Global Trade Analysis Project

Global Trade Analysis Project (GTAP) Circular Economy Data Base

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Introduction

- **Current material use patterns are projected to put tremendous pressure on the Earth's ecosystem**
  - Changes in incomes and population together with a global convergence in material use patterns could result in over 2.5 times increase in global material demand by 2050 (Steffen et al., 2015).
  - These trends would represent a major challenge for the climate mitigation and other conservation efforts.
  - The need to move toward a more sustainable material consumption patterns is widely recognized and is promoted within a Circular Economy (CE) concept.
- **Modelling of the Circular Economy transition requires an explicit representation of the primary and secondary production activities**
  - Represent country-specific production volumes of primary and secondary activities.
  - Distinguish between corresponding supply and cost structures, e.g. for steel, aluminum, copper, other metals, plastics.
  - Such representation is not available in the standard GTAP Data Base.

Overview of the previous efforts

- **Number of studies have represented the Circular Economy splits within the global CGE and IO modelling frameworks**
  - MRIO assessments based on the EXIOBASE (e.g. Tisserant et al., 2017; Wiebe et al., 2019).
  - CGE-based assessment focusing on selected sectors/commodities (e.g. Winning et al., 2017 for the case of steel).
  - GTAP-based assessments with a more detailed splits, e.g. OECD (2019), Dellink (2020), Bibas et al. (2021).
- **Selected limitations of the existing approaches:**
  - Are based on the EXIOBASE cost structures and output values, which do not always correspond to the actual observations (see e.g. Winning et al., 2017).
  - Focus on selected commodities or specific aggregate regional representations (e.g. steel, plastic, etc.).
  - Are not consistently updated over time.
  - **Not publicly available.**

GTAP-CE v11 introduces additional sectoral splits

No.	GTAP	New sector	Description
1	oxt	nmn	Non-metallic minerals mining
2		mio	Mining of iron ores
3		mao	Mining of aluminum ores
4		mco	Mining of copper ores
5		moo	Mining of other ores
6	rpp	rbr	Rubber products
7		plp	Plastic products – primary
8		pls	Plastic products – secondary
9		plr	Recycling - plastics
10	nmm	cem	Cement
11		nmx	Other mineral products
12	i_s	isp	Iron and steel – primary
13		iss	Iron and steel – secondary
14		ris	Recycling - iron and steel
15		isc	Iron and steel casting
16	nfm	app	Aluminum – primary
17		aps	Aluminum – secondary
18		ral	Recycling - aluminum
19		cpp	Copper – primary
20		cps	Copper – secondary
21		rcp	Recycling - copper
22		mpp	Other metals – primary
23		mps	Other metals – secondary
24		rom	Recycling - other metals
25		nfc	Non-ferrous metals casting
26	chm	nfr	Nitrogen fertilizer
27		pfr	Phosphorus fertilizer
28		kfr	Potassium fertilizer
29		xch	Other chemicals

76 GTAP-Power 11 Data Base sectors are disaggregated into 99 sectors

These sectoral splits provide a complete coverage of the CBAM commodities (except hydrogen)

The database construction process utilizes a variety of data sources

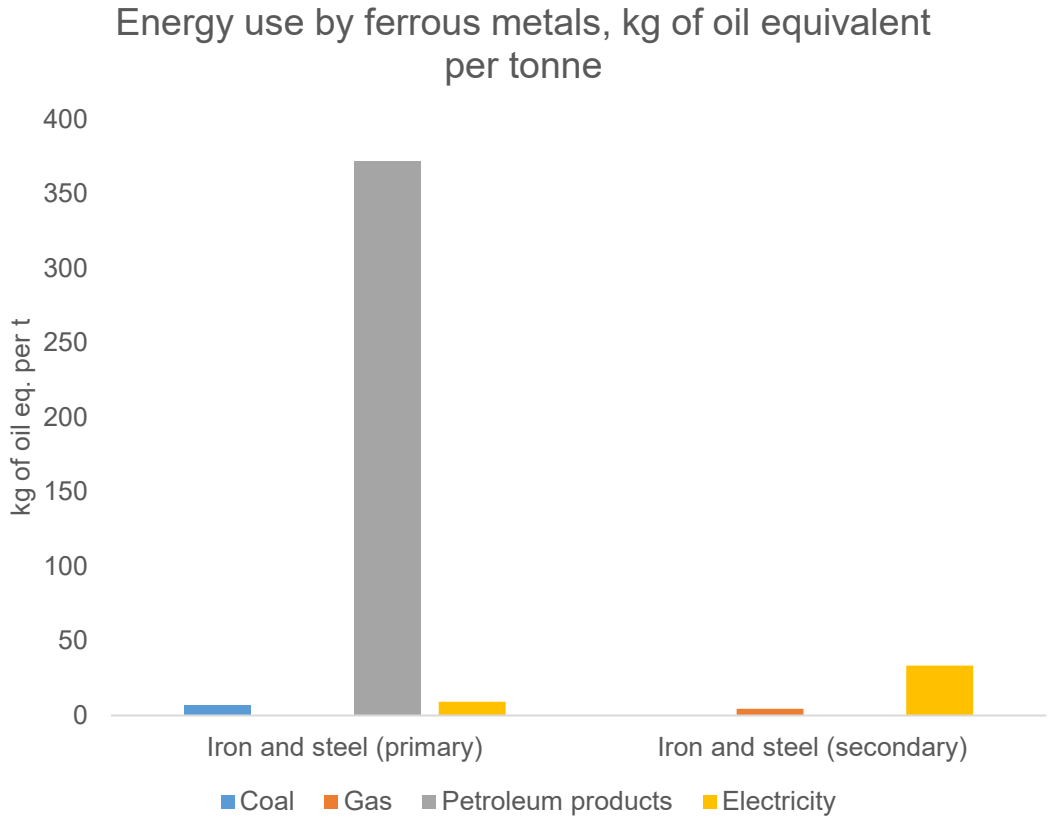
(1) Data preparation (output splits)	• ***Data:*** Volumes of primary and secondary production, volumes of waste, recycling rates, bilateral trade data for sectors or interest. • ***Data sources:*** USGS, UNIDO, BACI, UNEP IRP MFA, PRODCOM, World Steel, Jambeck et al. (2015), Plastics Europe, Veolia, multiple country-specific data sources (for plastic recycling rates), World Bank, International Fertilizer Association (IFA), FAO. • Construction of the production targets using volume and price data.
(2) Data preparation (supply/use splits)	• ***Data:*** Disaggregated individual country input-output tables (USA, Korea, Japan, Canada), EXIOBASE, specific cost structure assumptions. • Construction of the cost structure targets.
(3) Targets' reconciliation	• ***Data:*** GTAP 11 Power Data Base, data inputs from Steps 1 and 2. • Reconciliation of the production targets, supply/use structures and trade data for disaggregated SAMs extracted from the GTAP.
(4) Database split	• ***Data:*** Split targets from Step 3. • GTAP Data Base split using SPLITCOM.
(5) Construction of the final database	• ***Data:*** Disaggregated database from Step 4. • Incorporation of the energy and emission flows for disaggregated sectors. Compilation of the final database.

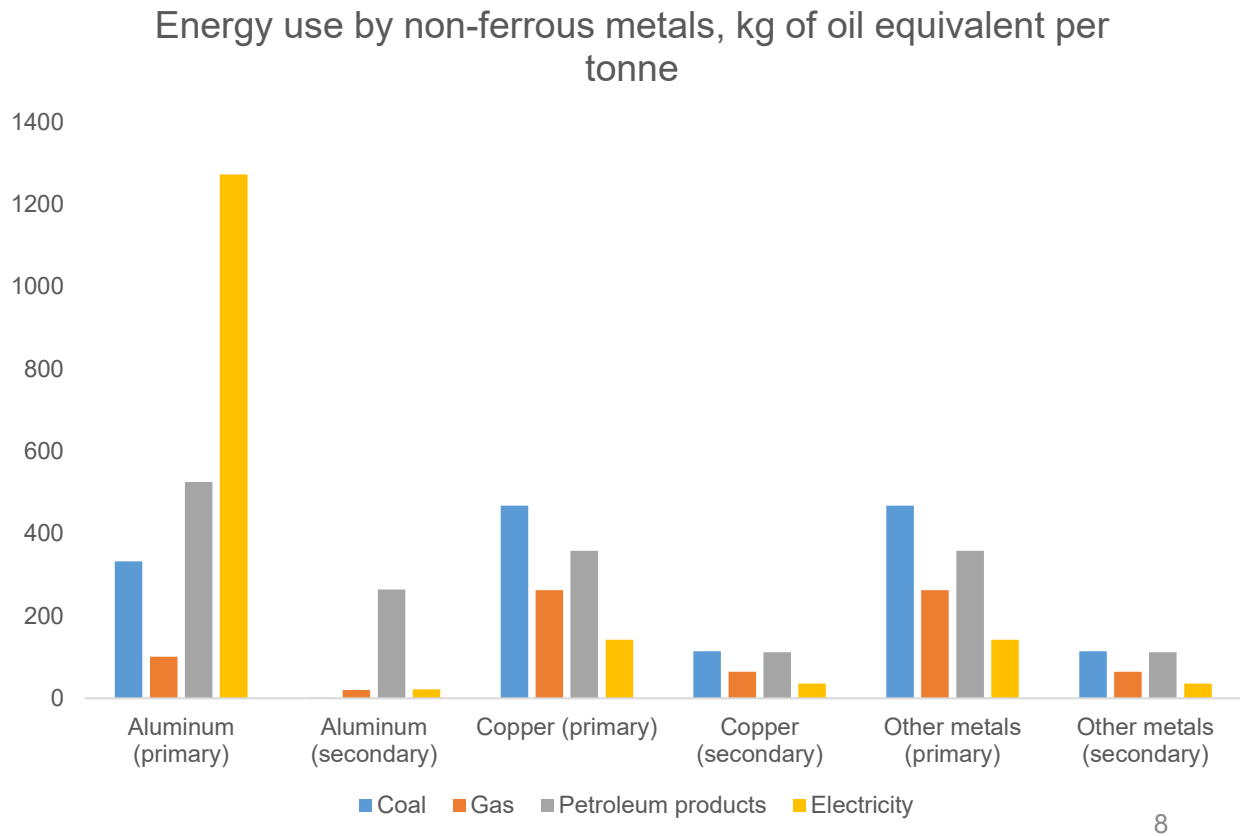
Data availability and reliability varies by countries and sectors: output and trade

