One third of the European Union's carbon footprint is due to its imports

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The European Union (EU) emits 1.5 times more greenhouse gases (GHG) per capita than the world average; the United States almost three times more. However, relative to their GDP, their GHG emissions are lower than the world average. The EU in particular emits less GHG to produce one euro of goods and services than any other geographical area. Within the EU, France's energy mix and, by extension, its overall production are less carbon intensive than that of its partners, notably Germany.

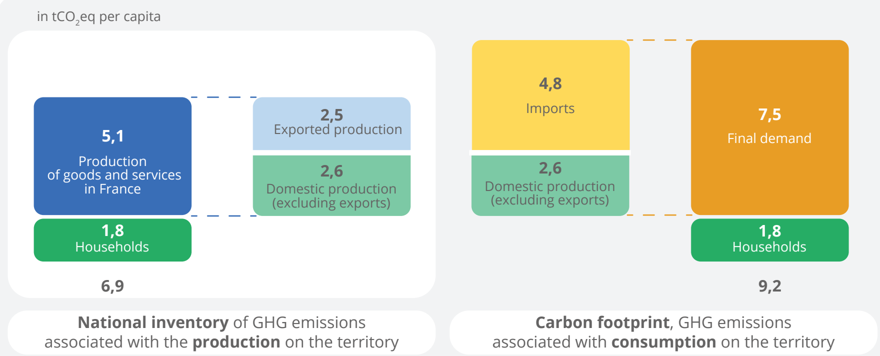
In the EU and the US, GHG emissions from final demand - the carbon footprint - are higher than emissions from production. Compared to the emissions inventory associated with production on a territory, the carbon footprint subtracts the emissions embodied in exported products but adds those embodied in imported products. In 2018, the EU's carbon footprint per capita was 11 tons of CO_2 equivalent, compared to 21 in the US and 8 in China. About one third of the EU's footprint was due to production processes located outside the EU.

Between 2000 and 2018, global GHG emissions increased by half when the population grew by a quarter. Emissions from the EU have decreased, but in China they have tripled during the same period of time.

Global **greenhouse gas (GHG)** emissions totalled 46.8 billion tons of CO_2 equivalent ($GtCO_2eq$) in 2018. These emissions are mainly produced through the use of fossil fuels (coal, natural gas and oil). They result from the economic and domestic (transport and housing) activities of households.

The geographical distribution of global emissions can be established using two methods: the first lists the emissions that are physically produced in a particular country. This method, known as the **national inventory**, is used for the international commitments of countries. The second method, referred to as the **carbon footprint**, measures the emissions associated with the consumption of products by the residents of a country, regardless of where those products were manufactured ► **Chart 1**. In this way, the production-related emissions of an exported good are attributed to the country of origin by the inventory method and to the consumer country by the carbon footprint method. It is possible to convert the inventory to the carbon footprint by subtracting the GHGs emitted domestically for exported products and adding the GHGs emitted abroad for imported products. The method used here to calculate the carbon footprint is particularly well-suited to highlighting these differences between inventory and carbon footprint, as it provides significant detail concerning imported emissions, their countries and sectors of origin and the link between the carbon contained within such imports and the value added imported ► **Methods**. Although there is a lot to be learned from the differences between these two indicators, it is the points that they have in common that provide the first elements of interest.

► 1. Greenhouse gas emissions, two methods: national inventory and carbon footprint



1 GHGs directly emitted by households, primarily linked to the combustion of fuel and fossil fuels for heating.
Notes: for rounding purposes, totals may differ to the nearest decimal place.
Reading note: it is possible to convert the inventory to the carbon footprint by subtracting the GHGs emitted domestically for exported products (2.5 tCO_2eq) and adding the GHGs emitted abroad for imported products (4.8 tCO_2eq).

In 2018, the Member States of the European Union (EU) accounted for 8.7% of global emissions according to the inventory method and 10.5% according to the carbon footprint method ► **Chart 2**. France accounted for 1.0% according to the inventory method and 1.3% according to the carbon footprint method. Italy is very similar to France, while Germany accounts for a larger share of the global inventory (2.1%) and the global carbon footprint (2.6%).

The share of emissions produced by the European Union appears to exceed its demographic weight, since the EU is home to just under 6% of the world's population. In other words, European countries produce more emissions per capita than the global average. However, the EU's share of global emissions is lower than its economic weight, measured by its GDP (gross domestic product) in terms of **purchasing power parity**, by around 16%.

From a qualitative point of view, the United States is in a similar situation to the European Union: its share of global emissions (12% according to the inventory method, 15% according to the carbon footprint method) is significantly higher than its demographic weight (a little more than 4%), but slightly lower than its economic weight (16%). However, the United States has much higher inventory and carbon footprint levels than the EU. Finally, China alone accounts for more than a quarter of global emissions, regardless of whether the inventory or carbon footprint method is used. This proportion not only exceeds its demographic weight (19%), but also its economic weight (17%).

Over the past two decades, there has been a degree of convergence at global level, with production becoming more economical in terms of GHG in developed economies that were previously heavy emitters ► **Box**. Conversely, China's emissions have increased dramatically, in spite of a slowdown beginning in 2014. In 2018, the carbon footprint of a Chinese citizen was 39% of that of an American citizen, compared with 12% in 2000. The gap between the European Union and the United States has also narrowed, but to a lesser degree: the carbon footprint of a person living in the EU increased from 48% of that of a person living in the United States in 2000 to 52% in 2018.

