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Modelling of Article 6 Implementation Scenarios

Significance for the EBRD Regions

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For the EBRD

Authors:
Szymon Mikolajczyk, Climate Focus
Lieke 't Gilde, Climate Focus
Nayera Ibrahim, Climate Focus
Stefano De Clara, IETA
Egbert Liese, Walburg Capital

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Climate Focus
Van Diemenstraat 170
1013 CP Amsterdam
The Netherlands

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Executive Summary

This report investigates the role emissions trading under Article 6 of the Paris Agreement can have in driving regional economic and environmental outcomes in the European Bank for Reconstruction and Development (EBRD) countries of operation. We present the results from simulations generated by the Global Change Assessment Model (GCAM), an integrated assessment model, by comparing outcomes under a scenario where no collaboration under Article 6 occurs between regions (the I-NDC scenario), and one where countries commit to an economically optimal collaboration scenario (the C-NDC scenario). The results of this study are a contribution to the currently limited amount of research work that has sought to quantify the potential impact of broader international cooperation in the context of meeting the Paris Agreement goals.

The simulation results indicate which EBRD regions on aggregate would represent net-buyers or sellers of emission reductions in the years 2030, 2050 and 2100 under an optimal collaboration scenario under Article 6, and allow us to quantify the financial size of such theoretical carbon market per region. Furthermore, the simulations allow us to assess the impact an increased level of ambition under a full collaboration scenario (the C-NDC increased scenario) would have on regional emission trajectories, and what the implications of such increased ambition would be on the value of a theoretical carbon market and the investments in mitigation action that it could trigger.

This report concludes with discussion points linked to the overall results of the analysis conducted for the EBRD region and its countries of operation, followed by the implications that these results can have on national and international climate policy development efforts.

Summary of results

Result 1: Collaboration under Article 6 can unlock economic benefits of $53 billion per year across EBRD regions by 2050, and $131 billion by 2100 under current ambition

Significant cost reductions can be achieved if countries pursue international collaboration to meet their NDC targets. Under a non-collaborative scenario and a current ambition level, the cumulative cost associated with realising the necessary emission reduction targets would amount to $68 billion per year by 2050 and $405 billion per year by 2100. This is $53 billion in excess of the economically optimal distribution of abatement actions, as modelled under the C-NDC scenario in the year 2050. By the year 2100, annual accrued economic benefit reaches $131 billion.

Result 2: Differences between simulated regional abatement prices and emission trajectories point to the sectors where low cost abatement opportunities exist

A deeper-dive analysis of the emission trajectories of different sectors and subsectors provides additional information on sectors where cost-effective abatement opportunities exist in the studied regions. For example, in the two key net-seller regions – Russia and the Middle East – results point towards low hanging fruit opportunities in the electricity sector, biomass, and refining. Such cost-effective investment opportunities could be realised under a scenario when regions decide to collaborate under Article 6 and carbon finance is used to promote investments in these sectors.

Result 3: International cooperation under a current ambition scenario leads to a cumulative virtual carbon market valued at $300 billion by 2100

When markets are used optimally under the current ambition scenario, the cumulative value of the carbon market is forecasted to reach $300 billion by 2100. Upon the end of the century, 2,797 $MtCO_2$ could be traded, at an average price of $107 per tonne. On a cumulative level, the

EBRD region is a net seller across all three studied timeframes, with the difference between overall sellers and buyers equalling \$16 billion in 2030, \$57 billion in 2050, and \$36 billion in 2100. This position as an overall net-seller is driven by Russia and the Middle East, which remain high-volume net-sellers throughout the studied timeframe.

Result 4: Simulation of the increased ambition scenarios provide insights into the costs associated with deeper emission reductions, and how carbon markets can cost-effectively enable this

Despite the smaller regional difference in shadow prices under an increased ambition scenario, international collaboration still delivers economic benefits across the EBRD region. Compared to the results of the current ambition scenarios, the increased ambition scenarios produce significantly higher regional average shadow prices over time. The reason for this is that all regions face higher costs when pursuing deeper cuts due to the limited supply of low-hanging fruit abatement opportunities. The global average shadow price now reaches \$110 per tCO_2 in 2050 and \$304 per tCO_2 in 2100.

Result 5: Modelling results of cumulative capital investment needs under both scenarios indicate that the region has an important role to play in lowering GHG emissions.

The GCAM model provides insight in the level of cumulative capital investment needs in the power sector up to 2100, both under current NDC targets and an increased ambition scenario. For the EBRD regions on aggregate, cumulative capital expenditure needs are estimated at \$338 billion per year by 2030 if no collaboration takes place, rising to \$384 billion per year by 2030 when global collaboration is pursued. This is due to the comparatively low cost of average abatements costs in the EBRD region vis-à-vis other regions in the world in the short-term, incentivising more investments in GHG mitigation activities in the region when full collaboration can take place. This provides an opportunity for the EBRD region to play an important role in supplying cost-effective credits for trade, hereby lowering global investment needs. Considering the financial constraints in the region, this also shows that international carbon markets could help scale up regional investments in GHG abatement activities, accelerating decarbonisation pathways. This, in turn, could increase the acceptability of countries to undertake more ambitious mitigation targets.

Over the longer-term, cumulative capital expenditure needs are forecasted to reach \$701 billion per year by 2100 under the current NDC ambition, compared to \$636 billion per year when full collaboration takes place. This reversal in cumulative investments in the power sector reflects the evolving average abatements cost in the EBRD region vis-à-vis other regions in the world, which becomes higher relative to other regions towards the end of the century. For sectors other than power, capital investment requirements could not be derived from the model at this stage.

Implications for policy makers

Implication 1: The upcoming NDC renewal cycle gives Parties the opportunity to re-evaluate the role carbon markets can play in facilitating increased ambition

Collaboration on Article 6 is sensible from the perspective of cost-effective global abatement as it allows trading partners to lower the overall costs of achieving global mitigation targets. International emissions trading can furthermore mobilise significant investment in mitigation action, as highlighted by the valuations of the theoretical carbon market that can exist under a full collaborative scenario. This is true for both the current ambition level, as well as a scenario where NDCs align with the 2°C temperature goal. By the economic savings generated as a result of the use of markets into further abatement action, countries could realise increased ambition at no additional cost. For example, this could be achieved by increasing emission reduction targets in the carbon markets in five-year cycles, aligned with increasing NDC ambition. As the Paris Agreement is based on bottom-up contributions that are to be reviewed and strengthened over time, the results from this study can contribute to the broader discussion on the role of markets in a post-2020 framework.

Implication 2: A robust international carbon market can influence domestic climate policy formulation

When collaboration between regions is pursued, investments in cost-effective emission reductions in certain sectors in regional economies will be unlocked that under an I-NDC scenario would not be viable. Potential access to carbon revenues for such sectors can have implications for national policy formulation. One example of this could be the resource allocation decisions for public subsidies. Another example of the impact international trade in emission reductions could have on domestic policy development is the ability of offsets to reduce the barrier to introduce national carbon tax schemes. Finally, the ability to achieve deeper emission cuts domestically could also have implications for related issues, such as strategies to fight local air pollution.

Implication 3: Policy makers will need to carefully consider potential interactions between ITMOs, domestic policies, and long-term decarbonisation pathways

There are a number of important interactions that decisions to buy or sell emission reduction units will have with domestic policy and long-term decarbonisation pathways. An international carbon price influences a domestic carbon price, the more so when carbon units can be traded across borders. But other international and national policies, such as taxation or energy efficiency targets, can also influence the ability of a country to meet its NDC target, and therefore affect the supply and demand of tradeable units. In order to ensure full environmental integrity, it is important that at a minimum the MRV and GHG accounting standards are kept high, and that any transfers can be tracked, whether conducted domestically or internationally. With a robust accounting and trading infrastructure in place, ITMO trading will afford countries greater flexibility in managing policy interactions to meet their NDCs. The existence of such international markets can furthermore influence the standardisation of monitoring, reporting and verification (MRV), contracts and other services, thereby lowering transaction costs over time and increasing the market’s effectiveness.

1. Introduction

1.1 Modelling Article 6

The Paris Agreement establishes a new framework for international climate change cooperation. Climate action under the Paris Agreement is rooted in nationally determined contributions (NDCs), which taken collectively currently are insufficient to limit global warming to 2°C above pre-industrial levels. To incentivise Parties to take on more ambitious commitments over time, a transparency framework requires countries to report on their progress in achieving these mitigation targets. In addition, Article 6 of the Paris Agreement promotes international cooperation to facilitate the implementation of NDCs and to allow for higher ambition in Parties' mitigation and adaption actions. Increased cost efficiencies resulting from such cooperation opportunities could be one of the triggers to convince countries to pursue deeper cuts in emissions in the next rounds of NDCs.

Many Parties to the Paris Agreement plan to utilise Article 6 to achieve their climate goals. However, to date, little attention has been dedicated to inform the creation of reproducible models and protocols that will explore an effective integration and utilisation of Article 6. In this context, the International Emissions Trading Association (IETA) and the University of Maryland (UMD) initiated a research project in 2019 to assess the potential economic impacts and investment needs of Article 6 under different policy and collaboration scenarios. The IETA-UMD project intends to estimate the value, both in terms of cost savings and additional mitigation, of Article 6 of the Paris Agreement. It evaluates, through modelling research, the value of Article 6 for different levels of ambition (current NDCs, 2°C pathway, etc.) as well as in different scenarios (alternative rule sets, limited trading, etc.). By doing so, the project intends to provide insight into the overall potential of Article 6 to reduce the cost of global mitigation action and how increased efficiency can support the achievement of the temperature goal of the Paris Agreement.

One of the principal analysis tools is the Global Change Assessment Model (GCAM), an open-source, global integrated assessment model. It links the energy, economy, agriculture, and land-use systems and has 32 energy-economic regions.[1] The model disaggregates the energy system into primary production (from depletable and renewable resources), energy transformation (e.g. crude oil to refined products, fossil fuels or solar or wind to electricity), and end use (including a detailed buildings sector, a detailed transport sector and a more aggregated industrial sector). It further models agriculture and land-use as an integrated system with energy and the economy. GCAM runs in 5-year time steps through the end of the century. Since early 1980s, GCAM was used to understand implications of uncertain inputs assumptions and parameters on outputs such as greenhouse gas emissions, energy consumption and prices, and trade patterns. A range of techniques has been used to explore the potential range of future outcomes, including scenario analysis, sensitivity analysis, and Monte Carlo simulations. In this study, we use GCAM version 4.1 to conduct a scenario analysis to understand implications of different policy options.

Integrated assessment models (IAMs) such as the GCAM are capable of tracing the impact of GHG emissions into GHG concentrations, changes in temperature, and ultimately economic benefits and costs resulting from temperature changes. A wide range of emission reduction policies and their economic effects can be projected in the GCAM, including the estimation of the economic cost and performance of emissions trading regimes. The model has also been used to create scenarios for IPCC assessments.

This analysis examines implications for cost savings and enhanced ambition when comparing scenarios in which countries independently and collaboratively implement their NDCs. The NDC scenarios assume that mitigation measures to achieve NDCs are undertaken where they are

[1] This includes the transport sector, which is subdivided into four sources: long-distance passenger air travel, (other) passenger travel, international freight shipping, and (other) freight.

most cost effective, and thus assume that a price on CO_2 emissions is implemented across all economic sectors. The model calculates the marginal abatement cost curves for each region in each period. Regional abatement prices are generated based on the quantity of abatement underpinning NDCs and the cost of abatement defined in the regional marginal abatement cost curves. These are labelled as ‘shadow prices’ in the terminology of GCAM and are a proxy for the climate policy costs associated with NDC implementation under different scenarios, with units of USD per tonne CO_2 (other GHGs are excluded from this analysis).

The economic results in this report are shown in 2015 USD. The potential buyers and sellers under Article 6 are defined as follows. If a region’s total CO_2 emissions under Article 6 are greater than its NDC commitment, it would be a potential buyer region, as it needs to purchase permits from other regions to meet its NDC. If a region mitigates more through Article 6 than what its NDC requires, it could be a potential seller region.

1.2 EBRD's Involvement and Report Objective

The European Bank for Reconstruction and Development (EBRD) is one of the key funders of the IETA-UMD project[2] and has helped in shaping the research questions and the overall direction of the project.[3] This report, commissioned by the EBRD and prepared by Climate Focus with inputs from the IETA-UMD team, presents the results of the GCAM model with a specific focus on the EBRD region and its countries of operation. The objective is to evaluate the impact Article 6 collaboration can have on the cost efficiency of achieving the NDC goals of countries within this region and builds on a quantification of investment needs under several alternative scenarios. The outcomes of this study may also inform the discussion on long-term Paris Alignment strategies and NDC target setting in the EBRD region of countries of operation, including supporting increased climate ambition.

For each of the EBRD regions we refer to the GCAM simulation results to visualise the CO_2 emission pathways of four different trajectories (Table 1). To start with, we first focus on the difference between the *I-NDC scenario* (where countries implement their NDCs independently and continue at the same pace of decarbonisation post-2030) and the *C-NDC scenario* (a full collaboration scenario that optimises the economic benefits of trading). These two scenarios assume a decarbonisation rate represented in the current NDCs, resulting in an average global temperature increase of 2.8°C. Following this, two additional scenarios are analysed, the *I-NDC increased* (where countries independently implement their NDCs and enhance ambition after 2030, following the 2°C path) and the C-NDC *increased* (i.e. where countries jointly implement their NDCs and enhance ambition after 2030, following the 2°C path).[4] The enhanced ambition scenario assumes regions decarbonise their economies at a higher rate of 5% per year.[5]

Table 1: Summary of NDC implementation scenarios covered in this report

Scenario	Description
I-NDC	The *independent* nationally determined contribution scenario assumes that countries meet their NDC commitments through 2030 without any collaborative efforts, and continue at the same level of decarbonisation without international cooperation post-2030, resulting in an average global temperature increase of 2.8°C.
C-NDC	The *collaborative* nationally determined contribution scenario assumes that countries implement their NDCs through optimal cooperative implementation facilitated by Article 6 of the Paris Agreement. As the I-NDC scenario, this scenario assumes that countries meet their 2030 targets and continue at the same rate of decarbonisation after 2030 but at adjusted abatement costs (due to international trading), resulting in an average global temperature increase of 2.8°C.
I-NDC-increased	The *independent* nationally determined contribution increased scenario assumes that countries meet their 2030 NDC ambitions individually, and enhance ambition after 2030 to align with the emission reductions required for meeting the 2°C temperature goal.
C-NDC increased	The *collaborative* nationally determined contribution increased scenario assumes that countries jointly implement their NDCs by optimal cooperative implementation facilitated under Article 6 of the Paris Agreement. After meeting their 2030 targets, this scenario assumes increased ambition by all countries required for meeting the 2°C temperature goal.

[2] For more information, refer to: https://www.ieta.org/resources/International_WG/Article6/CLPC_A6%20report_no%20crops.pdf
[3] Other funders include: The Carbon Pricing Leadership Coalition, Chevron, the German Government, the Government of Norway, Government of the United Kingdom, the Institute for Global Environmental Strategies, Shell, the Swedish Energy Agency.
[4] The original analysis uses scenarios consistent with Fawcett et al. (2015), which do not include a 1.5 °C scenario. Source: Fawcett, A.A., et al. 2015. "Can Paris pledges avert severe climate change?" Science, 350, 1168–1169.
[5] The I-NDC scenario assumes that countries continue to decarbonise their economies post-2030 with the same annual decarbonisation rate that was required to achieve their NDCs in the period 2020 to 2030. In cases where the applied decarbonisation rate was below 2% per year, a minimum decarbonisation rate of 2% was applied instead.

1.3 Summary of Global Results

Before presenting the EBRD region results, this section provides a high-level summary of the global results of the IETA-UMD research project, which focused on a global simulation covering the period 2020 to 2100. Figure 1 illustrates how global CO_2 emissions for all the 32 regions covered by GCAM are distributed under the I-NDC scenario (no collaboration on Article 6) and the C-NDC scenario (full collaboration). The global emissions level remains constant under both scenarios, but in the C-NDC scenario emissions are redistributed among the regions based on adjusted abatement costs enabled by international trading between the regions.

