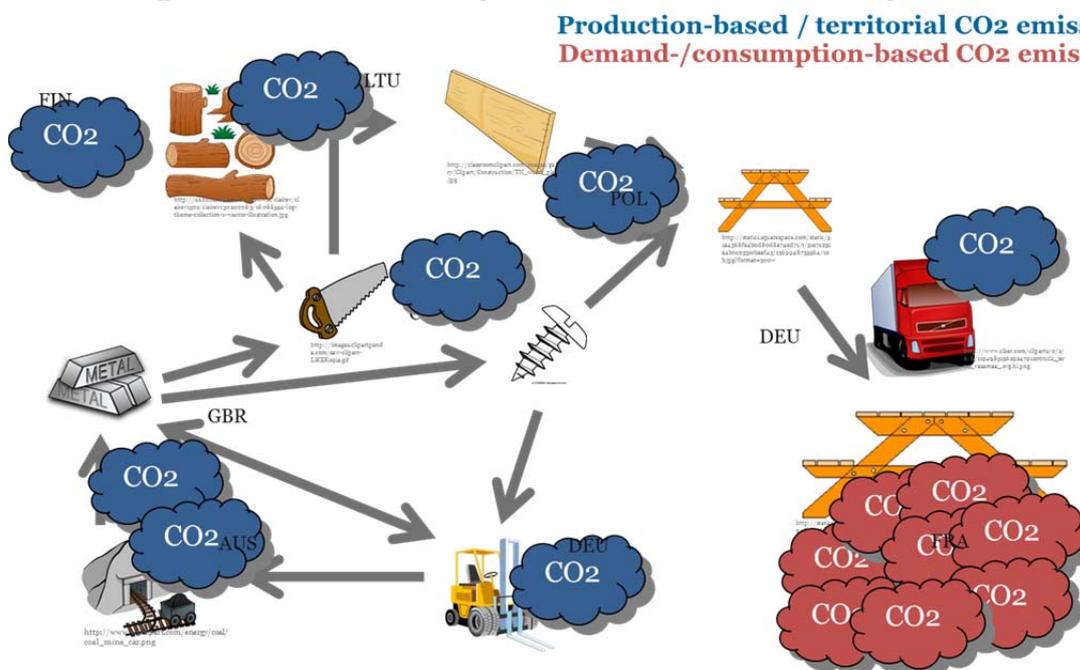


OECD CO₂ emissions embodied in consumption

What are consumption-based carbon emissions?

Reliable carbon emissions statistics are essential for formulating responses to climate change and to inform global negotiations such as those concluded in Kyoto in 1997 or recently in Paris at COP21. Typically, emissions statistics are compiled according to production-based or territorial emission accounting methods: measuring emissions occurring within sovereign borders. However, these estimates do not reflect production chains which extend across borders. Emissions associated with the production of a given good and or service may arise in many countries. The substitution of domestic for foreign suppliers of intermediate inputs may result in a reduction of a nation's emissions, but the effect on global emissions will depend on whether the foreign suppliers use less ("cleaner") or more ("dirtier") carbon-intensive energy and other inputs. To account for the origins of CO₂ emissions embodied in final demand, the OECD has developed consumption-based, or demand-based, estimates of carbon emissions. These provide a useful complement to the traditional production-based emission estimates. Figure 1 illustrates the difference between consumption- and production-based emissions.

Figure 1: The origins of emissions in the production of a wooden table (for illustrative purposes)