Many economies, such as the EU and, within it, France, have committed to significantly reducing their greenhouse gas emissions with a view to achieving carbon neutral status in 2050. In other words, they will not emit any more carbon than their territory absorbs *via* various carbon sinks (forests, soil, etc.). As their atmospheric CO_2 capture potential is limited, emissions must be reduced by more than 80% against the 2021 national inventory, provisionally estimated at 418 $MtCO_2eq$, in order to achieve annual emissions of around 80 $MtCO_2eq$ in 2050. These commitments therefore require a much more significant reduction in emissions over the next three decades (-80% between 2021 and 2050) than has been achieved over the last three decades (-23% between 1990 and 2021). France's commitment to reduce its GHG emissions by 55% in 2030 when compared to its 1990 level represents a 5.8% decrease in its emissions every year from 2022 to 2030; assuming that the 2030 target is met, achieving net zero emissions in 2050 equates to a 5.5% decrease in emissions each year from 2031 to 2050. The bar is high: the rate of reduction was 0.8% per year between 1990 and 2021 and 1.7% between 2005 and 2021.

In 2018, the carbon footprint of developed countries exceeded their inventory

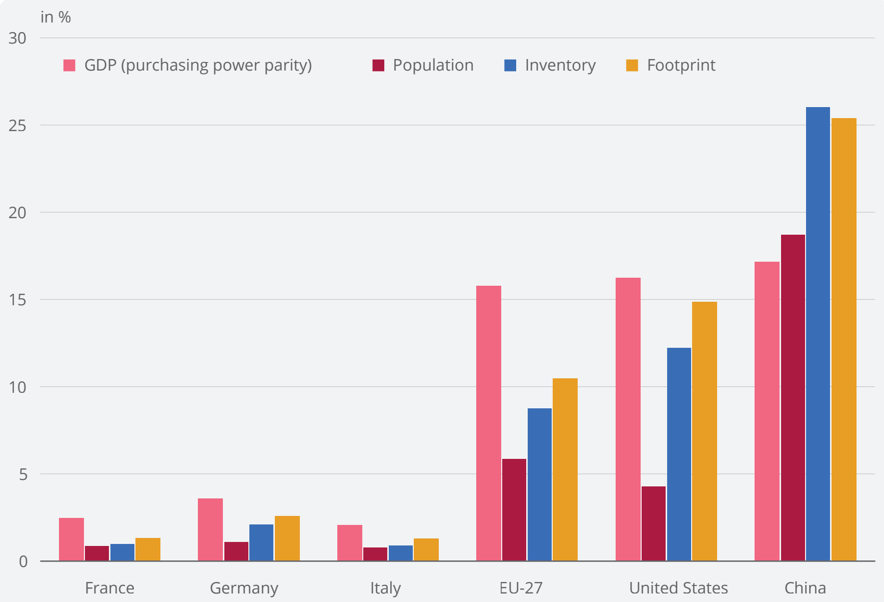
In 2018, global emissions reached 6.1 tCO_2eq per capita ► **Chart 3**. Direct household emissions accounted for 10% of this figure.

Across the EU-27 as a whole, in 2018, the inventory (9.2 tCO_2eq per capita) was lower than the carbon footprint (11.0 tCO_2eq per capita), since the bloc exported fewer GHGs (3.3 tCO_2eq per capita) than it imported (5.1 tCO_2eq per capita). The inventory per capita in the United States is by far the highest: 17.5 tCO_2eq. With the exception of China, all of the economies studied have a carbon footprint that is larger than their inventory, with the differences ranging from 1.8 tCO_2eq per capita for the EU to 3.8 tCO_2eq for the United States, indicating that they are net importers of GHGs. In China, the carbon footprint is slightly lower than the inventory at 8.3 tCO_2eq per capita compared with 8.5 tCO_2eq per capita. Moreover, direct emissions from China account for a smaller share of the carbon footprint than elsewhere (4%).

France sets itself apart with non-exported production that is particularly low in greenhouse gas emissions due to the importance of nuclear in electricity production. Half of the GHGs emitted by French production are exported: this is the highest proportion seen across all of the economies studied. Seen from another angle, the share of imported GHGs in the carbon footprint (excluding direct household emissions) is higher than elsewhere at around two-thirds.

An analysis of the discrepancies between the inventory and the carbon footprint indicates that there are two determining factors: the intensity of emissions (which will determine the quantity of GHGs emitted during production) and the flow of trade between geographical zones (which explains the switch from inventory to carbon footprint).

► 2. Distribution of GDP, the population, the inventory and the carbon footprint of different countries in 2018



Notes: GDP is measured in terms of purchasing power parity in 2017 euros; emissions are measured in tCO_2eq.
Reading note: France's GDP accounted for 2.5% of world GDP in 2018.
Sources: OECD ICIO IIOT database, emissions data taken from Exiobase 3 and the OECD, GDP data from the World Bank and Eurostat, population data from the OECD and Insee calculations.

► Box – Changes in GHG emissions and their determinants between 2000 and 2018

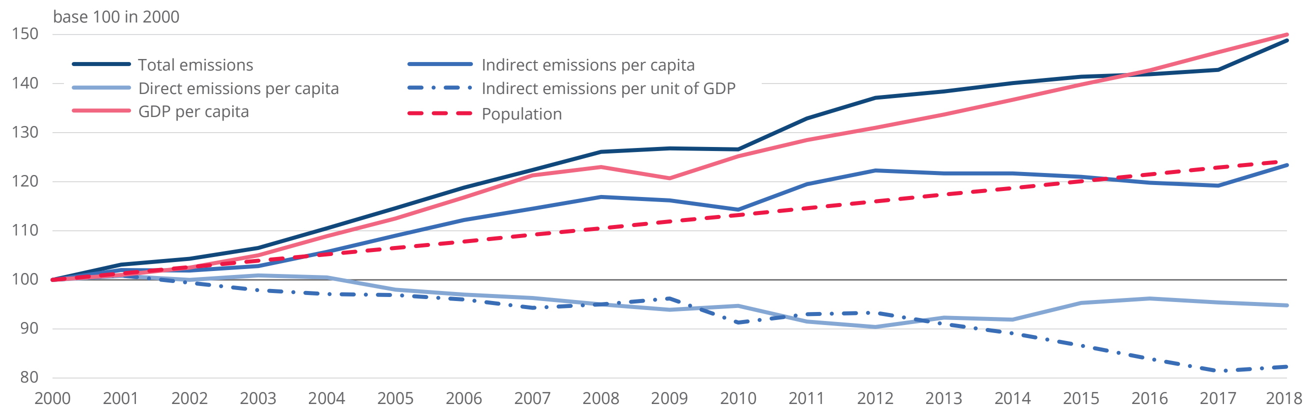
Between 2000 and 2018, global greenhouse gas emissions increased by half, twice faster than global population growth

