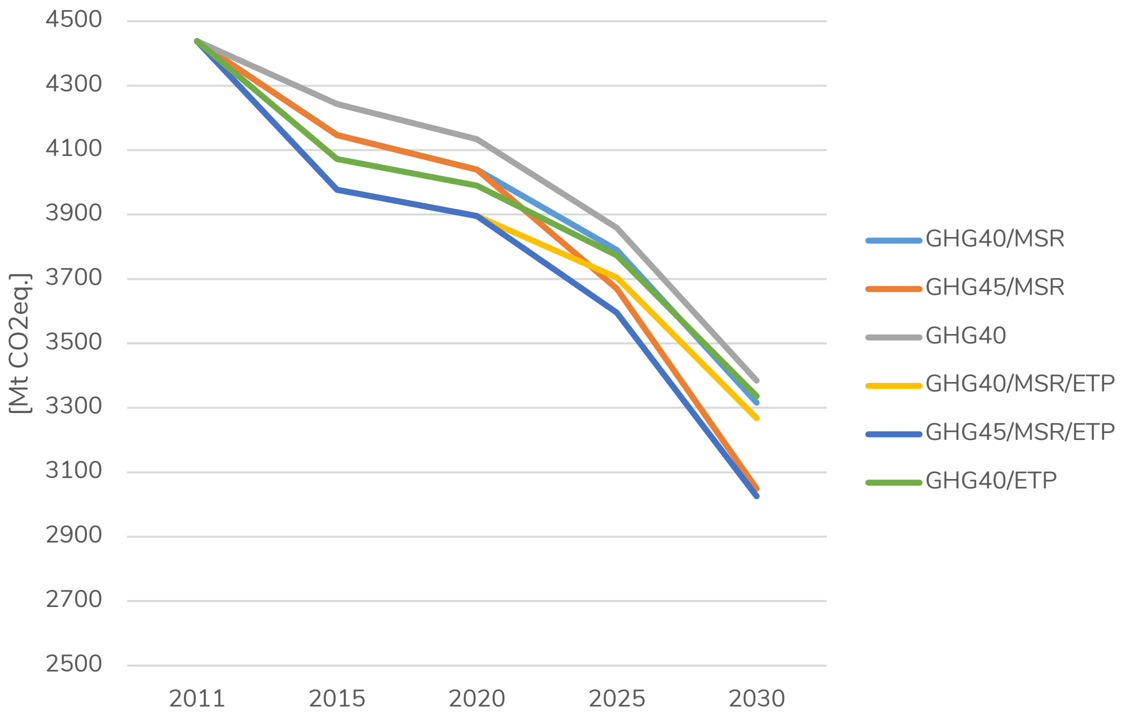
5.1. Aggregate results

5.1.1. GHG emissions

59. **In general, we expect fall in the EU total emissions until 2030 in all scenarios.** The difference between the 2011 (base year) and 2030 is equal to 1054 million tonnes in the non-technical progress version of the model and 1102 million tonnes in the version where technological progress is modelled. Therefore the difference is very small, because most of the sectors emit as much as they are allowed regardless of the change in the technologies. In that context, the reduction in carbon emissions is forced by regulations and the technology itself makes it easier to comply. The real difference lies in the emissions in non-EU regions, where technology helps to reduce carbon emissions faster and more efficiently.

[51] https://www.carbonbrief.org/paris-2015-tracking-country-climate-pledges

Figure 9. Total emissions in the EU in different scenarios



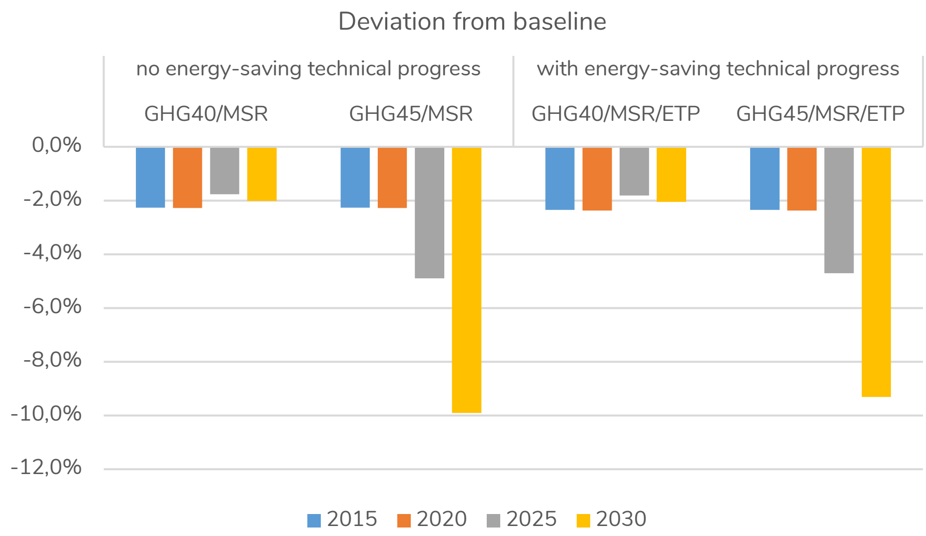
Source: CAKE/KOBiZE own study based on d-PLACE model results

60. **Increase of the emission reduction target to 45% (modelled as more stringent constraint to emissions, as described above) impacts more heavily in 2030 than introduction of the MSR, which altered emissions pathway only slightly.** In comparison to baseline in scenarios without technical progress, introduction of MSR decreases emissions in 2030 by 2% and further tightening of the reduction target to 45% by another 8% (10% in total). As long as energy-saving technical progress is included already in the baseline, the impact of policies (both MSR and tightening reduction targets) is very similar, as sectors comply to the regulations regardless of the technologies they have in place – consequently more stringent regulations are vital part of emission reduction policies.

61. **In the case of lack of binding emission reduction targets for the other than the EU world regions some carbon leakage would still be observed because their total emissions would not be capped in any way**. Alternatively, if there will be nationwide emissions cap, carbon leakage would not exists, because their emissions would equal their limits regardless of the EU actions. Therefore, the question of how binding are NDCs of other regions of the world is of crucial importance when carbon leakage is considered. Unfortunately, CGE model is not the best tool to extensively analyse how binding are emission constraints for the goverments outside the EU. Consequently, in the main part, we will assume, that regions other than EU have no emissions targets to show what theoretically would be carbon leakage in such situation. On the other hand, we will present

additional scenarios with binding reduction targets according to NDC's, as a sensitivity analysis in the results section. Nevertheless, this is important caveat and must be kept in mind, while analysing the results. Also, that (unrealistic) assumption is the reason, why these results should not be interpreted as a concrete answer on the question on whether the carbon leakage will occur or not (as the answer is "it depends"), but rather as a demonstration on how important assumptions are for the results of carbon leakage. In the future, there is also a need to use political economy model to analyse how the behaviour of countries will change as a result of more stringent climate policy in the EU.

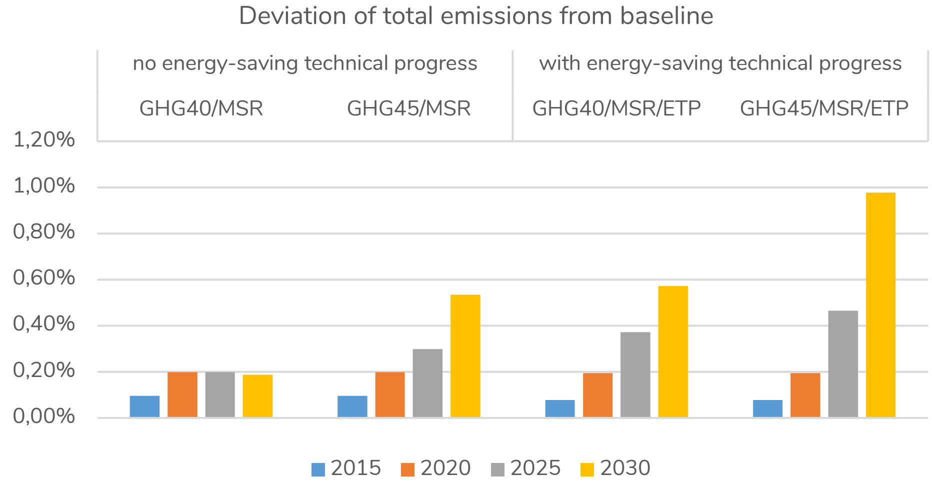
Figure 10. Deviation of total emissions from the baseline in scenarios with and without ETP in the EU ETS regions



Source: *CAKE/KOBiZE own study based on d-PLACE model results*

62. **The magnitude of increase in GHG emissions in the rest of the world is rather small and do not exceed 1%.** However, due to the higher base, the amount of "leakage" is quite substantial in absolute terms. For instance, introduction of MSR in version without taking into account energy-saving technical progress increases GHG emissions by 0.2% and 45% reduction target by another 0.1% in 2025. In the "technical progress" version of the model, these amounts are very similar, but the base is lower. However, even such a small number of emission reduction outside the EU is enough to outweight the emission reduction benefits of MSR/higher target in 2030 in some scenarios.

