Pathways towards a European Low Emission Society
Policy Briefs from the EUCalc project funded by the European Union's Horizon 2020 research and innovation programme

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Implications of decarbonizing the EU economy on trade flows and carbon leakages

Insights from the European Calculator

Wusheng Yu and Francesco Clora

Headlines

- Decarbonizing the EU economy to achieve the net-zero emission target affects both the demand and the production sides of the EU economy. The changes to the EU economy and its trade linkages with the rest of the world (ROW) will not only reshape the interdependencies between the EU and the ROW, but also result in "carbon leakage." This important issue will need to be addressed when formulating effective climate policy.
- Simulation results from the most ambitious EU decarbonization pathway in the EUCalc model show a sizable external trade deficit both in absolute monetary terms and as a share of GDP for the EU when the ROW is assumed not to commit to similar levels of decarbonization. This can be explained by a smaller improvement of EU's trade balance with fossil fuel exporting countries than the much larger deterioration of its trade balance with major manufacturing and services exporters. While increased trade deficit is not necessarily an issue by itself, the causes of reduced competitiveness of a particular sector and possible policy responses to that will need to be addressed when formulating decarbonization strategies.
- Our simulations provide a carbon leakage rate of 61.5% for the most ambitious EU decarbonization pathway. Under this ambitious pathway, for each tonne of CO_2e emissions avoided or sequestered within the EU, the ROW is calculated to increase its GHG emissions by 0.615 tCO_2e, resulting in a net reduction in emissions to the atmosphere of only 0.385 t CO_2e significantly delaying the achievement of the Paris Agreement targets worldwide. Therefore, independent, highly ambitious decarbonization efforts by the EU cannot effectively reduce global emissions. Without concerted worldwide action, carbon leakages and perverse international competition will damage effective global action on climate mitigation.

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The EUCalc model and the Transition Pathways Explorer

The EUCalc model user interface - the Transition Pathways Explorer - is a tool that allows users to build a pathway to a net-zero carbon future at European and Member State level. Its scientific mission is to provide a sophisticated, yet accessible, model to fill the gap between integrated climate-energy-economy models and the practical needs of decision-makers. The model relates emission reduction with human lifestyles, the exploitation and/or conservation of natural resources, job creation, energy production, agriculture, costs, etc. in one highly integrative approach and tool which enables decision-makers to get real-time policy support underpinned by comprehensive trade-off analyses.

Politicians, innovators and investors can use the EUCalc Transition Pathways Explorer to create their own pathways to a low-carbon future online, in real-time and together. This tool can help policy makers in the EU28 + Switzerland explore the routes they can take to delivering climate protection, whilst securing energy and other important policy priorities.

The EU Calc's Transboundary Effects Module

One of the key social economic challenges in decarbonizing the EU economy is to maintain the global competitiveness of the European economy during its transition to a low-carbon society. In this discussion, it is relevant to evaluate the potential economic consequences of various representative EU decarbonization pathways formulated in the EUCalc model. One particular dimension in this discussion is in relation to how EU decarbonization may reshape the economic linkages between the EU and the rest of the world (ROW). To achieve the net-zero emissions target (European Commission, 2019) within the EU, both the demand and the production sides of the EU economy will be impacted. For instance, consumers will have to make behavioral changes to live a low-carbon lifestyle; whilst on the production side, the energy system has to be further decoupled from fossil fuels and other emission-intensive sectors will also have to undergo fundamental changes. The adjustments to demand and production within the EU will likely reshape the interdependence between the EU and world economies. For example, for sectors or products where demand and supply mismatches arise within the EU as a result of EU decarbonization, trade flows between the EU and the ROW will have to adjust to restore market equilibrium and ensure key services are provided.