Between 2000 and 2018, global GHG emissions increased by 49% ► **Chart A**. Between these two dates, the global population grew by 24%, with emissions per capita increasing by 20%. Global emissions continued to increase throughout this period, without any obvious break in the trend, although periods of acceleration and slowdown can be observed, such as the stabilisation of emissions in 2009–2010 linked to the financial crisis and its economic fallout.

The emissions associated with production processes, referred to as indirect emissions, can be distinguished from those directly emitted by households for their travel and heating requirements ► **Methods**. Between 2000 and 2018, indirect emissions per capita increased by 23%. They are linked to economic activity, so it is natural to consider them in relation to GDP. They can therefore be viewed as the product of indirect emissions per unit of GDP (emission-intensity of GDP) and GDP per capita. The first factor, which measures the GHG content of GDP (GHG emissions required to produce one unit of GDP), has fallen by 18%. This has helped to reduce the carbon footprint. Conversely, the second factor, GDP per capita, has increased significantly (+50%), which has contributed to an increase in the carbon footprint. The second effect prevails, which explains the increase in emissions linked to production.

Between 2000 and 2018, direct emissions per capita fell by 5%, helping to reduce the carbon footprint, but only to a limited extent due to their moderate weight: in 2018, at global level, direct emissions accounted for 10% of the carbon footprint.

Chart A – Changes in global greenhouse gas emissions and their determinants between 2000 and 2018



Notes: the values are in base 100 in 2000. GDP is measured in terms of purchasing power parity in 2017 constant dollars; emissions are measured in tCO_2eq.
Reading note: global GHG emissions increased by 48.8% between 2000 and 2018, while the global population increased by 24.2%.
Sources: OECD ICIO IIOT database, emissions data taken from Exiobase 3 and the OECD, GDP data from the World Bank and Eurostat, population data from the OECD and Insee calculations.

Between 2000 and 2018, the GHG emissions produced by China tripled, while they fell in developed countries

The increase in global GHG emissions is the result of contrasting developments across the various economic zones. Between 2000 and 2018, inventories fell by 6% in the European Union and the United States, while they practically tripled in China ► **Chart B**. Within the EU, the rates of decline varied between the three largest economies: -19% in Italy, -11% in France, -5% in Germany.

The contribution of the per capita emissions largely explains the differences in the changes that have taken place in different countries. These per capita GHG emissions are increasing sharply in China, whereas they are falling in the other countries studied. In France, Germany, Italy and the United States, direct household emissions per capita have fallen, bringing about a drop in emissions of around 4 to 5 points per capita. Conversely, they have doubled in China, contributing to a 5 points increase in per capita emissions. The spectacular increase in the standard of living in China, which saw GDP per capita quadruple during the period in question, materialized in a sharp increase in indirect emissions per capita. In developed countries, unlike the homogeneous profile of direct emissions per capita, indirect emissions per capita have evolved differently: their contribution is -19 points in Italy, -16 points in France and the United States and -1 point in Germany (-8 points for the EU as a whole).

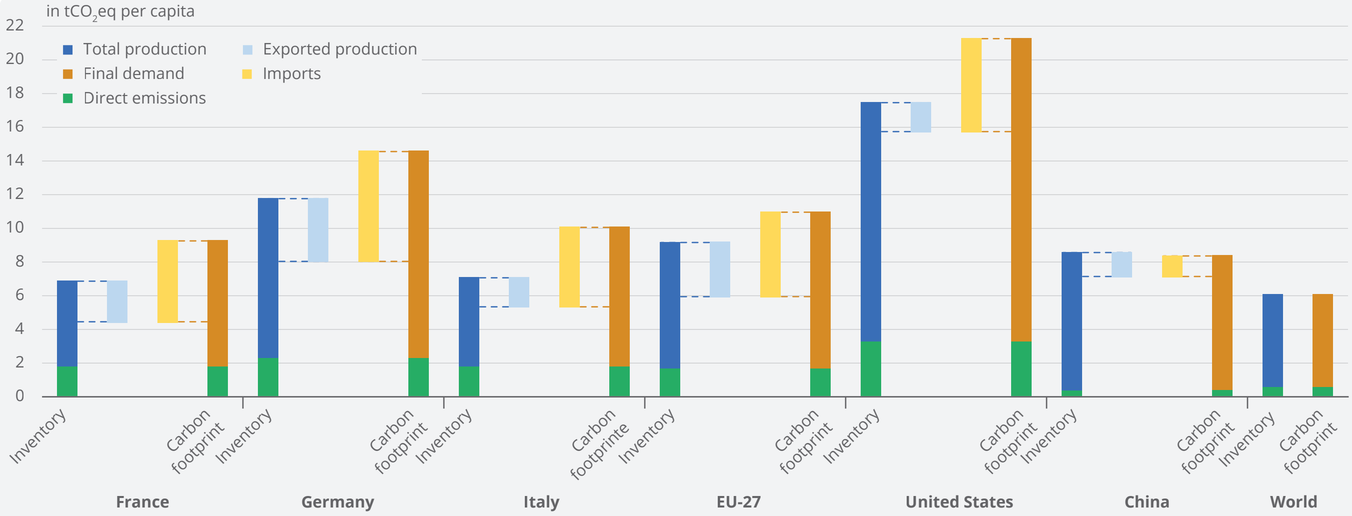
Demography also explains some of these changes. Demographic growth has contributed to the increase in emissions, particularly in China, the United States and France, where population growth between 2010 and 2018 exceeded 10%, but has had very little impact in Germany, where the growth rate is barely 1% ► **Methods**.