- Data on the volumes of **ore mining and production** of metals across technologies (e.g. electric arc furnaces vs blast furnaces) is directly available form USGS.
- **Price estimates for ores and metals** need to be implemented to construct value flows (domestic price estimates are scarce; trade-based prices need to be used).
- Data on **cement production** across countries has been sourced from USGS and **price data** from the WB's ICP estimates (country- and region-specific).
- For **fertilizers** split we follow the approach introduced in Bartelings et al. (2016), sourcing data on fertilizer **production** from FAO and **use by crop** from IFA. Prices are derived from trade data.
- Split between **plastic** and rubber production is based on the UNIDO database. Plastics production data is available across macro regions. Recycling rates are derived from a number of country-specific sources and complemented with regional averages.
- **Trade data** at the HS6 level is sourced from the CEPII BACI database.

Cost structures and energy inputs

- **Cost structures** for the disaggregated sectors are based on the inputs from EXIOBASE and selected country IOTs (e.g. USA, Canada, Korea, etc.).
- Additional adjustment are implemented for the **energy inputs** across commodities, primarily based on the literature review (techno-economic analyses). The latter provide estimates of energy inputs per unit of output.





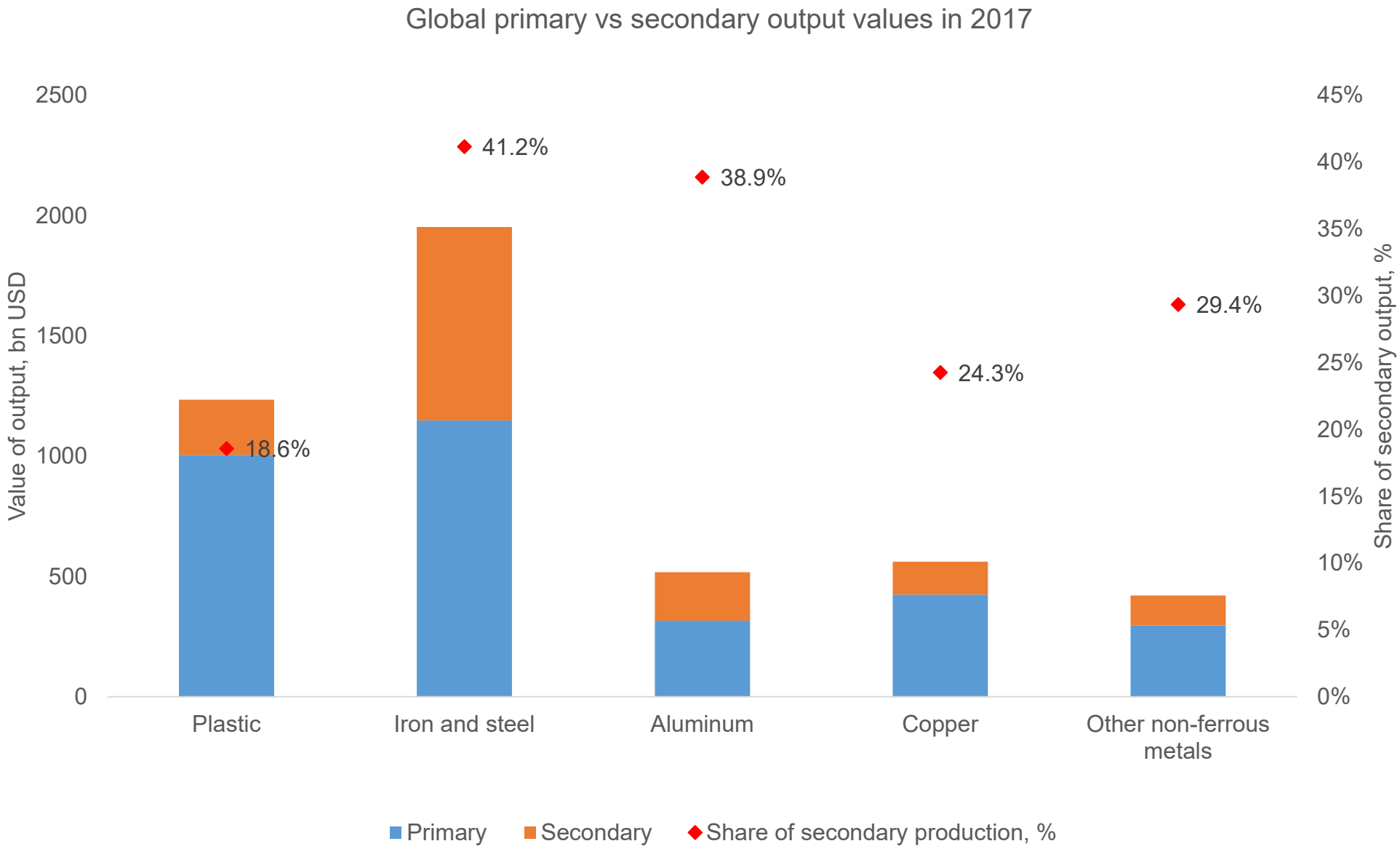
Emissions data covers GHG emissions and air pollutants

- Fossil fuel combustion CO_2 emission flows are estimated using the Tier 1 IPCC 2006 method, following the approach used in the main GTAP Data Base (Chepeliev, 2022).
- For the case of process emissions from cement production, estimates are sourced from EDGAR database.
- In the case of process emissions from fertilizers, these are calibrated to the FAO emission estimates.
- Where available, air pollutants and complementary GHG emissions for newly disaggregated sectors are directly sourced from the EDGAR database.
- If EDGAR database provides data at a less granular level (than GTAP-CE) emissions are distributed proportionally to energy of value flows (depending on the emission driver).