Figure 1: Comparison of the I-NDC (left) and C-NDC (right) emission trajectories for the all regions (global)

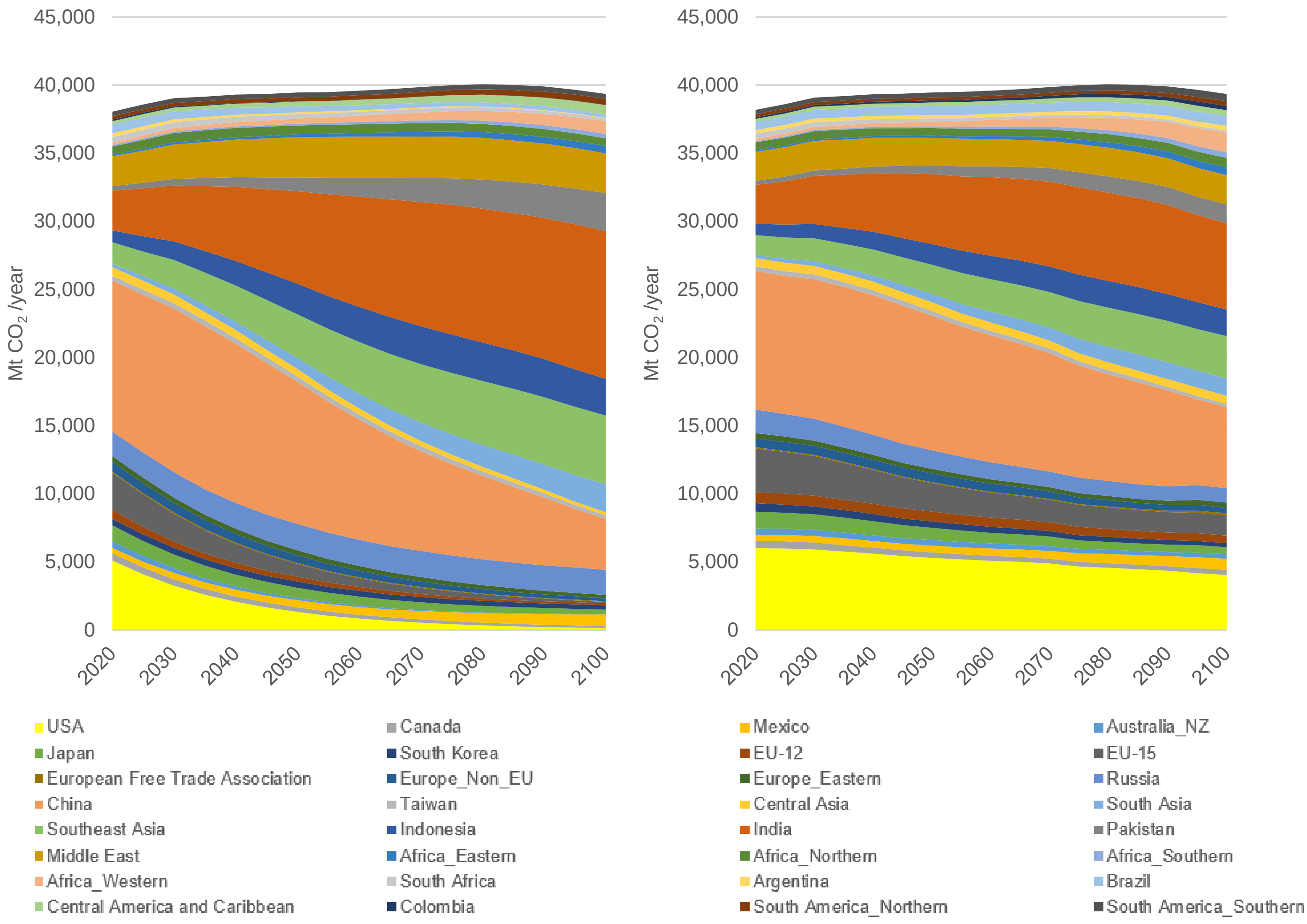
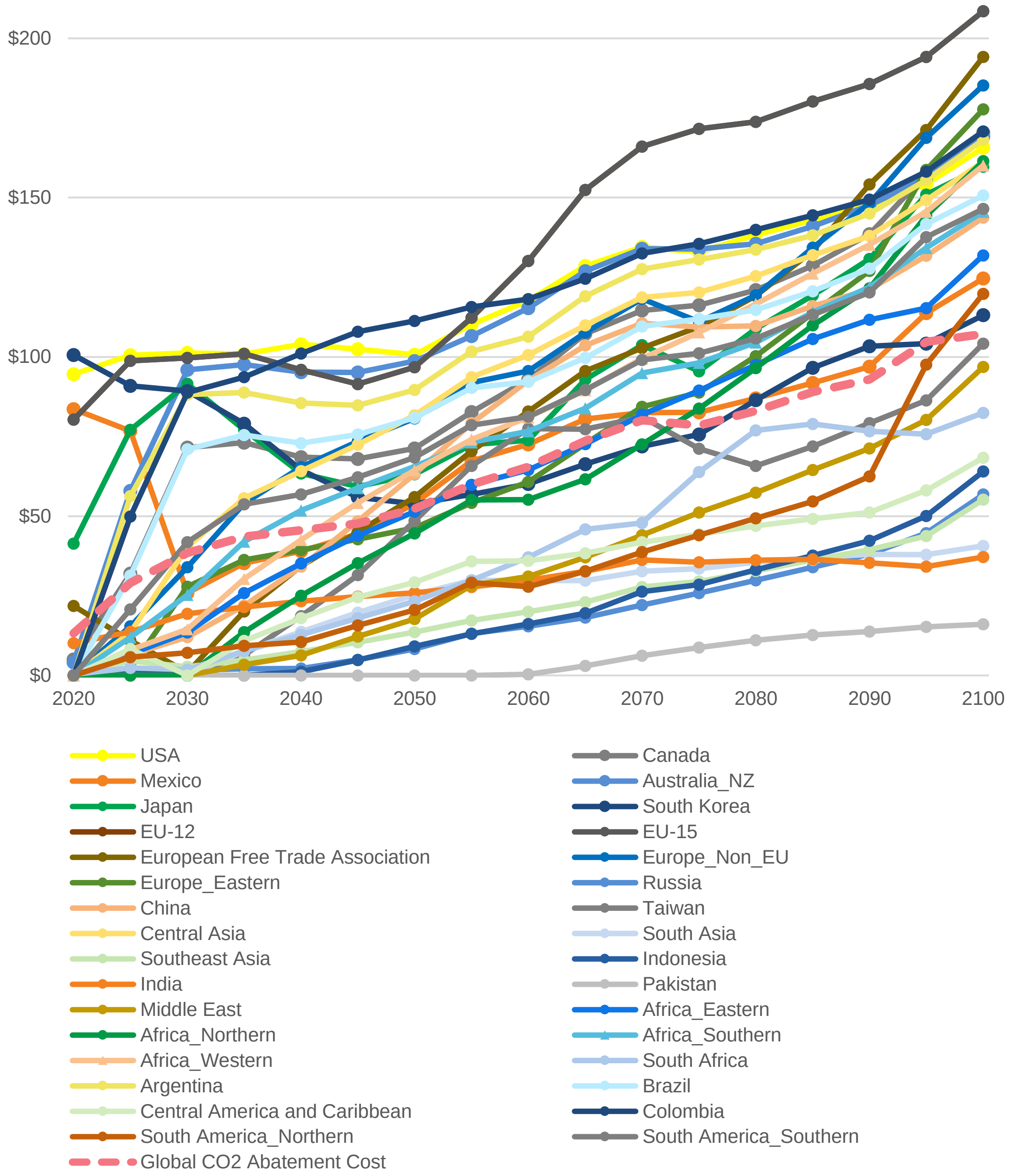


Figure 2 provides further insight into why the redistribution occurs. Regions have vastly different shadow prices, which determine the cost of domestic mitigation action under a scenario where no international collaboration occurs. Under full collaboration, however, the global average shadow price curve over time separates the regions into two groups, with abatement costs either above or below this global average. The global average shadow price curve is represented by the red line, which is simulated to reach \$38 per tCO_2 in 2030, \$52 per tCO_2 in 2050, and \$107 per tCO_2 in 2100. In an optimal economic scenario achieved under full collaboration this difference in shadow prices results in a redistribution of emissions. Given the long-term simulation until 2100, some regions shift from offering cheaper abatement opportunities to ones exceeding this global average. The financial size of such virtual carbon market would be valued at \$167 billion per year in 2030, at \$347 billion per year in 2050 and reach \$1,229 trillion/year in 2100.

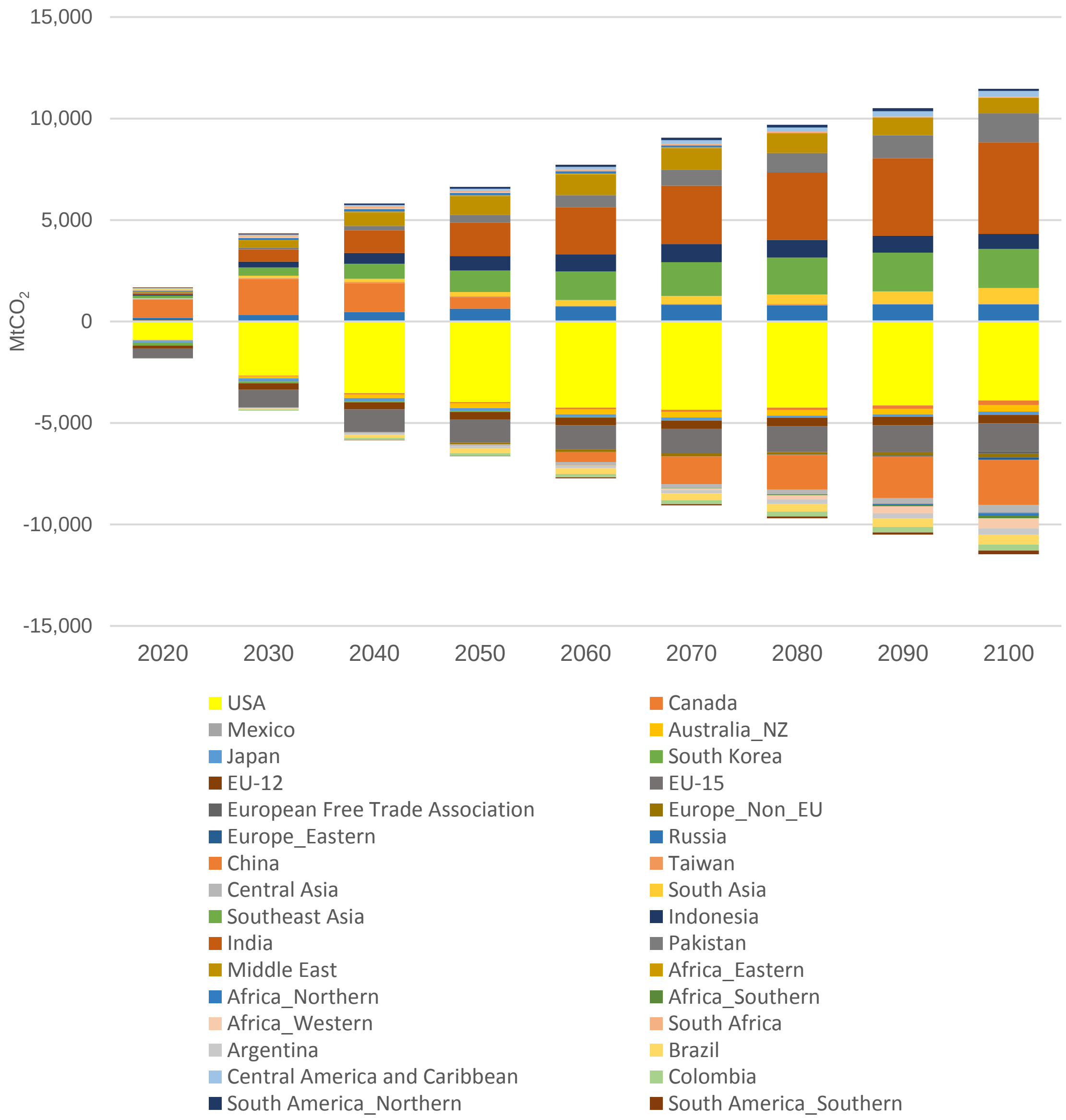
Figure 2: Global results of regional shadow prices under the I-NDC scenario, and global average shadow price curve under the C-NDC



Significant differences in shadow prices imply a large potential for economic efficiencies from international cooperation on Article 6. Figure 3 translates the results into regional differences between the two collaboration scenarios, indicating seller regions above the horizontal axis and buyer regions on the opposite side. Again, some regions move from buyers to sellers (or vice versa) over time.

The potential economic efficiencies that can be generated through collaboration on Article 6 on a global scale are significant. Compared to the I-NDC scenario, full collaboration reduces costs by $249 billion per year (63% decrease), $345 billion per year (41% decrease), and $988 billion per year (30% decrease), in 2030, 2050, and 2100, respectively. If we assume that these cost savings are reinvested into additional mitigation (therefore keeping the cost of NDCs as in the I-NDC scenario), annual global carbon emissions mitigation could be enhanced by approximately 5 $GtCO_2$ per year in 2030.

Figure 3: Change in CO_2 emissions when I-NDC trajectories of individual regions are compared to the C-NDC scenario (global)



Global emissions in the I-NDC and C-NDC scenarios result from an extrapolation of the current NDC commitments that countries have communicated to the UNFCCC. As the cumulative level of these commitments is not in line with a pathway necessary to meet the 2°C goal of the Paris Agreement, countries need to come up with more ambitious pledges in future NDCs. This is reflected in the modelling with the I-NDC increased and C-NDC increased scenarios, which, similarly to I-NDC and C-NDC, indicate independent and cooperative implementation of NDCs, but with strengthened commitments that lead towards a 2°C pathway. A similar approach was taken for the EBRD regional analysis presented in the remainder of this report.

Compared to the current ambition scenarios presented above, the increased ambition scenarios produce significantly higher regional average abatement costs over time, since all regions have more robust mitigation efforts. The global average shadow price curve now reaches $110 per tCO_2 in 2050 and $304 per tCO_2 in 2100. Compared to the I-NDC increased scenario, full collaboration reduces costs by roughly $525 billion per year (29% decrease), $280 billion per year (14% decrease), and $625 billion per year (7% decrease), in 2030, 2050, and 2100, respectively. The financial size of such virtual carbon market would be valued at $419 billion per year in 2050 and reach $1.6 trillion per year in 2100.

2. The Potential of Article 6 for EBRD Regions

This part of the report summarises the economic and environmental implications of full international collaboration on NDC implementation through Article 6 in EBRD regions of operation. In line with the presentation of the global results introduced at the start of this report, below we highlight the main results from the simulations generated by the GCAM by comparing the data under a non-collaborative I-NDC scenario, and one where countries commit to an economically optimal collaboration scenario (C-NDC). The results indicate which EBRD regions on aggregate represent net-buyers or net-sellers of emission reductions in the years 2030, 2050 and 2100, and quantify the financial size of this theoretical carbon market. Furthermore, we also assess the impact an increased level of ambition under a full collaboration scenario (C-NDC *increased*) would have on regional emission trajectories, quantifying the effect on cost of emission reductions and the value of the theoretical carbon market.

To highlight the cost savings that collaboration under Article 6 can realise in the short- to mid-term, the presented results focus on the data up to 2050. The rationale for this is two-fold. First, given the Paris Agreement's five-year cycles for updating NDCs, over the coming year countries will be looking at ways to increase ambition to accelerate the transition to low-carbon and eventually net-zero economies. Second, we recognise that short- to mid-term results are likely to have a higher accuracy level than forecasts covering the second half of this century. Nonetheless, reference to post-2050 data is also made throughout this report and included in all key visualisations, recognising the long-term nature of the problem at hand. Also, the dynamics between regions may change over time, with some regions acting as net-buyers pre-2050, and turning into net-sellers in the second half of the century – or vice versa.

It is important to note that while almost all of the EBRD countries of operation (with the exception of Greece and Kosovo) are represented in the data set used in the presented work, there is a discrepancy between the regional categorisation applied in the GCAM model and the make-up of countries in EBRD regions. Some GCAM regions, such as ‘Central Asia’, ‘Eastern Europe’ and ‘EU-12’ align closely with the associated EBRD regions, implying that the presented results can be deemed as representative to these EBRD regions of operation. Other GCAM regions, such as Northern Africa, do not align as well with EBRD’s regional definition and are composed of different abatement cost curves. Another case in point is Turkey, which in the GCAM falls in the category ‘Europe non-EU’, while in EBRD’s classification stands as an individual region in itself. Given that the GCAM model does not allow for a re-classification of regions, the only way to overcome these limitations is to analyse country-specific outcomes in future research work. Refer to Annex 1 for a complete comparison of the GCAM regions versus the EBRD regions of operations.

Another restriction posed by data aggregated on a regional level is that it does not allow for a detailed country-level analysis of abatement opportunities. The results presented in this chapter provide insight into sectors and subsectors on a regional level where ‘low-hanging fruit’ abatement opportunities exist. In addition, the results highlight which sectors deliver abatement measures at high cost and under full collaboration would contribute fewer abatement results than foreseen by individual country NDCs. Again, conducting deeper-dive scenario runs on the country-level in future research efforts would provide more granular outputs that could offer valuable considerations for country-level planning.

2.1 EU-12

Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovakia, Slovenia

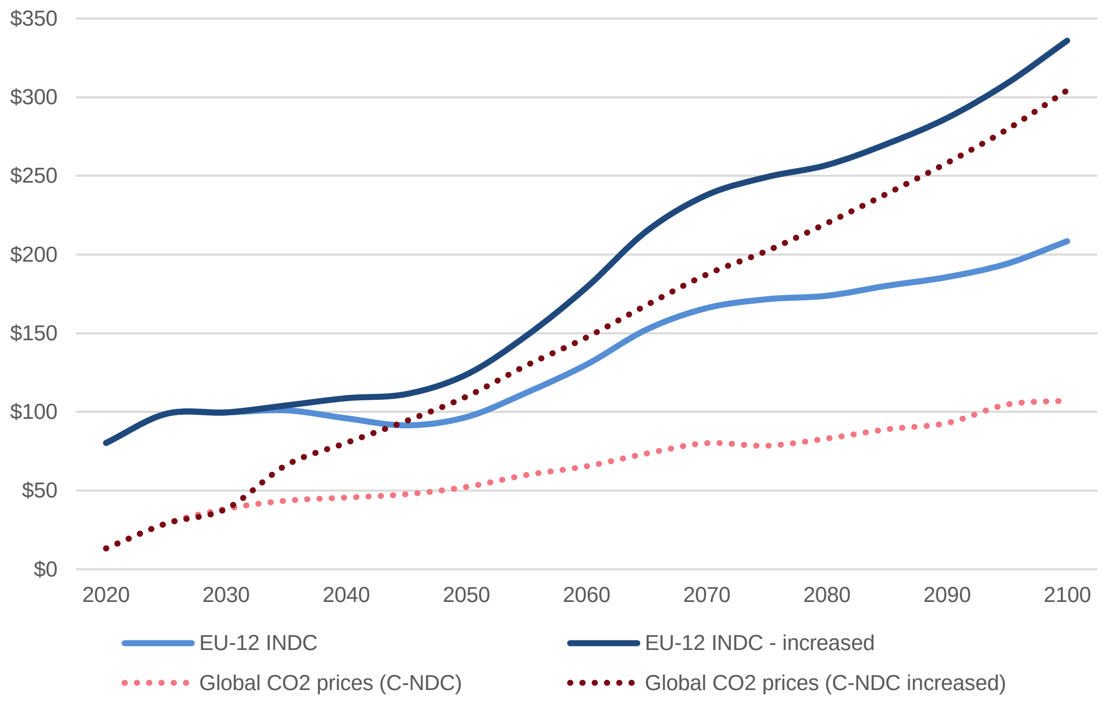
Evolution of regional abatement costs

Simulated shadow price curves are the driving factor determining whether regions are projected to be net-buyers or net-sellers under a full collaborative scenario. The cost curves also determine the extent of economic savings that can be generated under a scenario of full collaboration. Each regional section therefore starts with a visualisation of the evolution of the regional average shadow price curve until the end of this century.

Figure 4 shows that the average abatement cost of EU-12 countries is high relative to global counterparts throughout the studied period. From a perspective of cost-effectiveness, the region is incentivised to pursue collaboration opportunities in regions with lower abatement costs, and permit higher emissions domestically. The simulated shadow price for the EU-12 region reaches $100 per tonne in 2030 under the current I-NDC scenario, and more than doubles to a price of $208 by 2100. This exceeds the global average shadow price of $38 per tonne in 2030 and $107 per tonne by 2100. The larger the gap between the regional and the global average price curve, the higher the potential for economic efficiency benefits in the region under an Article 6 collaborative scenario.