Chart B – Breakdown of the changes in the greenhouse gas inventory between 2000 and 2018

		France	Germany	Italiy	EU-27	United States	China	World
(1) = (2) + (3)	**Total emissions (%)**	**– 10,7**	**– 4,6**	**– 19,1**	**– 6,4**	**– 6,2**	**175,0**	**48,8**
(2)	Population (in percentage points)	9,4	0,8	4,6	3,9	14,3	18,5	**26,6**
(3) = (4) + (5)	Total emissions per capita (in percentage points), of which :	– 20,2	– 5,4	– 23,7	– 10,3	– 20,5	156,5	**22,2**
(4)	*Direct emissions per capita*	*– 4,4*	*– 4,6*	*– 4,2*	*– 1,9*	*– 4,9*	*5,5*	*– 0,7*
(5) = (6) + (7)	*Indirect emissions per capita, of which:*	*– 15,7*	*– 0,8*	*– 19,4*	*– 8,4*	*– 15,6*	*151,0*	*22,9*
(6)	*Indirect emissions per unit of GDP*	*– 25,0*	*– 17,9*	*– 18,5*	*– 27,1*	*– 32,4*	*– 119,7*	*– 22,1*
(7)	*GDP per capita*	*9,3*	*17,1*	*– 1,0*	*18,6*	*16,7*	*270,7*	*45,1*

Note: GDP is measured in terms of purchasing power parity in 2017 constant dollars, and emissions are measured in tCO_2eq.
Reading note: France's GHG inventory fell by 10.7% between 2000 and 2018, with population growth contributing to a 9.4 percentage point increase and a decrease in per capita emissions contributing to a 20.2 percentage point decrease.
Sources: OECD ICIO IIOT database, emissions data taken from Exiobase 3 and the OECD, GDP data from the World Bank and Eurostat, population data from the OECD and Insee calculations.

► 3. From inventory to carbon footprint, GHG emissions per capita in 2018



Reading note: in total, French production emits 5.1 tCO_2eq per capita, of which 2.5 are exported. France imports 4.8 tCO_2eq per capita, which brings its carbon footprint, excluding direct household emissions, to 7.5 tCO_2eq per capita.
Sources: OECD ICIO IIOT database, emissions data taken from Exiobase 3 and the OECD, GDP data from the World Bank and Eurostat, population data from the OECD and Insee calculations.

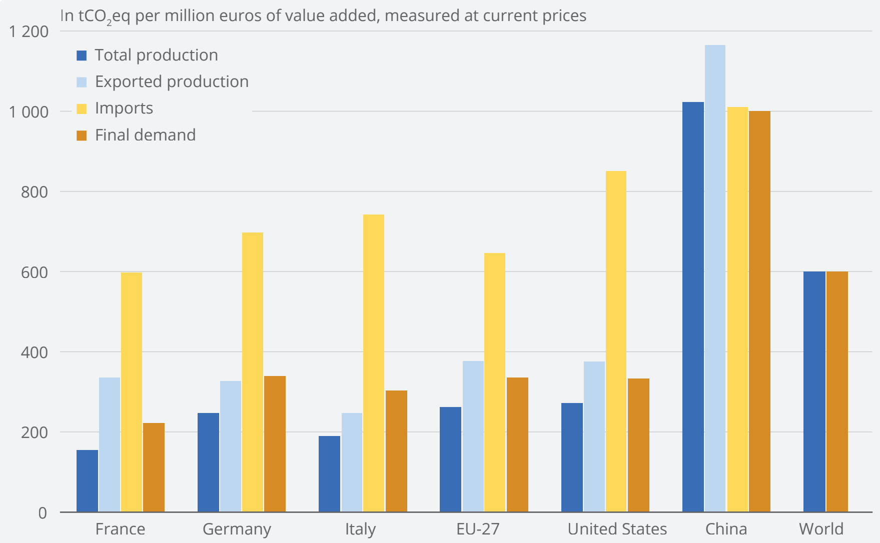
Lower-carbon production in developed countries

On a global scale, producing one million euros of value added resulted in average emissions of 600 tCO_2eq in 2018. This GHG content or GHG intensity of production varies greatly from one country to the next. For example, China has a very high GHG intensity, at 1,000 tCO_2eq, which is two-thirds higher than the global average ► **Chart 4**. The United States and the EU have much lower intensities, close to 45% of the global average. German production is the most carbon intensive of the top three economies in the EU, followed by Italy and France.

The differences in the carbon intensity of production in different countries have two possible explanations: a production structure that is centred to a greater or lesser degree on sectors with high GHG emissions (structure effect) and, where production structures are comparable, variations in the GHG intensity of production (energy efficiency and GHG intensity of the energy consumed).

Three observations can be made. Firstly, in all countries, the GHG content of production is high in the case of energy production, moderate for industry/agriculture and lower for services ► **Chart 5**. Having a small share in the value added for energy production and industry/agriculture therefore contributes to reducing the GHG intensity of production through the structure effect. A notable example of this situation is France. Conversely, these highly carbon-intensive sectors have a higher weighting in China than elsewhere, contributing to more GHG-intensive production.