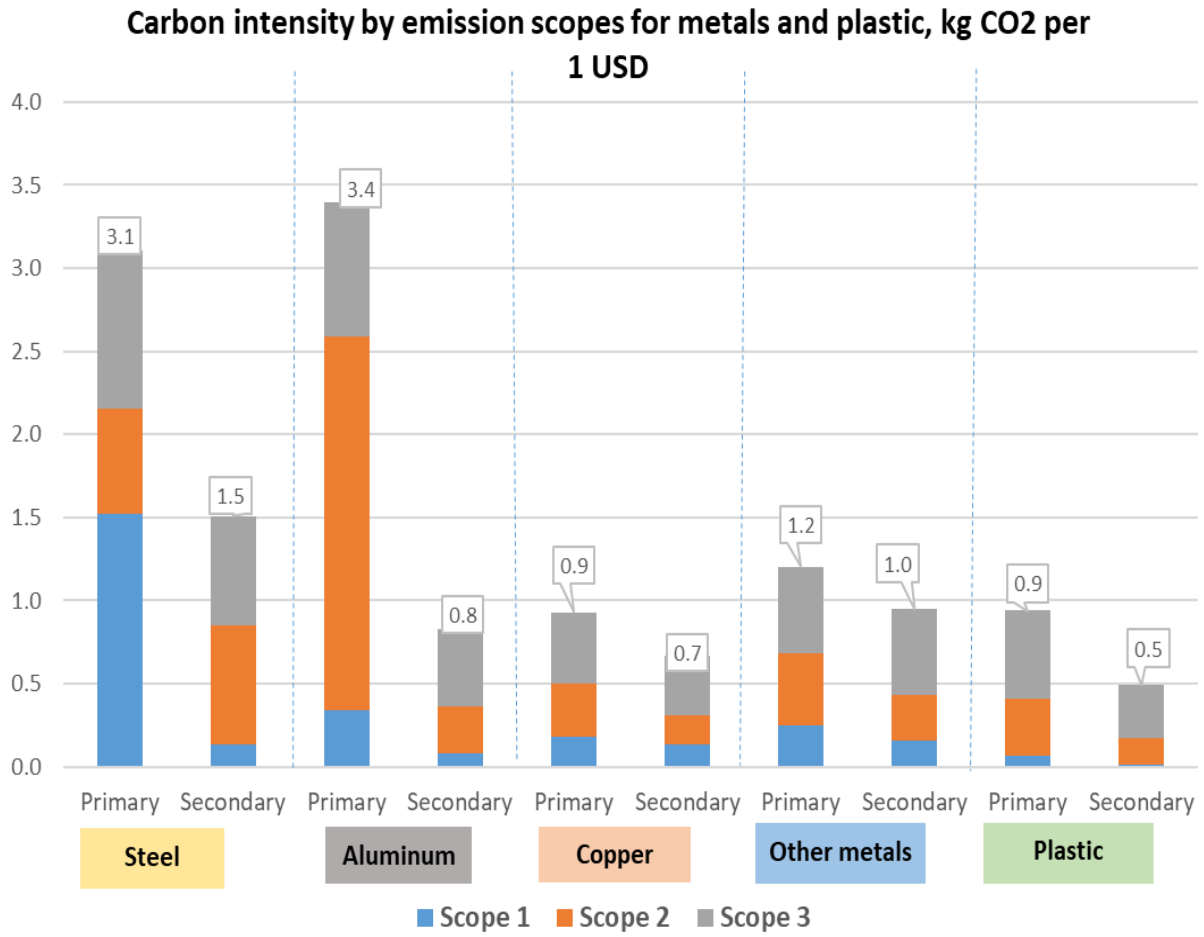
Selected data challenges

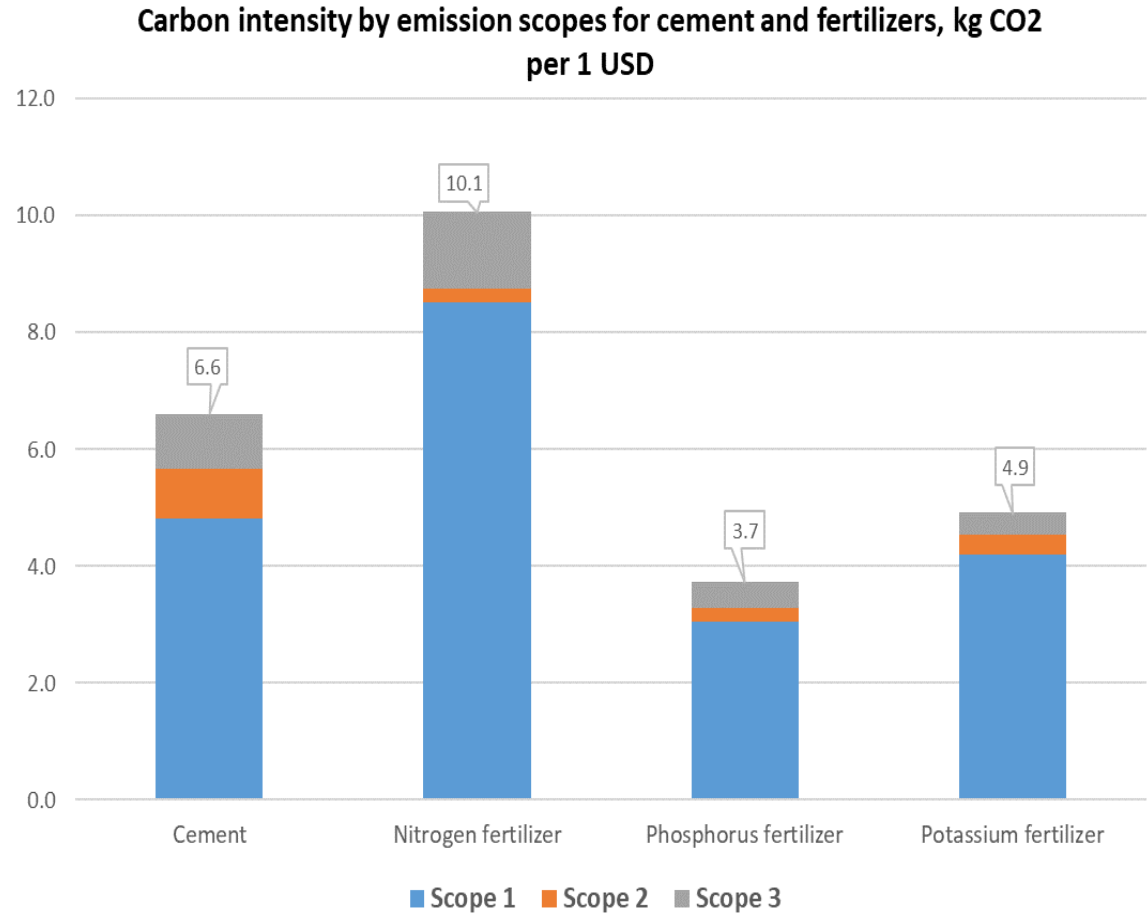
- **Inconsistencies between trade, output and underlying GTAP data** -> need to adjust other sectors in GTAP for a more precise targeting.
- **Value of output and intermediate supply of the GTAP 'wtr' sector** (includes waste management) **is much lower than targeted values** of scrap and recycled waste for almost all countries -> disaggregated recycling from the corresponding primary sector.
- **Not all supply/use structures are available** (e.g. recycling or secondary production).
- Use trade-based prices to derive output values targets, which are then scaled to the GTAP totals -> could use **domestic country-specific prices**, if available.
- Lacking explicit representation of the **country-specific sources of scrap/waste** by sectors and agents, particularly for plastic (used data from macro regions).

GTAP-CE: Sectoral composition (global average)



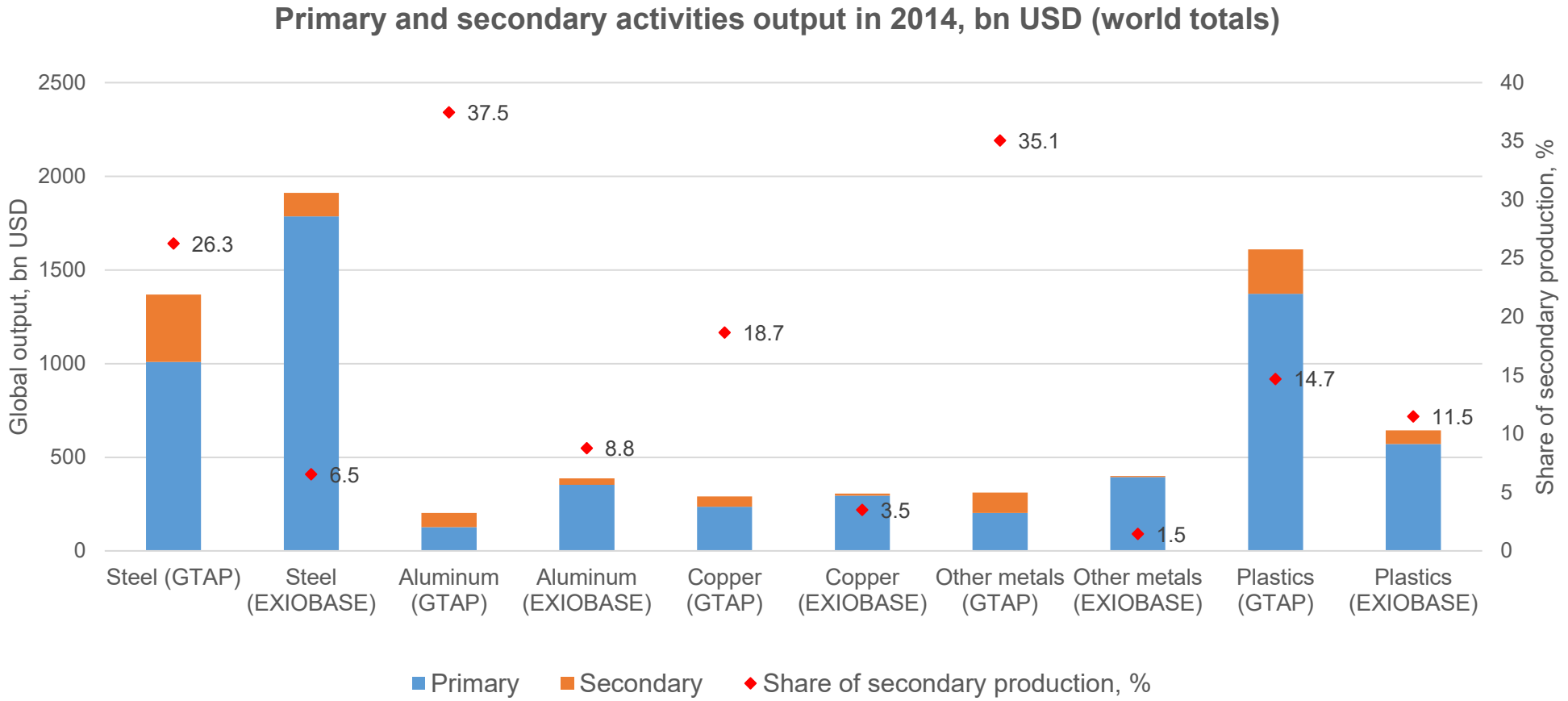
GTAP-CE: differentiated emission intensities across sectors (global average)





Comparisons with EXIOBASE

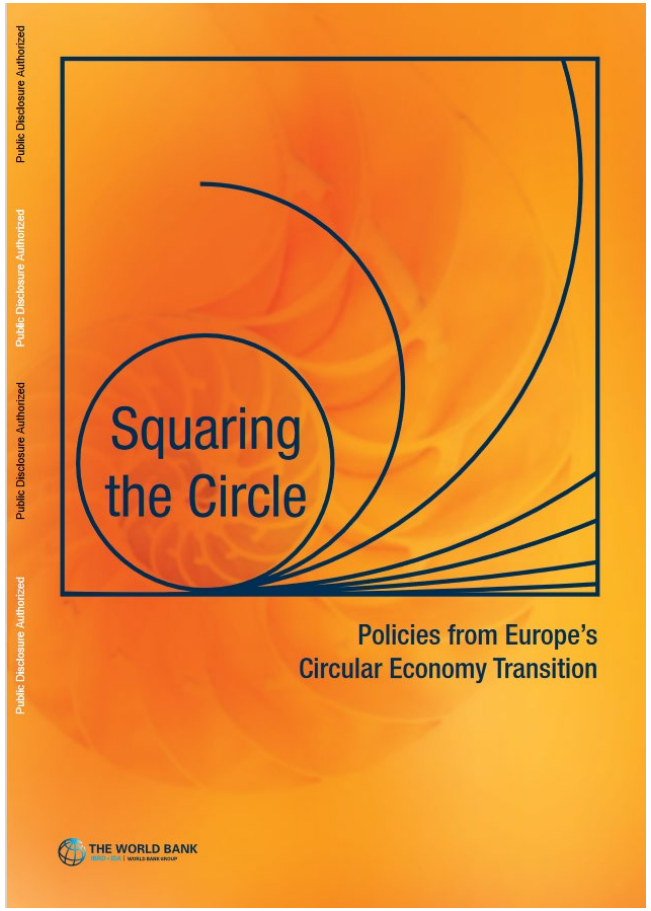
- While **EXIOBASE** is a rich source of information, it **should be used with some caution**:
  - Reporting 163 sectors, it aggregates some CE-related splits (e.g. casting, plastics and rubber, etc.). No explicit representation of waste/scrap processing. Limited regional coverage – 49 (mostly OECD).
  - Reports cases of negative value added (salary, capital returns), consumption or output. It might be consistent with actual IOTs, but not 'appreciated' by CGE models.
  - Some output values and cost structures are not always plausible.