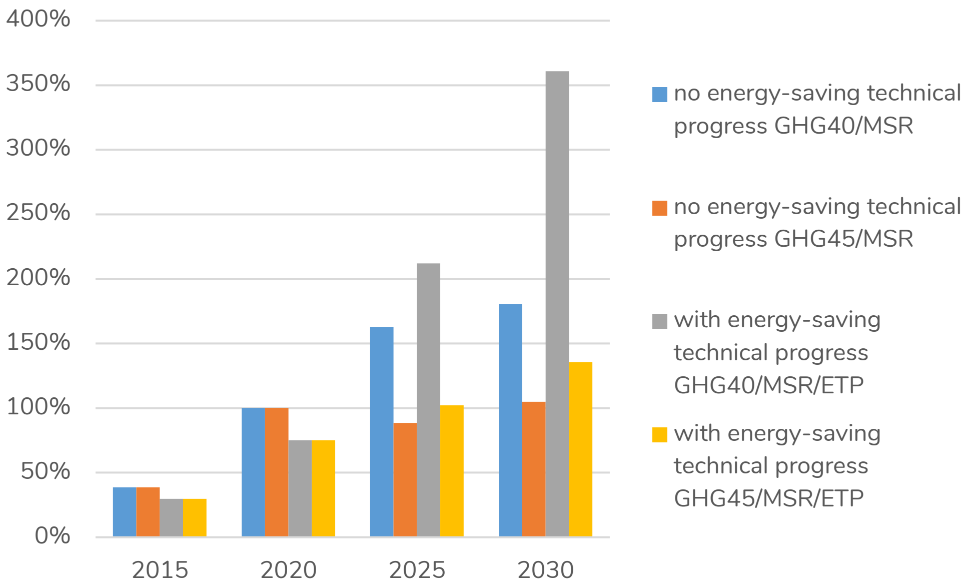
Figure 11. Deviation of total emissions from the baseline in versions with and without technical progress in rest of the world regions



Source: CAKE/KOBiZE own study based on d-PLACE model results

63. **The leakage rates (measured as a ratio of increased emission in rest of the world to avoided emission in Europe) are quite high and range from 30% in the most restrictive scenario in 2015 up to 361% in 2030 in the least restrictive scenario.** In general, leakage rates are higher in versions without technical progress in 2015-2025, but this changes in 2030, where leakage rates are higher in the scenarios with technological progress. When energy-saving technical progress is taken into account, both EU and non-EU countries are more energy efficient and therefore their production is less emission intensive. The scale of the leakage is still significant mostly due to the assumption on no reduction targets in the outside world.

Figure 12. Leakage rate in different policy scenarios

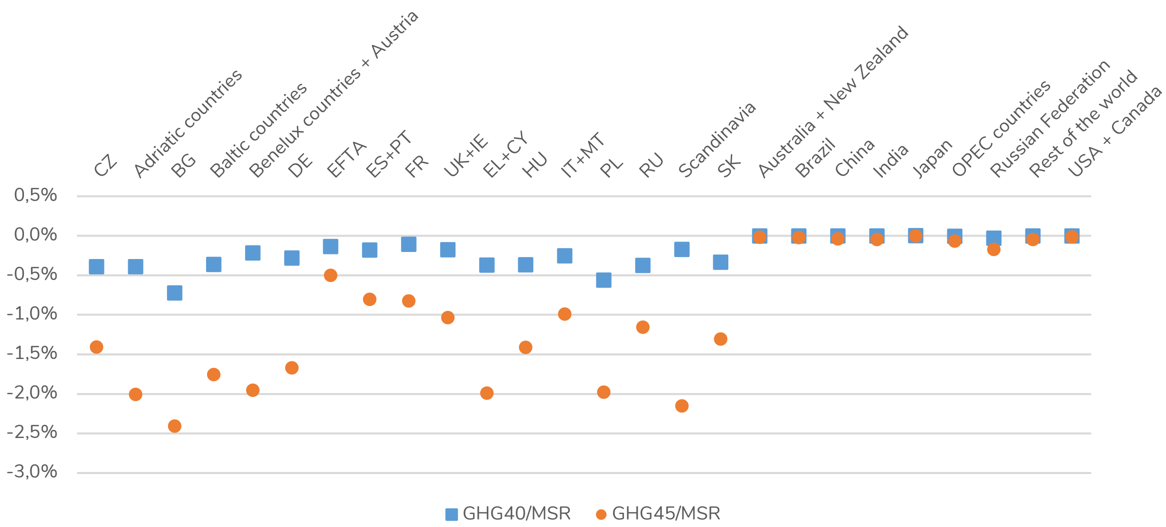


Source: CAKE/KOBiZE own study based on d-PLACE model results

5.1.2. GDP

64. **Impact of climate policies on GDP is similar in both versions of the model.** This result may seem quite surprising, as with more energy-efficient technologies it should be easier to reduce emissions. However, as sectors are allowed to emit greenhouse gases up to the certain limit, they use that limit regardless of the production technology. Therefore, they either sell their surplus emission allowances (in case of the EU ETS) or they just produce with relatively less capital and more energy, using the elasticities embodied in the production function. Conseqently, including the technological progress in the model does not alter the scale of the impact of additional reduction targets on GDP.

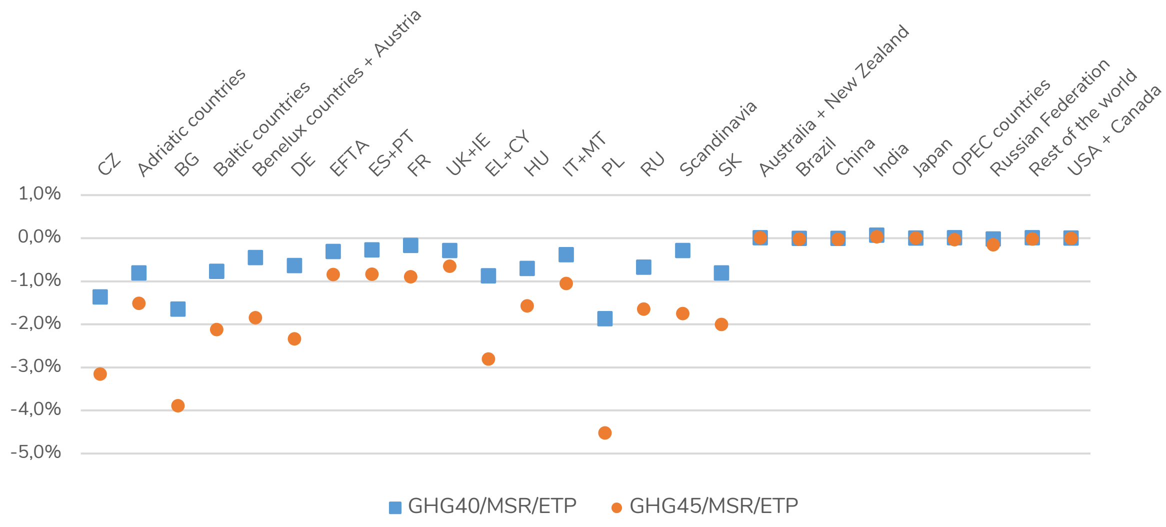
Figure 13. Impact on GDP - no technical progress scenarios, 2030 relative to the baseline



Source: CAKE/KOBiZE own study based on d-PLACE model results

65. **Within the EU ETS, the countries affected most are Bulgaria, Scandinavian countries, Poland, Greece, Adriatic and Benelux countries with Austria.** In these regions, the impact of MSR and reduction of GHG emissions by 45% exceeds 2% of GDP in 2030. The impact on the GDP in other EU countries is smaller and remains within the range of 0.5 - 2% of the baseline GDP value. The impact of MSR alone is quite small and in most cases it does not exceed 0.5% of baseline value of GDP. Bulgaria and Poland are exceptions, what can be attributed to quite high share of coal and lignite in energy mix. However, it is important to note that this MSR works earlier than in 2030 which is visible at chart and its impact should be visible before 2021.

Figure 14. Impact on GDP – energy-saving technical progress scenarios, 2030 relative to the baseline



Source: CAKE/KOBiZE own study based on d-PLACE model results

5.1.3. Decomposition of carbon leakage

66. **In this section we decompose the carbon leakage into the carbon intensity, competitiveness and demand channels.** Our results indicate that carbon intensity channel is the most important channel of carbon leakage, far more important than competitiveness or demand channels. In both versions of the model, the impact of carbon intensity channel on total change in emissions is positive. This phenomenon is understandable, given the use of fuels in the EU countries is significantly reduced in scenarios in comparison to the baseline and the production of energy intensive goods is outsourced to rest of the world countries. Also, as there is no convergence in energy-efficiency, these goods are produced using less effective and older technologies. Consequently, these outputs are even more energy and emission intensive if produced abroad.

Figure 15. Decomposition of change in CO_2 emissions in 2025

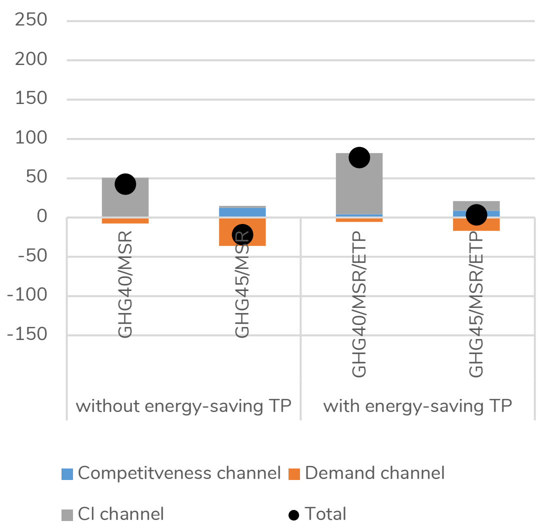
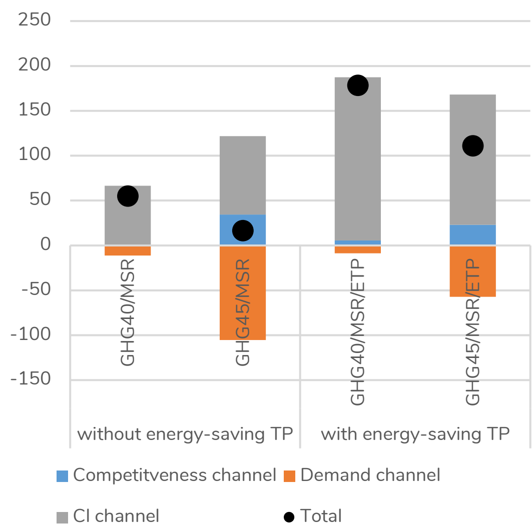


Figure 16. Decomposition of change in CO_2 emissions in 2030



Source: CAKE/KOBiZE own study based on d-PLACE model results

67. **Domestic demand channel is slightly more important in scenario with 45% reduction if exogenous energy-saving technical progress is taken into account.** In this case, changes in production structure alone are not sufficient to reduce carbon emissions in the EU countries to meet the targets. Therefore the domestic demand must be reduced. In general, the first response of the economy to changes in emission targets is to reduce emission intensity of GDP, either through substitution between the fossil fuels or through changes in the production patterns (e.g. changing technology to less emission intensive). Outsourcing production elsewhere or reduction of the domestic demand is the next step, when reduction in emission intensity of the economy is not sufficient to meet the target.