EU decarbonization actions may also alter the costs and prices at which products and services are produced within the EU, leading to further changes in the EU's trade patterns. In economic terms, the trade balance – measured as the difference between an economy's exports to and imports from its trading partners – is often used. Whilst a surplus or deficit in the trade balance by itself does not necessarily signal an economy's strength or weakness, large and rapid changes in the balance and its distribution across sectors may be economically destabilizing. Another important issue related to the trade balance or changes in trade balance due to decarbonization efforts is "carbon leakage." Carbon leakage arises when reduced emissions within the EU are partially offset by increased emissions in the ROW, resulting in a smaller net global emission reduction. This phenomenon is an important and significant issue that needs to be addressed when formulating climate policy. Tracking emissions embodied in trade flows provides the opportunity to calculate the carbon leakage rate that measures the net global emission reduction arising from a specified economy's decarbonization strategies.

The transboundary module of the EUCalc model provides a set of simulated effects in terms of changes in trade flows and the implied carbon leakage rates for a representative subset of EU decarbonization scenarios[1]. The results are generated from an economic model that is tailored to evaluate the trade and carbon leakage effects of the decarbonization pathways formulated in the core modules of the EUCalc model[2]. In a nutshell, detailed behavioral and technological assumptions adopted in the core modules of the EUCalc model are systematically "translated" as changes in relevant economic variables relative to their levels in a baseline case. These changes are then imposed as shocks onto the economic system model and its baseline data which generates a new set of economic outcomes. These outcomes encompass the detailed sectoral demand and supply structures for each economy (country) represented in the model, as well as bilateral trade linkages across the different economies. Coupling GHG emissions to the economic activities in the model also allows carbon leakage to be estimated. A significant modeling challenge that had to be addressed was to develop a model structure that translates and utilizes the very detailed "bottom-up" engineering data generated from the EUCalc core modules as shocks to the relevant economic variables in the

[1] The results shown here are based on the EUCalc version available in February 2020. Future updates of the calculator may affect some of the current results.
[2] Details of the modeling approach underlying the results presented in this brief can be found in Clora and Yu (2019). For a more technical description of the economic model upon which the transboundary module is based, readers are referred to Burniaux and Truong (2002), and McDougall and Golub, (2007).

economic model. Similarly, another modelling challenge was to redesign the economic model so that large deviations from both the demand and supply side of the economy can be implemented.

The simulated transboundary effects arising from two representative EUCalc pathways are summarised below. The impacts on the EU's external trade arising from these two pathways are compared with a projected baseline scenario that represents the EU Reference Scenario (European Commission, 2016), for the year of 2050 (the end year of the time horizon considered in the EUCalc model).

Key results from two representative pathways

As an illustration of the simulated transboundary effects from the EUCalc model, results from two representative pathways are presented[3]. Decarbonization pathways in the EUCalc model are constructed around a set of sectoral "levers" (e.g. lifestyle choices regarding food consumption and travel demands, and reduced use of fossil fuels in the energy system), each of which uses four "levels" ranging from 1 to 4, to represent increasing decarbonization ambitions. In the first pathway denoted as P1, all levers are set at the lowest decarbonization ambition levels (i.e. level 1), whereas in the second pathway P4, all levers are set at the highest ambition levels (i.e. level 4), representing the most ambitious decarbonization pathway in the EUCalc model. Note that P1 represents a decarbonization scenario that is less ambitious than the EU Reference Scenario.

Table 1 presents the changes in the EU's external exports, imports and net trade balance with the ROW, as compared to the EU Reference Scenario for the year 2050 (European Commission, 2016), and the associated carbon leakage rate.

If the EU reduces its climate mitigation ambitions relative to the EU Reference Scenario (i.e. P1), the net trade balance with the ROW is expected to improve, led by an increase in exports and a slight decrease in imports. The carbon leakage rate in this case is not a meaningful measure, as the EU would be increasing its emissions with respect to the baseline scenario. However, if the EU implements a very ambitious climate mitigation strategy as in pathway P4, simulation results suggest that the EU's exports to the ROW would decrease and imports would increase at the same time, leading to a strongly negative trade balance. The carbon leakage rate of 61.5% means that for each tonne of CO_2e reduction achieved in the EU, the ROW would increase its GHG emissions by approximately 0.615 tCO_2e. This carbon leakage rate is based on the average EU emissions level, although will vary across sectors and EU member states.