For the increased ambition scenario, we continue to witness a gap between the EU-12 and the global average shadow price, confirming the continued potential for this region to benefit from trading under Article 6 if deeper emission cuts are pursued. The simulated shadow price reaches a price of $336 by 2100, exceeding the global average shadow price of $304 per tonne by 2100.

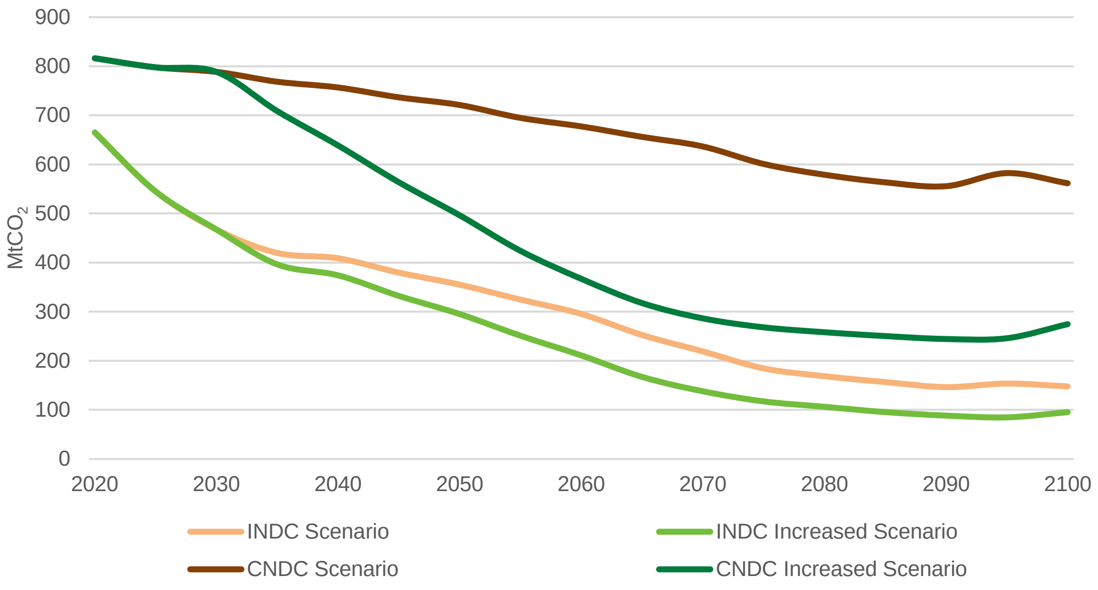
Figure 4: Average shadow price over time for EU-12 (in $2015/t$CO_2$)



Impact on emission trajectories

The observed difference between the EU-12 average shadow price curve and global prices implies that under a full collaboration scenario, EU-12 countries are incentivised to accept higher emissions domestically and engage in the purchase of ITMOs. Figure 5 points towards this trend by visualising CO_2 emission pathways for the four different trajectories for the EU-12 region. Under the I-NDC scenario, where no collaboration under Article 6 occurs, annual emissions in the EU-12 region are forecasted to decline from 665 $MtCO_2$ in 2020 to 467 $MtCO_2$ by 2030 (30% decrease) and 355 $MtCO_2$ by 2050 (47% decrease). When full collaboration is considered under the C-NDC, annual emissions of the region are projected to be considerably higher, starting with 816 $MtCO_2$ in 2020 and declining slowly to 788 $MtCO_2$ by 2030 (3% decrease) and 721 $MtCO_2$ by 2050 (12% decrease). This increase in domestic emissions arises from international trade in order to achieve a lower average abatement cost, with deeper cuts realised by the selling region. On a global-level emissions remain unchanged. Accounting by means of corresponding adjustments in line with the guidance in Article 6 of the Paris Agreement would have to safeguard that indeed no net increase in emissions at a global level occurs.

Figure 5: EU-12 regional I-NDC and C-NDC emissions scenarios, current and increased ambition pathways



When enhanced ambition is simulated under the *increased* scenarios, regional emission trajectories undergo deeper cuts post-2030 to reflect the additional effort that is required to align with a 2°C pathway. Under such I-NDC increased ambition scenario, annual emissions in the EU-12 region are forecasted to decline from 467 $MtCO_2$ in 2030 to 295 $MtCO_2$ by 2050. Under full collaboration, the emissions drop is more pronounced compared to the current C-NDC scenario, falling from 788 $MtCO_2$/year in 2030 to 496 $MtCO_2$/year by 2050. This is due to the fact that at deeper emission cuts the difference between the regional shadow prices and the global averages are smaller, implying more domestic abatement action is required to reach the target.

Value of the carbon market

In an optimal scenario where trading is used to minimise the region's abatement cost, EU-12 would use carbon markets to source a total of 321 $MtCO_2$/year by 2030, 366 $MtCO_2$/year by 2050, and 414 $MtCO_2$/year by the end of this century. In other words, these values represent the volumes of emission reductions that the region would purchase from the global carbon market where all 32 regions participate. Financially, this translates into a virtual carbon market size of $19 billion/year by 2050, and $44 billion/year by 2100 (both as a net-buyer). This financial value is determined by multiplying the size of the virtual carbon market in tonnes (change in CO_2 emissions C-NDC less I-NDC) by the average global shadow price for a particular year.

Through the use of carbon markets, the overall potential net economic benefit for the EU-12 countries reaches $11.81 billion by 2030 (representing a 44% cost saving vis-à-vis individual implementation) and $7.88 billion by 2050 (equivalent to a 22% cost saving). This net economic benefit calculation is based on the difference between the region's joint NDCs mitigation cost under an I-NDC scenario and the net cost of implementing the joint NDCs under a collaborative scenario, i.e., corrected for the costs or revenues associated with participation in international carbon markets. In the case of EU-12, the region represents a net-buyer throughout the studied timeframe and participation in the market is associated with a cost.

When increased ambition is pursued post-2030, under full collaboration the EU-12 would source a total of 201 $MtCO_2$/year by 2050, and 179 $MtCO_2$/year by 2100. Financially, this translates into a virtual carbon market size of $22 billion/year by 2050, and $55 billion/year by 2100 (both as a net-seller). The higher valuation despite the lower volume traded stems from the higher average shadow price that persists in the event of deeper cuts realised under the increased ambition scenarios. Table 2 quantifies the potential virtual carbon market under the current C-NDC scenario and the C-NDC increased scenario.

Table 2. Carbon market value in EU-12 under full collaboration, comparing current and increased ambition scenarios ($2015 billion)*

	C-NDC			C-NDC (*increased*)		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Market size	12.34	19.15	44.35	12.34	22.08	54.57

** Indicated in red are carbon market values of net-buying regions (negative values from the host region's perspective).*

Sectoral implications

The GCAM results allow us to identify the economic sectors that on a regional level (i) present the most cost-effective opportunities for emission reductions; and (ii) represent sectors where abatement measures are relatively expensive. For sectors in the second category, mitigation action is disincentivised under a collaborative implementation scenario. This information is a useful complement to the regional data on the carbon market valuation, as it provides an indication where carbon market potential can best be developed from the perspective of cost-effectiveness.

Given that the EU-12 region is projected to become a net buyer of ITMOs under the full collaboration scenario, for the majority of sectors, the emission cuts under the C-NDC scenario are lower than required under the I-NDC scenario. There is however one exception in the EU-12, which is the refining sector. While without collaboration the annual emissions from this sector are expected to rise to 76 $MtCO_2$ by 2050, under the full collaboration scenario deeper cuts are foreseen, resulting in annual emissions of 62 $MtCO_2$ by 2050. The main subsectors where the potential for deeper emission reductions exists include cellulosic ethanol production, biofuel production, and carbon capture and storage (CCS).

In terms of the sectors where abatement costs are high relative to measures in other regions and in which domestic mitigation action is disincentivised under a full collaboration scenario, the two leading sectors are biomass combustion and the electricity sector. For biomass[6], whereas without collaboration the annual emissions from this sector are expected to decline to -414 $MtCO_2$ by 2050, under the full collaboration scenario emissions from the sector stand reach -204 $MtCO_2$ by 2050, a 55% decline. For the electricity sector, without collaboration the annual emissions from this sector decline to 210 $MtCO_2$ by 2050, and under the full collaboration scenario emissions fall only to 332 $MtCO_2$ by 2050. The subsectors where less abatement occurs under full collaboration include pulverised coal combustion, conventional biomass combustion and natural gas steam reforming. Refer to Table 3 for a detailed summary of the emission trajectories of key sectors as modelled by the GCAM.

Table 3: CO_2 emission trajectories for low-hanging fruit opportunities and high abatement cost sectors in the EU-12 region ($MtCO_2$)

	I-NDC			C-NDC		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Low hanging fruit sectors						
Refining	52	76	83	32	62	50
High abatement cost sectors						
Regional biomass	-339	-414	-438	-133	-204	-171
Electricity	287	210	40	371	332	143

[6] Regional biomass in the GCAM primarily relates to lignocellulosic biomass used in the energy system.

2.2 Eastern Europe

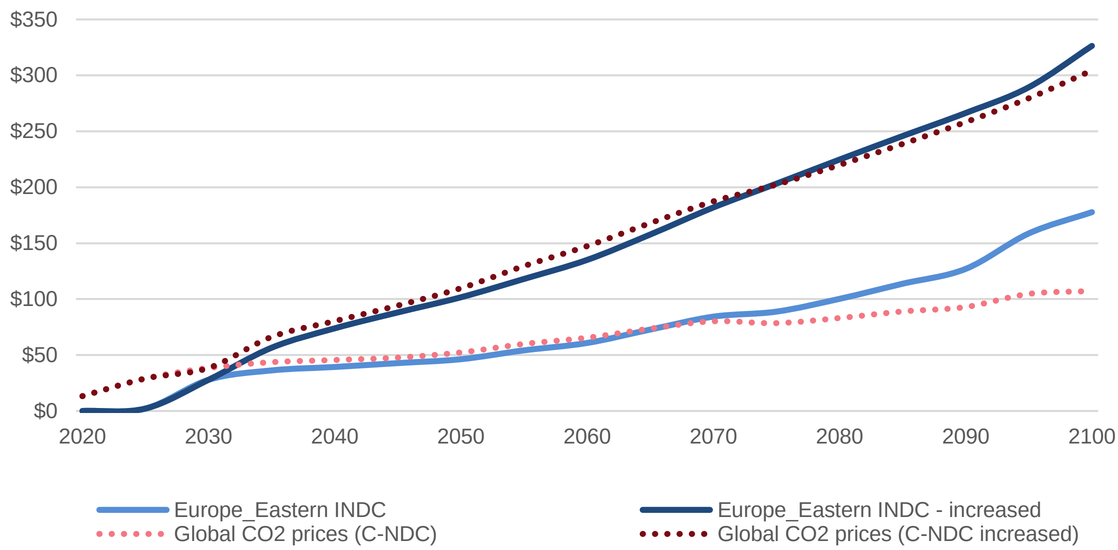
Belarus, Moldova, Ukraine

Evolution of regional abatement costs

Figure 6 shows that the average shadow price of the covered Eastern European countries generally tracks the global average shadow price curve. In the period 2020 to 2030, the region offers a window of opportunity for cost-effective emission reductions, which present prospects for Article 6 development. After 2070, the shadow price rises at a more rapid pace, indicating that seeking emission reductions abroad starts to become cost-effective the closer we get to the year 2100. The simulated shadow price for the region reaches $28 per tonne in 2030 under the current I-NDC scenario, and increases more than six times to a price of $178 by 2100.

For the increased ambition scenario we observe the same trend. The simulated shadow price in Eastern Europe remains slightly lower than the global carbon price up to 2075. The regional abatement price is simulated to reach $326 per tonne in 2100, exceeding the global average shadow price of $304 per tonne by 2100. Again, this would make the region a net-importer of ITMOs towards the end of this century, albeit at a lower rate than under the current C-NDC scenario.

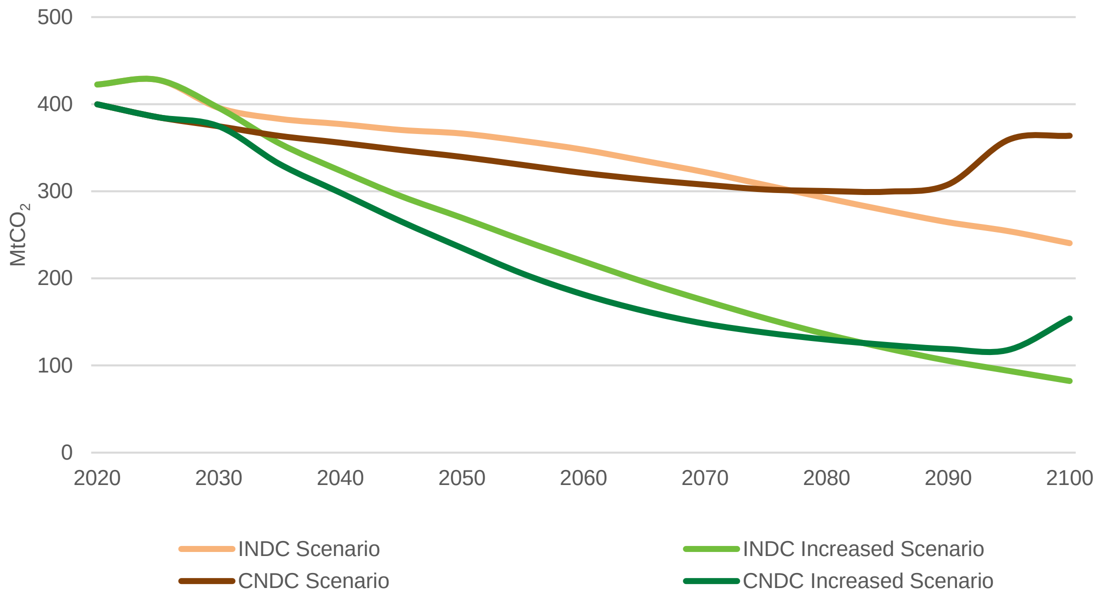
Figure 6: Average shadow price over time for the Eastern Europe region (in $2015/t CO_2)



Impact on emission trajectories

The observed interplay between the Eastern European average shadow price curve and global shadow price implies that under a full collaboration scenario, the region is initially incentivised to achieve deeper emission cuts domestically, only to shift its position and engage in the purchase of ITMOs towards the end of the century. Figure 7 points towards this trend by visualising CO_2 emission pathways for the four different trajectories for the region. Under the I-NDC scenario, where no collaboration under Article 6 occurs, annual emissions are forecasted to decline from 423 $MtCO_2$ in 2020 to 396 $MtCO_2$ by 2030 (6% decrease) and 366 $MtCO_2$ by 2050 (13% decrease). When full collaboration is considered, annual emissions are projected to be slightly lower up to 2050, starting with 400 $MtCO_2$ in 2020 and declining slowly to 375 $MtCO_2$ by 2030 (6% decrease) to reach 339 $MtCO_2$ by 2050 (15% decrease). Towards the end of the second half of the century a shift occurs, whereby domestic emissions under the C-NDC scenario start to exceed the emission levels observed under the I-NDC scenario.

Figure 7: Eastern Europe regional I-NDC and C-NDC emissions scenarios, current and increased ambition pathways



When enhanced ambition is simulated under the *increased* scenarios, regional emission trajectories undergo deeper cuts post-2030 to reflect the additional effort that is required to align with a 2°C pathway. Under such I-NDC increased ambition scenario, annual emissions in the Eastern Europe region are forecasted to decline from 396 $MtCO_2$ in 2030 to 270 $MtCO_2$ by 2050 (32% decrease). Under full collaboration, this drop is larger, falling from 375 $MtCO_2$/year in 2030 to 235 $MtCO_2$/year by 2050 (37% decrease).

Value of the carbon market

In an optimal scenario where trading is used to minimise the region's abatement cost, the covered Eastern European countries would use carbon markets to sell a total of 21 $MtCO_2$/year by 2030, 27 $MtCO_2$/year by 2050, and shift to become net-buyers by the end of this century, to compensate for a shortfall of 123 $MtCO_2$/year. Financially, this translates into a virtual carbon market size of $1.4 billion/year by 2050 (as seller), and $13 billion/year by 2100 (as buyer).

Through the use of carbon markets, the overall potential net economic benefit for the Eastern Europe region reaches $0.18 billion by 2030 (representing a 33% cost saving vis-à-vis individual implementation) and $0.35 billion by 2050 (equivalent to a 15% cost saving). This net economic benefit calculation is based on the difference between the region's joint NDCs mitigation cost under an I-NDC scenario and the net cost of implementing the joint NDCs under a collaborative scenario, i.e. corrected for the costs or revenues associated with participation in international carbon markets. In the case of Eastern Europe, for 2030 and 2050 carbon markets bring in capital, while by 2100 the region represents a net-buyer and participation in the market is associated with a cost.

When increased ambition is pursued post-2030, under full collaboration the Eastern Europe region would sell a total of 35 $MtCO_2$/year by 2050, and would need to buy 72 $MtCO_2$/year by 2100. Financially, this translates into a virtual carbon market size of $4 billion/year by 2050 (as seller), and $22 billion/year by 2100 (as buyer). The higher valuation despite the lower volume traded stems from the higher average shadow price that persists in the event of deeper cuts realised under the increased ambition scenarios. Table 4 quantifies the potential virtual carbon market under the current C-NDC scenario and the C-NDC increased scenario.

Table 4. Carbon market value in Eastern Europe under full collaboration, comparing current and increased ambition scenarios ($2015 billion)*

	C-NDC			C-NDC (*increased*)		
	2030	2050	2100	2030	2050	2100
Market size	0.81	1.41	13.23	0.81	3.80	21.85

** Indicated in red are carbon market values of net-buying regions (negative values from the host region's perspective).*

Sectoral implications

Given that over time the status of Eastern Europe changes from being a net-seller of ITMOs to a net-buyer, for a number of sectors the emission cuts under the C-NDC scenario turn out to be lower than under the I-NDC scenario up to 2080, reversing the trend in the final two decades of this century.