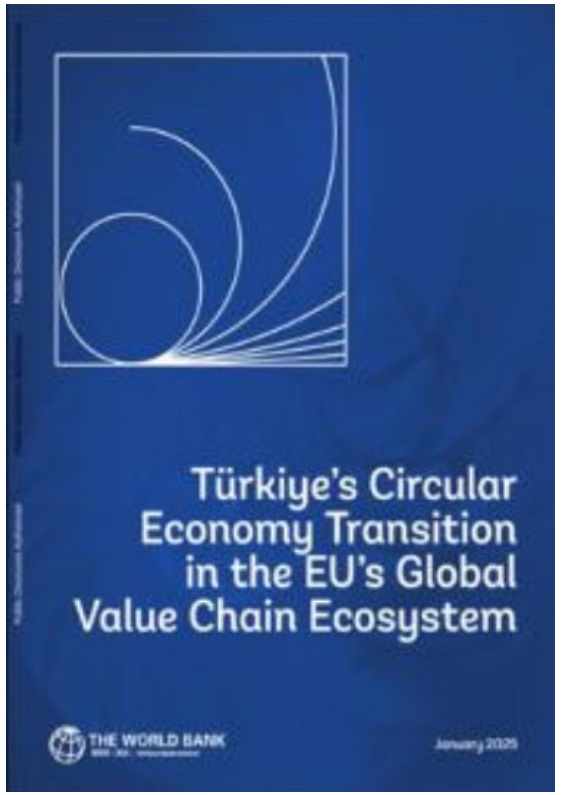


GTAP-CE Data Base is available in a user-friendly format

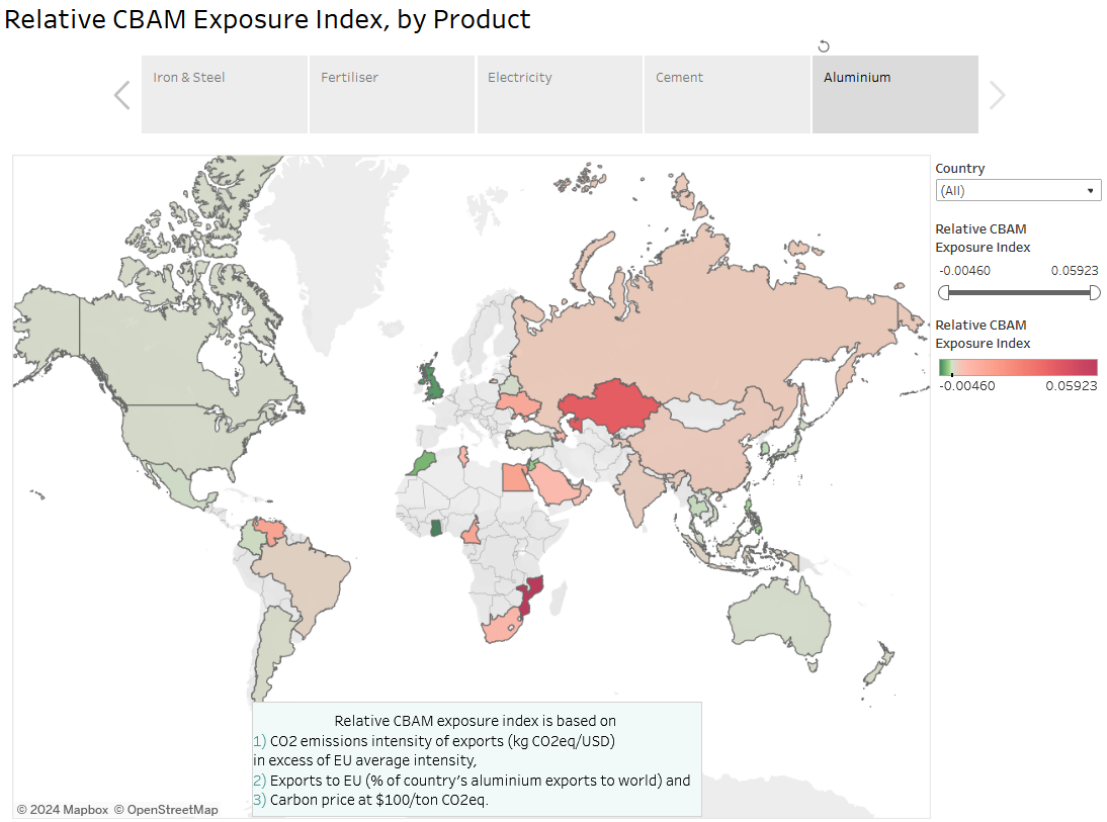
- The developed GTAP-CE v11 Data Base is distributed in three data formats, similar to the standard GTAP Data Base.
- These include GTAPAgg and Flexagg archives (with HAR files), as well as GDX containers (GAMS files).
- These data distributions report information for a single reference year, i.e. 2017, covering 99 commodities/activities and 160 countries/regions.
- The developed database reports emissions of both greenhouse gases and air pollutants and can be directly used with the GTAP family of models or other global CGE models.
- The GTAP-CE v11 Data Base is available for download on the GTAP website (https://www.gtap.agecon.purdue.edu/) together with other GTAP Data Base satellites and extensions.

The GTAP-CE Data Base has been used in a number of studies looking at the CE transition and decarbonization





The GTAP-CE Data Base has been also applied to explore different aspects of the CBAM



The *Relative CBAM Exposure Index* is designed to *identify countries with high exposure to the EU CBAM*, using carbon emissions intensity and exports of CBAM products to the EU.

Source: WB (2023)
https://www.worldbank.org/en/data/interactive/2023/06/15/relative-cbam-exposure-index

GTAP-CE has been also coupled with GTAP-E and ENVISAGE models in a number of studies looking at the impacts of the CBAM on EU and it's trading partners.

Featured GTAP-CE application:

“Circular Economy Transition in Europe Requires Ambitious Policies Beyond Climate Mitigation”

Based on:

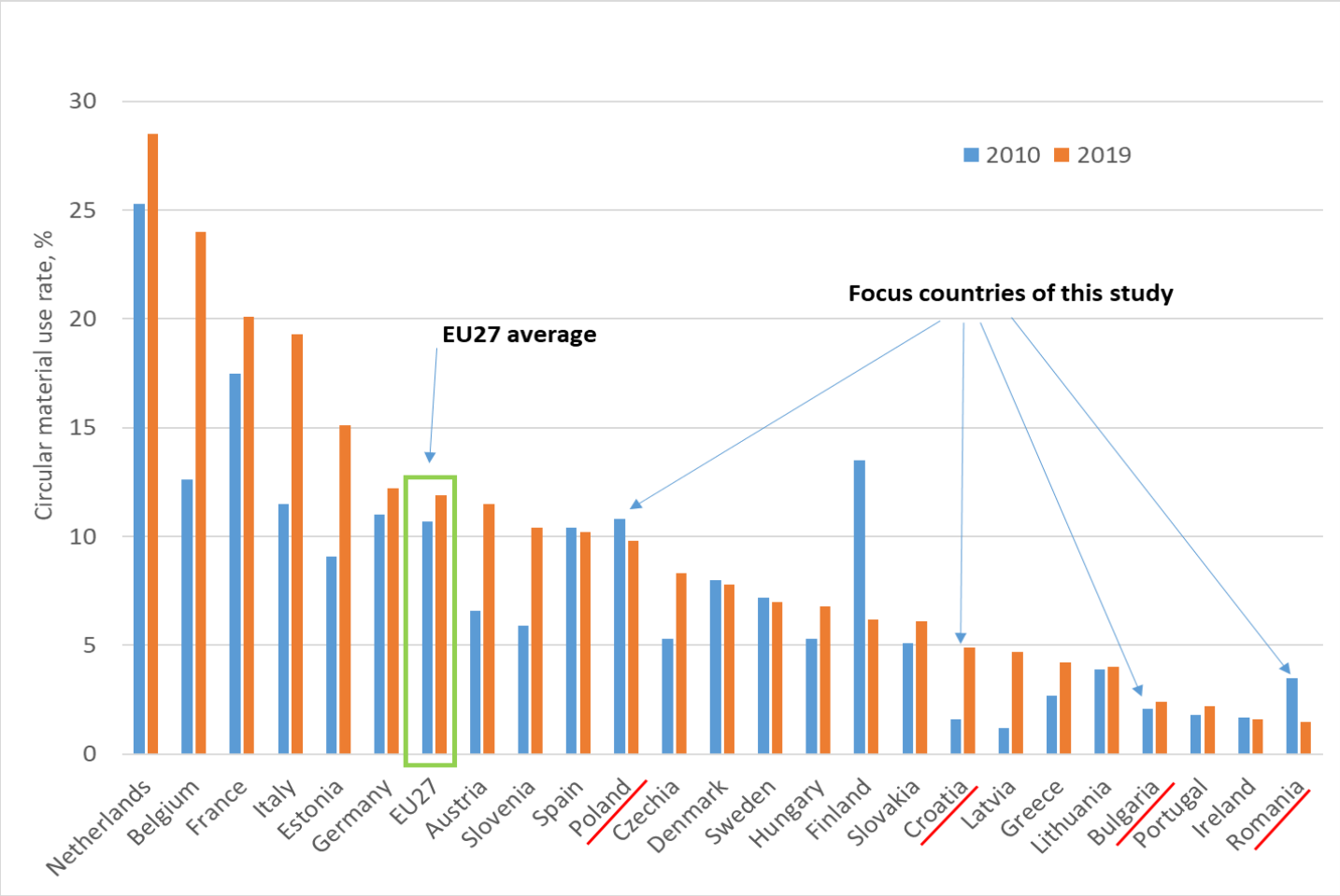
Chepeliev, M., Aguiar, A., Farole, T., Liverani, A., and van der Mensbrugghe, D. 2025.
Circular Economy Transition in Europe Requires Ambitious Policies Beyond Climate Mitigation.
Preprint available at SSRN: http://dx.doi.org/10.2139/ssrn.5175563