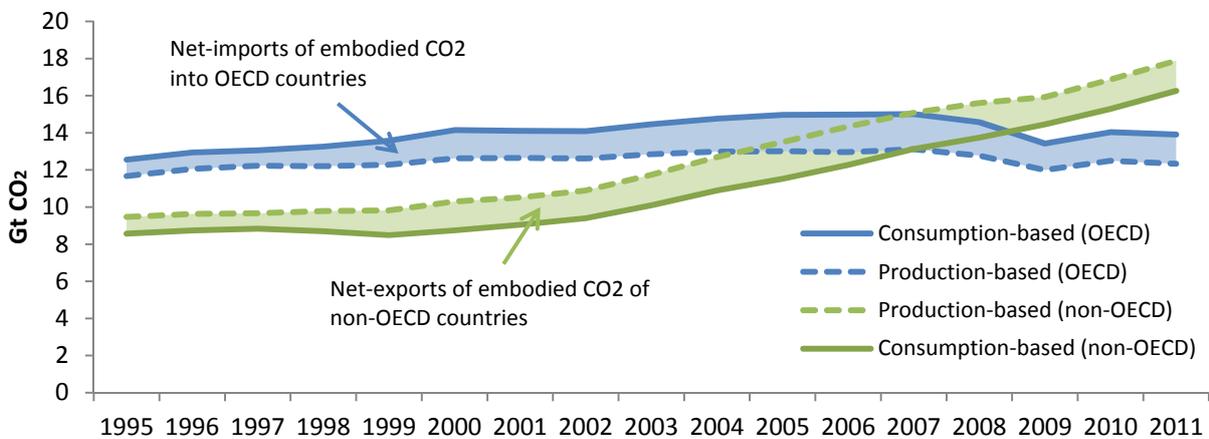


A wooden table is bought by a consumer in France. It was transported by a German logistics company from Poland, where it was assembled from screws produced in China and wooden planks produced in Lithuania. China provided the tools to cut the timber from Finland into wooden planks. The screws were manufactured in China from metal, produced in the UK using Australian iron ore and German machinery. CO₂ is emitted at each step along the production chain: transport through Poland, Germany and France, assembly (using electricity) in Poland, cutting the timber (using diesel generators) in Finland, etc. The blue clouds indicate where CO₂ is emitted along the production chain. These are production-based or territorial emissions. Demand-/consumption-based emissions are exactly the same, but in this case they are allocated to the country of the final use of the wooden table, i.e. France.

The terms consumption-based emissions and demand-based emissions can be used interchangeably and include emissions embodied in final consumption (households and government) as well as gross fixed capital formation (investment), changes in inventories and direct purchases abroad by residents. The calculation of production-based and territorial emissions differs according to the allocation of non-resident emissions. For example, for territorial emissions, the emissions associated with fuel-purchases by non-residents are allocated to the country where the fuel is purchased, while for production-based emissions the same emissions are allocated to the country of residence of the emitting source.

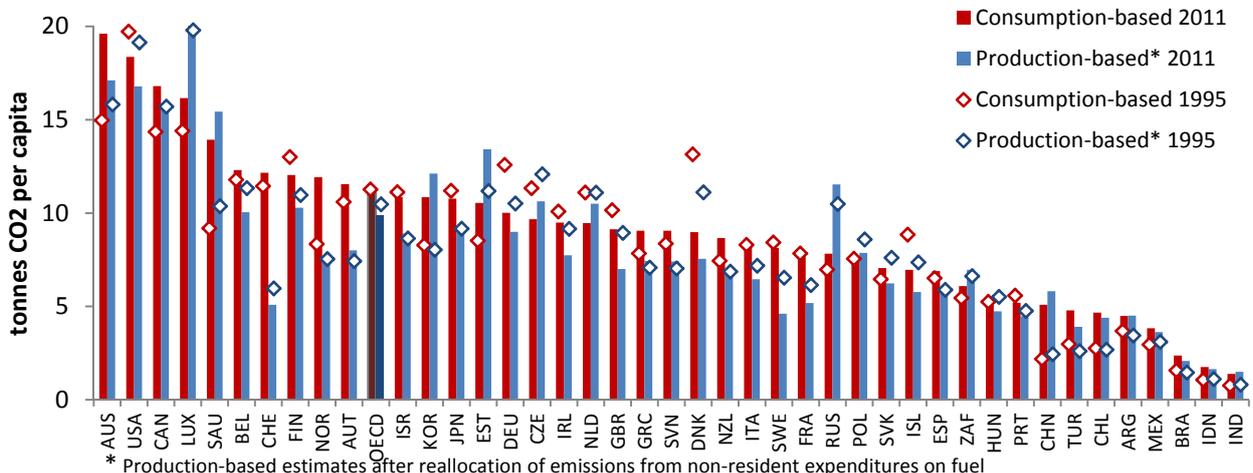
The evolution of production-based and consumption-based carbon emissions over recent years is highlighted in Figure 2. While the OECD countries in total have been, and still are, net importers of embodied carbon (the solid blue line representing consumption-based emissions is above the dashed blue line representing production-based emissions), non-OECD countries are net-exporters. Note that by construction, the shaded blue (OECD net imports) and green (non-OECD net exports) areas have the exact same size, i.e. OECD net-imports are equal to non-OECD net-exports of embodied carbon.

Figure 2: CO₂ emissions from fuel combustion (OECD and non-OECD countries)



However, there are differences at the level of the individual country, with some OECD countries being net exporters, and some non-OECD countries being net importers. Figure 3 shows per capita production- and consumption-based emissions for all OECD and G20 countries. The countries are ordered according to consumption-based emissions in 2011. If the red bar representing consumption-based emissions is taller than the blue bar representing production-based emissions, the country is a net-importer of CO₂ emissions. This reveals that the Netherlands and Korea are, for example, net-exporter of emissions and Brazil is a net-importer of emissions. However, the difference in per capita emissions between OECD and non-OECD countries remains large.