Regional biomass is one of the key sectors where this trend is reflected. Projected emission cuts under full collaboration are 6 $MtCO_2$ higher by 2030 and 17 $MtCO_2$ higher by 2050, but decline below the I-NDC levels between 2080 and 2100 (-50 $MtCO_2$ by 2100). Electricity is another major sector in the region which follows this pattern. Here, emissions under the C-NDC scenario are projected to be lower than in the I-NDC scenario through 2080 (-5 $MtCO_2$ by 2030 and -7 $MtCO_2$ by 2050), with a reversal by 2100 (15 $MtCO_2$). For industrial energy use a similar tendency is observed.

There are however a number of exceptions to this projection, which can be found in the refining sector. For example, in the case of Fischer-Tropsch (FT) biofuels and cellulosic ethanol, emissions are projected to be higher under the full collaboration scenario compared to the individual implementation scenarios already from 2030 onward. This means that emission cuts for these subsectors are relatively expensive in Eastern Europe relative to measures in other regions, and would be disincentivised under a full collaborative scenario. Also for unconventional oil production, emissions under the C-NDC scenario are higher compared to the I-NDC scenario already in 2030 and 2050, although here the trend reverses again by 2100. Refer to Table 5 for a detailed summary of the emission trajectories of key sectors as modelled by the GCAM.

Table 5: CO_2 emission trajectories for low-hanging fruit opportunities and high abatement cost sectors in the Eastern Europe region ($MtCO_2$)

	I-NDC			C-NDC		
	2030	2050	2100	2030	2050	2100
Low hanging fruit sectors						
Regional biomass	-18	-38	-139	-23	-57	-89
Electricity	125	97	19	120	90	34
Industrial energy	93	82	35	87	79	50
High abatement cost sectors						
Refining (FT biofuels)	1	3	4	1	4	5
Refining (cellulosic ethanol)	1	4	5	1	5	6
Unconventional oil production	4	9	110	5	10	128

2.3 Europe Non-EU

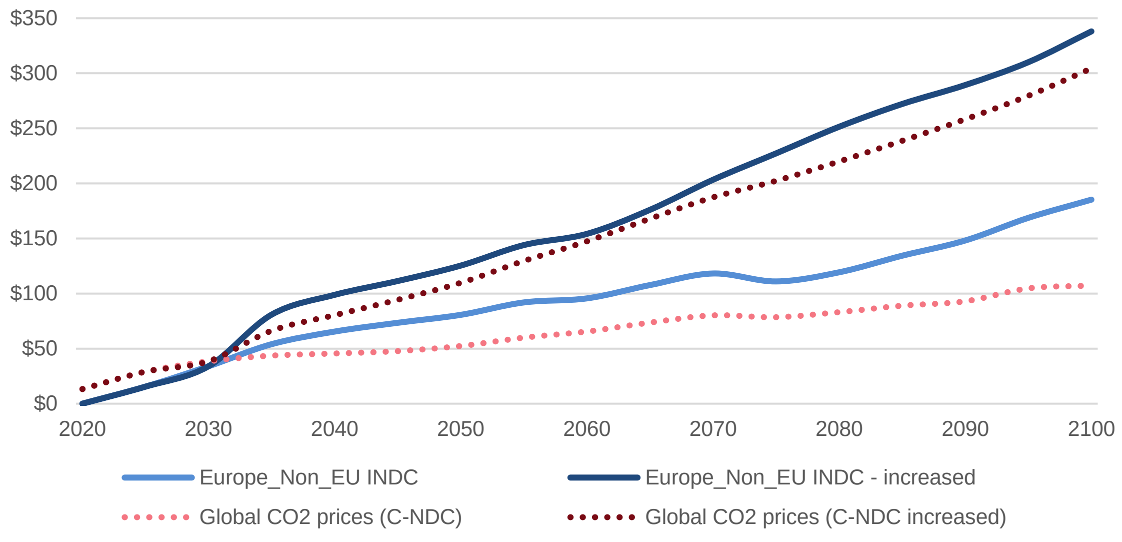
Albania, Bosnia Herzegovina, Croatia, Macedonia, Montenegro, Serbia, Turkey.

Evolution of regional abatement costs

Figure 8 shows that the average abatement cost of the countries included in the Europe non-EU region generally exceed the global average shadow price curve. In the period 2020 to 2030, similar to the Eastern Europe results, the region offers a window of opportunity for cost-effective emission reductions, but post-2030 the shadow price rises above the global average cost curve. This indicates that seeking emission reductions elsewhere is cost-effective post-2030. The simulated shadow price for the region reaches $34 per tonne in 2030 under the current I-NDC scenario, and increases gradually to a price of $185 by 2100.

For the increased ambition scenario, we continue to witness a gap between the Europe Non-EU region and the global average shadow price, confirming the continued potential for this region to benefit from trading under Article 6 in the event of deeper cuts. The simulated shadow price reaches a price of $338 by 2100, exceeding the global average shadow price of $304 per tonne by 2100.

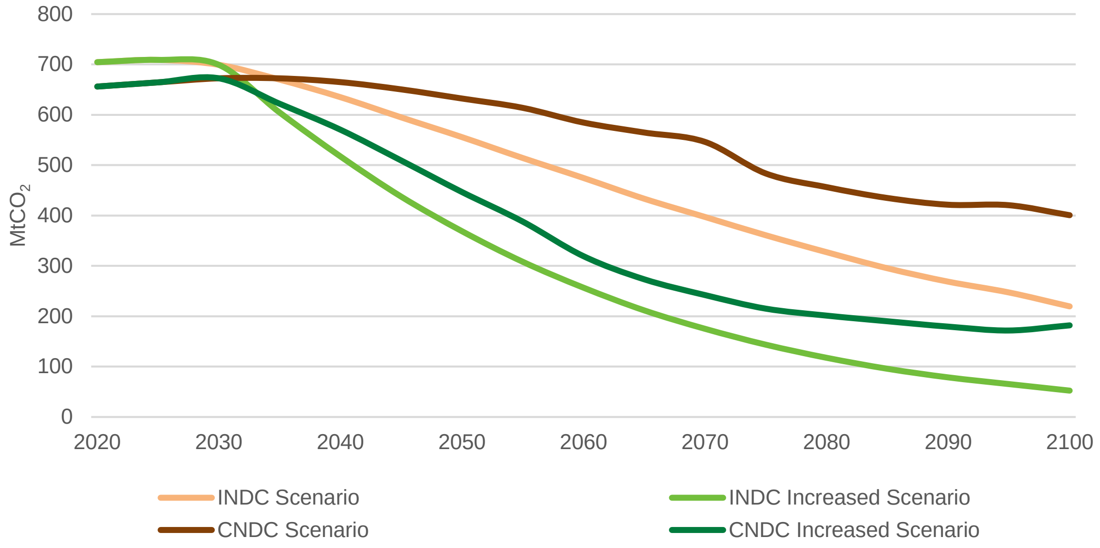
Figure 8: Average shadow price over time for the Europe non-EU region (in $2015/t$CO_2$)



Impact on emission trajectories

The observed relationship between the Europe non-EU average shadow prices and global shadow prices implies that under a full collaboration scenario, the region is initially – similar to the Eastern Europe region – incentivised to generate deeper emission cuts domestically. The shift to becoming a source of demand for ITMOs however occurs earlier, as from 2030 onwards the region is forecasted to become a net-buyer of emission reductions. Figure 9 points towards this trend by visualising CO_2 emission pathways for the four different trajectories for the region. Under the I-NDC scenario, where no collaboration under Article 6 occurs, annual emissions are forecasted to decline from 705 MtCO_2 in 2020 to 699 MtCO_2 by 2030 (>1% decrease) and 556 MtCO_2 by 2050 (21% decrease). Under full collaboration, annual emissions are projected to start at a level of 656 MtCO_2 in 2020, and increase slightly to 673 MtCO_2 by 2030 (3% increase). From 2035 onwards emissions start decreasing again, reaching 632 MtCO_2 by 2050 (6% decrease from the 2030 level).

Figure 9: Europe non-EU regional I-NDC and C-NDC emissions scenarios, current and increased ambition pathways



When enhanced ambition is simulated under the *increased* scenarios, regional emission trajectories undergo deeper cuts post-2030 to reflect the additional effort that is required to align with a 2°C pathway. Under such I-NDC increased ambition scenario, annual emissions in the Europe non-EU region are forecasted to decline from 699 $MtCO_2$ in 2030 to 369 $MtCO_2$ by 2050 (47% decrease). Under full collaboration, this drop is more pronounced, falling from 673 $MtCO_2$/year in 2030 to 447 $MtCO_2$/year by 2050 (34% decrease).

Value of the carbon market

In an optimal scenario where trading is used to minimise the region's abatement cost, the Europe non-EU region would use carbon markets to sell a total of 27 $MtCO_2$/year by 2030, becoming a net-buyer later on and sourcing 77 $MtCO_2$/year by 2050, and 181 $MtCO_2$/year by the end of this century. Financially, this translates into a virtual carbon market size for the region of $4 billion/year by 2050, and $19 billion/year by 2100 (both as buyer).

Through the use of carbon markets, the overall potential net economic benefit for the region reaches $0.22 billion by 2030 (representing a 14% cost saving vis-à-vis individual implementation). By the year 2100 the market value reaches $8.30 billion (equivalent to a 17% cost saving). This net economic benefit calculation is based on the difference between the region's joint NDCs mitigation cost under an I-NDC scenario and the net cost of implementing the joint NDCs under a collaborative scenario, i.e. corrected for the costs or revenues associated with participation in international carbon markets. In the case of Europe non-EU countries, the region represents a net-buyer in the years 2050 and 2100, and participation in the market is associated with a cost post-2030.

When increased ambition is pursued post-2030, under full collaboration the Europe non-EU region would source a total of 78 $MtCO_2$/year by 2050, and 130 $MtCO_2$/year by 2100. Financially, this translates into a virtual carbon market size of $9 billion/year by 2050, and $39 billion/year by 2100 (both as buyer). The higher valuation despite the lower volume traded stems from the higher average shadow price that persists in the event of deeper cuts realised under the increased ambition scenarios. Table 6 quantifies the potential virtual carbon market under the current C-NDC scenario and the C-NDC increased scenario.

Table 6: Carbon market value in Europe non-EU under full collaboration, comparing current and increased ambition scenarios ($2015 billion)*

	C-NDC			C-NDC (*increased*)		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Market size	1.03	4.01	19.41	1.03	8.54	39.43

** Indicated in red are carbon market values of net-buying regions (negative values from the host region's perspective).*

Sectoral implications

Given that the Europe non-EU region is projected to be a net seller of ITMOs under full collaboration in the first period of 2020 to 2030, there is an opportunity for realising higher emission cuts across sectors under the C-NDC scenario. The electricity sector, and conventional pulverised coal in particular, stands out as one of the low hanging fruit opportunities in the region. Also industrial energy use can be identified as a sector where additional emission cuts are incentivised in 2030. The extent of additional cuts is however not high – while without collaboration emissions in this sector are expected to be 217 $MtCO_2$ in 2030, emissions from this sector would drop in the collaborative scenario to 204 $MtCO_2$ (6% decrease). This is due to the fact that the region is projected to only have a small total surplus of emission reductions under the C-NDC scenario, thereby limiting large-scale opportunities for cost-effective additional emission reductions as observed in other regions.

In other key sectors, emissions are projected to be somewhat higher under the C-NDC scenario. For biomass technology (residual heating), for instance, emissions are projected to be 19% higher in 2030 when full collaboration applies. Also in the refining sector, with cellulosic ethanol in particular, 2030 emissions are projected to be higher (by 45%) under the C-NDC scenario compared to the I-NDC scenario. This implies that already by 2030, abatement costs for these technologies are relatively high, disincentivising mitigation action in absolute terms.

In 2050 and beyond, the Europe non-EU countries are projected to become a net-buyer of ITMOs under the full collaboration scenario. This means that for virtually all sectors, emission cuts under the C-NDC scenario are lower than required under the I-NDC scenario, and that domestic mitigation action is disincentivised under full collaboration. Refer to Table 7 for a detailed summary of the emission trajectories of key sectors as modelled by the GCAM.

Table 7: CO_2 emission trajectories for low-hanging fruit opportunities and high abatement cost sectors in the Eastern Europe region ($MtCO_2$)

	I-NDC			C-NDC		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Low hanging fruit sectors						
Electricity (pulverised coal)	217	163	10	204	179	46
Industrial energy use	162	130*	66*	158	155*	98*

** Indicates sectors which shift from being either a low hanging fruit opportunity or high abatement cost intervention at some point of the simulation. In this example, deeper emission reductions in industrial energy use are cost-effective in Eastern Europe in 2030, but by 2050 become too expensive. This means that under a full collaboration scenario, the emissions from this sector are projected to rise above the levels simulated under the non-collaborative scenario in 2050 and onwards. The same logic applies for the results presented in other regions.*

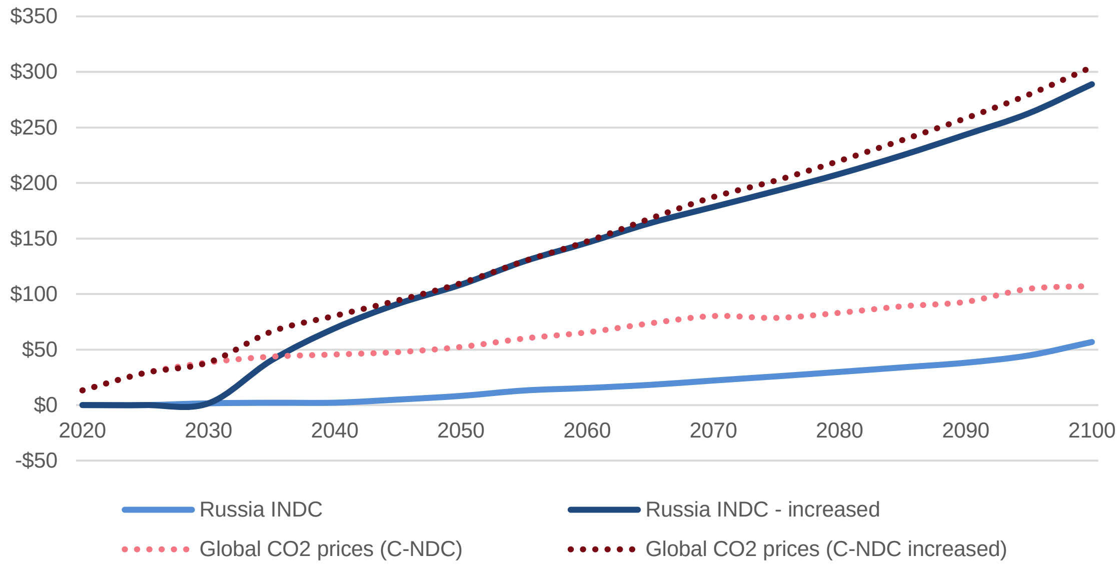
2.4 Russia

Evolution of regional abatement costs

Russia stands out as a region where average abatement costs throughout the century remain significantly below the global average shadow price. Figure 10 visualises this trend. The simulated shadow price for Russia starts at $1.60 per tonne in 2030 under the current I-NDC scenario, and increases to a price of $57 by 2100, which the global abatement prices sit at $38 per tonne in 2030 and $107 per tonne by 2100. This gap between Russia and the rest of the world points to the potential for the region to become a sizeable net-seller of ITMOs under Article 6.

For the increased ambition scenario, we continue to witness a gap between Russia and the global average abatement prices, confirming its status as a net-seller of emission reductions also in the event of deeper cuts. The simulated shadow price reaches a price of $289 by 2100, still below the global average shadow price of $304 per tonne by 2100. In absolute terms, however, the amount of emission reductions that can be cost-effectively realised in Russia under the C-NDC is only a fraction when compared to the I-NDC scenario, as can be seen be the tighter gap between the two upper lines.

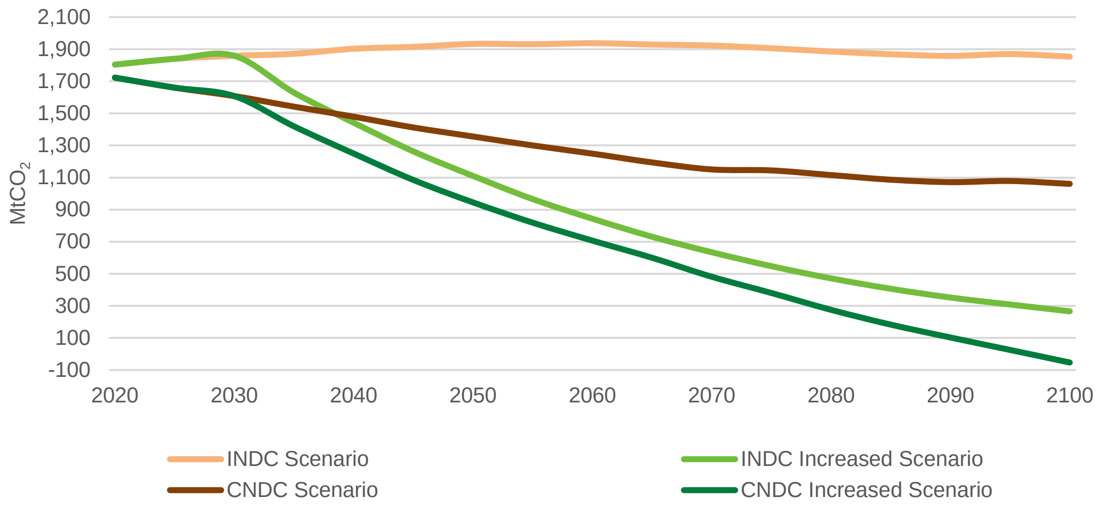
Figure 10: Average shadow price over time for Russia (in $2015/t$CO_2$)



Impact on emission trajectories

The projected lower average shadow prices that imply that under a full collaboration scenario, the country could accept deeper cuts domestically throughout the entire studied timeframe. Figure 11 points towards this trend by visualising CO_2 emission pathways for the four different trajectories for the region. Under the current I-NDC scenario, annual emissions in Russia are forecasted to increase from 1,804 MtCO_2 in 2020 to 1,859 MtCO_2 by 2030 (3% increase) and 1,933 MtCO_2 by 2050 (4% increase from the 2030 level). Under full collaboration, annual emissions are projected to be considerably lower, starting with 1,722 MtCO_2 in 2020 and declining slowly to 1,608 MtCO_2 by 2030 and 1,356 MtCO_2 by 2050. This means that by 2050, domestic emissions would be 30% lower under the C-NDC scenario when compared to a situation without collaboration.