Table 1: Change in exports, imports and net trade balance of EU with Rest of World (ROW) (bln USD), and carbon leakage rate, relative to the EU Reference Scenario in the EUCalc.

	Export	Import	Trade Balance	Carbon leakage rate
P1 - EUREF	325	-26	352	n/a
P4 - EUREF	-520	343	-863	61.5%

Simulated changes in EU exports and imports (and the corresponding change in the trade balance) with other economies in the ROW from P1 and P4 are displayed in Figures 1 and 2, respectively. With very ambitious climate efforts in the EU (and no change in ROW climate efforts), the EU's balance of trade would improve with respect to Russia, the rest of Europe and other Former Soviet Union countries (see the Appendix 1 table for details of the aggregated regions used in the model simulation). Additionally, we observe a decrease in imports from Middle East and North Africa. These changes are mainly due to reduced EU demand for fossil fuels (e.g. oil and gas, EU has historically been a net importer). With other countries and regions (especially China and the US), it can be observed that there is a simultaneous decrease in exports and increase in imports, mainly driven by the deteriorating trade balance in sectors such as manufacturing and services. In contrast, lower ambitions as in P1 lead to an opposite situation where the EU's imports from countries and regions exporting fossil fuels (i.e. Russia, rest of Europe, other Former Soviet Union countries, Middle East and North Africa) increase and its trade balance with other major economies improves.

[3] It is important to note that, as in any other modeling exercise that projects outcomes of alternative scenarios well into the future, there are inherent uncertainties associated with the numerical results.

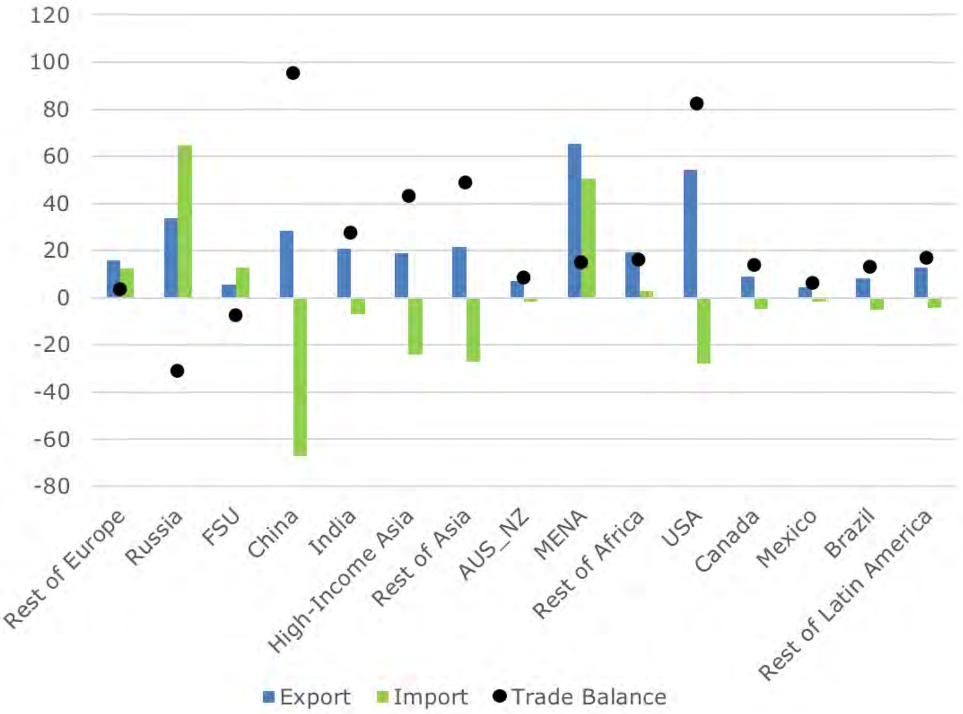

Figure 1: Change in aggregate trade of EU vs ROW economies in P1, relative to the EU Reference Scenario (bln USD), in 2050.