Figure 17. Decomposition of change in greenhouse gases emissions in GHG40/MSR scenario

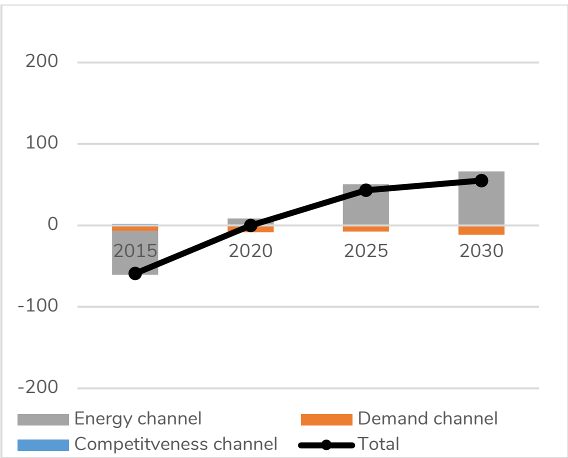


Figure 18. Decomposition of change in greenhouse gases emissions in GHG45/MSR scenario

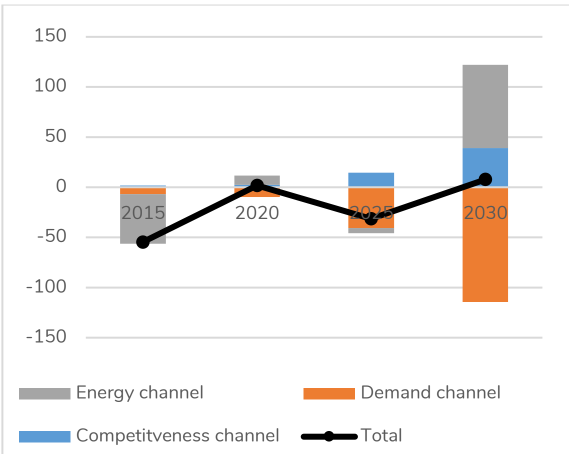


Figure 19. Decomposition of change in greenhouse gases emissions in GHG40MSR/ETP scenario

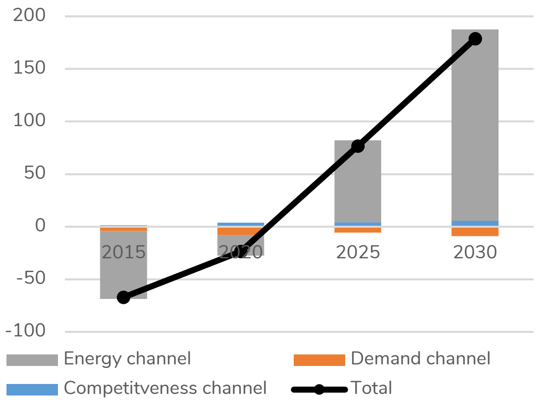
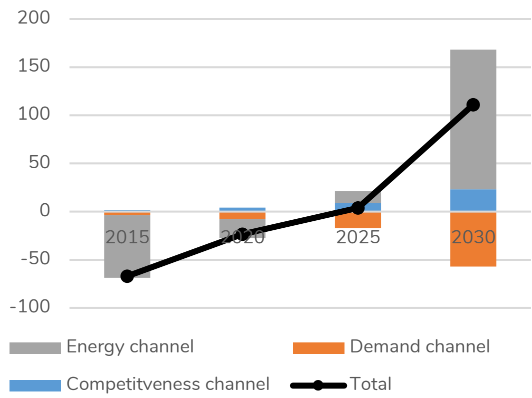


Figure 20. Decomposition of change in greenhouse gases emissions in GHG45/MSR/ETP scenario



Source: CAKE/KOBiZE own study based on d-PLACE model results

5.2. Output by sector

68. **Figure 21 presents the output by industry in the EU and the rest of the world countries and clearly shows, in which sectors the production is moved outside the EU.** In case of GHG40/MSR scenario, there is almost perfect substitution between goods produced in the EU and outside EU countries in chemicals, oil and iron and steel sectors – this is hardly surprising given that the production in these sectors are the most carbon intensive and these goods are easily tradeable. The high decrease in output for air transport may seem surprising, but given the rising demand for air travelling in developing countries and the impact of policies on global fuel prices, this may be expected. In line with expectations is also fall of output in services, as the consumers in the EU will have less disposable income to buy imported services from abroad.

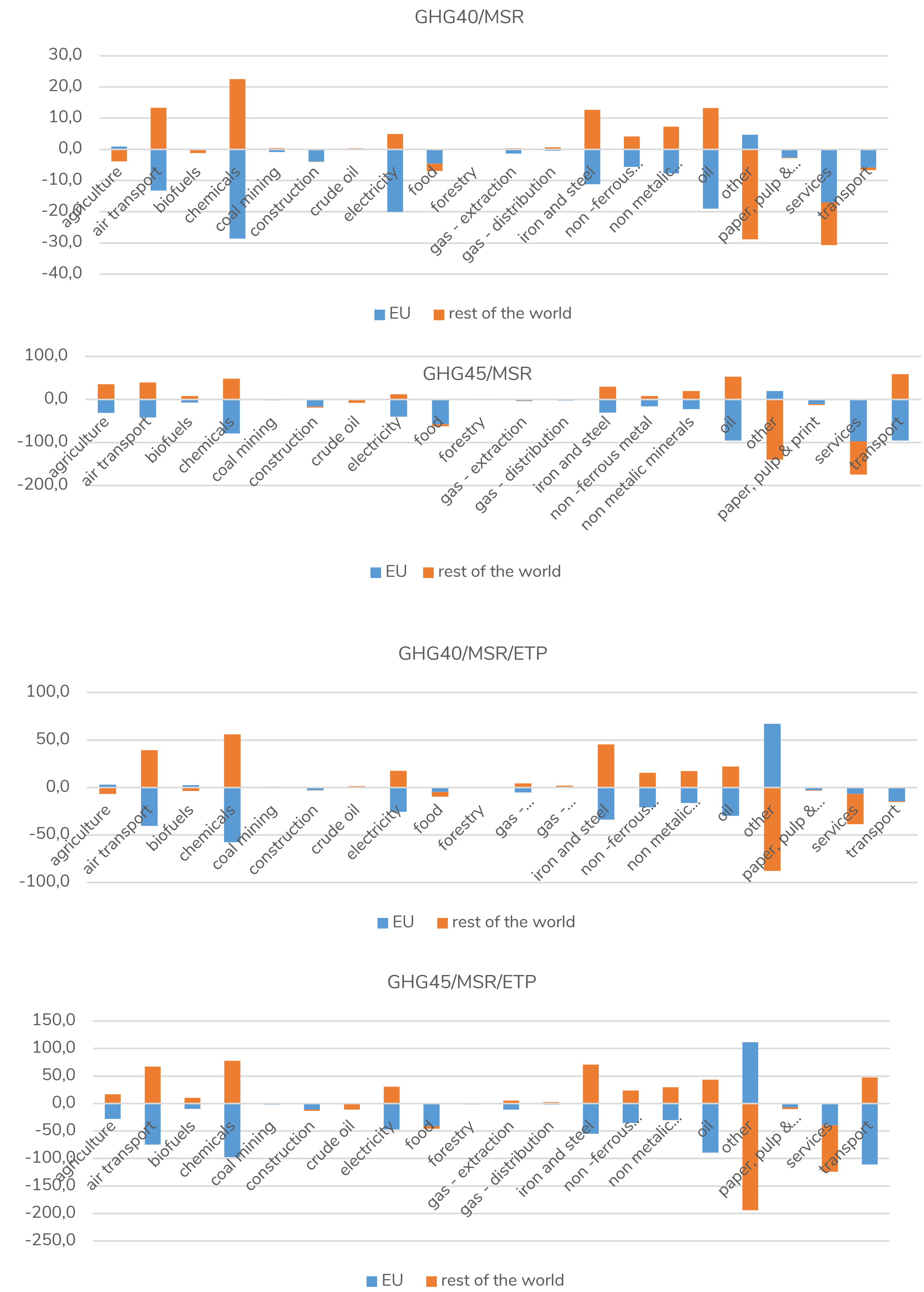
69. **In comparison to 40% reduction, introducing more stringent reduction target will lead to stronger fall in production in the EU and higher increase in the rest of the world.** The sectors in which the production will fall mostly are unchanged (coincide with those identified in the analysis of the carbon leak rate) – again these are chemicals, iron and steel and oil. The change of production in these emission-intensive tradable sectors are more or less twice as large than in scenarios with just MSR in place. Also, with this stringent reduction target, also change of output in agriculture and transport are observed, which was not the case in 40% scenario.