Motivation

- **Limited progress on circularity transition in Europe**
  - Policy makers are often not well equipped with sufficient knowledge of the circularity principles and the potential impact of corresponding policies on their national economies (Domenech and Bahn-Walkowiak, 2019).
- **A number of earlier studies have looked into circularity transition for specific countries and sectors in the EU**
  - Lack of assessments exploring comprehensive forward-looking CE policies in Europe.
  - A number of studies assumed cost-free implementation of the CE policies.
  - Lack of studies that looked into interaction of existing (e.g. climate mitigation) and complementary CE policies.
- This study examines the **interactions between circular economy and climate mitigation policies**
  - Focus is on Europe, in particular, four Eastern European Member States – Poland, Romania, Bulgaria and Croatia.
  - Examining a wide range of socio-economic and environmental impacts

Circular material use rates vary widely across EU

- In 2015, the European Commission adopted the first Circular Economy (CE) Action Plan.
- This plan was updated in 2020 – one of the main blocks of the European Green Deal.
- The level of efforts toward CE transition at the EU country level is something decided by national and subnational governments.

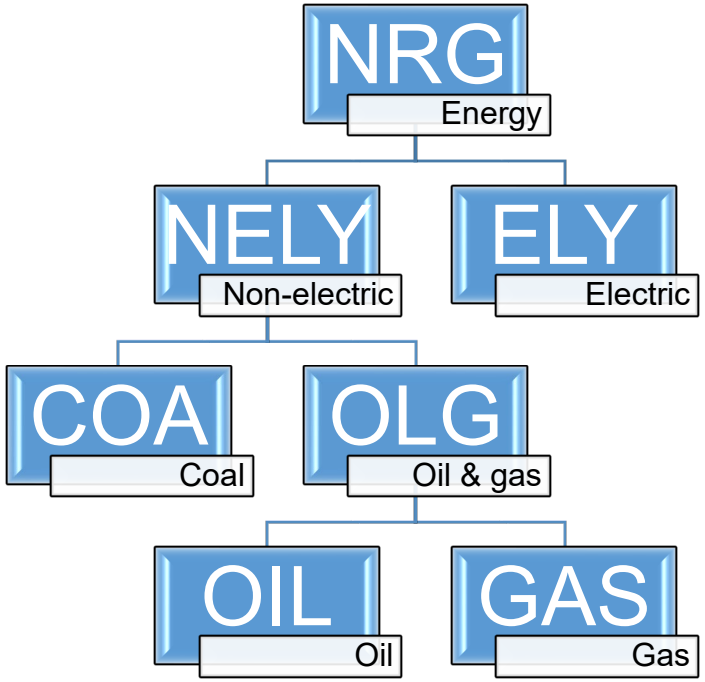


Circular material use rate in the selected EU countries in 2010 and 2019, %

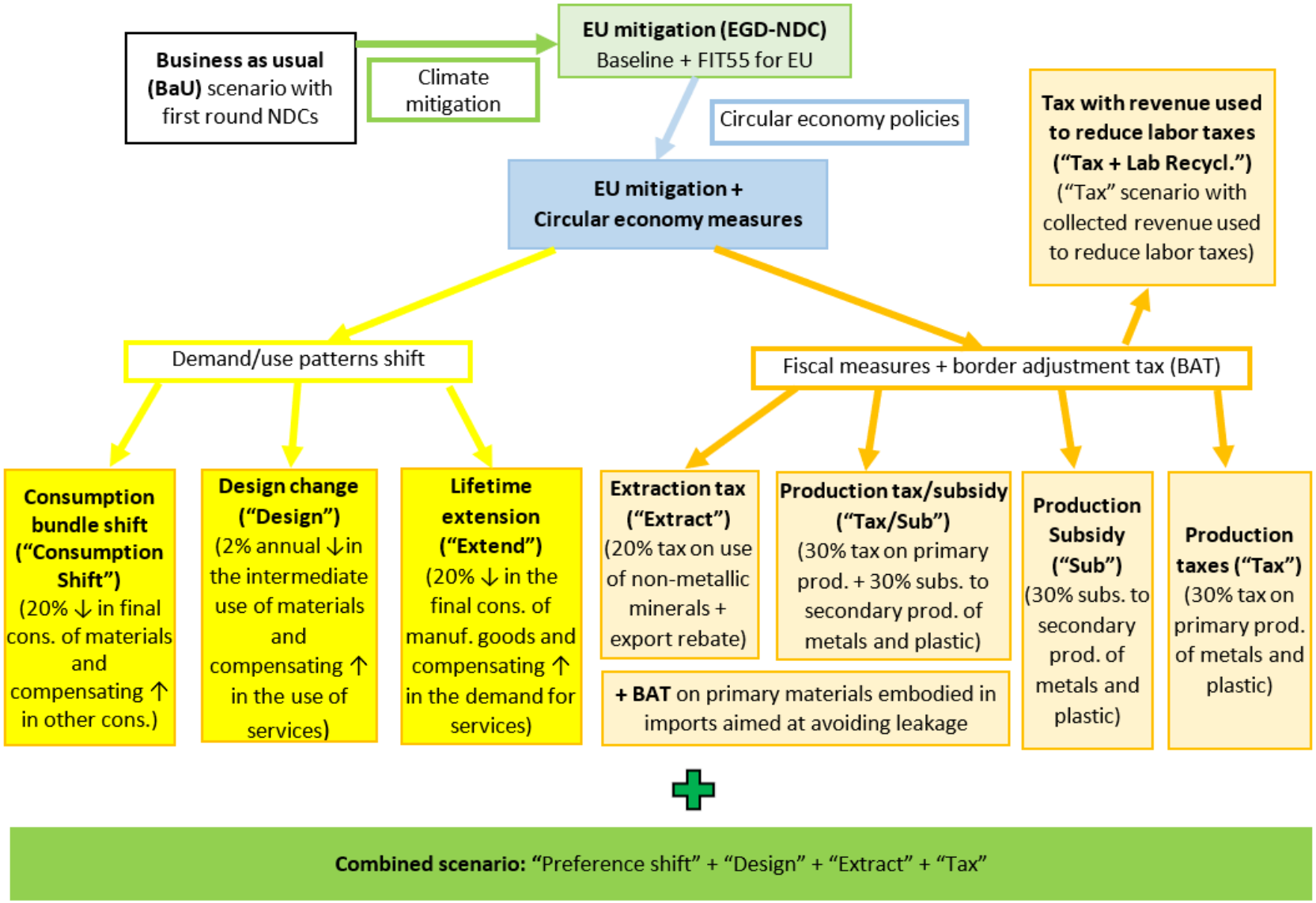
Notes: The indicator measures the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use.
Source: EC (2020b).

The GTAP-CE is coupled with ENVISAGE CGE model

- **Global computable general equilibrium model**
  - Recursive-dynamic (2014-2030).
  - Vintage capital.
  - Unemployment closure.
- **Nested energy demand**
  - Alternative generation technologies (GTAP-Power database).
- **Preference shifts/technological changes**
  - Decreasing cost of renewables; increasing preferences toward renewable energy; increasing electrification rates; energy efficiency improvements.
- **Model aggregation:** 20 regions and 42 activities.