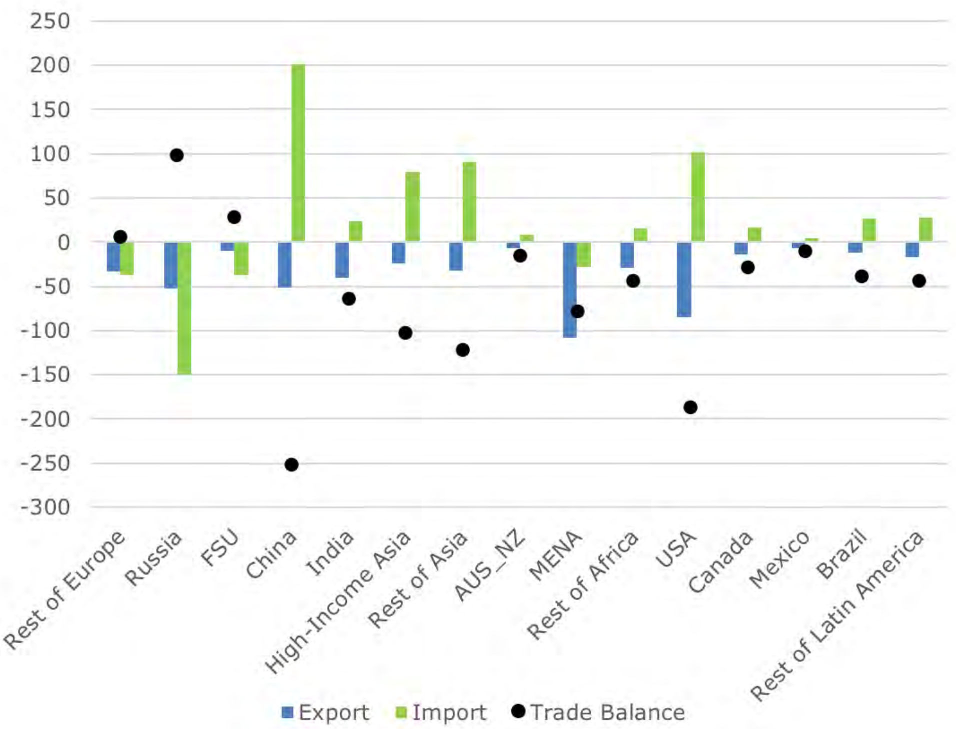

Figure 2: Change in aggregate trade of EU vs ROW economies in P4, relative to the EU Reference Scenario (bln USD), in 2050.

To further understand the trade balance results, simulated changes in EU exports, imports (and the implied trade balance) at the sectoral level are presented in Figures 3 and 4. In the highest mitigation ambition scenario (i.e. P4), changes in trade patterns and trade balances vary across sectors (Figure 4). For instance, the shift towards a more plant-based diet requires the EU to import more crops and grains from the ROW and to slightly reduce its imports of meat and other animal foods. Moreover, the EU's fossil fuel imports decrease, following its declining demand. In terms of trade volume, the more significant trade pattern changes are in the manufacturing and service sectors. With the decarbonization ambitions reducing manufacturing outputs, the EU would have to import more to make up for the shortfall in consumer and intermediate demands for manufacturing products. For the service sectors (excluding transportation services), increased demand arising from reallocated consumer budget towards less emission-intensive services (and away from emission-intensive products) would result in increased import demand for services. For transportation services, assumed technical enhancements in supplying transport services in the EU would lead to an improved trade balance with the ROW.

In contrast to the results from P4, if the EU reduces its mitigation efforts relative to the EU Reference Scenario, opposite changes in the EU's external trade balance at sectoral level are expected. According the results from P1 (Figure 3), demand for fossil fuels by consumers and industries would increase. Emission-intensive manufacturing production would go up and exceed domestic demand in the EU, thus allowing the EU's net exports to go up. As such, in this scenario the EU would improve its trade balance with the ROW in manufacturing products but increase its net fossil fuel imports. From the consumption side, as EU consumers are assumed to allocate more budget towards emission-intensive products, the EU's service exports would therefore increase.