► 4. GHG emission intensity of production, exports, imports and final demand in 2018

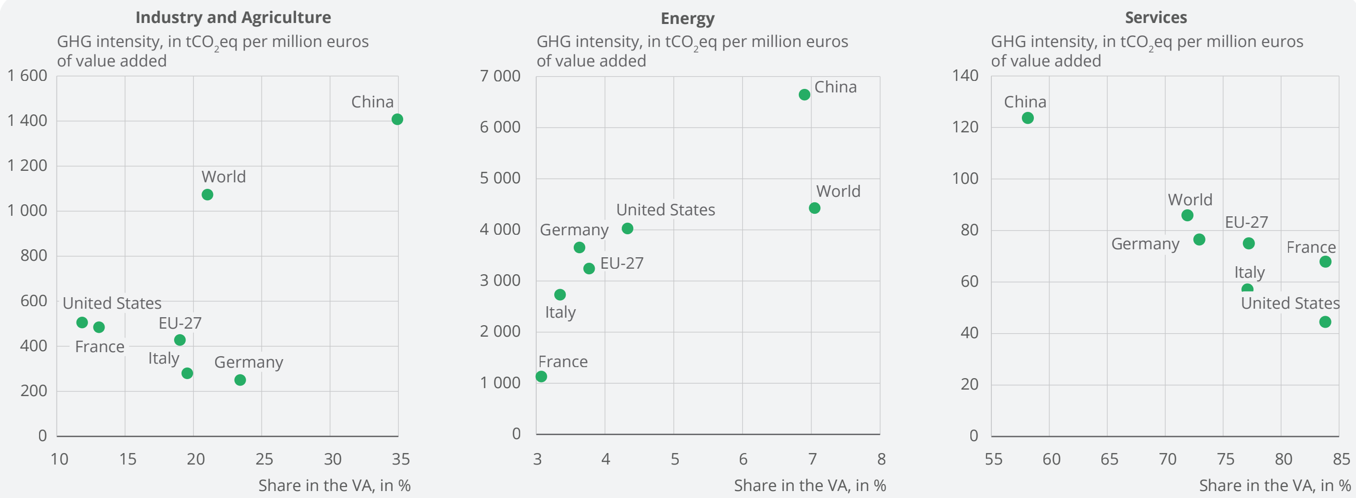


Reading note: French production emits 155.2 tCO_2eq per million euros of value added. One million euros of final demand contains 221.5 tCO_2eq.
Sources: OECD ICIO IIOT database, emissions data taken from Exiobase 3 and the OECD, GDP data from the World Bank and Eurostat, population data from the OECD and Insee calculations.

Secondly, the production intensity of a particular sector differs significantly from country to country. China emits more GHGs across all sectors to produce one euro of value added. As a result, in this country, the two components, namely the structure effect and the GHG intensity of production in each sector, contribute to a significantly elevated GHG content when compared with production elsewhere. For its part, when it comes to energy production, France has the lowest emissions of the countries studied, with a GHG intensity that is three times lower than those of Germany and the United States: its energy mix is less carbon-intensive due to the higher share of nuclear energy.

Finally, international trade involves products with relatively high GHG content. Indeed, international trade more often concerns industrial, agricultural or energy goods and less often concerns services. In addition, some of the products imported by developed countries are manufactured in areas where production is more GHG-intensive, such as China. Indeed, the emissions incorporated in imports correspond to those generated throughout the value chain of those products, including the production of their intermediate consumption. This contributes to the fact that, outside of China (and some other countries that are not isolated here), one euro of final demand contains more greenhouse gas emissions than one euro of value added.

► 5. Greenhouse gas intensity and share in the value added of each sector in 2018



Notes: the energy sector includes the extraction of raw energy materials, coking and the refining of petroleum products, and ultimately, electricity, gas and waste management. The industry and agriculture sector includes the manufacturing industry, excluding coking and refining, together with agriculture, forestry and fishing. Services incorporate the remaining sectors.
Reading note: in France, in 2018, the energy sector represented 3.1% of total value added and the greenhouse gas intensity reached 1,132.1 tCO_2eq per million euros of value added.
Sources: OECD ICIO IIOT database, emissions data taken from Exiobase 3 and the OECD, GDP data from the World Bank and Eurostat, population data from the OECD and Insee calculations.

A third of the EU's carbon footprint results from its imports, compared with a quarter for the United States

Although the inventory of an economy only reflects the GHG intensity of its domestic production, the carbon footprint depends on the GHG intensity of all of the world's countries due to the emissions incorporated into imports. By analysing international production chains, it is possible to describe in detail the geographical origin of the emissions incorporated into the goods and services imported.

The EU-27, the United States and China are three relatively closed economic zones, in the sense that 85% of their final demand is satisfied from within each of these zones (in the case of the EU, this figure does not represent the average of each of the 27 countries, but that of the Union taken as a whole) ► Chart 6. It is therefore hardly surprising that the majority of emissions linked to their final demand are produced domestically. That being said, production in the EU and, to a lesser extent, the United States, is less carbon-intensive than in many of their trading partners. This explains why, when direct household emissions are disregarded, 40% of the EU's carbon footprint comes from its imports. This share is 31% for the United States, compared with just 14% for China, in line with the imported share of final demand. When direct household emissions (which are emitted domestically) are added to this, the share of imported emissions in the carbon footprint is 33% in the EU (of which 5.5% is from China and 1.8% from the United States), 26% in the United States and 14% in China.