Figure 3: Per capita CO₂ emissions from fuel combustion



* Production-based estimates after reallocation of emissions from non-resident expenditures on fuel

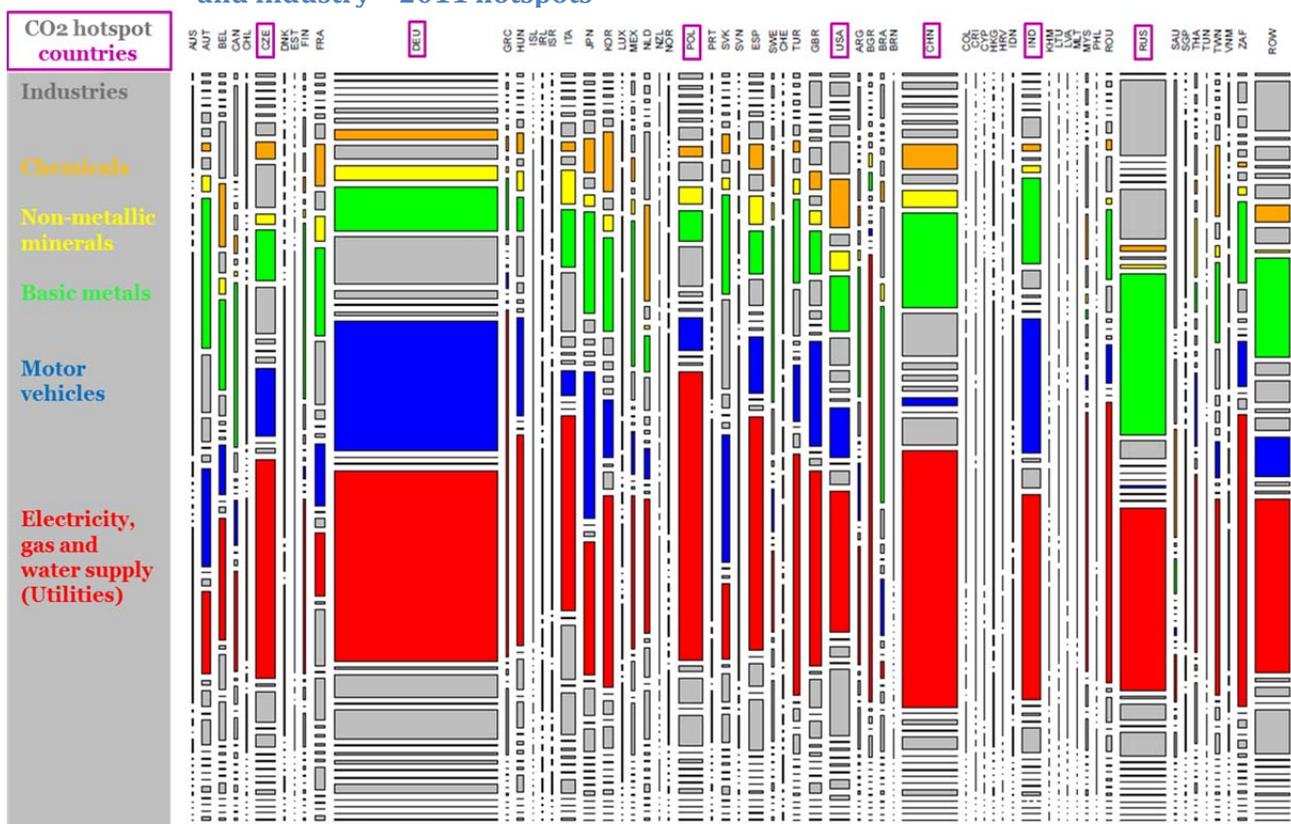
Results at country and industry level

Figure 4 displays the origin of emissions embodied in Germany’s demand for motor vehicles by source industry (vertical axis) and source country (horizontal axis): identifying “CO₂ hotspots”

The coloured rectangles represent those industries which have the highest share of emissions embodied in the motor vehicles bought by final consumers in Germany: chemicals, non-metallic minerals, basic metals, motor vehicles and electricity, gas and water supply. Encircled in pink are those countries mainly responsible for the CO₂ emissions embodied in Germany’s final demand for motor vehicles: Czech Republic, Poland, United States, China, India and Russia. The data set also allows analysis across other dimensions e.g. the final demand industries and countries using CO₂ emitted by Australia’s basic metals industry, for any year between 1995 and 2011.