70. **Changes in output also show, how differently the economy is affected if technical progress is taken into account.** First of all, the required changes in output in chemicals, iron and steel and oil are greater to satisfy the reduction targets – this is self-explanatory, as with lower emission intensity, greater is the required change in production. However,

these freed resources do not remain unused – there is huge spike of output in "other manufactures" sector. It is obvious textbook result – more stringent climate policy shifts comparative advantage of the EU countries from emission intensive goods (chemicals, oil, iron and steel) towards other manufacturing. Consequently, more goods in this sector are produced in the EU and less are imported. Other manufacturing sector[52] is the only branch of the economy in which output will significantly rise because of the climate policy – and increase in production will be driven both by change in demand structure and availability of resources. Summing up, including exogenous technical progress in the model increase the estimated changes in sectoral structure of production, even though it hardly affects the projected impact of climate policy on GDP.

[52] Other manufacturing sector include: motor vehicles and parts, transport equipment, machinery and equipment, minerals, wood products, textiles, wearing apparel, leather products, metal products, manufactures.

Figure 21. Change in output in the EU and rest of the world countries by industry (mln USD 2011)



Source: CAKE/KOBiZE own study based on d-PLACE model results

5.3.Emissions by sector

71. **Carbon intensity channel is the most important channel through which the emission reduction occurs.** Therefore it is a good idea to further decompose the changes in emission intensity of the GDP into sectors**.** Such decomposition will allow us to identify the driving factors behind the change in emission intensity.

Figure 22. Decomposition of "carbon intensity channel" impact on emissions in GHG40/MSR scenario

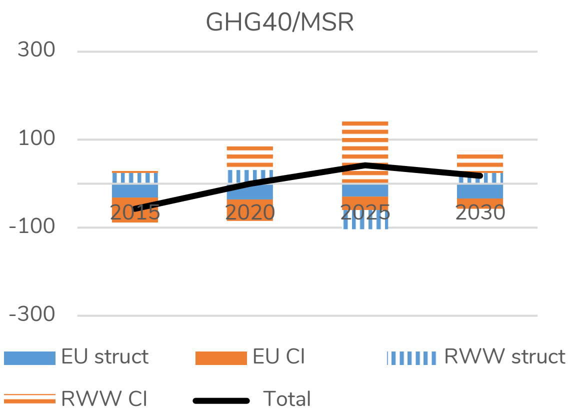


Figure 23. Decomposition of "carbon intensity channel" impact on emissions in GHG45/MSR scenario

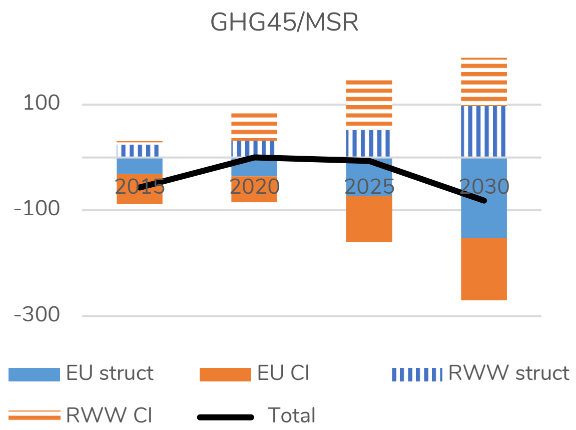


Figure 24. Decomposition of "carbon intensity channel" impact on emissions in GHG40MSR/ETP scenario

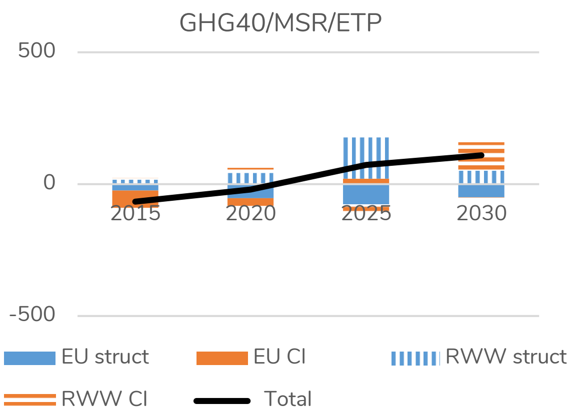
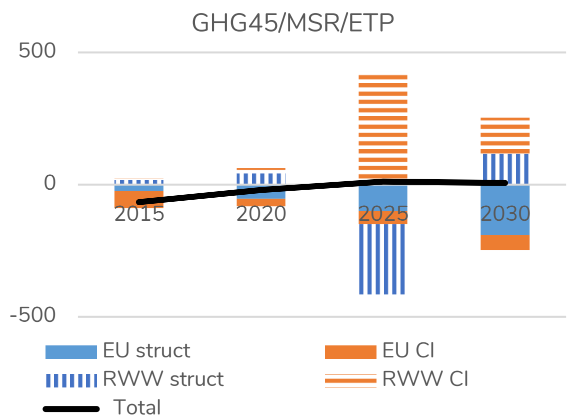


Figure 25. Decomposition of "carbon intensity channel" impact on emissions in GHG45/MSR/ETP scenario

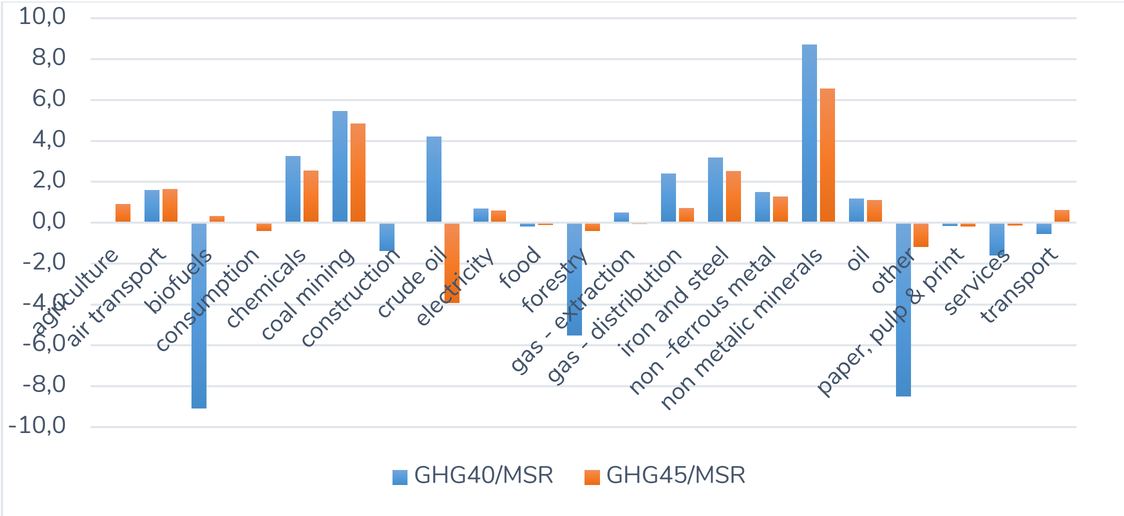


Source: CAKE/KOBiZE own study based on d-PLACE model results

72. **Results show that change in production structure and changes in sector specific carbon intensities contribute to the changes in emissions to a similar degree.** To illustrate this, we can use an example, if we would like to reduce emissions in Poland, the production of steel and iron needs to be moved to third countries or more efficient furnaces need to be installed. The first action contributes to changes in the production structure, the second allows for improvement in sector-specific emission intensity. Emission reduction targets in the EU Member States without any protective measures leads to both types of such action**.** However there are some differences in the contribution of different factors between the scenarios. For instance, in the GHG40/MSR scenario, the reduction within sector carbon intensity in the EU ETS countries is relatively small, while changes in carbon intensity of production in rest of the world countries play substantial role. Such increase in rest of the world countries suggests substantial switch towards more carbon intensive energy sources and overall increase of energy intensity there triggered by induced change in the energy prices. On the other hand, the impact of changes in production structure in rest of the world countries mirrors the effect of policies on the production structure in the EU states. This suggests that no behavioural change is observed and carbon intensive products produced domestically are substituted by the same carbon intensive products produced abroad. This result is, however, to a large extent determined by very low elasticity of substitution between products in the consumption structure assumed in the model. This assumption was adopted on the basis of other similar GTAP-based model, such as Burniaux and Truong (2002) or Rutherford and Paltsev (2000). We plan to extend the consumption structure in the next versions of the model.

73. **The increase in greenhouse gases emissions in the rest of the world countries (resulting from changes in the production structure within-sector) is quite significant in both versions of the model.** The reason for that is that even though carbon intensity of production is reduced (due to technical progress), cheaper prices of energy and increased productivity (induced by energy-saving technical progress) allows foreign companies to increase production less costly. Therefore there is apetite to change fuel consumption towards more emission intensive sources regardless of the production technology. Therefore, the emission limits in rest of the world countries are vital factor determining the efficiency of the EU carbon mitigation policy.