Scenario framework combines climate mitigation, supply- and demand-side CE policies

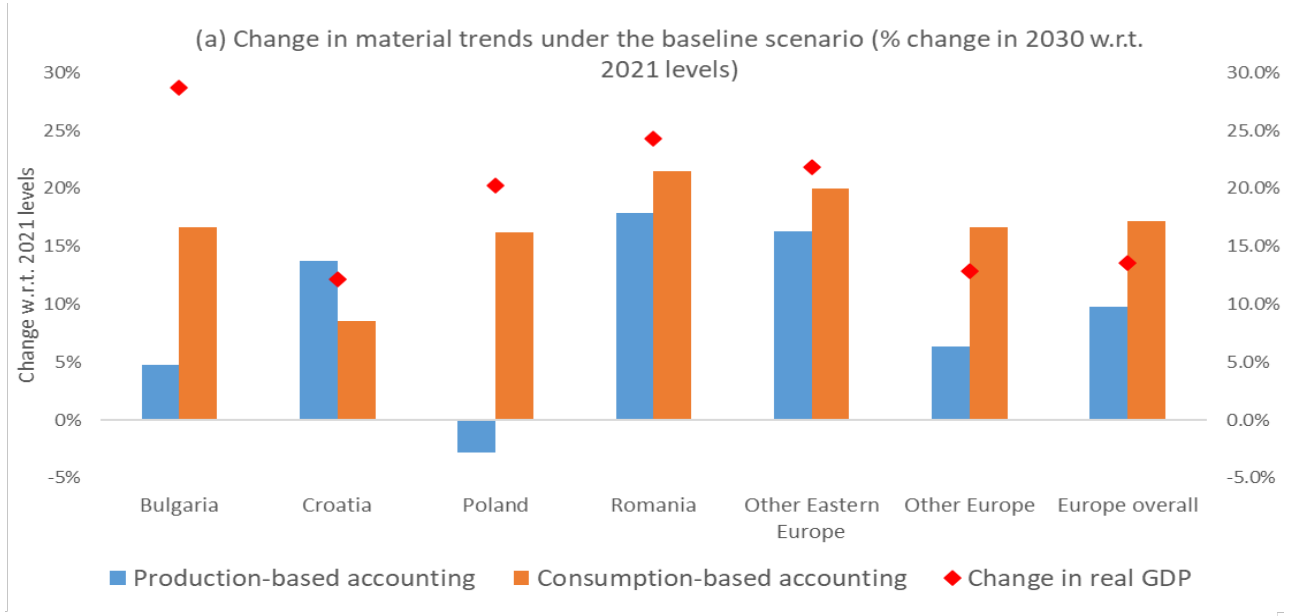


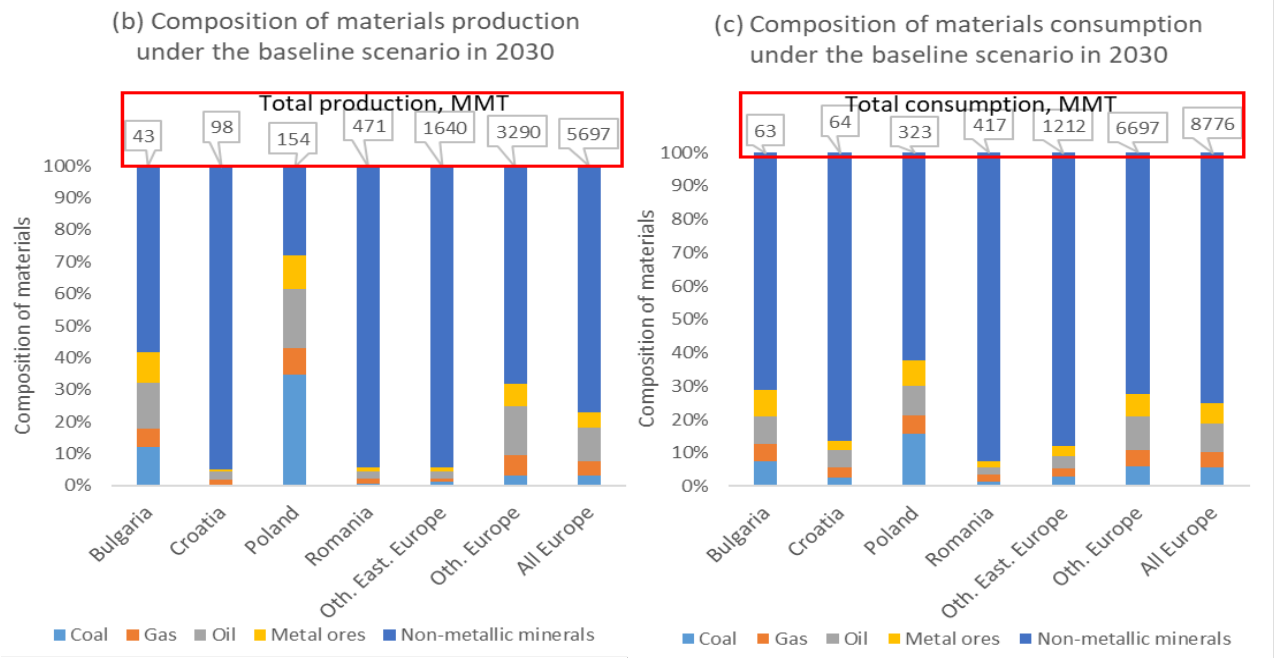
Baseline scenario sees growing material use

Under the business-as-usual (*BAU*) scenario, production and use of primary materials continue to grow, maintaining recent trends towards relative, but not absolute, decoupling.

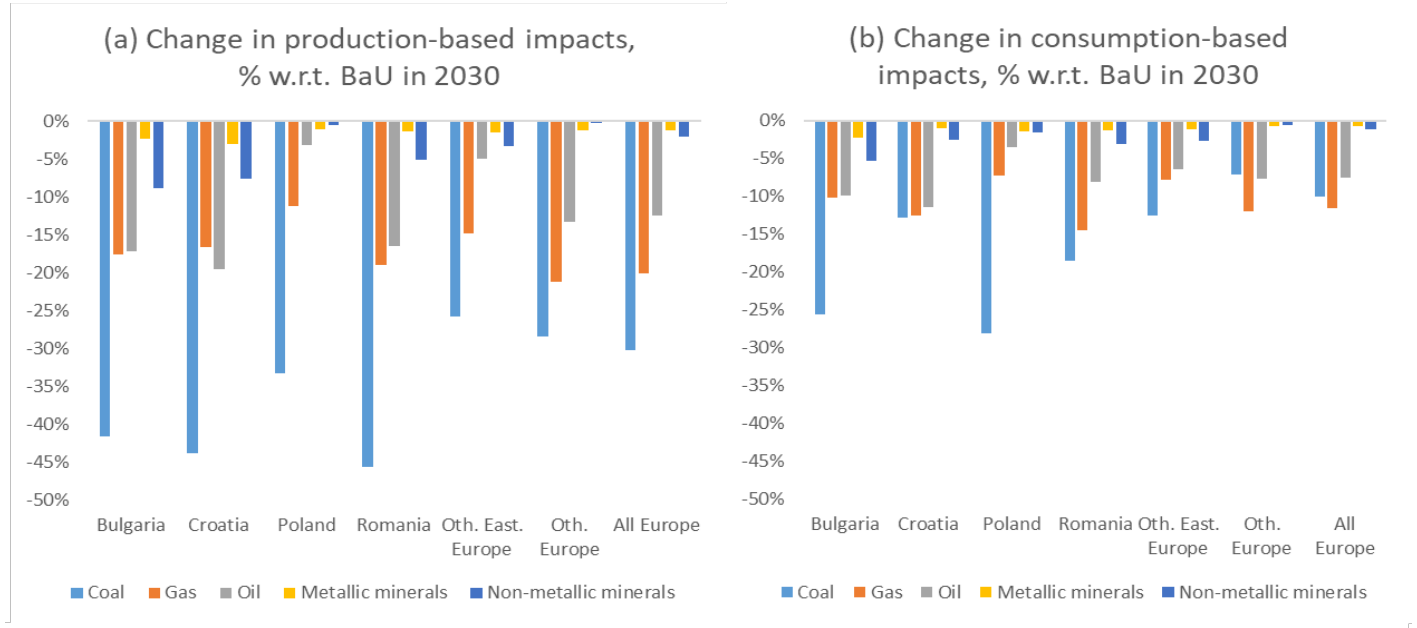
The historically observed trend toward shifting the production of material-intensive goods outside European borders continues in the baseline scenario.

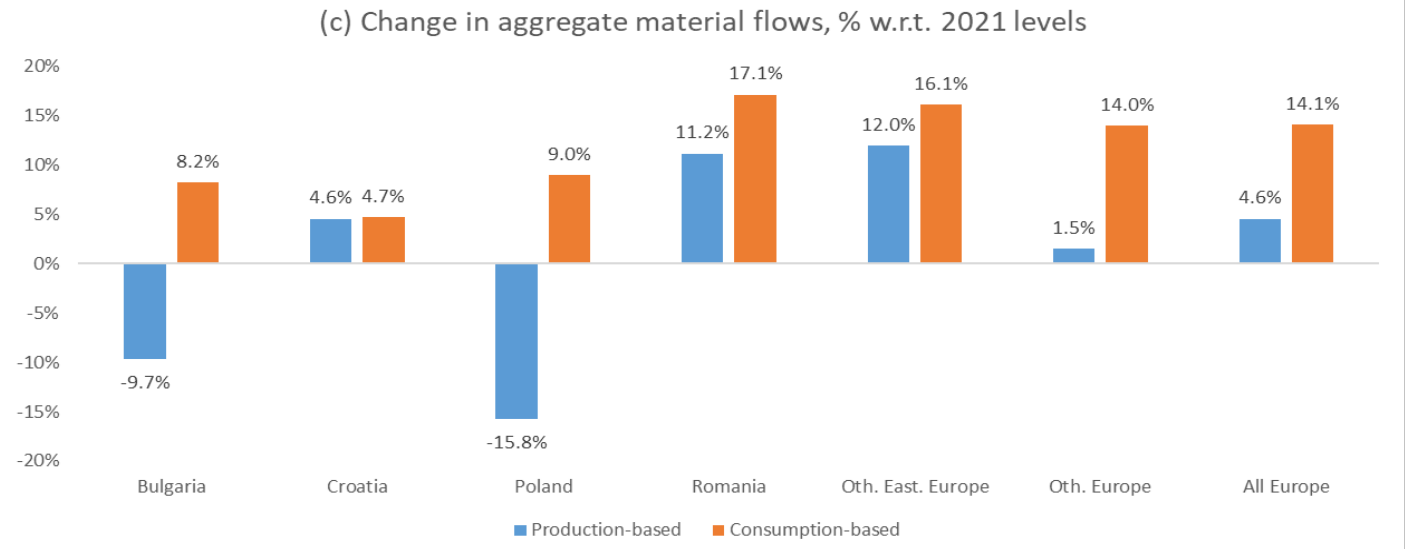
Non-metallic minerals represent a bulk share of material flows – 77% (production) and 75% (consumption) for the European average. Substantial variations across countries are observed, especially on the production side.