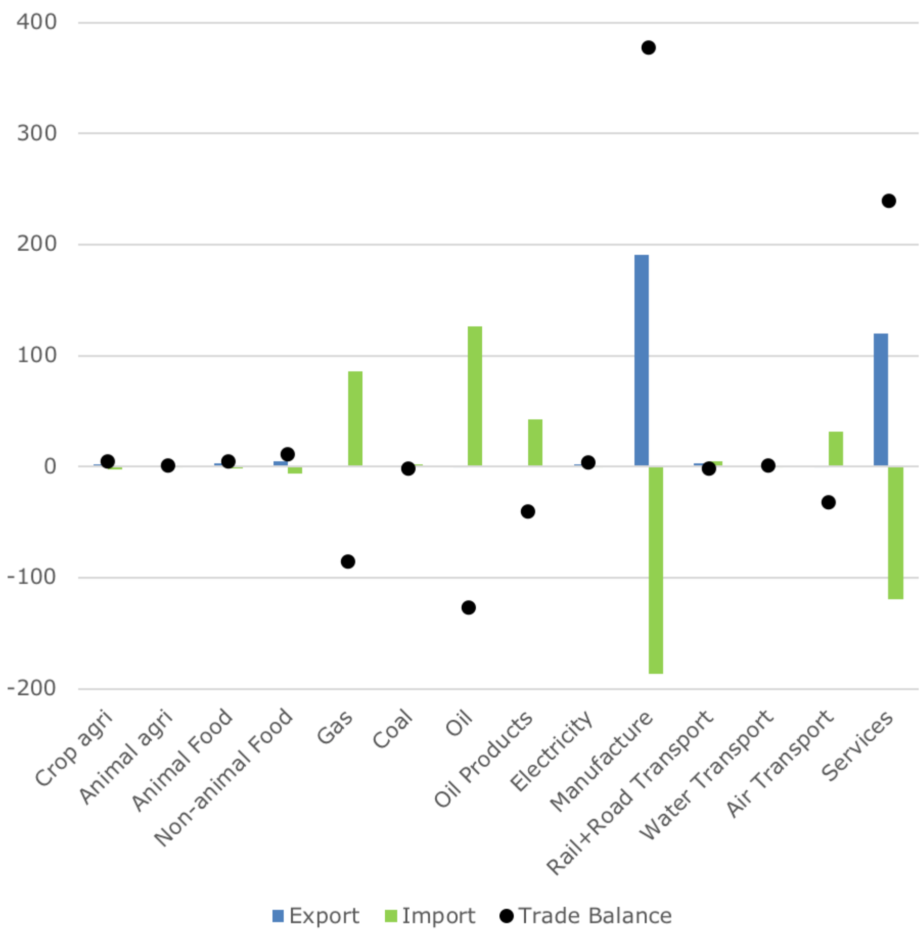

Figure 3: Change in sectoral trade of EU vs aggregate ROW in P1, relative to the EU Reference Scenario (bln USD), in 2050.