Figure 26. Leakage rate by sector, no energy-saving technical progress action scenarios in 2030



Source: CAKE/KOBiZE own study based on d-PLACE model results

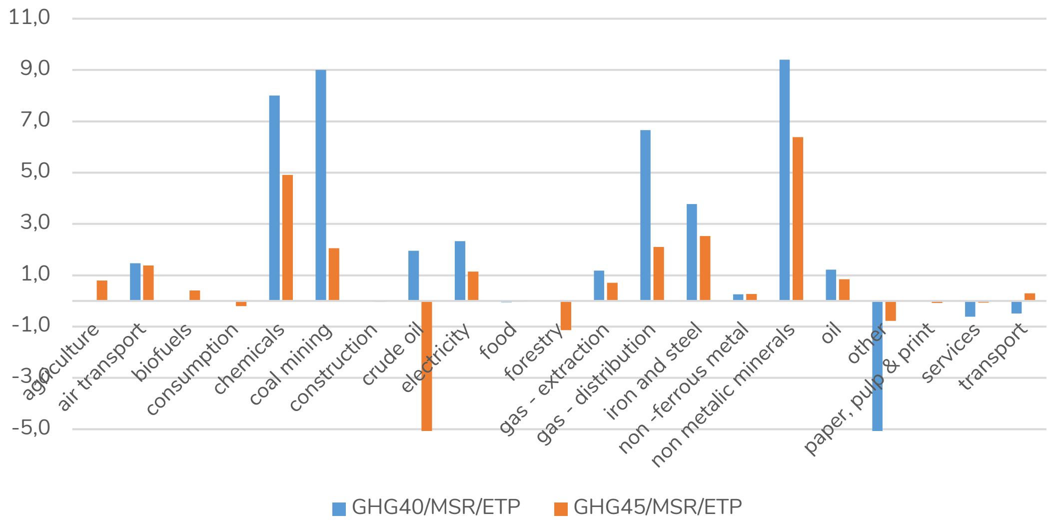
74. **Figures 26 and 27 depicts the carbon leakage rates by sector in the energy-saving technical progress and without such feature.** Not surprisingly the highest rates are observed in energy intensive industrial sectors, such as e.g. non-metalic minerals, iron and steel or chemicals. In these sectors, as well as in air transport, gas distribution, non-ferrous metals and oil, leakage rates are often higher than one. This means that an increase in emissions in the rest of the world countries is higher than reduction achieved in the EU states. This is not surprising, given the very rigid consumption structure in the model and more energy efficient technologies used in these sectors by now. However, these results strongly depends on the model assumptions on the elasticities of substitution between different consumption goods.[53]

75. **Also negative leakage rates for biofuels, forestry and other services in GHG40/MSR scenarios are worth commenting.** As in this scenario, the reduction is achieved mostly through changes in emission intensity, carbon intensive energy fuels (such as oil, gas etc.) are replaced by biofuels, and wood. Therefore, production (and emissions) from biofuels and forestry sector will increase both in the EU and in rest of the world. When bigger emission reduction is required (in GHG45/MSR scenario), substituting fossil fuels by biofuels is not sufficient and also changes in production structure is required – so there is no increase in output in biofuels and forestry. In contrary, as oil extraction can produce emissions, in GHG40/MSR scenario, the emissions (and production) of crude oil sector in the EU is reduced and it is substituted by imported oil, so there is a small, positive, leakage. In GHG45/MSR scenario, the use of oil in EU is reduced to such extent, that also the import is smaller than in the baseline scenario. Therefore, the production and emissions from

[53] Sensitivity analysis are planned for the near future.

crude oil are reduced both in the EU and in rest of world and leakage rate is negative. Moreover, when energy technical progress is accounted for, the use of energy is already reduced – so there is no need to replace fossil fuels by biofuels and wood and there is no increase in production. In case of other services, there is noticeable shift from industrial to services sector – therefore the production in the EU (and emissions) will increase both in the EU and rest of the world. When more stringent carbon reduction targets are considered, this actions are not sufficient, so the "negative" leakage is much smaller.

Figure 27. Carbon leakage rates by sector, scenarios with energy technical progress



Source: CAKE/KOBiZE own study based on d-PLACE model results

76. **If energy technical progress is taken into account, the carbon leakage rates are very similar – the important difference is visible only in tradable, emission-intensive goods, where there are significant differences in technologies between the EU and the rest of the world, such as chemicals, iron and steel and non-metallic minerals.** These sectors are the most vulnerable to carbon leakage, as their products can be easily substituted by energy-intensive goods from abroad. Moreover, the differences in technologies between the EU and rest of the world are very important factor that affect the scale of the carbon leakage. Therefore, it is very important to spread the more energy-efficient technologies to limit the negative impact of production reallocation on emissions.

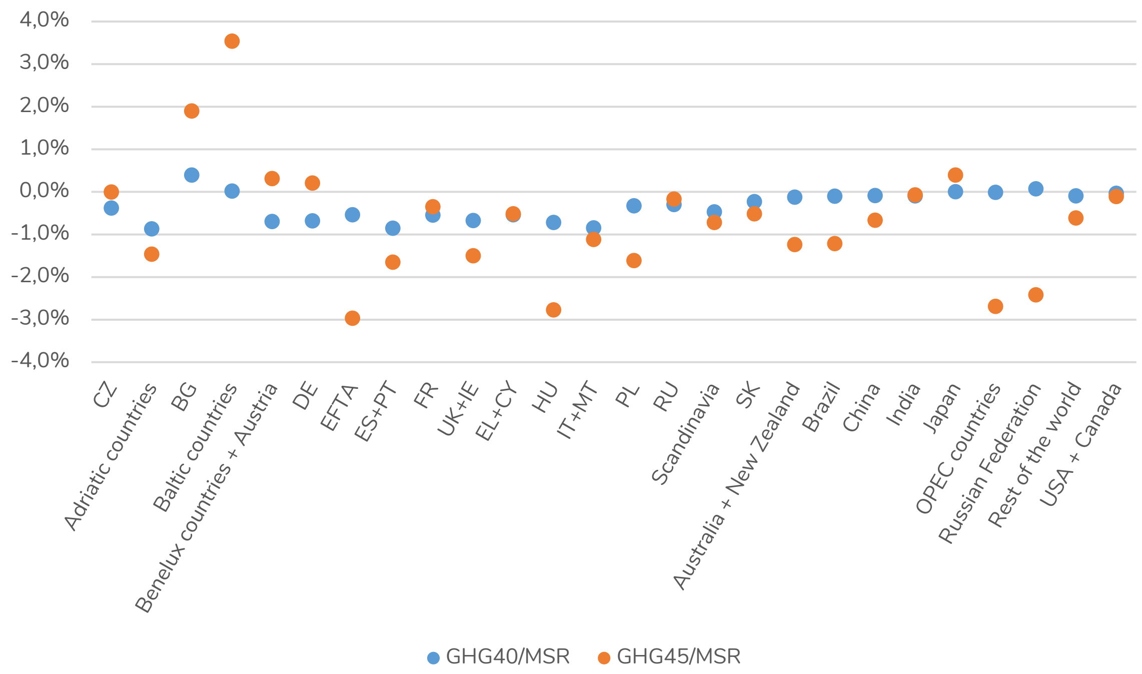
6. Additional scenarios with NDCs implemented and free allocation of emission allowances in the EU ETS

6.1. Impact on output and GDP

77. As the purpose of this paper was to decompose the carbon leakage understood as the increase in emission in the rest of the world, we did not include NDCs (Nationally Determined Contribution) into the model. With such targets, each country on the world will emit up to their own limit regardless of whether the reduction target in the EU28 is 40% or 45%. However, this assumption makes our analysis quite distant from the real world in which NDCs exist. The scale of the carbon leakage with other countries where NDCs are in place depends, to large extent, on how binding these targets are. In this section, we will present the impact of MSR and strengthening the EU reduction target to 45% on European production and GDP. These results can be compared to presented in the main part of the paper to assess the scale of the loss in GDP that can be attributed to the non-binding targets in the rest of the world.

78. The other policy measure that was not presented in the main part of the paper and is presented now is free allocation for particularly vulnerable sectors existing in the EU ETS. In the main part of the paper, for the sake of clarity, we decide to skip free-allocation (which is modelled as a subsidy to particularly vulnerable sectors), but in real policy simulation, this feature must be included in the model.

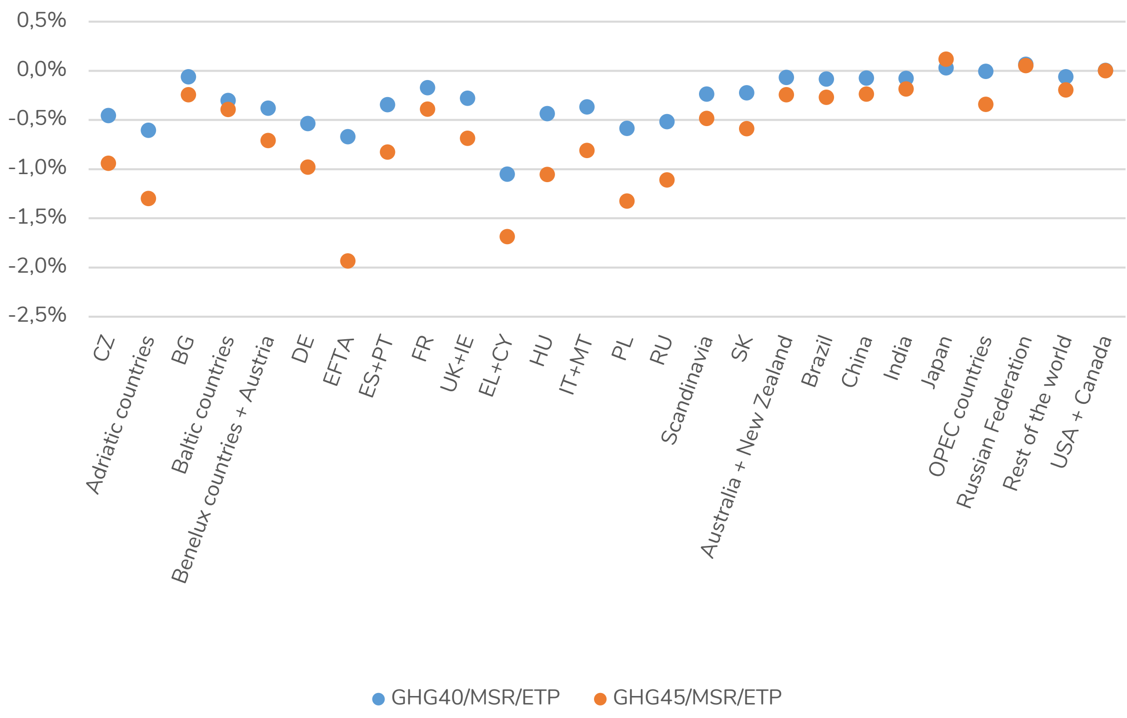
Figure 28. Impact on GDP without energy-saving technical progress scenarios, 2030 relative to the baseline [%]