► 6. Breakdown of carbon footprint and final demand by source in 2018

a. Carbon footprint (excluding direct household emissions)

in % (unless otherwise stated)

	EU-27	China	United States	Rest of the world	*Inventory ($MtCO_2eq$)*
UE-27	60,4	0,9	2,2	2,9	***3 327***
China	6,5	85,5	7,1	6,1	***11 668***
United States	2,2	0,7	68,7	2,1	***4 637***
Rest of the world	31,0	12,9	22,0	89,0	***22 449***
Footprint ($MtCO_2eq$)	***4 140***	***11 382***	***5 876***	***20 708***	***42 105***

b. Final demand

in % (unless otherwise stated)

	EU-27	China	United States	Rest of the world	*Value added (in billions of euros)*
UE-27	85,2	2,3	2,5	5,3	***12 726***
China	2,0	85,7	2,2	3,6	***11 417***
United States	2,5	1,7	87,8	3,8	***17 084***
Rest of the world	10,2	10,3	7,6	87,4	***28 987***
Final demand (in billions of euros)	***12 334***	***11 383***	***17 644***	***28 853***	***70 214***

c. Carbon footprint with direct emissions

in % (unless otherwise stated)

	EU-27	China	United States	Rest of the world	*Inventory ($MtCO_2eq$)*
UE-27	66,6	0,8	1,9	2,6	***4 095***
China	5,5	86,1	6,0	5,4	***12 179***
United States	1,8	0,7	73,6	1,9	***5 714***
Rest of the world	26,1	12,4	18,6	90,1	***24 820***
Footprint ($MtCO_2eq$)	***4 905***	***11 886***	***6 950***	***23 066***	***46 808***

Notes: the rows represent the countries of origin of the emissions and the columns the countries in which the carbon footprint or final demand are being broken down. The carbon footprints and inventories are given in $MtCO_2eq$, while final demand and value added are given in billions of euros. The calculations are performed in current dollars, converted into current euros, for the year 2018. Unlike Figure 2, which makes use of GDP in purchasing power parity, final demand and value added are expressed in euros.
Reading note: in 2018, 6.5% of the carbon footprint of the EU-27, excluding direct household emissions, was emitted in China, while 2.0% of the value added making up the final demand of the EU-27 originated in China. 66.6% of the carbon footprint of the EU-27, including direct household emissions, were emitted in the EU-27.
Sources: OECD ICIO IIOT database, emissions data taken from Exiobase 3 and the OECD, GDP data from the World Bank and Eurostat, population data from the OECD and Insee calculations.

For the United States and the EU, the share of GHG flows from China in the carbon footprint is roughly the same (around 7% excluding direct household emissions) and significantly higher than China's share of final demand (around 2%). The flows in the opposite direction are low (less than 1%). Finally, the amount of GHGs being exchanged between the EU and the United States is relatively small at 2% in both cases.

A higher proportion of the carbon footprint is imported in France than in Germany

A trade surplus can be accompanied by a 'GHG deficit', in the sense that the GHGs contained within the imports (and emitted abroad) are higher than the GHGs contained within the exports (and emitted domestically). As a result, in Germany, the Netherlands and, to a lesser extent, Italy and Spain, the value added exported exceeds that which is imported, while these four countries are net importers of GHGs.

The proportion of the carbon footprint that is imported is highly variable among European countries. There are two factors at play here: on the one hand, the degree of openness to international trade (the more open a country is, the more goods and services it imports and the more it imports the GHGs necessary for their production), on the other hand, the GHG content of the goods and services that the country imports relative to those that it produces.

In 2018, the share of the carbon footprint imported from countries outside of the EU was 33% in Germany (very close to the European average), which was lower than in France (39%) ► **Chart 7**. The inclusion of imports from EU countries has little impact on the finding: in 2018, the proportion of the carbon footprint that was imported was 46% in Germany and 52% in France. This seven-point gap (without rounding) reflects, on the one hand, the trade balances, since, unlike Germany, France imports more than it exports. On the other hand, production is significantly less carbon-intensive in France than in Germany, so the share of imported emissions in its carbon footprint is automatically higher. However, in terms of their level, imports of GHGs are lower in France than in Germany (4.8, versus 6.6 tCO_2eq per capita).

The imported share of the carbon footprint of EU countries varies from 26% to 85%. Poland, which has a carbon-intensive energy mix, has the smallest proportion. At the opposite end of the spectrum, Malta, a small country that is very open to international trade, has the highest proportion of imports in its carbon footprint in the EU. Luxembourg, where the services sector is highly developed, imports two-thirds of its carbon footprint. The situation in countries with large populations, such as Germany, Spain, Italy and France, is moderate.

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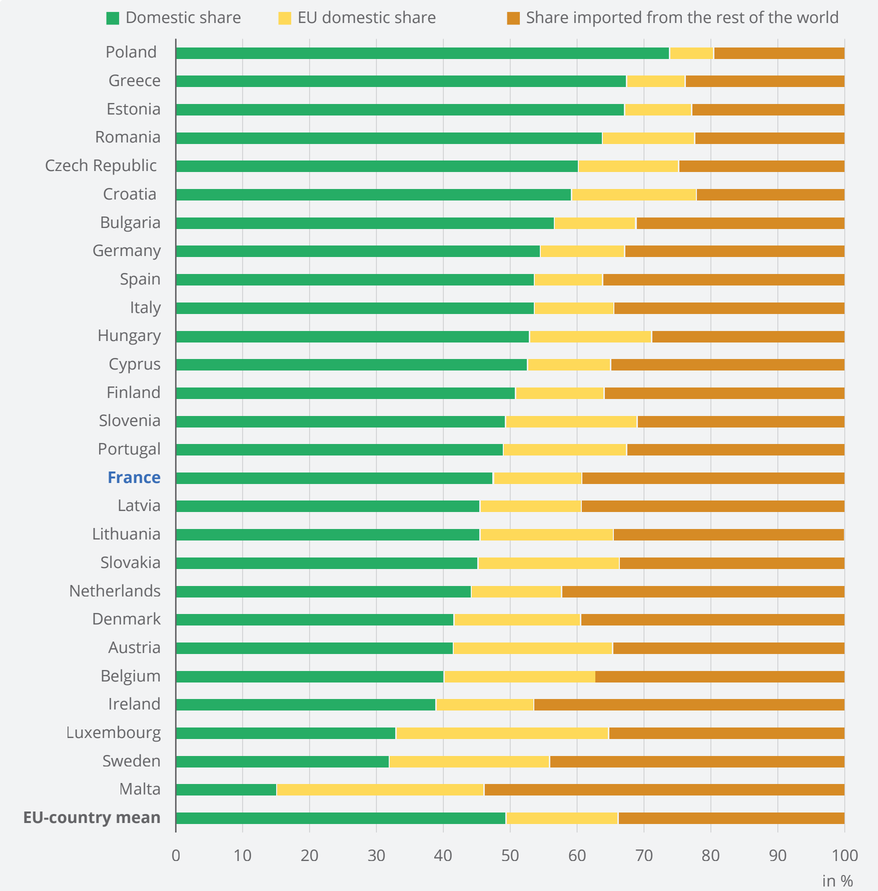
► 7. Origin of the carbon footprint of EU countries in 2018