Figure 11: Russia's I-NDC and C-NDC emissions scenarios, current and increased ambition pathways



When enhanced ambition is simulated under the *increased* scenarios, regional emission trajectories undergo deeper cuts post-2030 to reflect the additional effort that is required to align with a 2°C pathway. Under such I-NDC increased ambition scenario, annual emissions in Russia are forecasted to decline from 1,859 $MtCO_2$ in 2030 to 1,110 $MtCO_2$ by 2050. Under full collaboration, the drop shows a decline of a similar magnitude, falling from 1,608 $MtCO_2$/year in 2030 to 945 $MtCO_2$/year by 2050.

Value of the carbon market

In an optimal scenario where trading is used to minimise the region's abatement cost, Russia would position itself in a global carbon market as a net-seller throughout the 2020 – 2100 period. Total sales would amount to 251 $MtCO_2$/year by 2030, 577 $MtCO_2$/year by 2050, and 793 $MtCO_2$/year by the end of this century. Financially, this translates into a virtual carbon market size of $30 billion/year by 2050, and $85 billion/year by 2100 (both as net-seller). Given the high level of aggregate emissions and the relatively large gap between the regional and global average shadow prices, Russia represents the largest carbon market within the studied group of regions.

Through the use of carbon markets, the overall potential net economic benefit for Russia reaches $5.05 billion by 2030 and $16.44 billion by 2050. The value would almost triple to a value of $42.56 billion by 2100. This net economic benefit calculation is based on the difference between the region's joint NDCs mitigation cost under an I-NDC scenario and the net cost of implementing the joint NDCs under a collaborative scenario, i.e. corrected for the costs or revenues associated with participation in international carbon markets. In the case of Russia, the region represents a net-seller throughout the studied timeframe. Participation in the international carbon market is therefore associated with revenues, which can be used to finance domestic mitigation action.

When increased ambition is pursued post-2030, under full collaboration Russia would offer a total of 165 $MtCO_2$/year by 2050, and 319 $MtCO_2$/year by 2100. Financially, this translates into a virtual carbon market size of $18 billion/year by 2050, and $97 billion/year by 2100 (both as net-seller). As in the previous regions, the higher valuation despite the lower volume traded stems from the higher average shadow price that persists in the event of deeper cuts realised under the increased ambition scenarios. Table 8 quantifies the potential virtual carbon market under the current C-NDC scenario and the C-NDC increased scenario.

Table 8. Carbon market value in Russia under full collaboration, comparing current and increased ambition scenarios ($2015 billion)

	C-NDC			C-NDC (*increased*)		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Market size	9.64	30.21	85.02	9.64	18.13	97.15

Sectoral implications

Given that Russia is projected to be a net-seller of ITMOs under the full collaboration scenario, for the majority of sectors the emissions under the I-NDC scenario exceed what would be required under the C-NDC scenario. In terms of sectors where abatement costs for Russia are attractively priced, and where mitigation action is incentivised in absolute terms, the three leading sectors include biomass, electricity and gas processing.

For biomass, emission cuts under the C-NDC scenario are significantly higher compared to emission cuts under the I-INDC scenario, implying that lower emissions are projected under full Article 6 collaboration. Under individual implementation, emission cuts from biomass reach 80 $MtCO_2$ in 2050, compared to 323 $MtCO_2$ in 2050 under the collaborative scenario.

For electricity, conventional pulverised coal and gas (combined cycle) stand out as technologies with a large abatement potential under the C-NDC scenario. For pulverised coal, whereas without collaboration annual emissions are expected to decrease to 137 $MtCO_2$ in 2050, in the full collaboration scenario this decrease is more pronounced, resulting in 100 $MtCO_2$ in 2050. In addition, whereas for gas (combined cycle) an increase in emissions is projected in both scenarios up to 2050, the increase is significantly lower in the C-NDC (at 52 $MtCO_2$) compared to the I-NDC (87 $MtCO_2$). Regarding gas processing, for coal gasification emissions under the I-NDC scenario are projected to be 30 $MtCO_2$ in 2050, whereas under the C-NDC these only reach 8 $MtCO_2$ in 2050.

Finally, for the refining sector, for the first half of the century deeper emission cuts are incentivised through full collaboration. However, by 2100, this trend reverses and additional emission cuts in the refining sector in Russia are disincentivised from a cost-effectiveness perspective. In particular for the biomass liquids, emissions are projected to be higher in the C-NDC scenario compared to the I-NDC scenario by 2100. While without collaboration the annual emissions from this sector are expected to be 112 $MtCO_2$ in 2100, with full collaboration emissions increase significantly more, up to 154 $MtCO_2$ in by 2100.

Except for the refining sector by 2100, there are no sectors in Russia where deeper emission cuts are strongly disincentivised under the full collaboration scenario. Refer to Table 9 for a detailed summary of the emission trajectories of key sectors as modelled by the GCAM.

Table 9: CO_2 emission trajectories for low-hanging fruit opportunities and high abatement cost sectors in Russia ($MtCO_2$)

	I-NDC			C-NDC		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Low hanging fruit sectors						
Regional biomass	-44	-80	-80	-83	-323	-573
Electricity	502	408	215	471	306	93
Electricity (pulverised coal)	176	137	73	166	100	16
Electricity (gas combined cycle)	25	87	102	22	52	47
Gas processing (coal gasification)	8	30	88	2	8	26
Refining	75	164	112*	65	146	154*

** Indicates sectors which shift from being either a low hanging fruit opportunity or high abatement cost intervention at some point of the simulation.*

2.5 Central Asia

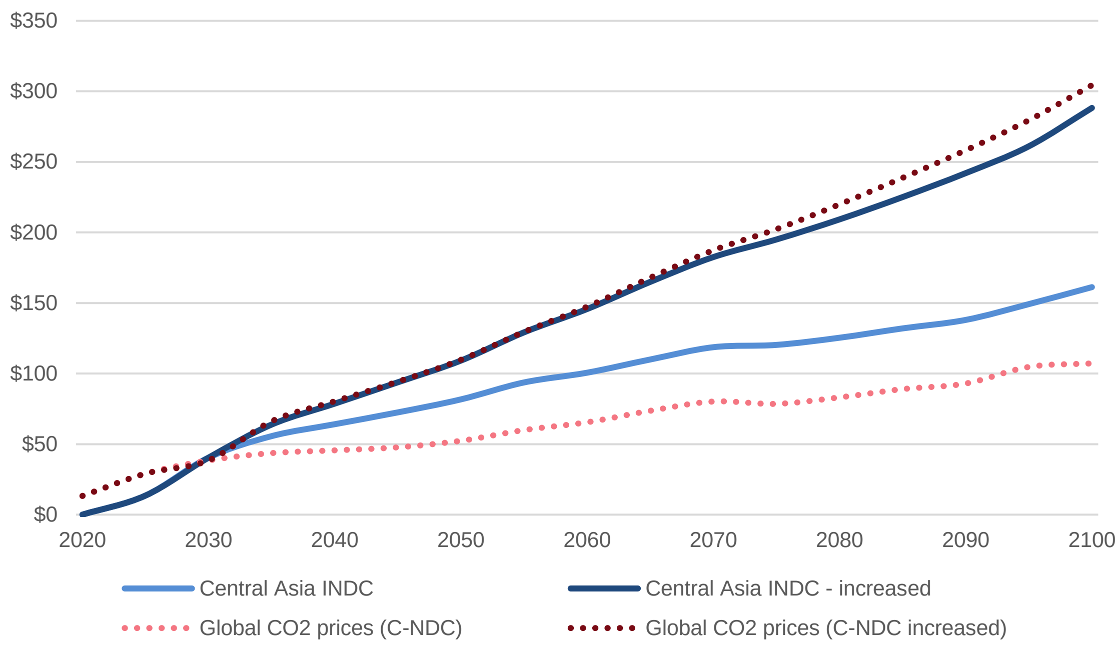
Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Mongolia, Tajikistan, Turkmenistan, Uzbekistan.

Evolution of regional abatement costs

The relationship between Central Asia's average abatement cost curve and that of global costs varies depending on which ambition scenario is simulated. Figure 12 shows that under the current I-NDC scenario, shadow prices exceed the global average from 2030 onwards. The simulated shadow price for the region is $82 per tonne in 2050 under the current I-NDC scenario, and doubles to reach $161 by 2100. This exceeds the global average shadow price of $52 per tonne in 2050 and $107 per tonne by 2100. This widening gap between the Central Asia region and the global average shadow prices points to the growing potential for the region to benefit from collaboration under Article 6.

For the increased ambition scenario, we witness a reversal in this relationship. The simulated shadow price reaches a price of $288 by 2100, which is lower than the global average shadow price of $304 per tonne by that year. This implies that Central Asia could present cost-effective abatement opportunities in the second half of this century, albeit the total volume is restricted. This is because of the small observed gap between the two price curves, reducing the benefit that engagement in international cooperation on Article 6 could deliver in the event of deeper emission cuts.

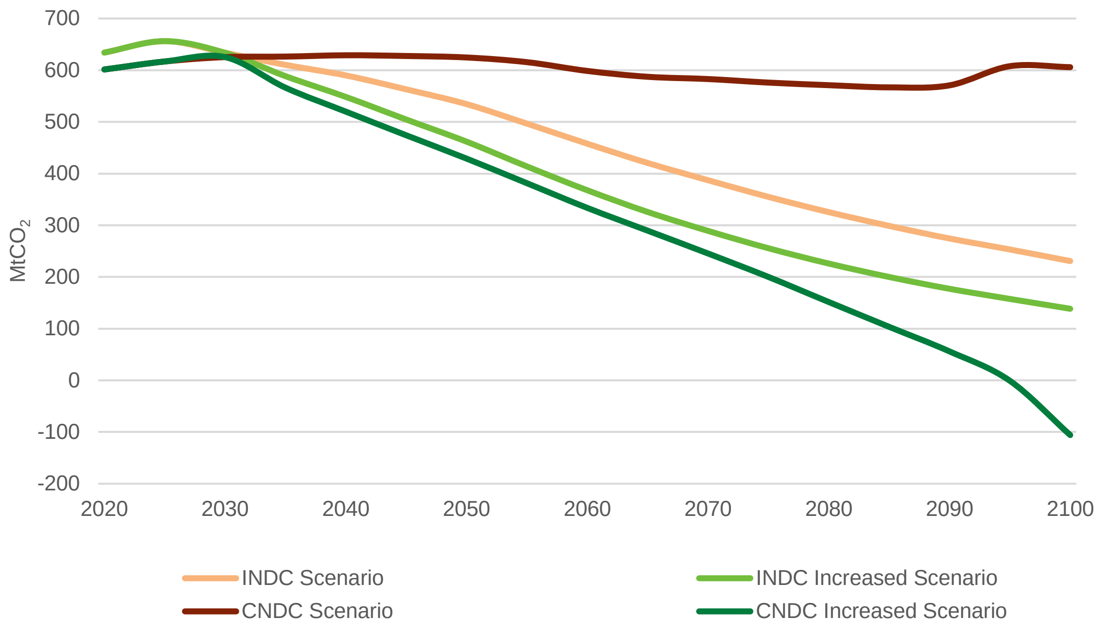
Figure 12: Average shadow price over time for Central Asia (in $2015/t$CO_2$)



Impact on emission trajectories

Figure 13 points towards this opposing trend by visualising CO_2 emission pathways for the four different trajectories for the region. Under the current I-NDC scenario, annual emissions in Central Asia are forecasted to stay virtually constant at 634 MtCO_2 in 2020 through 2030, decreasing to 534 MtCO_2 by 2050 (a 16% decrease). Under full collaboration, annual emissions are projected to start at a slightly lower level (601 MtCO_2 in 2020), increasing slowly to 625 MtCO_2 by 2030 and staying virtually the same at 625 MtCO_2 through 2050. The observed gap in the two emission trajectories widens over time, explained by the persisting difference in the shadow prices discussed above. In the period 2020 – 2030, the region offers cost-effective emissions reductions when collaboration is simulated, similar to the trend observed in Europe non-EU and Russia in these early years.

Figure 13: Central Asia's I-NDC and C-NDC emissions scenarios, current and increased ambition pathways



When enhanced ambition is simulated under the *increased* scenarios, regional emission trajectories undergo deeper cuts post-2030 to reflect the additional effort that is required to align with a 2°C pathway. Under such I-NDC increased ambition scenario, annual emissions in the Central Asian region are forecasted to drastically decline from 634 $MtCO_2$ in 2030 to 461 $MtCO_2$ by 2050. Under full collaboration, this drop is similar, falling from 625 $MtCO_2$/year in 2030 to 429 $MtCO_2$/year by 2050, and even becoming negative towards the end of the century.

Value of the carbon market

In an optimal scenario where trading is used to minimise the region's abatement cost, the Central Asian region would use carbon markets to sell a total of 8 $MtCO_2$/year by 2030, but would become a net-buyer of emission reductions at rates of 90 $MtCO_2$/year by 2050, and 375 $MtCO_2$/year by the end of this century. Financially, this translates into a virtual carbon market size of $5 billion/year by 2050, and $40 billion/year by 2100 (both as net-buyer).

Through the use of carbon markets, the overall potential net economic benefit for the region reaches $0.14 billion by 2030 and $0.51 billion by 2050. As the emissions gap between the I-NDC and the C-NDC widens in the second half of the century, the economic benefit grows to reach $11.81 billion by 2100. This net economic benefit calculation is based on the difference between the region's joint NDCs mitigation cost under an I-NDC scenario and the net cost of implementing the joint NDCs under a collaborative scenario, i.e. corrected for the costs or revenues associated with participation in international carbon markets. In the case of Central Asia, the region represents a net-seller at the start, but turns into a net-buyer in the years 2050 and 2100. Participation in the international carbon market is therefore associated with revenues at the beginning, and costs later on.

When increased ambition is pursued post-2030, under full collaboration the Central Asian region would become a net-supplier throughout the entire timeframe, supplying a total of 33 $MtCO_2$/year by 2050 and 244 $MtCO_2$/year by 2100. Financially, this translates into a virtual carbon market size of $3.60 billion/year by 2050, and $74.36 billion/year by 2100 (both as net-seller). See Table 10 for an overview.

Table 10. Carbon market value in Central Asia under full collaboration, comparing current and increased ambition scenarios ($2015 billion)*

	C-NDC			C-NDC (*increased*)		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Market size	0.32	4.72	40.20	0.32	3.60	74.37

** Indicated in red are carbon market values of net-buying regions (negative values from the host region's perspective).*

Sectoral implications

Given that the Central Asian region is projected to become a net-buyer of ITMOs under the full collaboration scenario (assuming no increased ambition), for the majority of sectors emission cuts under the C-NDC scenario are lower than required under the I-NDC scenario. This implies that leading sectors in Central Asia have high shadow prices relative to measures in other regions, disincentivising mitigation action under a full collaboration scenario.

The largest sector where this this is observed in absolute terms is regional biomass, which presents fewer net negative emissions under the C-NDC scenario. While emissions are expected to be -146 MtCO_2 under the I-NDC in 2050, under the C-NDC annual emissions would be less deep at -123 MtCO_2 by mid-century. The difference towards the end of the century is even more pronounced, as can be viewed in Table 11.

Another relevant sector is industrial energy use, where without collaboration the annual emissions are expected to decline to 141 MtCO_2 in 2050, under the full collaboration scenario emissions from the sector are projected to be 161 MtCO_2 for that year. Finally, for the electricity sector 119 MtCO_2 would be emitted under the I-NDC in 2050, while under the C-NDC annual emissions would be higher at 141 MtCO_2 by mid-century.

The refining sector shows that emissions under the C-NDC scenario are at par or slightly above the emission levels assuming no collaboration, indicating at some points in time higher abatement cost relative to other sectors.

For 2030, lower emissions are projected both the regional biomass and electricity sectors under the C-NDC scenario compared to the I-NDC scenario. Also for coal to liquids, in the refining sector, in 2030 additional emission cuts will be incentivized by full collaboration. However, none of these sectors and technologies can be considered low hanging fruit for deeper emission cuts in the long run.

Table 11: CO_2 emission trajectories for low-hanging fruit opportunities and high abatement cost sectors in Central Asia (MtCO_2)

	I-NDC			C-NDC		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
High abatement cost sectors						
Industrial energy use	160	141	93	161	162	115
Electricity	180	120	24	176*	141	49
Regional biomass	-23	-146	-563	-31*	-123	-282
Refining	26	59	80	27	62	79*

** Indicates sectors which shift from being either a low hanging fruit opportunity or high abatement cost intervention at some point of the simulation.*

2.6 Middle East

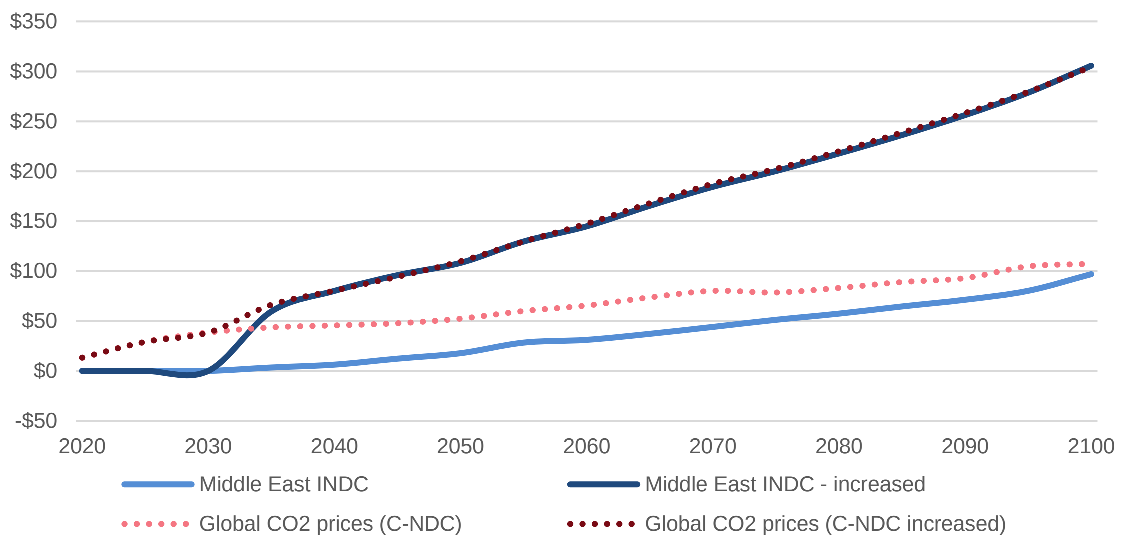
United Arab Emirates, Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, Yemen.