Source: CAKE/KOBiZE own study based on d-PLACE model results

79. As should be expected, the impact of climate policies on GDP is lower, if other countries in the world have binding reduction targets and the fall of GDP in oil and gas exporting countries (Russia, OPEC) is quite high – they can not compensate the loss of revenues from natural resources with change in production in other sectors or they can not sell these resources to other countries. However, free allowances if their price are high results in benefits from more stringent climate policy in some countries, such as the Baltic countries, Germany, Benelux and Bulgaria. In such case, some production shifts can be observed within the EU and less production is shifted to other states. On the other hand, there are countries like Poland, Hungary, Portugal and Spain or EFTA countries which will lose in comparison to no-NDCs and no free allocation of emission allowances.

Figure 29. Impact on GDP – energy-saving technical progress scenarios, 2030 relative to the baseline [%]

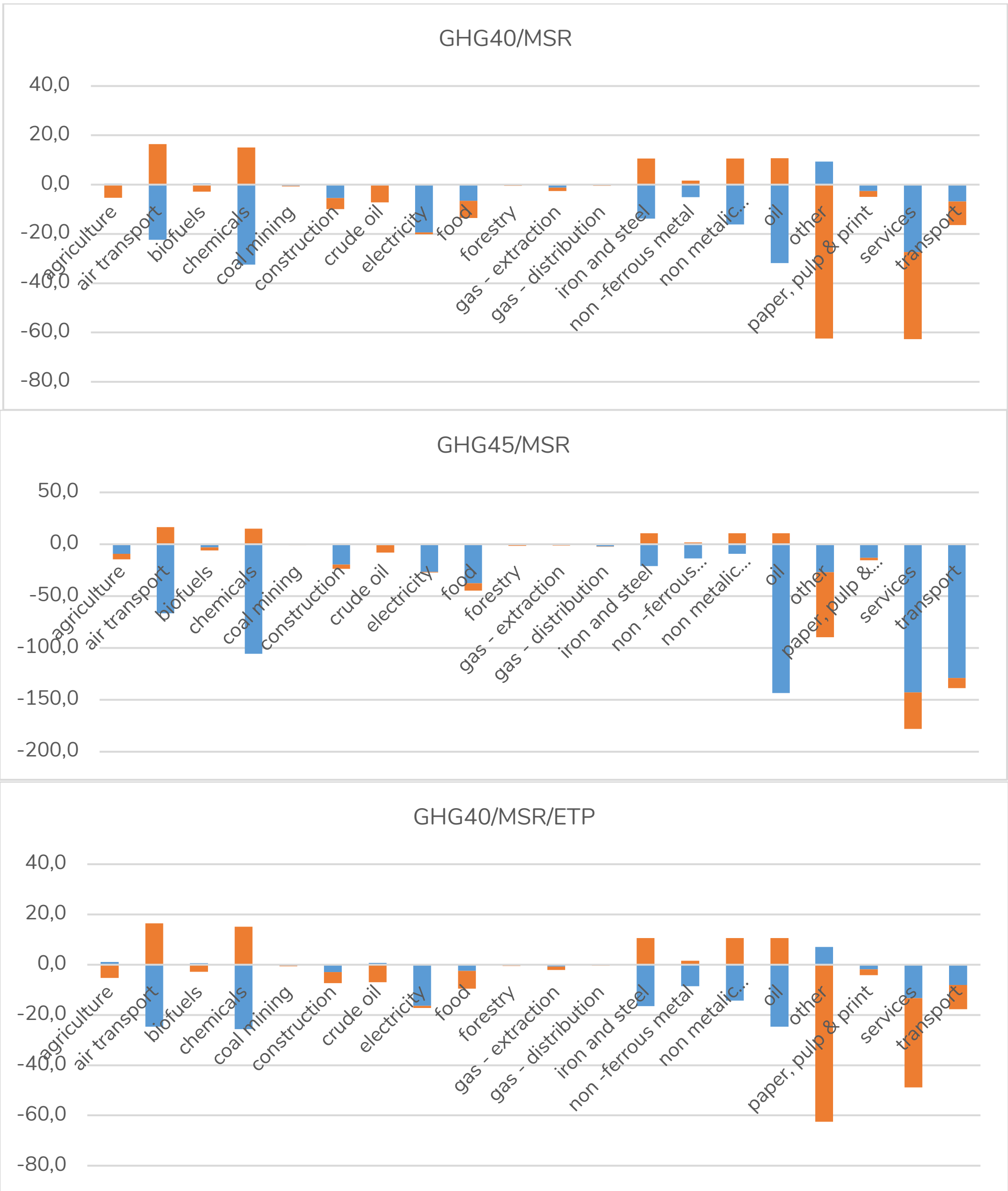


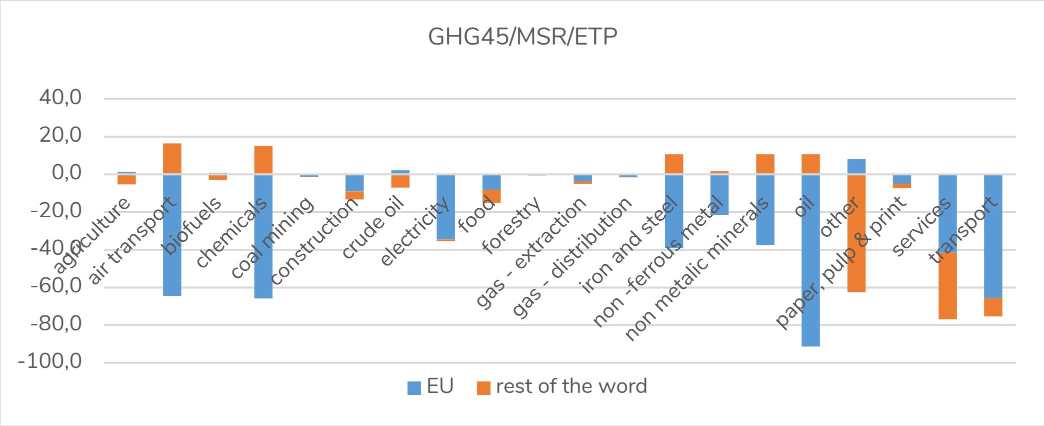
Source: CAKE/KOBiZE own study based on d-PLACE model results

80. If energy-saving technical progress is taken into account, the projected impact of policies on GDP is smaller. Baltic states and Bulgaria do not benefit from more restrictive policy, but rather lose 0-0.5% of GDP. In contrary, EFTA countries included in the EU ETS lose 2% instead of 3% in the no technical progress scenario. The change of GDP in oil-exporting countries is also relatively small.

All these observations can be explained by how inclusion of technical progress in the model will affect the price of emission allowances. If more energy efficient technologies are included in the production function, the price of allowances will be smaller. Therefore countries such as Baltic states and Bulgaria will not benefit from this subsidy. On the other hand, the production will not be relocated from Poland, Hungary and EFTA countries, because they will benefit from better technologies as well. Also, the change in the import of energy resources in comparison to the baseline will be smaller, because reduction is achieved easier – so Russia and OPEC would not be hurt economically by the MSR and more stringent emission reduction policies.

Figure 30. Change in output in the EU and rest of the world countries by industry (mln USD 2011)





Source: CAKE/KOBiZE own study based on d-PLACE model results

81. Figure 30 shows that free allocation of allowances indeed works – such sectors as food, iron and steel or non metallic minerals in the EU lose much less production than in case of no free alloacation of emission allowances. In contrary, as the EU ETS limit remains the same in scenarios with free allocation to the industry, the electricity sector bears most of the burden. Significant changes in output are also visible in non-ETS transport sectors – both air and land transport. Sectors such as food, non-metalic minerals and iron and steel reduce their outputs, but change in production is much smaller than in case of scenarios without taking into account NDCs and free allocation of emission allowances in the EU ETS.