Climate mitigation efforts have limited implications for material use





Impacts of the EU climate mitigation policies ('EGD-NDC' scenario) on primary materials production and consumption, % difference w.r.t. baseline scenario volumes in 2030

Pursuing decarbonization objectives under the European Green Deal makes a limited contribution to resource efficiency gains.

Mitigation policies have large impact on fossil fuel production and a smaller, but still significant, impact when measured on a consumption basis.

Relatively limited impact on metals and non-metallic minerals: less than 1% reduction relative to BAU for metals and 1-2% for non-metallic minerals Europe-wide.

When impacts on fossil fuels and other minerals are combined, overall material trends differ by countries, depending on their material profiles.

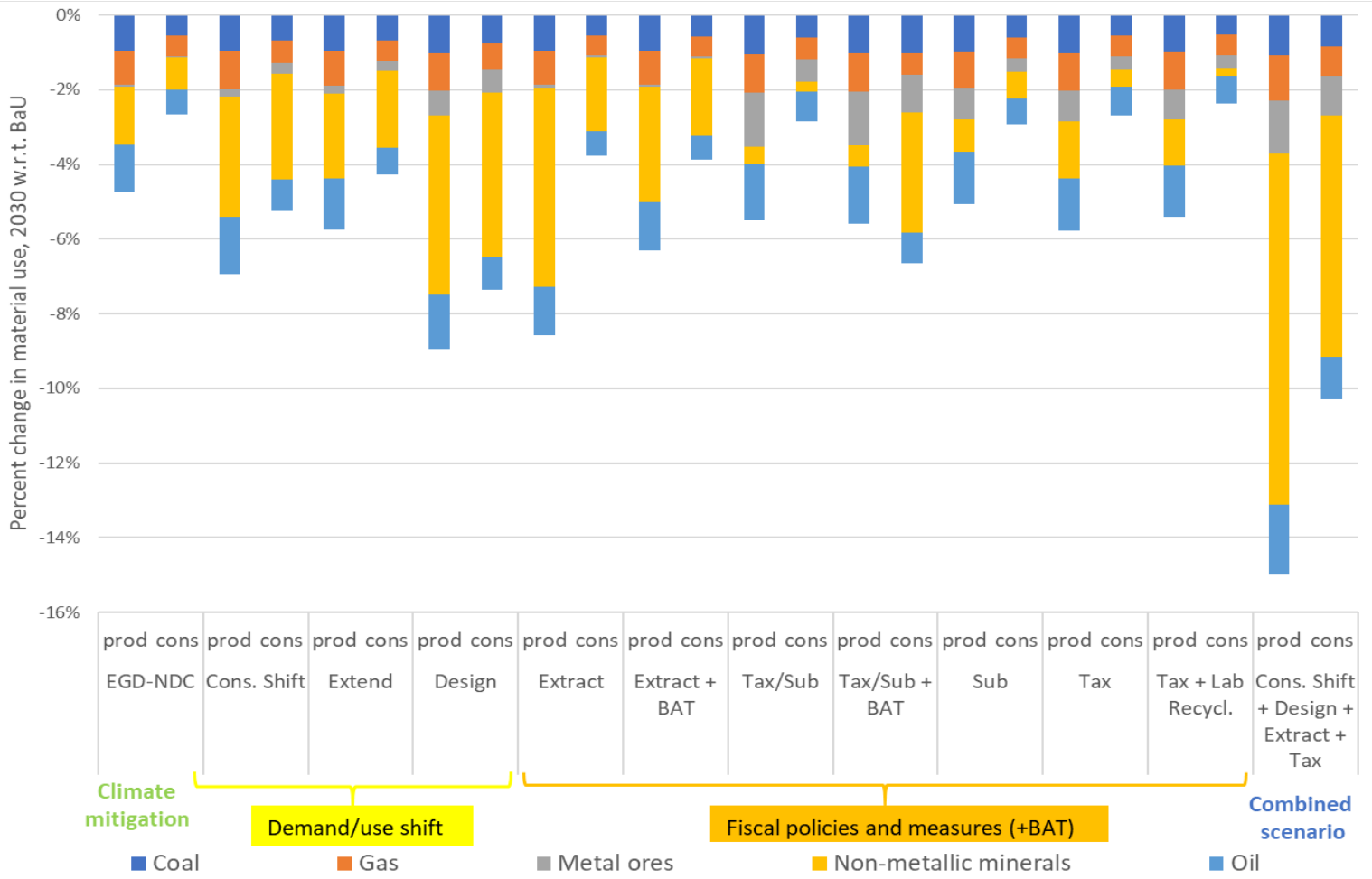
A comprehensive mix of domestic policy instruments is needed to achieve substantial progress on circularity

The analysis of alternative CE scenarios highlights the complementarity of the various CE policies that target materials across stages of the value chain.

Demand-side policies target both intermediate and final demand leading to a reduction in overall material use (impacting both domestically-sourced and imported goods).

Fiscal policies, on the other hand, target the production process explicitly penalizing the activities that rely on virgin materials, thus changing the composition of production processes.

The most substantial reduction in materials production and use is achieved when multiple CE policies targeting all stages of the value chain are combined.

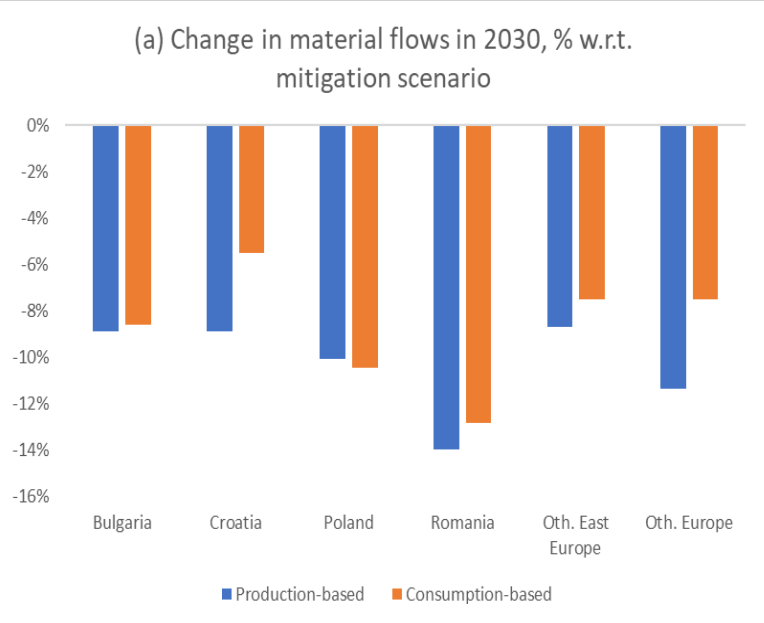


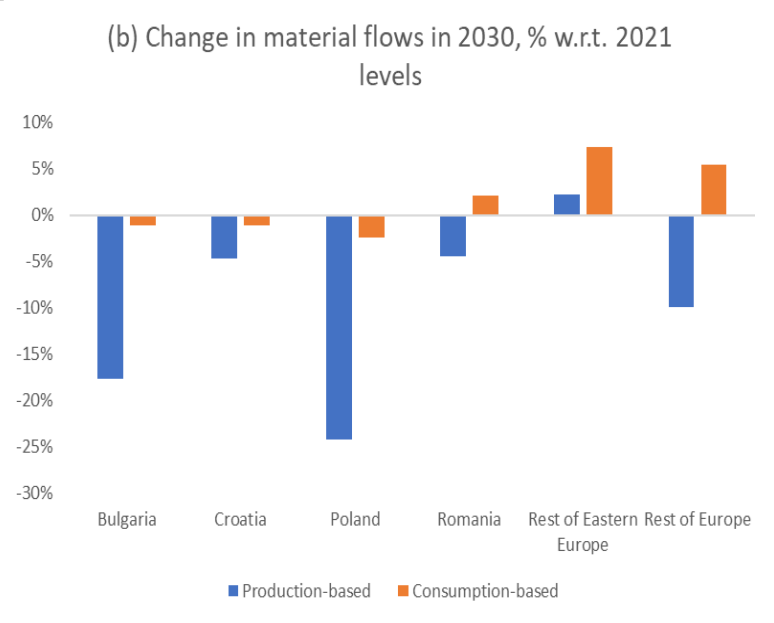
Change in Europe-wide material use across scenarios and materials, % change w.r.t. baseline scenario levels in 2030