Notes: the average for the EU countries is a simple average of the shares of the 27 Member States.
Reading note: in 2018, 47.5% of France's carbon footprint was emitted domestically, 13.2% in the rest of the EU and 39.3% in the rest of the world.
Sources: OECD ICIO IIOT database, emissions data taken from Exiobase 3 and the OECD, GDP data from the World Bank and Eurostat, population data from the OECD and Insee calculations.

► Methods

The carbon footprint associates with each product the GHGs emitted during the various stages of its production. This can be calculated using input-output modelling, which links the resources and uses of each economic product in INSEE's national accounts input-output table (IOT). The resources and uses of the economy are linked by the intermediate consumption matrix, a key element in the modelling that describes the intermediate inputs of the national production process, regardless of whether they are domestic or foreign. Input-output modelling is extended in inter-country format within multi-regional databases (such as the OECD ICIO tables), thereby describing all transnational relations, regardless of whether they are direct relations (for example, the direct purchase of a finished product imported from Germany by a French household) or indirect relations (for example, the purchase of Spanish raw materials by a French company as an input for its production process in order to meet French final demand). More specifically, they provide information on the intermediate consumption of each sector within each country of products of all sectors across all countries. These multi-regional databases make it possible to carry out 'global value chain' calculations, i.e. calculations that describe the emissions associated with each stage of the transformation of a product throughout the value chain. This methodology therefore makes it possible to take account of the fact that imported goods can have a higher or lower carbon content depending on whether the production technology used in each of the countries contributing to the production of a given product is more or less carbon-intensive.

The production by country *i* within sector *k* can be used in a number of ways: as intermediate consumption by a sector within the same country or in a different country (which therefore constitutes an export of intermediate consumption from *i* to that other country), as final demand within country *i* or in another country (export of final goods from *i* to that other country). Therefore, if we use *P* to denote the vector of global production by sector in terms of value (by stacking production per sector for the various countries), Df_j as the vector of the final demand of country *j* in each sector of each country, and *CI* as the square matrix of intermediate consumption in value ($CI_{(i,k),(j,l)}$ provides information regarding the amount of product *k* from country i that sector *l* in country j uses as intermediate consumption), the balance of resources and uses of the production of sector *k* within country *i* in terms of the global economy is: $P_{(i,k)} = \Sigma_{(j,l)} CI_{(i,k),(j,l)} + \Sigma_j DF_{(i,k),j}$. DF_j aggregates the various components of final demand, in particular household consumption, business investment or inventory changes.

When intermediate consumption $CI_{(i,k),(j,l)}$ is divided by production in sector *l* in country *j* $P_{(J,L)}$, the result is coefficients $A_{(i,k),(j,l)}$, which form the square matrix *A* of the technical coefficients of the input-output table. This matrix indicates, for example, how much a sector consumes as an intermediate product from other sectors within the scope of its production process in order to produce one unit. Where *n* is the number of sectors and *p* is the number of countries, the dimension of vectors *P* and DF_j is $(n \times p, 1)$, and the dimension of matrices *A* and *CI* is $(n \times p, n \times p)$. Where $CI_{(i,k),(j,l)}$ is replaced with $A_{(i,k),(j,l)} P_{(j,l)}$ in the balance of resources and uses, and where the matrix that allows the transition from final demand to production to take place is denoted as *L* (inverse Leontief matrix defined by $L = (I - A)^{-1}$), we obtain $P - A \cdot P = \Sigma_j DF_j$, or $P = L \cdot \Sigma_j DF_j$.

By pre-multiplying the two elements of the latter equation by E', the line vector of dimension (1, $n \times p$) made up of the ratio of the GHG emissions of a (country, sector) pairing to the production of that (country, sector) pairing, and by noting Ed_j, the number corresponding to the direct household emissions of country *j*, we arrive at the global greenhouse gas emissions, which can be broken down according to the inventories or carbon footprints of each country:

$$E' \cdot P + \Sigma_j Ed_j = E' \cdot L \cdot \Sigma_j DF_j + \Sigma_j Ed_j$$

$$\Sigma_j (\Sigma_k E'_{jk} P_{jk} + Ed_j) = \Sigma_j (E' \cdot L \cdot DF_j + Ed_j)$$

The inventory of country *j* is given by $\Sigma_k E'_{jk} P_{jk} + Ed_j$, and its carbon footprint by $E' \cdot L \cdot DF_j + Ed_j$.

Although this method differs from that adopted by the Statistical Data and Studies Service (*Service des données et des études statistiques* - SDES), the carbon footprint it provides for France is close to that produced by the SDES. The method used by the SDES to calculate the carbon footprint is based on the symmetrical IOT produced by INSEE, which distinguishes between a domestic share and a share for the rest of the world, without distinguishing between countries. The estimate of emissions for the rest of the world is based on the EU-level consolidated symmetrical IOT disseminated by Eurostat. Weightings allow European data to be adjusted to the specific features of several large geographical areas. However, unlike methods that make use of international input-output tables, this calculation does not create a 'global loop': imported emissions are allocated in full to the last importing country, without taking account of trade between the last importing country and the rest of the world.