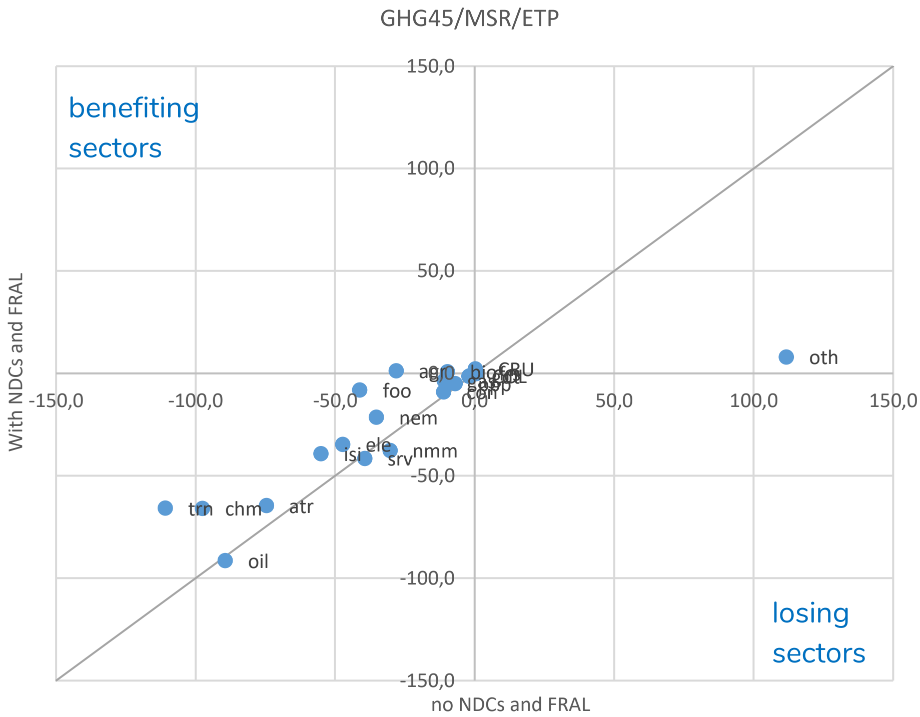
82. The impact of NDCs on such sectors as electricity, transport and services is visible. While the production in such sectors as non-metallic minerals or iron and steel is still moved from the EU to the rest of the world (but to much less extent), the output in sectors that are not exposed to the carbon leakage (electricity, transport and services) is significantly reduced also in rest of the world. This reduction is caused by implementation of NDCs in the rest of the world – as some leakage in iron and steel and non metallic minerals will occur, they will need to reduce emissions in electricity to reach their emission tagets. The scale of this reduction is smaller if technical progress is taken into account.

6.2. Comparison between scenarios with and without NDCs and free allocation of emission allowances in the EU ETS

83. Direct comparisons of no NDCs and free allocation and with NDCs and free allocations scenarios reveals some interesting information on the change of output by sectors. No technical progress version of the model overestimates the impact of policies of almost all sectors. That is quite obvious, given that NDCs for the rest of the world reduces the scale of the carbon leakage and impact of policies on domestic industries. Interestingly, also the influence of 45% reduction target and MSR on *other services* sector is also overestimated. If free allocation is taken into account then households revenues is smaller (transfer of

revenues from the auction of allowances from government to households is lower) and therefore less money can be spent on other services.

Figure 31. Change in the output in EU ETS countries in GHG45/MSR/ETP scenario with and without NDCs and free allocation of emission allowances in 2030 (mln USD 2011)



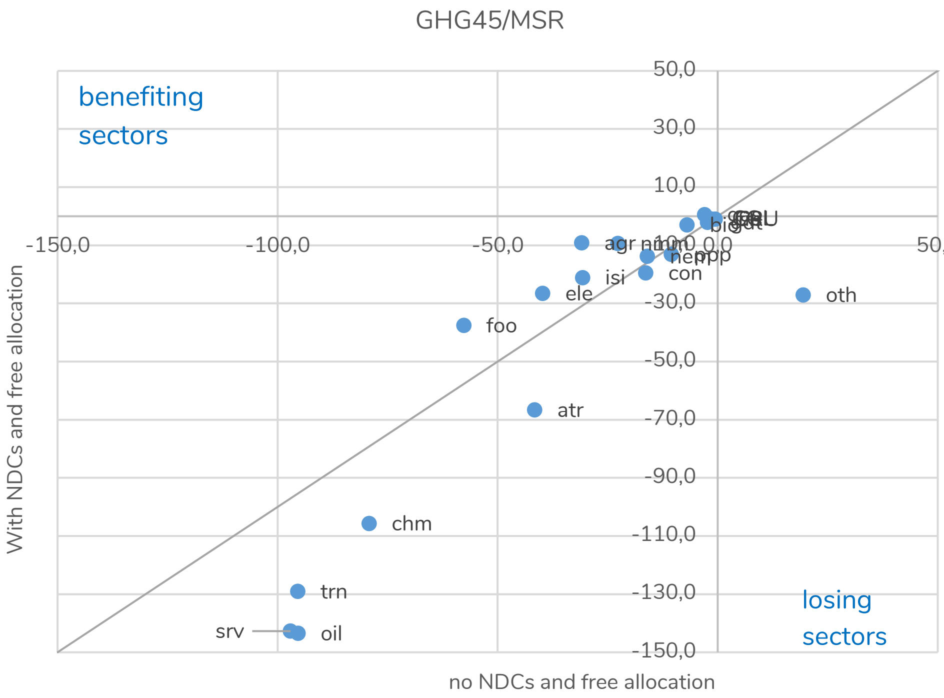
Source: CAKE/KOBiZE own study based on d-PLACE model results

Note: *The x axis of each chart depicts the impact of GHG45/MSR(/ETP) scenario in no NDCs and free allocation of emission allowances for given country/sector and y axis of each chart depicts the impact of GHG45/MSR(/ETP) scenario in NDCs and free allocation. Therefore, if given country/sector is above the 45 degree line, that means that impact in NDCs and free allocation is smaller in case of negative or bigger in case of positive, than in variant without such feature. Consequently, countries/sectors above the 45 degree line are benefiting from introduction of free allocation of emission allowances and NDCs and countries/sectors below that line are losing.*

84. If exogenous technical progress is not taken into account, than the picture changes. In such case, the free allocation mechanism as well as emission intensity of particular sectors is more important, as the reduction is much more difficult. Sectors that loses are those who are outside the EU ETS – transport, services and other manufactures because the required scale of reduction is similar in all scenarios and they do not benefit from free allowances. Other sectors that lose are: oil and air transport. The fall in production of oil sector is direct

consequence of decrease in demand for fuels used for transportation. The air transport is likely to lose due to the relative decrease in consumer demand (due to the lower consumer expenditures)[54]. In contrary, those who receive free allocation (food industry, iron and steel) benefits and the scale of leakage is smaller.

Figure 32. Change in the output in EU-ETS countries in GHG45/MSR scenario with and without NDCs and free allocation of emission allowances in 2030 (mln USD 2011)



Source: CAKE/KOBiZE own study based on d-PLACE model results

85. It is hardly surprising that the impact of 45% reduction target and MSR on countries which are the most emission intensive is smaller if NDCs and free allocation is taken into account. Greece, Poland, Bulgaria, Czechia and Slovakia are examples of such countries. Moreover, if NDCs are taken into account, more stringent reduction targets in the EU harm also rest of the world which is natural – less production in the EU means smaller demand for intermediate goods imported from the rest of the world, and moving of the production is not so profitable (as rest of the world has their own reduction target).

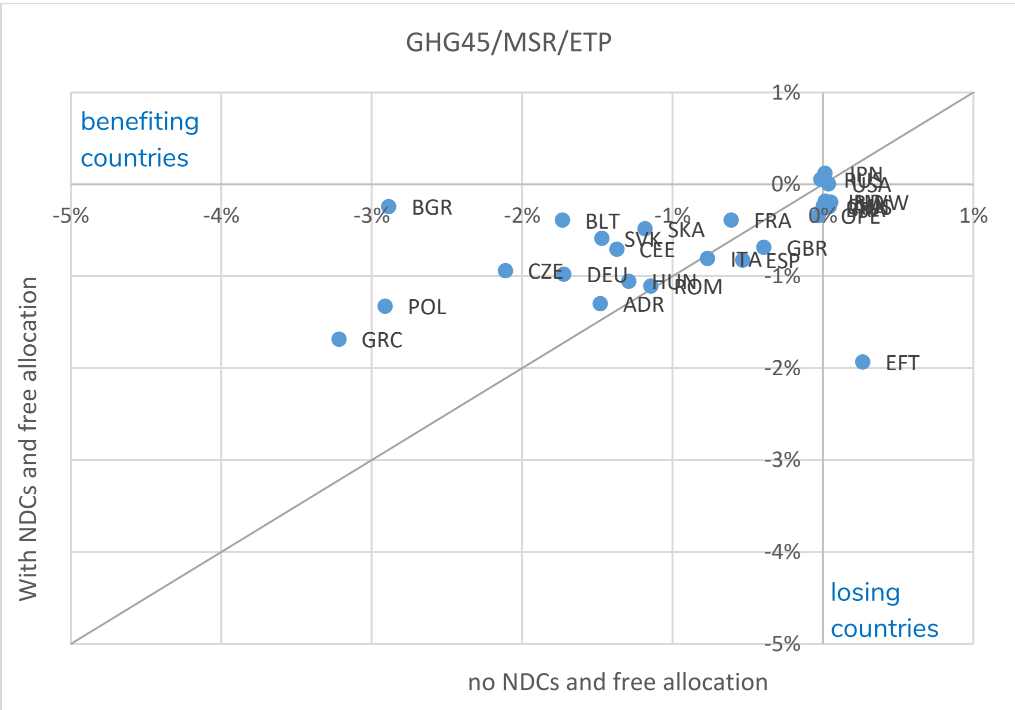
86. If exogenous technical progress is not taken into account, more countries loses in NDCs and free emission allocation scenarios. The reason for that is the fact that reduction is much more difficult also for the rest of the world and they decrease their demand for goods

[54] It should be noted that the aviation sector does not benefit from free allocation of emission allowances. The aviation sector was excluded from the allocation of free emission allowances in our scenarios due to temporary exclusion of international aviation from the EU ETS ("stop-the-clock"). The GTAP database includes emissions from both domestic and international flights in aviation sector. Emissions from international aviation exceed the domestic emission significantly and we do not have information on historical free allocation for international flights in the EU ETS data bases. Such lack of data is significant problem in determination of the exogenous free allocation for aviation sector.

imported from the EU. Nevertheless, the biggest difference between scenarios with and witout NDCs and free emission allocation is visible again for the Baltic states, Bulgaria and Slovakia and for the oil producing countries – Russia, OPEC, Norway. As other countries also have NDCs, the production will be relocated to smaller extent and there is less demand for oil that they produce.