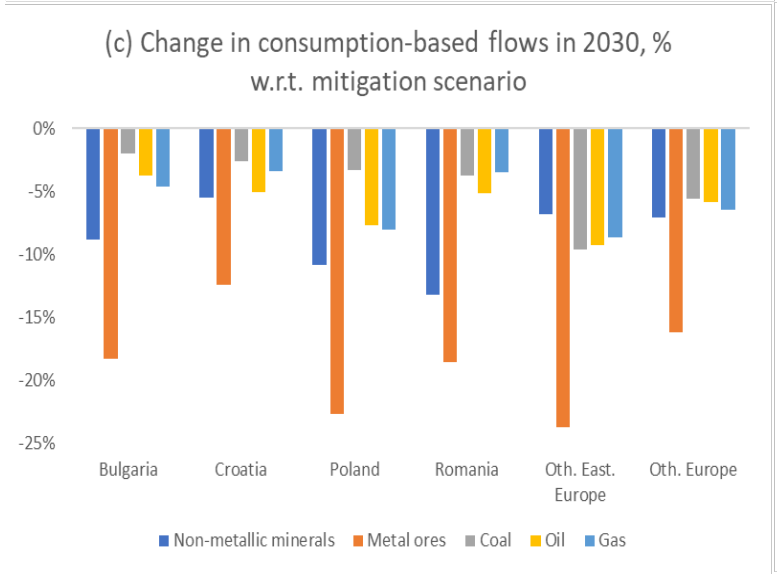
Notes: Percent change in material production and consumption across material types are estimated relative to the total material use (across all types) within the baseline scenario.

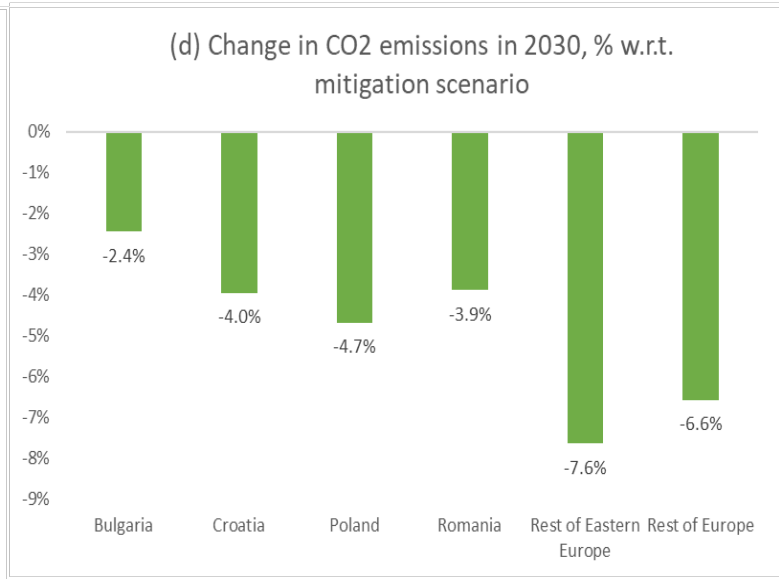
Heterogeneity of the CE policy impacts across European countries

Change in material flows (panels 'a', 'b' and 'c') and emissions (panel 'd') under Combined scenario across European countries and regions







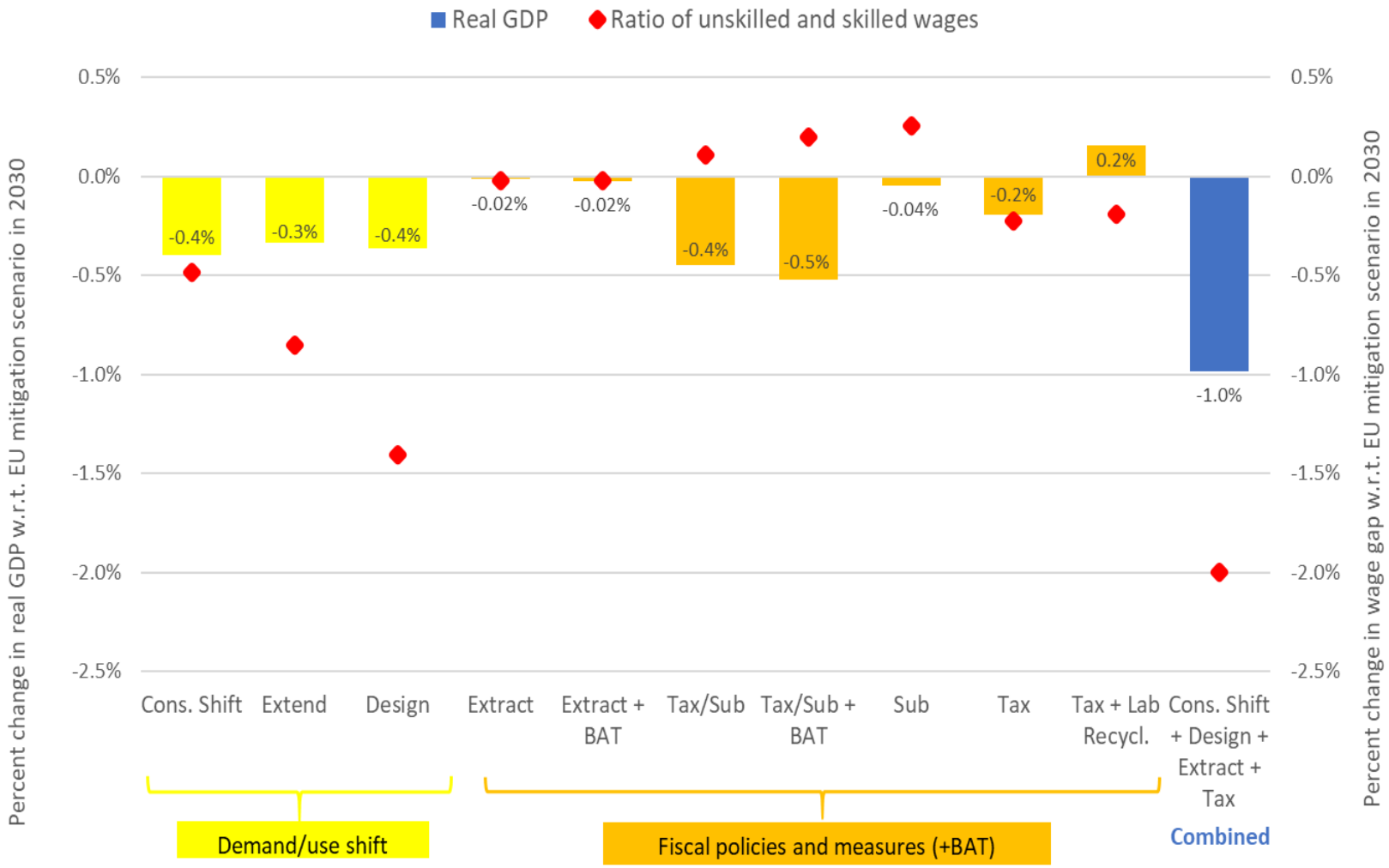


From the production-based perspective, reductions in material flows vary from over 14% in Romania to 9% in Croatia, Bulgaria and Other Eastern European countries (w.r.t. mitigation scenario levels in 2030).

Variation in the consumption-based material use across European countries is somewhat more substantial than differences in production patterns.

All four Eastern European countries manage to achieve absolute decoupling between material production and economic growth, while three out of four (all, except Romania) also manage to achieve decoupling from the consumption-based perspective.

Macro-economic costs of the CE policies are moderate but distributional implications might require targeted policy interventions



Change in real GDP (left axis) and skill wage gap (right axis) in Europe across scenarios, % change in 2030 w.r.t. climate mitigation (*EGD-NDC*) scenario

Notes: Wage gap is estimated as a ratio of unskilled to skilled workers' wages. Negative changes in the ratio imply a relative increase in skilled workers' wages, while positive changes indicate a relative increase in unskilled workers' wages.

At the Europe-wide level, the overall cost of implementing the Combined CE scenario is around 1% of GDP in 2030, while for most individual policy scenarios the cost does not exceed 0.3%-0.4%

CE policies could potentially result in regressive distributional outcomes, with unskilled workers' wages declining relative to skilled workers' wages.

Most of the decline in wage ratio is associated with design change policies.

Key takeaways from the analysis of CE policies in Europe

- **Climate and CE policies are complementary**.
- **CE measures can lead to absolute decoupling:** aggregate production-based material use in the EU could decline up to 6% (in 2030 w.r.t. 2021).
- **Measures must be targeted:** response to CE polices substantially varies by materials.
- **Leakage may arise with production-based policies:** benefits and drawbacks of BAT to be considered.
- Using CE production taxes' revenue to **reduce labor taxes increases growth and welfare:** allows to achieve double dividends.
- **Increasing skill premium** could result in regressive distributional impacts; targeted compensatory policies might be required.

Conclusions

GTAP circular economy database introduces additional sectoral splits to the GTAP-Power v11 Data Base:

- Total number of sectors is extended from 76 to 99. Selected activities (metals and plastic) are split into primary and secondary allowing for an explicit assessment of the CE-related policies.
- The developed database provides a complete coverage of the CBAM commodities (except hydrogen), covering both GHGs and air pollutants.

The database can be coupled with GTAP-based models:

- The developed database is distributed in the format of the core GTAP Data Base packages and provides additional capabilities for the analysis of various policies.

Future developments:

- Focus on the incorporation of the detailed critical minerals supply chains.
- Additional sectoral and technological splits are also considered and a new data disaggregation routine is developed in collaboration with colleagues from Polimi.

Global Trade Analysis Project

Thank you!
Questions/Comments?

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