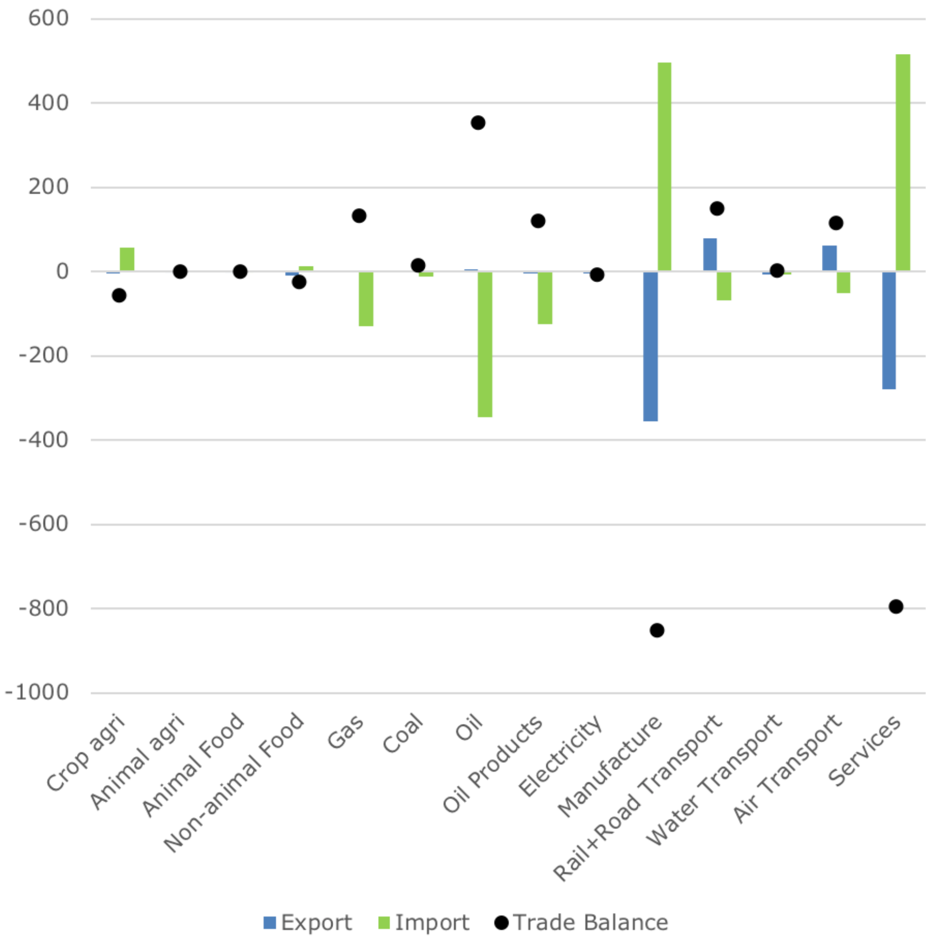

Figure 4: Change in sectoral trade of EU vs aggregate ROW in P4, relative to the EU Reference Scenario (bln USD), in 2050.

Conclusions

Ambitious EU decarbonizing pathways require new lifestyle choices, energy system transitions, and changes in GHG emission-intensive industries. These changes will have fundamental implications for the EU's economic system by creating internal imbalances between demand and supply and changing costs and prices of goods and services, which in turn influence the EU's external trade linkages with the ROW. The changing external trade patterns and trade flows caused by the actions to reduce the EU's internal emissions means that the direct emissions reductions may be partially offset by increased emissions elsewhere. This carbon leakage phenomenon is an important issue that needs to be addressed in formulating climate policy, as recognized in the European Green Deal proposal (European Commission, 2019).

Tracking emissions embodied in trade flows provides the opportunity to calculate the carbon leakage rate for measuring the net global emission reduction arising from a particular economy's decarbonization efforts. Simulation results from the EUCalc model suggest that the EU's external trade balance may be negatively affected if the EU conducts ambitious decarbonization in the absence of similar actions from the ROW. For instance, in the most ambitious EU decarbonization scenario envisioned in the model, increased external imports and reduced external exports would lead to a sizable external trade deficit for the EU. Underlying this result is an improved trade balance with fossil fuel exporting countries (as imports of fossil fuels into the EU are expected to decrease) outweighed by a deteriorating trade balance with China, other major Asian economies, the US, among others, with which the EU would import more emission-intensive manufacturing products and services. The underlying reasons and possible policy responses to a particular sector's competitiveness warrants attention when formulating decarbonization strategies. These policy options include innovation-related investment measures, domestic tax instruments such as carbon tax rebates and distribution of free allowances within the EU ETS, and trade policy measures such as border carbon adjustment mechanisms. When applying these options, it is important to carefully evaluate their efficacy in incentivizing other countries to commit to similar decarbonization efforts.