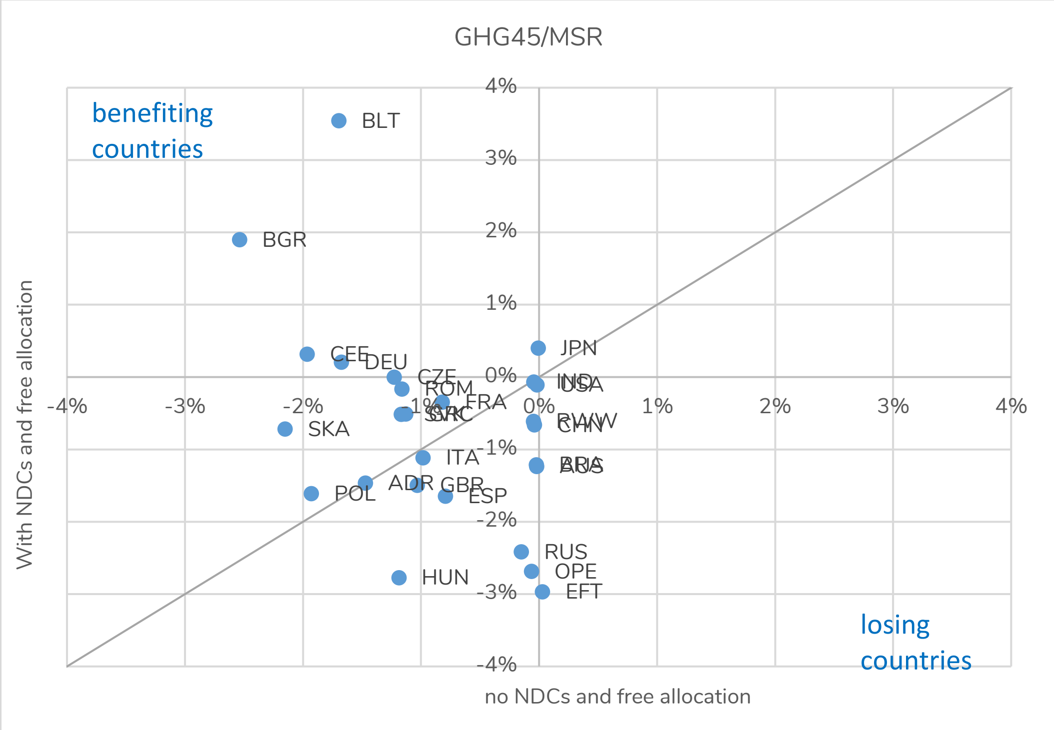
87. In conclusion, introduction of free allowances and NDCs for other countries clearly affects the modelling conclusions. Therefore, if such results are aimed to support policy, these features should be included in the models. Moreover, the differences indicate that there is a need to develop consistent and reliable methodology to include NDCs emission targets in the CGE models.

Figure 33. Change in the GDP in GHG45/MSR/ scenario with and without NDCs and free allocation of emission allowances in 2030



Source: CAKE/KOBiZE own study based on d-PLACE model results

Figure 34. Change in the GDP in GHG45/MSR scenario with and without NDCs and free allocation of emission allowances in 2030



Source: CAKE/KOBiZE own study based on d-PLACE model results

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Annex I

1. Free allocation of emission allowances and auction volume in the EU ETS in the period 2013-2020

1. The number of allowances to be auctioned in the period 2013-2020 is the difference between the total number of allowances in the EU ETS and the sum of allowances allocated free of charge and allowances allocated for the NER reserve and NER300 Fund.
2. The EU ETS Directive (on the basis of the art. 10a par. 5 and par. 4) sets a limit (industry cap) for distribution of the allowances free of charge to the installations. This limit represents the maximum annual number of allowances, which according to EU ETS Directive cannot be exceeded. Additionally to the free allocation in the EU ETS, there is a reserve for new installations - New Entrant Reserve (NER[55]), which was defined as 5% of the total number of allowances available in the EU ETS. From the initial NER cap (around 780 million allowances) amount of 300 million of allowances were deducted for funding innovative low carbon energy demonstration project Innovation Fund NER300. The Innovation Fund supports modern technologies in RES and industry, and CCS[56].

2. Free allocation of emission allowances and auction volume in the EU ETS in the period 2021-2030 (for 43% target in 2030 compared to 2005)

3. The number of allowances allocated for auctions in the years 2021 - 2030 is set as 57% of the total numer of allowances in the EU ETS, pursuant to the the revised EU ETS Directive (Directive (EU) 2018/410)[57]. It has been assumed that the share of the auction allowances would be reduced by 3% to increase the free allocation[58].
4. The Modernization Fund is a part of auction cap. The Modernization Fund will be operational since 2021 and it will accounts for 2% of the total number of allowances available in the period 2021-2030 (310 million EUA). The Fund for Greece (25 million EUA which will come from the unallocated allowances until 2020) supplements the Modernization Fund.
5. The share of the auction allowances (used in our modeling simulations) has been reduced by 5% (3% of free allocation and 2% for Modernization Fund) and set at the level of 52% of the total number of allowances in the EU ETS.

[55] Allowances set aside for new installations and installations that increase capacity, which allows for additional free allocation in the EU ETS.
[56] https://ec.europa.eu/clima/policies/lowcarbon/ner300_en
[57] Directive (EU) 2018/410 of the European Parliament and of the Council of 14 March 2018, amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, and Decision (EU) 2015/1814
[58] Based on the art. 10a 5a) of EU ETS Directive (2003/87/EC)

6. The reserve for new installations NER (New Entrants Reserve) in the period 2021-2030 will be composed of 200 million allowances from the MSR reserve plus approx. 120 million allowances (according to KOBiZE estimates) from unallocated allowances which were not issued free of charge until 2020.
7. The Innovation Fund (NER450) was set at the level of 450 million allowances (325 million from the allowances which should be allocated free of charge, 75 million allowances from auctions and 50 million allowances from MSR reserve).
8. Under the EU ETS for the period 2021-2030, all allowances that are not sold at auctions and are not allocated to the Modernization Fund or the Innovation Fund will be distributed free of charge to the sectors.

3. Non-ETS annual emission limits in the period 2021-2030 (for 36% target in 2030 compared to 1990)

9. The emission reduction target for the EU Member State with GDP per capita closest to the EU average was set at the level of reduction required in the EU (equal to -36%). Countries with GDP per capita below the average (Poland can be an example) will have targets ranging from -5% to -36% and for countries with GDP per capita above average targets were set from -36% to -55%.
10. We modified the method used to determine the original targets set in Effort Sharing Regulation. Originally EU Member States firstly agree on the range of targets and then targets were estimated using line passing through two points: the maximum target and maximum GDP per capita and minimum target and minimum GDP per capita index. After that in the place of the average value of GDP per capita the line was "lowered" in order to reach the -30% target for the entire EU. This approach results in a faster reduction of the target along with rising incomes in the group of countries with GDP per capita below the EU average. In our approach the reduction target remains proportional to the value of GDP per capita. Note that two countries with the highest GDP per capita were not taken into account in these calculations and have the same maximum reduction targets.

Annex II

1. List of regions in d-PLACE model

PL	Republic of Poland
CZ	Czech Republic
DU	Germany
FR	French Republic
HU	Hungary
RO	Romania
SK	Slovak Republic
BG	Bulgaria
ADR	Adriatic countries (Slovenia, Croatia)
BLT	Baltic countries (Republic of Lithuania, Republic of Latvia, Republic of Estonia)
BEN+AT	Benelux countries (Belgium, the Netherlands, Luxembourg) + Austria
ESP	Spain + Portugal
GBR	United Kingdom + Ireland
GRC	Greece + Republic of Cyprus
ITA	Italian Republic + Republic of Malta
SKA	Scandinavia (Denmark, Sweden, Finland)
EFTA	EFTA countries involved in EU ETS (Kingdom of Norway, Principality of Liechtenstein, Republic of Iceland)
AUS	Commonwealth of Australia + New Zealand
BRA	Federative Republic of Brazil
CHN	People's Republic of China
IND	Republic of India
JPN	Japan
RUS	Russian Federation
USA	United States of America + Canada
OPE	OPEC countries
RWW	Rest of the world

2. List of sectors in d-PLACE model

col	Coal mining
cru	Crude oil (extraction and service activities)
gas	Natural gas (extraction and service activities)
gdt	Gas distribution and heating
oil	Refined oil products, coke, nuclear fuels
ele	Electricity
bio	Biofuels agricuIure
agr	Rest of agriculture and fishing
foo	Food industry

frs	Forestry
chm	Chemical industry
nmm	Non-metallic minerals
isi	Iron and steel industry
nem	Non-ferrous metals
ppp	Paper–pulp–print
con	Construction
oth	Other manufactures
atr	Air transport
trn	Other transport
srv	Services

3. List of sectors in d-PLACE model included in the EU ETS

col	Coal mining
cru	Crude oil (extraction and service activities)
gas	Natural gas (extraction and service activities)
gdt	Gas distribution and heating
oil	Refined oil products, coke, nuclear fuels
ele	Electricity
foo	Food industry
chm	Chemical industry
nmm	Non-metallic minerals
isi	Iron and steel industry
nem	Non-ferrous metals
ppp	Paper–pulp–print
atr	Air transport