Evolution of regional abatement costs

The abatement cost simulation illustrated in Figure 14 for the Middle Eastern region shows prices of below $1 per tonne in 2030 under the current I-NDC scenario, increasing to $97 by 2100. Throughout this full timeframe the price levels remain below global average shadow prices. This gap, which is more pronounced in the first half of this century, points to the potential for the region to generate relatively cheap emission reductions that it can transfer internationally through Article 6.

For the increased ambition scenario, this gap in pricing virtually disappears post 2035, as reflected by the two curves joining in tandem throughout the remainder of this century. This implies that in the event of deeper cuts, there is a short-term opportunity for cost-effectiveness, where the Middle East could act as a net-seller of emission reductions. By 2100, the region's average shadow price is forecasted to reach $306 per tonne, $2 above the global average.

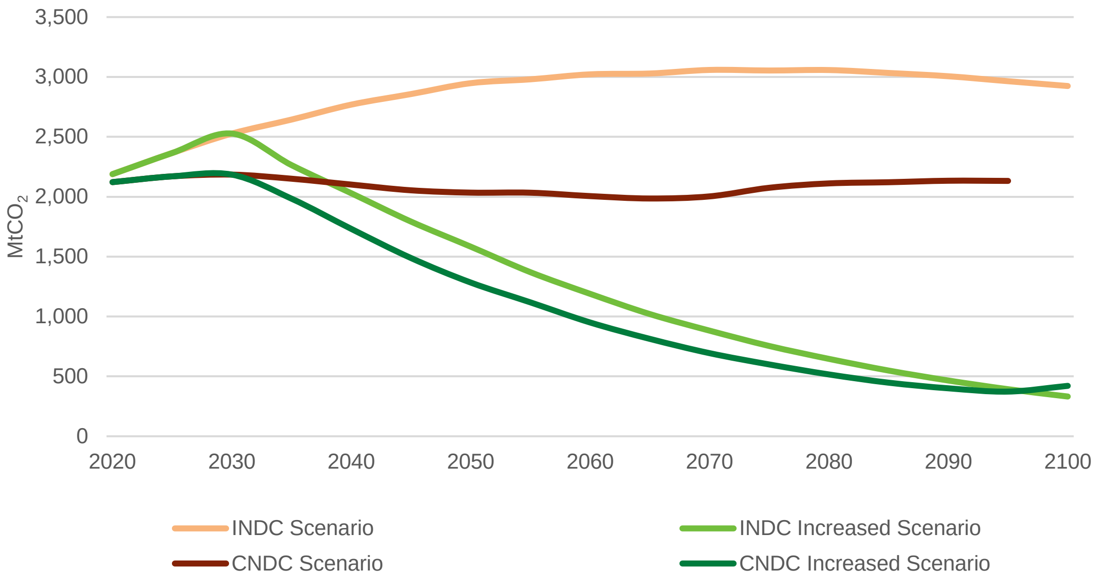
Figure 14: Average shadow price over time for the Middle East (in $2015/tCO$_2$)



Impact on emission trajectories

The lower average shadow prices that are projected to exist in the current ambition scenario imply that under a full collaboration scenario, deeper emission cuts in the region are incentivised throughout the entire studied timeframe. Figure 15 points towards this trend by visualising CO_2 emission pathways for the four different trajectories for the region. Under the current I-NDC scenario, annual emissions in the Middle East are projected to reach 2,527 MtCO_2 in 2030 and further increase to 2,948 MtCO_2 by 2050 (17% increase from 2030 levels). Under full collaboration, deeper cuts are foreseen given the relative cost-effectiveness of domestic abatement action, resulting at 2,185 MtCO_2 by 2030 and decreasing slightly to 2,034 MtCO_2 in 2050. This means that by 2050, domestic emissions would be about 30% lower under the C-NDC scenario when compared to a situation without collaboration.

Figure 15: Middle Eastern I-NDC and C-NDC emissions scenarios, current and increased ambition pathways



When enhanced ambition is simulated under the *increased* scenarios, regional emission trajectories undergo deeper cuts post-2030 to reflect the additional effort that is required to align with a 2°C pathway. Under such I-NDC increased ambition scenario, annual emissions in the Middle Eastern region are forecasted to decline considerably to a level of 1,583 $MtCO_2$ by 2050. Under full collaboration, this drop is similar, falling to a level of 1,284 $MtCO_2$/year by 2050.

Value of the carbon market

In an optimal scenario where trading is used to minimise abatement costs, the Middle Eastern region would use carbon markets under a current ambition scenario to sell a total of 343 $MtCO_2$/year by 2030, 914 $MtCO_2$/year by 2050, and 772 $MtCO_2$/year by the end of this century. Financially, this translates into a virtual carbon market size of $48 billion per year by 2050, and $83 billion per year by 2100 (both as net-seller). This represents the value of the monetary flows received from the sale of ITMOs, which could be used to finance investments in domestic abatement action.

Through the use of carbon markets, the overall potential net economic benefit for the Middle East reaches $6.97 billion by 2030 and $26.25 billion by 2050. The increase in economic benefit by the end of the century is only a little higher due to the diminishing gap between shadow prices, and is valued a $33.97 billion by 2100. This net economic benefit calculation is based on the difference between the region's joint NDCs mitigation cost under an I-NDC scenario and the net cost of implementing the joint NDCs under a collaborative scenario, i.e. corrected for the costs or revenues associated with participation in international carbon markets. In the case of the Middle East, the region represents a net-seller throughout the studied timeframe, and participation in the international carbon market is associated with revenues that can be used to finance domestic mitigation action.

When increased ambition is pursued post-2030, under full collaboration the Middle Eastern region would remain a seller until mid-century, transacting 300 $MtCO_2$/year by 2050. By 2100, the region would become a net-buyer, sourcing 89 $MtCO_2$/year. Financially, this translates into a virtual carbon market size of $33 billion per year by 2050 (net-seller), and $27 billion per year by 2100 (net-buyer). Table 12 provides an overview of the potential virtual carbon market under the current C-NDC scenario and the C-NDC increased scenario.

Table 12. Carbon market value in the Middle East under full collaboration, comparing current and increased ambition scenarios ($2015 billion)*

	C-NDC			C-NDC (*increased*)		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Market size	13.16	47.83	82.79	13.16	32.88	27.12

** Indicated in red are carbon market values of net-buying regions (negative values from the host region's perspective).*

Sectoral implications

Given that the Middle East is projected to become a net-seller of ITMOs under the full collaboration scenario, for the majority of sectors, the emission cuts under the C-NDC scenario are higher than required under the I-NDC scenario. In terms of sectors where abatement costs are relatively low and in which mitigation action is incentivised, regional biomass and the electricity sector again stand out as the leading sectors.

Opposite to the situation observed in Central Asia, the largest single sector where deeper cuts are witnessed in absolute terms is regional biomass, which presents higher net negative emissions under the C-NDC scenario. While emissions are expected to be -262 MtCO_2 under the I-NDC in 2050, under the C-NDC annual emissions triple to reach -794 MtCO_2 by mid-century. The difference towards the end of the century is even more pronounced, as can be viewed in Table 13.

For electricity, emissions under the individual implementation scenario are projected to first rise to 787 MtCO_2 by 2050, after which a decline sets in to 510 MtCO_2 by 2100 (a 35% decline). Through collaborative implementation, emissions for the sector are projected to decrease to 578 MtCO_2 by 2050, with the difference available for international transactions. Within electricity, the main subsectors where potential for deeper emission reductions exists are gas, refined liquids, and pulverised coal.

There is one key sector where abatement costs are first cost-effective, and then shift to a level where deeper cuts under a collaborative scenario are disincentivised: the refining sector. Without collaboration the annual emissions from this sector are expected to be 456 MtCO_2 in 2050, while under the full collaboration scenario emissions remain lower at 424 MtCO_2 for that year. By 2100, however, by 2100 the I-NDC emissions drop to 271 MtCO_2, while under the full collaboration scenario emissions are reported to be higher at 387 MtCO_2, 85% higher.

Table 13: CO_2 emission trajectories for low-hanging fruit opportunities and high abatement cost sectors in the Middle East (MtCO_2)

	I-NDC			C-NDC		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Low hanging fruit sectors						
Regional biomass	-83	-262	-501	-163	-794	-1243
Electricity	749	787	510	655	578	389
Refining	251	456	271	209	424	387*

** Indicates sectors which shift from being either a low hanging fruit opportunity or high abatement cost intervention at some point of the simulation.*

2.7 Northern Africa

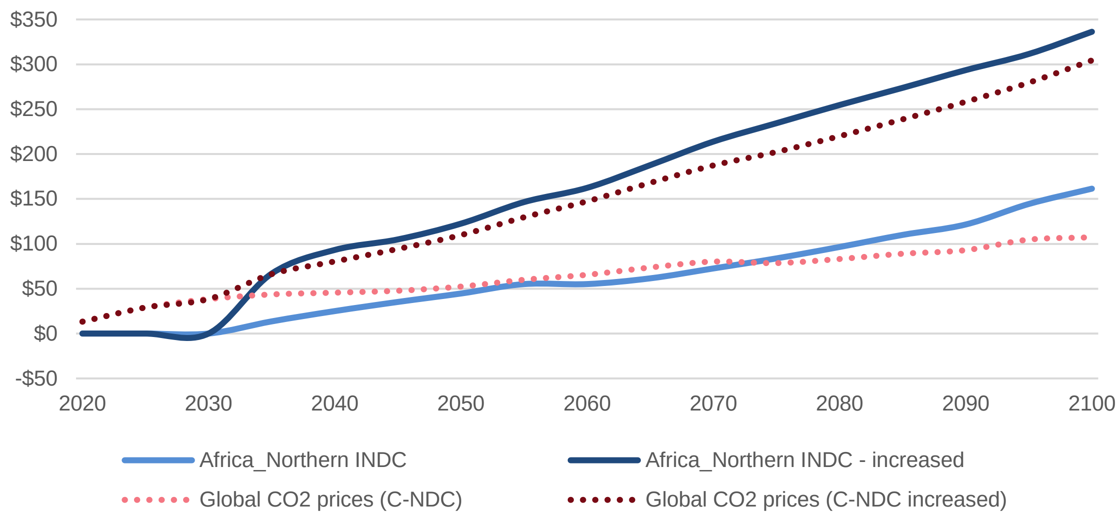
Algeria, Egypt, Western Sahara, Libya, Morocco, Tunisia.

Evolution of regional abatement costs

Figure 16 shows that the average abatement cost of the countries included in the Northern Africa region start low, but over time get closer to the global average shadow price, and exceed this global average post-2070. This gap between the Northern African region and the global average shadow price points to the potential for deeper emission cuts in the region through until that time, albeit the gap tightens already by 2050 and the space for collaboration is reduced going forward. By 2100, the simulated shadow price for the region reaches $161 per tonne, while the global price is lower at $107 per tonne.

For the increased ambition scenario, the cross-over between the two cost curves occurs earlier. In the period 2020 to 2030, similar to many of the other EBRD regional results, the region offers a window of opportunity for cost-effective emission reductions, but post-2035 the shadow price rises at part with the global average cost curve, limiting the room for cost-effective emission reductions at scale. The simulated shadow price for the region reaches $122 per tonne in 2050 and increases gradually to a price of $336 per tonne by 2100.

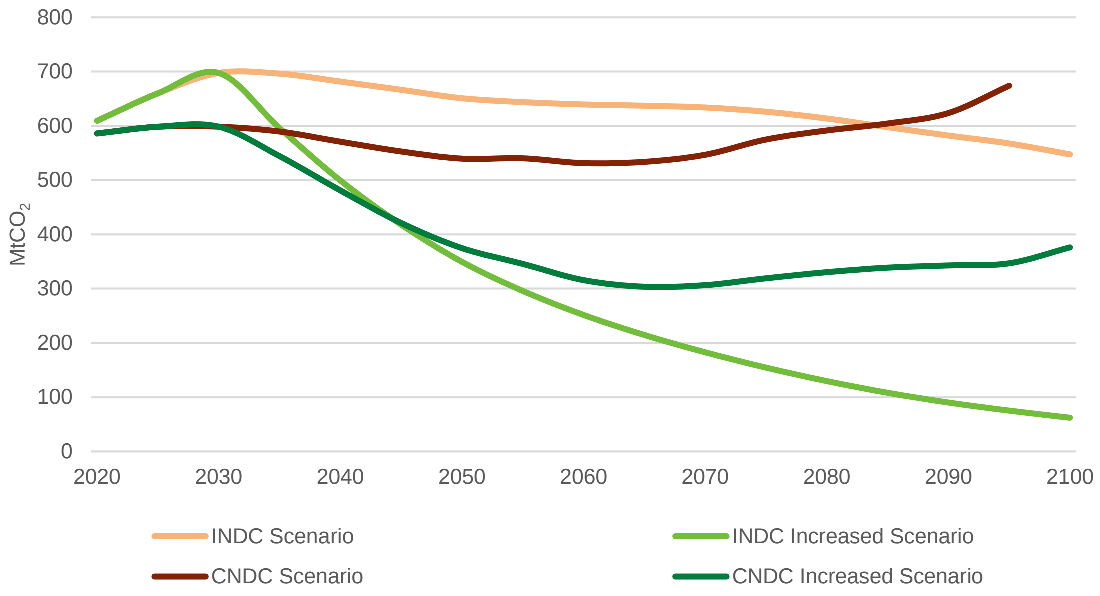
Figure 16: Average shadow price over time for Northern Africa (in $2015/t$CO_2$)



Impact on emission trajectories

The lower average abatement costs that are projected to exist in the first years imply that under a full collaboration scenario, the region could accept deeper cuts. Figure 17 points towards this trend by visualising CO_2 emission pathways for the four different trajectories for the region. Under the current I-NDC scenario, annual emissions in Northern Africa are projected to increase from 609 MtCO_2 in 2020 to 698 MtCO_2 by 2030 (15% increase), and decrease somewhat to 651 MtCO_2 by 2050 (7% decrease). Under full collaboration, annual emissions are reported to be lower at 599 MtCO_2 by 2030 and continue to decline to 540 MtCO_2 by 2050. This means that by 2050, domestic emissions would be about 8% lower under the C-NDC scenario when compared to a situation without collaboration.

Figure 17: Northern Africa's I-NDC and C-NDC emissions scenarios, current and increased ambition pathways



When enhanced ambition is simulated under the *increased* scenarios, regional emission trajectories undergo deeper cuts post-2030 to reflect the additional effort that is required to align with a 2°C pathway. Under such I-NDC increased ambition scenario, annual emissions in the Northern African region are forecasted to significantly decline from 698 $MtCO_2$ in 2030 to 350 $MtCO_2$ by 2050. Under full collaboration, the trend is similar, with domestic emissions falling to 375 $MtCO_2$/year by 2050. The extent of the drop is however more subdued due to the higher abatement cost that would apply under a more ambitious abatement scenario.

Value of the carbon market

In an optimal scenario where trading is used to minimise the region's abatement cost, the North African region would use carbon markets to sell a total of 99 $MtCO_2$ per year by 2030 and 111 $MtCO_2$ per year by 2050, while it would become a net-buyer of 139 $MtCO_2$/year by the end of this century. Financially, this translates into a virtual carbon market size of $6 billion per year by 2050 (net-seller), and $15 billion per year by 2100 (net-buyer). Given the low level of aggregate emissions and the relatively small gap between the regional and global average shadow prices, this represents the smallest carbon market within the studied group of regions.

Through the use of carbon markets, the overall potential net economic benefit for the region reaches $2.02 billion by 2030 and $2.04 billion by 2050. The value would more than double to a value of $5.97 billion by 2100. This net economic benefit calculation is based on the difference between the region's joint NDCs mitigation cost under an I-NDC scenario and the net cost of implementing the joint NDCs under a collaborative scenario, i.e. corrected for the costs or revenues associated with participation in international carbon markets. In the case of North Africa, the region represents a net-seller initially but turns into a net-buyer in 2050 and 2100. Participation in the international carbon market is therefore associated with revenues at first, but costs later on in the century.

When increased ambition is pursued post-2030, under full collaboration the Northern African region acts as a net-buyer, sourcing a total of 25 $MtCO_2$ per year by 2050 and 314 $MtCO_2$ per year by 2100. Financially, this translates into a virtual carbon market size of $3 billion per year by 2050, and $96 billion per year by 2100. As in the previous regions, the higher valuation despite the lower volume traded stems from the higher average shadow prices that persists in the event of deeper cuts realised under the increased ambition scenarios.

Table 14 provides an overview of the potential virtual carbon market under the current C-NDC scenario and the C-NDC increased scenario.

Table 14. Carbon market value in the Middle East under full collaboration, comparing current and increased ambition scenarios ($2015 billion)*

	C-NDC			C-NDC (*increased*)		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Market size	3.80	5.83	14.85	3.80	2.77	95.56

** Indicated in red are carbon market values of net-buying regions (negative values from the host region's perspective).*

Sectoral implications

The Northern African region is projected to be a net-seller of ITMOs until the period 2080 under the full collaboration scenario. As such, for the majority of sectors, emission cuts under the C-NDC scenario are higher than required under the I-NDC scenario. There are four key sectors where this difference stands out most: the electricity sector, cement sector, refining and regional biomass. In these sectors, regional shadow prices are relatively low compared to international prices, thereby incentivising deeper emission reductions domestically.

For the electricity sector, emissions in the I-NDC scenario are projected at 212 $MtCO_2$ in 2030, whereas they are projected to be 13% lower at 184 $MtCO_2$ in the C-NDC scenario. Also in 2050, emissions in the sector are projected to be 16% lower in the C-NDC scenario at 159 $MtCO_2$. This trend is however reversed in 2100, coinciding with when the North African region has become a net-buyer of ITMOs. By then, emissions in the electricity sector are projected to be 35% higher in the C-NDC scenario compared to the I-NDC scenario. Within the sector, gas (steam/CT) offers the largest absolute mitigation potential.

Regarding the cement sector, a similar trend is observed. It is one of the sectors with the highest potential for deeper emission cuts in 2030, where emissions under the C-NDC scenario are projected to be 33% lower at 30 $MtCO_2$ compared to the I-NDC scenario. The potential for cost-efficient abatement becomes less significant in 2050, when emissions under the C-NDC scenario are only projected 5% below the emissions in the I-NDC scenario. Again, by 2100, abatement in the cement sector in Northern Africa has become relatively expensive compared to other regions, and emission cuts are disincentivised in absolute terms. Within the refining sector, a similar trend is observed. In this sector, coal to liquids are a technology for which deeper emission cuts are incentivised under the C-NDC scenario.