As a result of these simulated changes in external trade flows in addition to modifications occurring to domestic and external production and consumption structures, a sizeable share of the EU emission reductions in the most ambitious scenario may be counterbalanced by increased emissions in the ROW (assuming the latter does not take similar actions). Decarbonization efforts by the EU alone cannot reduce global emission effectively. Therefore, concerted actions by the world – for example under the auspice of the Paris Agreement – are needed if significant levels of carbon leakage are to be avoided and global GHG reductions realized. We conclude that there is an urgent need to carefully balance potentially conflicting policy options for supporting decarbonization efforts in the EU, safeguarding national industries under transition, and incentivizing the rest of world to join climate effective worldwide decarbonization efforts.

References:

[1] BURNIAUX, J.-M. & TRUONG, T. 2002. GTAP-E: An Energy-Environmental Version of the GTAP Model. Department of Agricultural Economics, Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP).

[2] CLORA, F. & YU, W. 2019. EUCalc transboundary effects module documentation. EUCalc Report.

[3] EUROPEAN COMMISSION, DG ENERGY, DG CLIMATE ACTION & DG MOBILITY AND TRANSPORT 2016. EU Reference Scenario 2016. Energy, transport and GHG emissions Trends to 2050.

[4] EUROPEAN COMMISSION 2019. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of regions - The European Green Deal. COM(2019) 640 final.

[5] MCDOUGALL, R. & GOLUB, A. 2007. GTAP-E: A Revised Energy-Environmental Version of the GTAP Model. Department of Agricultural Economics, Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP).

Appendix 1. Concordance between aggregated regions shown in Figures 1 and 2 and individual countries/regions

Aggregated Regions used in Figures 1 and 2	Individual countries/regions.
Rest of Europe	Norway (NOR), Rest of EFTA (XEF), Albania (ALB), Ukraine (UKR), Rest of Eastern Europe (XEE), Rest of Europe (XER)
FSU (Former SovietUnion)	Kazakhstan (KAZ), Tajikistan (TJK), Azerbaijan (AZE), Belarus (BLR), Georgia (GEO), Kyrgyzstan (KGZ), Rest of Former Soviet Union (XSU), Armenia (ARM)
High-Income Asia	Hong Kong (HKG), Japan (JPN), Korea (KOR), Taiwan (TWN), Singapore (SGP)
Rest of Asia	Rest of Oceania (XOC), Mongolia (MNG), Rest of East Asia (XEA), Brunei Darussalam (BRN), Cambodia (KHM), Indonesia (IDN), Laos (LAO), Malaysia (MYS), Philippines (PHL), Thailand (THA), Viet Nam (VNM), Rest of Southeast Asia (XSE), Bangladesh (BGD), Nepal (NPL), Pakistan (PAK), Sri Lanka (LKA), Rest of South Asia (XSA)
AUS_NZ	Australia (AUS), New Zealand (NZL)
MENA (Middle East and North Africa)	Israel (ISR), Bahrain (BHR), Iran (IRN), Kuwait (KWT), Oman (OMN), Qatar (QAT), Saudi Arabia (SAU), United Arab Emirates (ARE), Rest of Western Asia (XWS), Rest of North Africa (XNF), Jordan (JOR), Turkey (TUR), Egypt (EGY), Morocco (MAR), Tunisia (TUN)
Rest of Africa	Benin (BEN), Burkina Faso (BFA), Cameroon (CMR), Côte d'Ivoire (CIV), Ghana (GHA), Guinea (GIN), Nigeria (NGA), Senegal (SEN), Togo (TGO), Rest of Western Africa (XWF), Central Africa (XCF), South-Central Africa (XAC), Ethiopia (ETH), Kenya (KEN), Madagascar (MDG), Malawi (MWI), Mauritius (MUS), Mozambique (MOZ), Rwanda (RWA), Tanzania (TZA), Uganda (UGA), Zambia (ZMB), Zimbabwe (ZWE), Rest of Eastern Africa (XEC), Botswana (BWA), Namibia (NAM), South Africa (ZAF), Rest of South African Customs Union (XSC), Rest of the World (XTW)
Rest of Latin America	Argentina (ARG), Chile (CHL), Paraguay (PRY), Peru (PER), Uruguay (URY), Rest of South America (XSM), Costa Rica (CRI), Guatemala (GTM), Honduras (HND), Nicaragua (NIC), Panama (PAN), El Salvador (SLV), Rest of Central America (XCA), Dominican Republic (DOM), Jamaica (JAM), Puerto Rico (PRI), Trinidad and Tobago (TTO), Rest of Caribbean (XCB), Bolivia (BOL), Colombia (COL), Ecuador (ECU), Venezuela (VEN)