Such measures are valuable complements to production-based emissions accounting in policy discussions. On the one hand, understanding the origins of CO₂, emitted along global production chains, to meet a country’s final demand can provide insights regarding both the effectiveness of national and regional (e.g. EU ETS) policy initiatives for decreasing CO₂ emissions. On the other hand, such measures also provide valuable information to facilitate international cooperation in mitigation efforts.

Figure 4: Germany’s demand for motor vehicles – origin of emissions by country and industry – 2011 hotspots



Data and Methodology

The origins of emissions embodied in final demand can be estimated using OECD’s Inter-Country Input-Output (ICIO) system using a similar methodology to that used for estimating the origins of value added embodied in final demand for the Trade in Value Added (TiVA) Database. The OECD has been developing and regularly updating estimates of consumption-based CO₂ emissions since the mid-1990s (Wyckoff and Roop, 1994; Ahmad and Wyckoff, 2003; Nakano et al., 2009; OECD, 2011; GGKP; 2013).

The mathematical notation builds on input-output theory. **B** and **y** are part of the OECD ICIO tables and are used to calculate the TiVA indicators as well. Instead of multiplying the matrices with value added to output ratios, to calculate embodied emissions, the matrices are multiplied by emission factors (ef): that is CO₂ emissions in kt (or Mt, some physical unit) per unit of industry output. These emissions factors are different for all industries in all countries. They are estimated by combining IEA CO₂ emissions from fuel combustion statistics and data from the ICIO. In addition, we need to consider direct emissions of final demand, i.e. residential emissions (e.g. domestic use of gas oven / stove / water boiler) and emissions from private road transport.

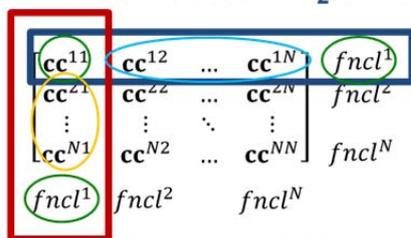
$$CO_2 \text{ emissions}_{c,i,p} \mathbf{cc} = \mathbf{ef} \mathbf{B} \mathbf{y} + \mathbf{fncl} \text{ direct emissions of final demand}$$

IEA CO₂ emissions from fuel combustion & OECD ICIO
OECD ICIO

$$ef_{c,i} = \frac{Emissions_{c,i}}{Output_{c,i}}$$

- B** = $(\mathbf{I} - \mathbf{A})^{-1}$ Global Leontief inverse matrix
- efB** Emissions multiplier matrix
- y** Global final demand { Domestic final demand
Foreign final demand
- c, p** Country, partner country
- i** Industry

Production-based CO₂ emissions



Consumption-based CO₂ emissions

cc matrix of CO₂ emissions by country, industry and partner
fncl direct emissions of final demand

The matrix **CC** has the same dimensions as the global final demand matrix and needs to be read as follows: Encircled in green is domestically emitted CO₂ which is also embodied in domestic consumption and the direct emissions from final demand. Encircled in light blue is CO₂ emitted domestically, but which is embodied in final demand of other countries. Thus, it is embodied in exports. Adding domestically produced and consumed and domestically produced and exported emissions gives production-based emissions: encircled in dark blue. Encircled in yellow is CO₂ emitted abroad, but embodied in domestic final demand. Adding domestically produced and consumed and CO₂ emitted abroad embodied in domestic final demand gives consumption-based emissions: encircled in red.

Links to data

- OECD embodied CO₂ emissions <http://oe.cd/io-co2>
- OECD Inter-Country Input Output tables <http://oe.cd/icio>
- OECD Trade in Value Added indicators <http://oe.cd/tiva>
- IEA CO₂ Emissions from Fuel Combustion <http://www.iea.org/statistics/topics/co2emissions/>

Contact

Send an email to stan.contact@oecd.org mentioning **Embodied CO₂** in the title of your message.

Literature

Ahmad, N. and A. Wyckoff (2003), "Carbon Dioxide Emissions Embodied in International Trade of Goods", OECD Science, Technology and Industry Working Papers, No. 2003/15, OECD Publishing, Paris, <http://dx.doi.org/10.1787/421482436815>.

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Wyckoff, A. and J. Roop (1994), The Embodiment of Carbon in Imports of Manufactured Products, Energy Policy 22(3), 187-194.