Finally, regional biomass is forecasted to have net negative emissions of -27 $MtCO_2$ by 2030 and -91 $MtCO_2$ by 2050 under the I-NDC scenario, while under full collaboration emission cuts are deeper to reach -172 $MtCO_2$ by mid-century. Again, by 2100, this trend is reversed, and more negative emissions are projected in the I-NDC scenario compared to the C-NDC scenario.

Table 15: CO_2 emission trajectories for low-hanging fruit opportunities and high abatement cost sectors in Northern Africa ($MtCO_2$)

	I-NDC			C-NDC		
	2030	**2050**	**2100**	**2030**	**2050**	**2100**
Low hanging fruit sectors						
Electricity	212	188	81	184	159	109*
Cement	44	27	7*	28	25	19*
Refining	50	79	71	40	85	87*
Regional biomass	-27	-91	-261	-47	-172	-236*

** Indicates sectors which shift from being either a low hanging fruit opportunity or high abatement cost intervention at some point of the simulation.*

3. Discussion

We conclude this report with discussion points linked to the overall results of the analysis conducted for the EBRD region and its countries of operation, followed by the implications that these results can have on national and international climate policy development efforts. Before doing so, it is worthwhile to take note of some of the limitations of this study and the referred GCAM simulation results.

- Overall, the results presented in this report point towards a theoretical framework of collaboration, assuming a perfect operationalisation and implementation of Article 6 across all global actors. For this to hold, Article 6 rules would need to be able to accommodate such optimal re-allocation of abatement actions across regions, without introducing sectoral or other forms of constraints (such as whether sectors not covered in the NDC scope could be eligible for Article 6 transactions). Furthermore, countries would have to follow a purely economic rationale in decided how to utilise Article 6, when to invest in domestic mitigation action versus sourcing emission reductions from abroad (or selling). Finally, the modelled results also assume that Article 6 implementation can commence from 2021 on a global scale.

- Next to this, the presented GCAM results cover CO_2 emissions from energy and industrial sources, with some important sectors such as land-use being left out. The reason for this exclusion is the original design of scenarios focusing on emissions from fossil fuel and industry. As land use policies are included in many country NDCs and will play an important in global climate change mitigation efforts, exclusion of this sector paints an incomplete picture of the abatement opportunities that may exist across regional economies. Recent GCAM analysis on Article 6 includes nature-based solutions.

- Finally, the analysis assumes that countries achieve their current NDCs and post-2030 mitigation efforts through a uniform price on carbon across sectors, while in reality a wider pricing range would apply as countries chose to reduce their emissions through different types of policies and programmes. This creates the possibility for economically inefficient policies to be implemented, reducing the potential benefits from the optimal Article 6 implementation modelled in this study.

Nonetheless, the results of this study are a contribution to the currently limited amount of research work that has sought to quantify the potential impact of broader international cooperation in the context of meeting the Paris Agreement goals. Recognising that many country NDCs were prepared within a short timeframe lacking insight into shape and scope of new market mechanisms post-2020, the findings of this report aim to inform policymakers and negotiators of EBRD countries of operations on the role market-based approaches can have in enabling cost-effectively emission reduction strategies and boosting the ambition of future NDCs.

3.1 Results

Result 1: Collaboration under Article 6 can unlock economic benefits of $53 billion per year across EBRD regions by 2050, and $131 billion by 2100 under current ambition

The results of this study reveal that significant cost reductions can be achieved if countries pursue international collaboration to meet their NDC targets. Under a non-collaborative scenario and current ambition, the cumulative cost associated with realising the necessary emission reduction targets would amount to $68 billion per year by 2050 and $405 billion per year by the end of this century. This is $53 billion in excess of the economically optimal distribution of abatement actions, as modelled under the C-NDC scenario in the year 2050. By the year 2100, annual accrued economic benefit reaches $131 billion.

To understand how this value is unlocked, we have to look closer at the simulated distribution of emission reductions under a non-collaborative scenario and full collaboration. Figure 18 shows the cumulative emission trajectories of the I-NDC scenario (left panel) and the full collaboration C-NDC scenario (right panel). Collectively, the studied regions are modelled to undergo deeper emission cuts under the C-NDC scenario, implying that abatement action in these regions is on average more cost-effective than many other global regions. The extent of these deeper cuts is however on aggregate not high, with cumulative emissions of all regions declining to 6,164 $MtCO_2$ by 2100 without collaboration, and 5,831 $MtCO_2$ by 2100 with collaboration. It should be noted that this analysis does not treat the EBRD region as an isolated system but rather examines it as a subset with exchanges possible among all global regions.

Figure 18: Comparison of the I-NDC (left) and C-NDC (right) emission trajectories for the EBRD regions

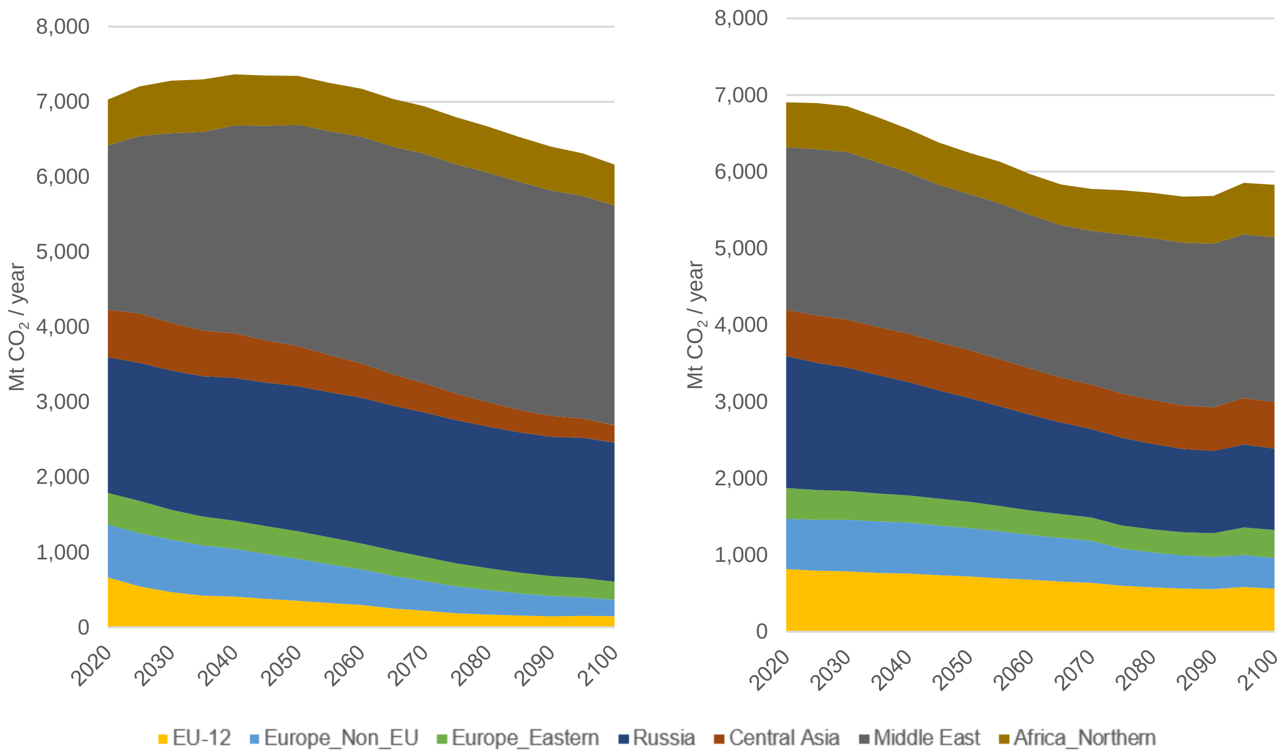
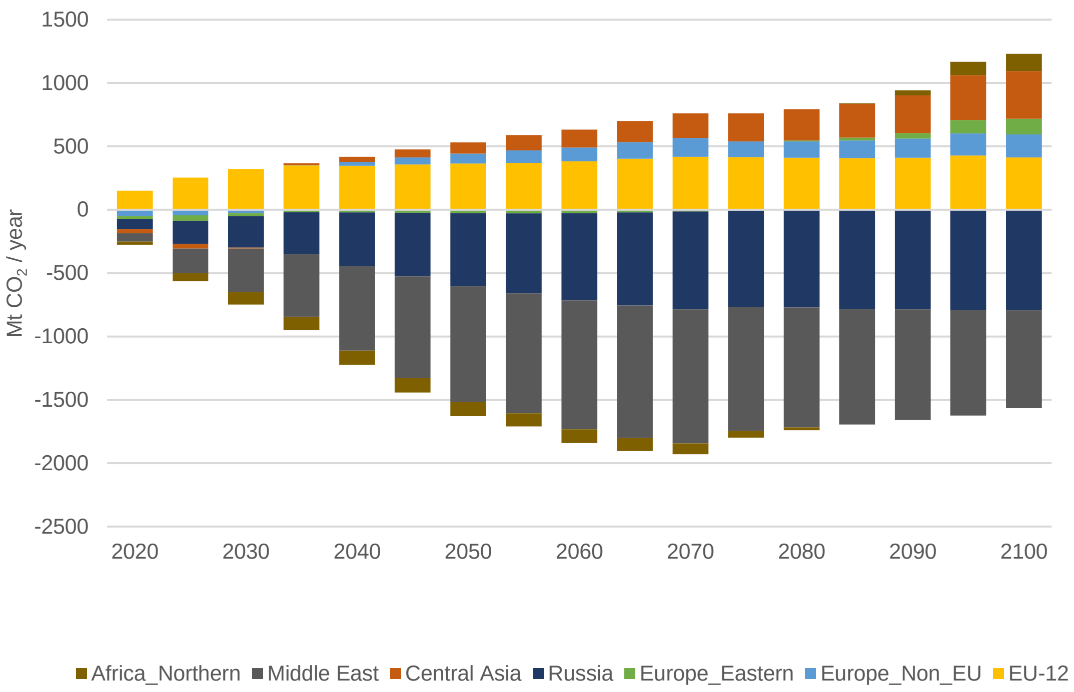


Figure 19 below illustrates the change in CO_2 emissions when I-NDC trajectories of individual regions are compared to the C-NDC scenario (thereby representing the delta between the two graphics depicted in the previous Figure 18). This visualises the level of abatement action allocation – and subsequently the positioning of regions as net-buyers or net-sellers in a global carbon market – within the studied regions shifts under an optimal collaboration scenario.

The results indicate that the EU-12 is the only region that acts as a net-buyer of ITMOs throughout the entire studied period, sourcing ITMOs through trade with other partner regions under an optimal scenario. All other regions start the initial trading period (2020 – 2030) as net-sellers, with the Middle East and Russia remaining net-sellers until the end of the century. Europe Non-EU and Central Asia switch to become net-buyers of ITMOs from 2035 onwards, while Eastern Europe and Northern Africa become net-buyers from 2080 and 2085, respectively. The reason for this evolution is the rise of the abatement cost in these regions, which occurs at a faster pace than the global average abatement price. The Middle East and Russia are the two key regions that drive EBRD-regional emission reductions under the C-NDC scenario, as visualised by the grey and dark blue columns in Figure 19.

Figure 19: Change in CO_2 emissions when I-NDC trajectories of individual regions are compared to the C-NDC scenario

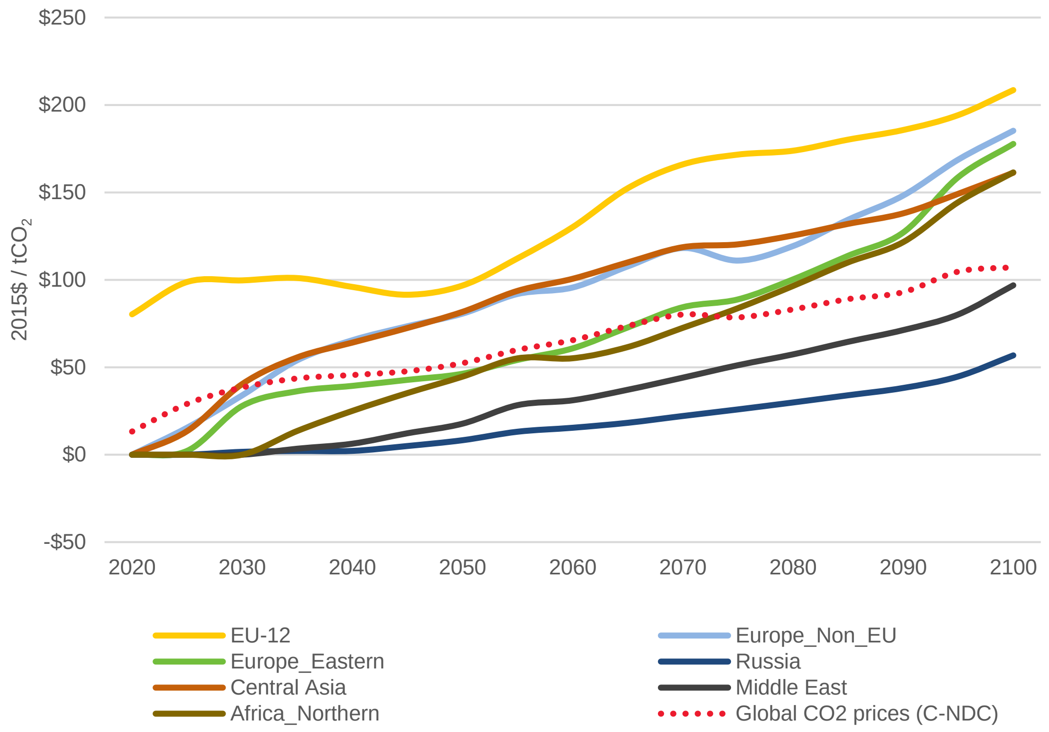


Whether regions are positioned as net-buyers or net-sellers in the international carbon market is dependent on the cost of the abatement opportunities that are available regionally. This is explored in further detail below.

Result 2: Differences between simulated regional abatement prices and emission trajectories point to the sectors where low cost abatement opportunities exist

Figure 20 illustrates the evolution of the average shadow price under the I-NDC scenario assuming current ambition, highlighting that some regional economies contain sectors with inherently higher shadow prices that exceed the global average price curve. The EU-12 countries prominently feature as economies with the highest shadow prices through the studied timeframe, reaching $208 per tonne by the end of the century. This is almost double the value of the global average shadow price, which by 2100 reaches $107 per tonne. Shadow prices of Russia and the Middle East remain below the global average price curve throughout this century, with Russia' shadow price reported at just over half ($57 per tonne) of the global average by 2100. Shadow prices show the most rapid increase in Northern Africa, growing five-fold between 2030 and 2100.

Figure 20: Average shadow price per region under the I-NDC scenario (current ambition)



A deeper-dive analysis of the emission trajectories of different sectors and subsectors provides additional information on sectors where cost-effective abatement opportunities exist in the studied regions. For example, in the two key net-seller regions – Russia and the Middle East – low hanging fruit opportunities exist in the electricity sector (mainly gas, refined liquids, and pulverised coal), biomass (co-generation), and refining. Such cost-effective investment opportunities could be realised under a scenario when regions decide to collaborate under Article 6 and carbon finance is used to promote investments in these sectors.

These findings can be useful in the context of shaping Article 6 activities to support the implementation of regional NDCs.[7] Furthermore, the sectoral data can provide important insights to countries looking to increase the ambition level of their NDCs when they are due for renewal. Finally, market mechanisms could also have implications for domestic policy makers, as discussed later on in this chapter.

Result 3: International cooperation under a current ambition scenario leads to a cumulative virtual carbon market valued at $300 billion by 2100

Taking the difference in CO_2 emissions in the I-NDC and C-NDC scenarios depicted earlier for all studied regions in any given year and multiplying this by the respective average global shadow price allows us to quantify the value of this virtual carbon market. When markets are used optimally under the current ambition scenario, the cumulative value of the carbon market is forecasted to reach $300 billion by 2100. Upon the end of the century, 2,797 $MtCO_2$ could be traded, at an average price of $107 per tonne. Table 16 summarises the forecasted market capitalisations per region under the current ambition scenario over the studied timeframe.

[7] It should be noted that one important limitation of the sectoral results in this study is the fact that the GCAM data is assessed on a regional level, making it impossible to pinpoint for individual countries which sectors provide the lowest-hanging fruit opportunities, and could supply cost-effective emission reductions to net-buying countries. Conducting deeper-dive scenario runs on the country-level in future research efforts would provide more granular outputs that could offer valuable considerations for country-level planning going forward.