About the author:

Professor Wusheng Yu, from the University of Copenhagen in Denmark, conducts quantitative economic analysis in the areas of international trade, trade policy, agricultural and food policy, and climate change economics. His research has been funded by several EU projects and various other international/national/private funding sources. Within the EUCalc project, he leads the transboundary effects module.

Francesco Clora is a PhD Fellow in quantitative economics at the University of Copenhagen in Denmark. His main research work includes international trade and trade policy, climate change and computable general equilibrium modeling. Francesco has participated in the design and development of the transboundary effects module in the EUCalc project.

Contact:

Wusheng Yu (wusheng@ifro.ku.dk),
University of Copenhagen, Denmark.

Francesco Clora (fc@ifro.ku.dk),
University of Copenhagen, Denmark.

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Further information on the EUCalc project:

The EUCalc project aims at providing a highly accessible, user-friendly, dynamic modelling solution to quantify the sectoral energy demand, greenhouse gas (GHG) trajectories and social implications of lifestyle and energy technology choices in Europe.

The novel and pragmatic modelling approach is rooted between pure complex society-energy systems and integrated impact assessment tools. The EUCalc model with its user interface - the Transition Pathways Explorer - has been designed to be both accurate but also accessible to decision-makers and practitioners. It covers all sectors and can be used by one or many people. The model is also open source so that experts can refine the model itself. The tool will have an e-learning version, the “My Europe 2050” tool as well as a Massive open online course (MOOC). See more on the EUCalc project, its scientific reports and all other outputs and access the Transition Pathways Explorer at:

www.european-calculator.eu

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Policy Briefs - Pathways towards a European Low Emission Society

The Policy Briefs on Pathways towards a European Low Emission Society, summarises key finding of the EUCalc project with a clear policy orientation, which provides practical climate change mitigation insights to both EU and individual Member States decision-makers. These policy briefs cover the following topics:

No. 1	The role of lifestyles changes in EU climate mitigation - Insights from the European Calculator
No. 2	Innovation and technology development - Decarbonisation pathways for manufacturing & production sector
No. 3	Long-Term Renovation Strategies: How the building sector can contribute to climate neutrality in the EU
No. 4	Avoid, shift, improve - Decarbonisation pathways for the transport sector in Europe
No. 5	Mitigating GHG Emissions through Agriculture and Sustainable Land Use - An Overview on the EUCalc Food & Land Module
No. 6	Decarbonizing the EU electricity sector - From ageing powerplants to renewable energy futures
No. 7	Implications of decarbonizing the EU economy on trade flows and carbon leakages - Insights from the European Calculator
No. 8	Impacts of European air pollution on human health - A brief assessment of the EUCalc scenarios
No. 9	Pathways towards a fair and just net-zero emissions Europe by 2050

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Find out more:

Potsdam Institute for Climate Impact Research (PIK)
Telegraphenberg A 31
14473 Potsdam – Germany

Prof. Dr. Jürgen Kropp
E-Mail: nsp@pik-potsdam.de
www.european-calculator.eu
Twitter: @EU_Calculator

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