Contribution of factors to the GHG inventory

The change in the GHG inventory from one year to the next is the sum of the changes in direct emissions *(Ed)* and those emitted during production processes *(Ei)*. If *Ei* is considered as the product of emissions per unit of GDP (*Ei/Q*, where GDP is denoted in PPP dollars in 2017, noted as Q), GDP per capita *(Q/P)* and the number of inhabitants *(P)*, and *Ed* as the product of direct emissions per capita and the number of inhabitants, we arrive at:

$$Ei + Ed = P \cdot (Ed/P + Ei/Q \cdot Q/P)$$

Changes to the inventory can be analysed according to the changes in each of the factors within this formula. In order to do this, the contributions are calculated. The contribution of *P* to increases in inventory is the increase in *Ei* + *Ed* resulting from the increase in *P*; this contribution differs from the growth of *P*.

There are different ways of calculating these contributions for a product of factors; we use the mean of two additive decompositions, polar decompositions, which closely replicates the change in the principal variable [Dietzenbacher, Los, 1998]. Ultimately, the variation in the inventory between two dates is broken down into 4 contributory factors:

Δ(*Inventory*) = contribution(*Population*) + contribution(*Direct emissions per capita*) + contribution(*Indirect emissions per unit of GDP*) + contribution(*GDP per capita*).

► Sources

The data used to calculate the carbon footprint are made up of two components: (1) an international Input-Output Table (IIOT) and (2) a database of greenhouse gas emissions. The database chosen for the IIOT is the OECD ICIO tables (November 2021 version) in which some countries have been aggregated within the 'rest of the world' geographical area in the interest of only including the Exiobase countries (i.e. 45 countries, including a 'rest of the world' zone). This database covers the years 1995 to 2018, with 45 sectors. The economic flows described in these international input-output tables are converted into a common unit, the current dollar [OECD, 2021] **► Methods**. The emissions database used is Exiobase 3 (version 3.8 from November 2020), which covers emissions of the three main greenhouse gases (carbon dioxide, methane and nitrous oxide) for the years 1995 to 2018. The Exiobase 3 emissions database is initially broken down into 163 sectors, aggregated here into 45 sectors corresponding to those in the ICIO tables using the weighted conversion tables (specific weighting for each EU country and mean EU weighting for the remaining countries, including the rest of the world). Data concerning direct household emissions are taken from the OECD air emission accounts and list all greenhouse gases. The inventory and carbon footprint are both measured net of land use, land-use change and forestry (LULUCF), which absorbed 3.5 $GtCO_2eq$ from the atmosphere in 2018 [UNEP, 2019]. Emissions data, at the format of air emission accounts, are expressed according to the concept of residence.

Gross domestic product (GDP) data are expressed in terms of purchasing power parity in 2017 constant dollars and are provided by the World Bank. Population data are provided by the OECD.

The economies studied are France, Germany, Italy, the EU-27, the United States, China and the world as a whole.

► Définitions

The **greenhouse gases (GHGs)** taken into account here are carbon dioxide (CO_2), methane, nitrous oxide and four fluorinated gases (halocarbons). Greenhouse gas emissions are expressed in tons of CO_2 equivalent (tCO_2eq), where the equivalence takes account of the 100-year warming potential specific to each gas, as per the standards set by the United Nations.

The **national inventory** (in UNFCCC format) calculates the quantities of greenhouse gases physically emitted within the country (territorial approach) by households (vehicles and dwellings) and economic activities (consumption of fossil fuels, industrial processes and agricultural emissions). Inventory data, drawn up each year to meet the standards of the United Nations Framework Convention on Climate Change (UNFCCC) are the most commonly used. They are currently the preferred method for monitoring national policies and for drawing international comparisons. The national inventory (in the format of air emission accounts) is based on an inventory in UNFCCC format, but which classifies the sources of emissions into 64 sectors of activity and, in the case of transport, takes account of the residence principle: emissions produced by French people abroad are included and those produced by foreign visitors to France are excluded.

The **carbon footprint** represents the amount of greenhouse gases (GHG) produced in connection with domestic final demand within a country (household consumption, public administrative bodies and non-profit organisations and investment), regardless of whether the goods or services consumed are produced domestically or imported.

The carbon footprint is therefore made up of:

• GHGs emitted directly by households (primarily in connection with the combustion of fuel for private vehicles and the combustion of fossil fuels to heat homes);

• GHG emissions associated with the domestic production of goods and services for the purposes of satisfying domestic demand (i.e. excluding exports);

• GHG emissions associated with imported goods and services, for intermediate consumption by companies or for final usage by households.

The latter two items constitute indirect GHG emissions. Taking the inventory method as a starting point, the carbon footprint is calculated by adding the GHG emissions resulting from the production of imported goods and subtracting the GHG emissions caused by the production of exported goods in France ► **Chart 1**.

The example of GHG emissions linked to fuels helps to illustrate these concepts. The GHGs emitted during the extraction, transportation and refining of such fuels are accounted for as indirect emissions in the inventory of the countries performing the various activities. They will also be accounted for as indirect emissions in the carbon footprint of the country that consumes those fuels. The GHGs emitted during the use of the fuels in question by households (for example for the purposes of transport or heating) are counted as direct emissions in both the inventory and the carbon footprint of the country using them.

Purchasing Power Parity (PPP) is a monetary conversion rate that allows the purchasing powers of different currencies to be expressed as a common unit. This rate expresses the differences in the quantity of monetary units needed in different countries to buy the same 'basket' of goods and services.

► Pour en savoir plus

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