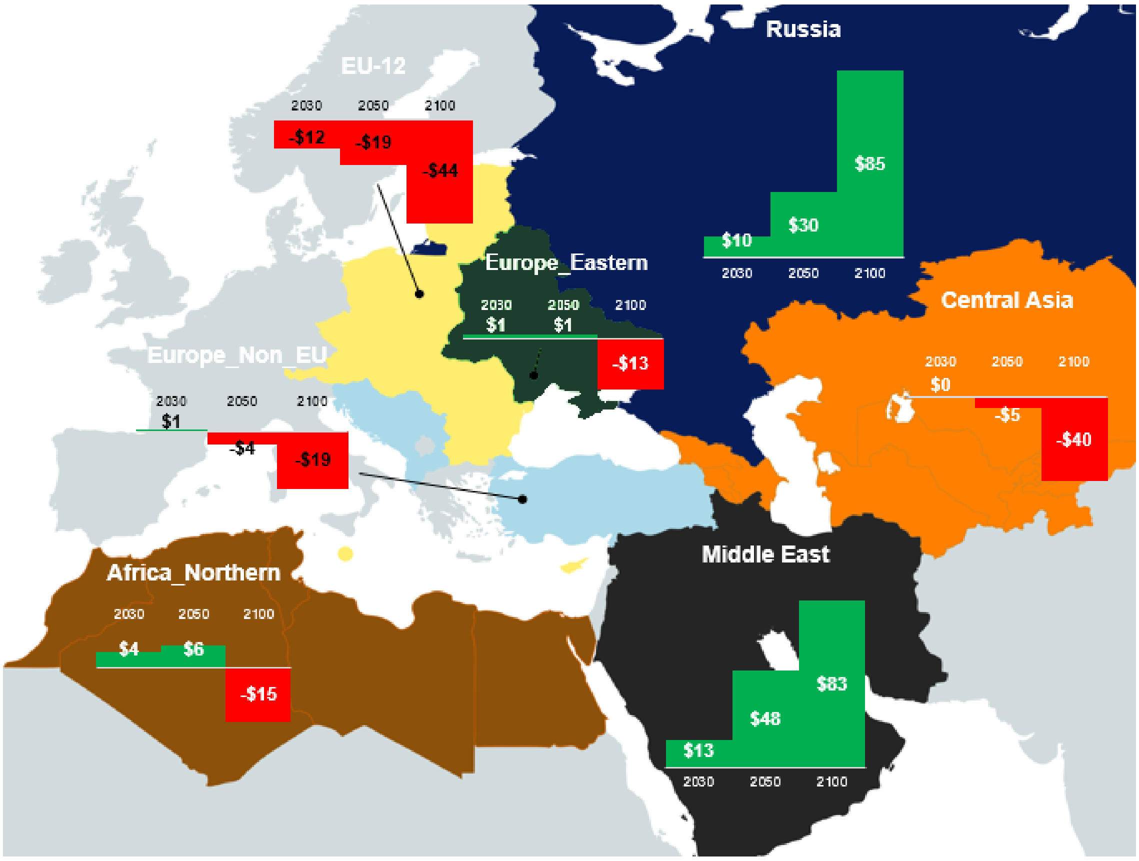
Table 16: Carbon market value for all studied regions under full collaboration and the current ambition scenario ($2015 billion)*

	C-NDC (*current*)		
	2030	**2050**	**2100**
EU-12	12.3	19.2	44.4
Europe non-EU	1.0	4.0	19.4
Europe Eastern	0.8	1.4	13.2
Russia	9.6	30.2	85.0
Central Asia	0.3	4.7	40.2
Middle East	13.2	47.8	82.8
Northern Africa	3.8	5.8	14.9
Total	**41.1**	**113.2**	**299.9**

* *Indicated in red are carbon market values of net-buying regions (negative values from the host region's perspective)*

Figure 21 shows a visual representation of the above results. The red columns indicate carbon market values of net-buyers in any given year, while the green columns point towards carbon market values of net-sellers. While net-buyers need to allocate capital to source emission reductions, it should be noted that these regions are accruing economic benefits by doing so as they source emission reductions from regions that offer lower abatement cost opportunities. On a cumulative level, the EBRD region is a net seller across all three timeframes, with the difference between the red and green columns equalling $16 billion in 2030, $57 billion in 2050, and $36 billion in 2100. This position as an overall net-seller is driven by Russia and the Middle East, which remain high-volume net-sellers throughout the studied timeframe.

Figure 21: Carbon market value visualised for all studied regions ($2015 billion)*



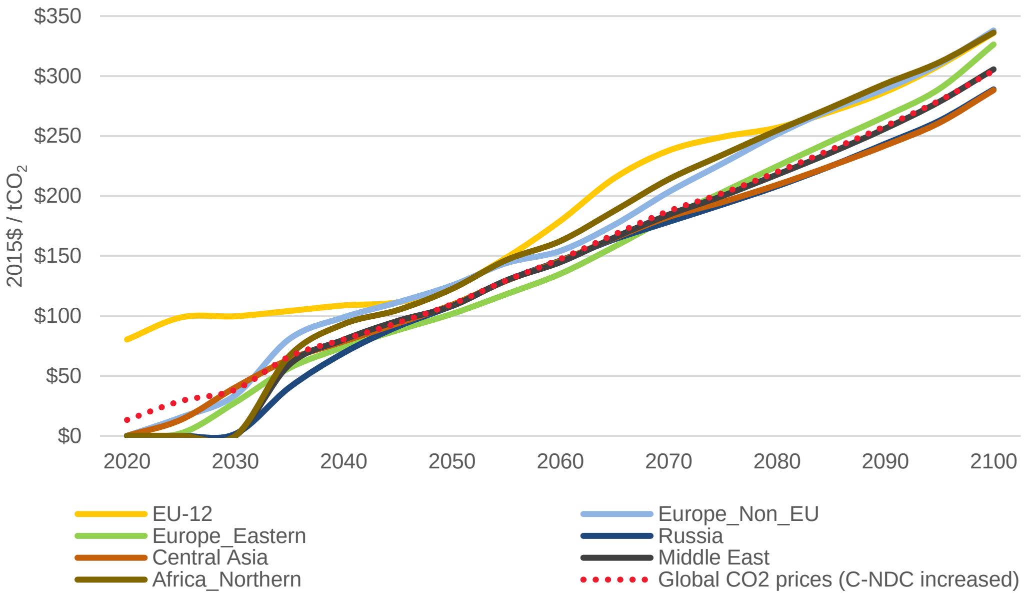
* *Indicated in red are carbon market values of net-buying regions (negative values from the host region's perspective)*

Result 4: Simulation of the increased ambition scenarios provide insights into the costs associated with deeper emission reductions, and how carbon markets can cost-effectively enable this

The collaborative nationally determined contribution increased scenario assumes that countries jointly implement their NDCs by optimal cooperative implementation facilitated under Article 6 of the Paris Agreement. After meeting their 2030 targets, this scenario assumes increased ambition by all countries required for meeting the 2°C temperature goal.

Compared to the results of the current ambition scenarios presented above, the increased ambition scenarios produce significantly higher regional average shadow prices over time, since all regions have more robust mitigation efforts. The global average shadow price now reaches \$110 per tCO_2 in 2050 and \$304 per tCO_2 in 2100. Figure 22 illustrates the evolution of the average shadow price under the I-NDC scenario when increased ambition is pursued, showing a much less diversified spectrum of shadow prices as when compared to the current ambition scenario presented in Figure 20 earlier. The reason for this tighter range is that all regions face higher costs when pursuing deeper cuts due to the limited supply of low-hanging fruit abatement opportunities.

Figure 22: Average abatement price per region under a no-collaboration scenario (increased ambition)



Despite the smaller regional difference in shadow prices, international collaboration still has the potential to deliver economic benefits across the EBRD region. The EBRD region as a whole remains a net-seller of emission reductions in 2030 and 2050, with the Middle East and Russia representing the largest sellers in absolute terms. However, by 2100, the EBRD region becomes a net-buyer, mainly due to the Middle East shifting to become a net-buyer by the end of the century.

Table 17: Carbon market value for all studied regions under full collaboration and the increased ambition scenario ($2015 billion)*

	C-NDC (*increased*)		
	2030	**2050**	**2100**
EU-12	12.3	22.1	54.6
Europe non-EU	1.0	8.5	39.4
Europe Eastern	0.8	3.8	21.9
Russia	9.6	18.1	97.2
Central Asia	0.3	3.6	74.4
Middle East	13.2	32.9	27.1
Northern Africa	3.8	2.8	95.6
Total	**41.1**	**91.8**	**410.0**

** Indicated in red are carbon market values of net-buying regions (negative values from the host region's perspective)*

Under the scenario of enhanced ambition, while the tradable volumes drop (due to a tighter market), given a higher global average shadow price, carbon market valuations increased further, reaching $410 billion by 2100.

Result 5: Modelling results of cumulative capital investment needs under both scenarios indicate that the region has an important role to play in lowering GHG emissions.

The GCAM model provides insight in the level of cumulative capital investment needs in the power sector up to 2100, both under current NDC targets and an increased ambition scenario. For the EBRD regions on aggregate, cumulative capital expenditure needs are estimated at $338 billion per year by 2030 if no collaboration takes place, rising to $384 billion per year by 2030 when global collaboration is pursued. This is due to the comparatively low cost of average abatements costs in the EBRD region vis-à-vis other regions in the world in the short-term, incentivising more investments in GHG mitigation activities in the region when full collaboration can take place. This provides an opportunity for the EBRD region to play an important role in supplying cost-effective credits for trade, hereby lowering global investment needs. Considering the financial constraints in the region, this also shows that international carbon markets could help scale up regional investments in GHG abatement activities, accelerating decarbonisation pathways. This, in turn, could increase the acceptability of countries to undertake more ambitious mitigation targets.

Over the longer-term, cumulative capital expenditure needs are forecasted to reach $701 billion per year by 2100 under the current NDC ambition, compared to $636 billion per year when full collaboration takes place. This reversal in cumulative investments in the power sector reflects the evolving average abatements cost in the EBRD region vis-à-vis other regions in the world, which becomes higher relative to other regions towards the end of the century. For sectors other than power, capital investment requirements could not be derived from the model at this stage.

Table 18: Cumulative capital expenditure investment needs for 2030, 2050, and 2100 for the two scenarios (all EBRD region, $2015 billion)

	INDC	CNDC	INDC *increased*	CNDC *increased*
2030	338	384	338	384
2050	418	419	615	620
2100	701	636	1,028	1,019

Table 18 confirms that cumulative investment costs are not always lower for the EBRD regions throughout the three time-frames when the INDC scenario is compared to the full collaboration scenario. The reason for this is that the GCAM compares the EBRD countries with other regions in the world, explaining why for instance in the year 2030 investments under the CNDC scenario exceed the figures assumed under the INDC. This relates to the finding described above that seller and buyer regions change over time, and sectoral mitigation opportunities change over time. EBRD regions that retain the status of net buyers throughout all time-frames (i.e. EU-12) do observe consistently lower capital expenditure needs. The reverse applies to net sellers (i.e. Russia, Middle East), where cumulative capital investments are always higher under a full collaboration scenario.

3.2 Implications for policy makers

Implication 1: The upcoming NDC renewal cycle gives Parties the opportunity to re-evaluate the role carbon markets can play in facilitating increased ambition

As the Paris Agreement is based on bottom-up contributions that are to be reviewed and strengthened over time, the results from this study can contribute to the broader discussion on the role of markets in a post-2020 framework. From the 194 INDCs submitted by Parties, 100 mention the intention to use markets to support the implementation of their NDCs, while 47 Parties explicitly exclude the use of markets.[8] Many countries that at this stage make reference to the use of market mechanisms are careful at framing their position, using wording such as 'having the intention to' or 'retaining the option of' the use of market mechanisms. The outcomes of this study support the case for a broader inclusion of cooperative approaches in Parties' NDCs, and come at a time where considerably more certainty exists about the scope of international market mechanisms than was the case when the first NDCs were developed ahead of signing the Paris Agreement. It is anticipated that the COP25 in Chile will deliver the final rulebook for Article 6, thereby instilling further confidence to countries that market mechanisms will become operationalised in the near-term future.

The findings of this report show that collaboration on Article 6 is sensible from perspective of cost-effective global abatement as it allows trading partners to lower the overall costs of achieving global mitigation targets. International emissions trading can furthermore mobilise significant investment in mitigation action by building novel relationships that otherwise would not exist. We note that the valuations of the theoretical carbon market can exist under a full collaborative scenario, but it is not likely that such full ambition can be realised, due to other barriers and policy overlaps. But the figures are substantive and large enough to underpin the rationale of a global market under Article 6. This is true for both the current ambition level, as well as a scenario where NDCs align to with the 2°C temperature goal. Though the economic savings generated as a result of the use of markets, countries could achieve increased ambition. Results of the global simulation conducted by IETA-UMD show that when the economic gains are used to realise additional mitigation (therefore keeping the cost of NDCs as in the I-NDC scenario), annual global carbon emissions mitigation could by increased by roughly 5 $GtCO_2$ per year in 2030. This represents 50 percent more mitigation compared to the I-NDC scenario. A similar message[9] is reported by the Environmental Defense Fund (EDF), whose modelling results indicate that using the cost savings from global emissions trading between 2020 – 2035 could nearly double the emissions reductions under current NDCs, at no additional cost.[10] These findings should encourage countries to not only more prominently feature Article 6 in their existing commitments, but also to view markets as an enabler of deeper emission reduction cuts, which are needed to support the achievement of the temperature goal of the Paris Agreement.

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[8] As reported by the NDC Partnership (2019). See http://ndcpartnership.org/climate-watch/ndcs

[9] The 5 $GtCO_2$ per year in 2030 reported by IETA-UMD represents the additional mitigation from savings in the energy sector. This figure grows to 9 $GtCO_2$ when land-use is included, representing an almost doubling of the emission reductions at no additional cost.

[10] EDF (2018) The power of markets to increase ambition: New evidence supports efforts to realize the promise of Paris

For markets to be effective, accounting by means of corresponding adjustments in line with the guidance in Article 6 of the Paris Agreement will have to safeguard that the international transfer of emission reductions does not result in net increase in emissions at a global level. A lack of robust rules and guidelines from the start creates the risk that the role of markets could be undermined, which may be detrimental to the achievements of the Paris goals. More prominent use of market mechanisms in updated country NDCs therefore has to be introduced alongside national efforts to ensure the environmental integrity of the emission reductions generated under these mechanisms, including the set-up of national registries, adoption of procedures around the implementation of corresponding adjustments in case of ITMO sales, or progress reporting on NDC implementation.

Implication 2: A robust international carbon market can influence domestic climate policy formulation

When collaboration between regions is pursued, investments in cost-effective emission reductions in certain sectors in regional economies will be unlocked that under an I-NDC scenario would not be viable. Potential access to carbon revenues for such sectors can have implications on national policy formulation. One example of this could be the resource allocation decisions for public subsidies. Public funds originally earmarked for sector-specific subsidies, such as energy efficiency measures in the industrial sector or biomass combustion in the energy sector, could be reallocated to support mitigation action in sectors that would not benefit from international trade. This could be an effective strategy for sectors where MRV is complex, such as in the transport sector. Deeper emission cuts in sectors that would be eligible for crediting under a market mechanism could be (partly) financed through revenues generated from the sale of emission reductions. The economic benefits arising from the transfer of emission reductions from these sectors would have to be weighed against the repercussions the sale of ITMOs would have on the ability to achieve domestic NDC targets.

Another example of the impact international trade in emission reductions could have on domestic policy development is the ability of carbon credits to reduce the barrier to introduce national carbon tax schemes. Enabling covered entities to partially source offsets to reduce their cost of compliance could make such regulation more palatable to industry, especially at the onset where concerns on international competitiveness are strong. Carbon tax schemes in Colombia, Mexico, and South Africa allow or intend to allow for the partial use of offsets for this reason. Again, a trade-off exists here that policymakers will need to account for, namely the fact that such allowance of offset use will reduce the level of revenue that is generated by a carbon tax.

Finally, the ability to achieve deeper emission cuts domestically could also have implications for related issues, such as strategies to fight local air pollution. By participating in international carbon markets, net-seller countries stand to benefit from the impacts these abatement measures will have on local air quality. This in turn could result in significant health benefits over time, the economic implications of which have not been valued in this research work.

Implication 3: Policymakers will need to carefully consider potential interactions between ITMOs, domestic policies, and long-term decarbonisation pathways

There are a number of important interactions that decisions to buy or sell emission reduction units will have with domestic policy and long-term decarbonisation pathways. An international carbon price influences a domestic carbon price, the more so when units can be traded across borders. But other international and national policies, such as taxation or energy efficiency targets, can also influence the ability of a country to meet its NDC target, and therefore affect the supply and demand of tradeable units. For example, a decision to change the price or cap trajectory of a carbon price of a net-buyer country would impact the revenue generated through the carbon price. In the event that this revenue was to be allocated to support emissions mitigation measures, such decision may influence domestic mitigation beyond the direct effect of the imposed carbon price.

Policymakers should also consider the dynamic cost-effectiveness of the policy package being used to achieve long-term decarbonisation. Dynamic cost-effectiveness involves minimising the cost of emission reductions over the duration of the policy or target. In considering dynamic cost-effectiveness, policymakers need to compare short-term versus long-term costs. For instance, a less ambitious short-term target and consequent lower carbon price may result in new thermal power plants being established in net-buyer countries, which would otherwise not be financially viable. If these technologies need to be decommissioned before the end of their viable lifespan, this may end up being more costly than having simply built renewable energy in the first place. Such dependencies are difficult to model, but should be kept in mind by policymakers when evaluating the benefits of sourcing emission reductions from other jurisdictions.

In order to ensure full environmental integrity, it is important that at a minimum the MRV and GHG accounting standards are kept high, and that any transfers can be tracked, whether conducted domestically or internationally. With a robust accounting and trading infrastructure in place, ITMO trading will afford countries greater flexibility in managing policy interactions to meet their NDCs. The existence of such international markets can furthermore influence the standardisation of MRV, contracts and other services, thereby lowering transaction costs over time and increasing the market's effectiveness.

Annex: Comparison of EBRD Regions and GCAM Regions

Legend: ● Aligns fully with GCAM ● Aligns but in other GCAM region ● Covered separately by GCAM

EBRD regions and countries	GCAM regions and countries
South-eastern Europe	**Europe Non EU**
Albania	Albania
Bosnia and Herzegovina	Bosnia and Herzegovina
Bulgaria	Croatia
Cyprus	Macedonia
Greece	Montenegro
Kosovo	Serbia
Montenegro	Turkey
North Macedonia	
Romania	
Serbia	
Southern and Eastern Mediterranean	**Africa Northern**
Egypt	Algeria
Jordan	Egypt
Lebanon	Western Sahara
Morocco	Libya
Tunisia	Morocco
West Bank and Gaza	Tunisia
	Middle East
	United Arab Emirates,
	Bahrain
	Iran
	Iraq
	Israel
	Jordan
	Kuwait
	Lebanon
	Oman
	Palestine
	Qatar
	Saudi Arabia
	Syria
	Yemen
Central Europe and Baltic States	**EU-12**
Croatia	Bulgaria
Czech Republic	Cyprus
Estonia	Czech Republic
Hungary	Estonia
Latvia	Hungary
Lithuania	Lithuania
Poland	Latvia
Slovak Republic	Malta
Slovenia	Poland
	Romania
	Slovakia
	Slovenia
Russia	**Russia**
Turkey	
Eastern Europe and the Caucasus	**Europe Eastern**
Armenia	Belarus
Azerbaijan	Moldova
Belarus	Ukraine
Georgia	
Moldova	
Ukraine	
Central Asia	**Central Asia**
Kazakhstan	Armenia
Kyrgyz Republic	Azerbaijan
Mongolia	Georgia
Tajikistan	Kazakhstan
Turkmenistan	Kyrgyzstan
Uzbekistan	Mongolia
	Tajikistan
	Turkmenistan, Uzbekistan