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End-user GHG emissions from energy

Reallocation of emissions from energy industries to end users 2005–2010

Summary

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European Environment Agency

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Summary

The objective of this report ([1]) is to help improve the understanding of past greenhouse gas (GHG) emission trends in the energy sector from the demand or end-user side. To do this, the report develops a methodology to redistribute emissions from energy industries to the final users (by sector) of that energy. This reallocation is done on the basis of Eurostat's energy balances and GHG inventories for the energy sector as reported to the United Nations Framework Convention on Climate Change (UNFCCC) for the period 2005–2010.

Background

The European Union (EU), as a party to the UNFCCC, reports annually on GHG inventories for the year t–2 (i.e. two years after the reference year) and within the area covered by its Member States. The European Environment Agency (EEA) is responsible for the compilation of the EU's GHG inventory to the UNFCCC. Trends in GHG emissions have traditionally been explained based on the sectoral classification used in UNFCCC reporting. This internationally-agreed reporting system requires Annex I Parties to estimate and report (territorial) GHG emissions using UNFCCC Guidelines and Intergovernmental Panel on Climate Change (IPCC) methods. Data are reviewed annually and are the basis for assessing progress towards GHG emission targets.

GHG emissions for the energy sector consist of two main blocks: energy combustion and fugitive emissions ([2]). For reporting purposes, the main combustion categories are: energy industries, manufacturing and construction, residential, commercial and agriculture/fishing/forestry. This means that, for example, emissions from the transformation of primary fuels in thermal stations to deliver heat and electricity to the residential sector are reported under energy industries, whereas emissions from the burning of coal in a stove by a household would be reported as part of emissions from the residential sector. The official sectoral breakdown based on UNFCCC provides no information on emissions from energy industries by end user.

This report develops a methodology to reallocate emissions from the energy transformation sector to the final users of energy. These end users are allocated a share of emissions from energy industries. For the purpose of this report, emissions from the energy transformation industries (and fugitives) which are reallocated to end users are termed 'indirect emissions'. This is different from the meaning of 'indirect emissions' in relation to GHG inventories covering carbon dioxide (CO_2) from the oxidation of methane (CH_4), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs) in the atmosphere. Emissions resulting from combustion activities as reported to UNFCCC are termed 'direct emissions'.

In essence, the end-user methodology splits direct and indirect GHG emissions by reallocating all GHG emissions from energy transformation industries to end users using final energy flows. End-use emissions allow a better understanding of the underpinning trends from the demand side by linking final energy use and GHG emissions. This is useful from a different policy perspective as, for example, policies to improve the insulation of residential buildings could reduce both direct and indirect emissions. Moreover, the method also highlights the relative importance and emission effects of trade in energy flows between EU Member States.

([1]) The present summary and the main report published alongside this summary are available at http://www.eea.europa.eu/publications/end-use-energy-emissions/ online.

([2]) Fugitive emissions are releases of GHGs from anthropogenic activities such as exploration, production, processing, transmission, distribution and storage of fuels. Combustion emissions are included here if they do not support a productive activity (e.g. flaring of natural gases at oil and gas production facilities).

Box 1 Policy context

The EU Climate and Energy package adopted by the European Council on 6 April 2009 represents the EU's response to limiting the rise in global average temperature to no more than 2 °C above pre-industrial levels. European Union leaders also agreed to the so-called '20-20-20' climate and energy targets:

i A reduction in EU GHG emissions of at least 20 % below 1990 levels;
ii 20 % of EU energy consumption to come from renewable resources;
iii 20 % reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

All sectors of the economy must contribute to the EU's objective of reducing GHG emissions by 20 % compared to 1990 by 2020. A single EU-wide cap on emission allowances under the EU Emissions Trading Scheme (ETS) will apply from 2013 and the number of allowances will be reduced by 21 % in 2020 compared to 2005. Emissions from sectors not covered by the EU ETS will be governed by the EU Effort Sharing Decision (ESD), where Member States agreed to binding national targets to reduce the EU's overall emissions from non-ETS sectors by 10 % by 2020 compared to 2005. The non-trading sectors represent about 60 % of total GHG emissions in the EU-27 and broadly include 'direct' emissions from households and services, as well as emissions from transport, waste and agriculture. Direct emissions from energy transformation industries are by and large regulated by the EU ETS.

Furthermore, EU governments should reduce emissions in sectors subject to national targets under the ESD, as opposed to sectors where reductions are by and large market driven (EU ETS). As with the Kyoto Protocol, meeting the 2020 national targets set out in the EU Climate and Energy package will by and large be determined by how countries reduce emissions in the non-trading sectors. Under the Kyoto Protocol, the EU-15 took on a common commitment to reduce emissions by 8 % between 2008 and 2012 compared to emissions in the base year. When Member States set national emission caps for installations under the EU ETS for the period 2008–2012, they allocated part of their Kyoto emission budget (Kyoto Assigned Amounts) to the EU ETS and fixed the overall contribution of EU ETS sectors towards reaching Kyoto Protocol national targets.

The end-user approach provides additional information on the effect of energy demand or sectoral policies on GHG emissions that can be helpful in the context of the ESD. For example, more district heating from combined heat and power (CHP), replacing old stoves in households, or higher demand for electric-powered vehicles may drive emissions from non-trading sectors (where there are national targets) to trading sectors (governed by carbon prices). Thus, the end-user approach to GHG emissions can also help policymakers target GHG emission reductions more effectively.

The end-user approach also provides information on the GHG effect of cross-border trading of energy flows, such as electricity. These energy-trade effects can be very large in some countries, and can also vary significantly from year to year.

Although the focus of this report is on GHG emissions, policies to mitigate climate change can help reduce air pollution, and policies to improve air quality can also help reduce GHG emissions. There can be both synergies and trade-offs. The end-user methodology allows a better understanding of both GHG emission and air pollution trends in the energy sector from the end-user side that can be helpful in the context of combined climate and air pollution policies.

It should be noted that the end-user method is not directly linked to monitoring of progress towards targets. It is rather a tool to help understand the links between energy use and emissions at a more disaggregated level, including the emission effects from energy trade between EU Member States.

Notwithstanding differences between energy statistics and activity data, the reallocation of emissions from energy transformation to end users is done on the basis of Eurostat's energy balances and UNFCCC GHG emissions from the energy sector. One key objective from this exercise is to better analyse the link between GHG emissions as reported to the UNFCCC and the final energy demand driving the source of emissions.

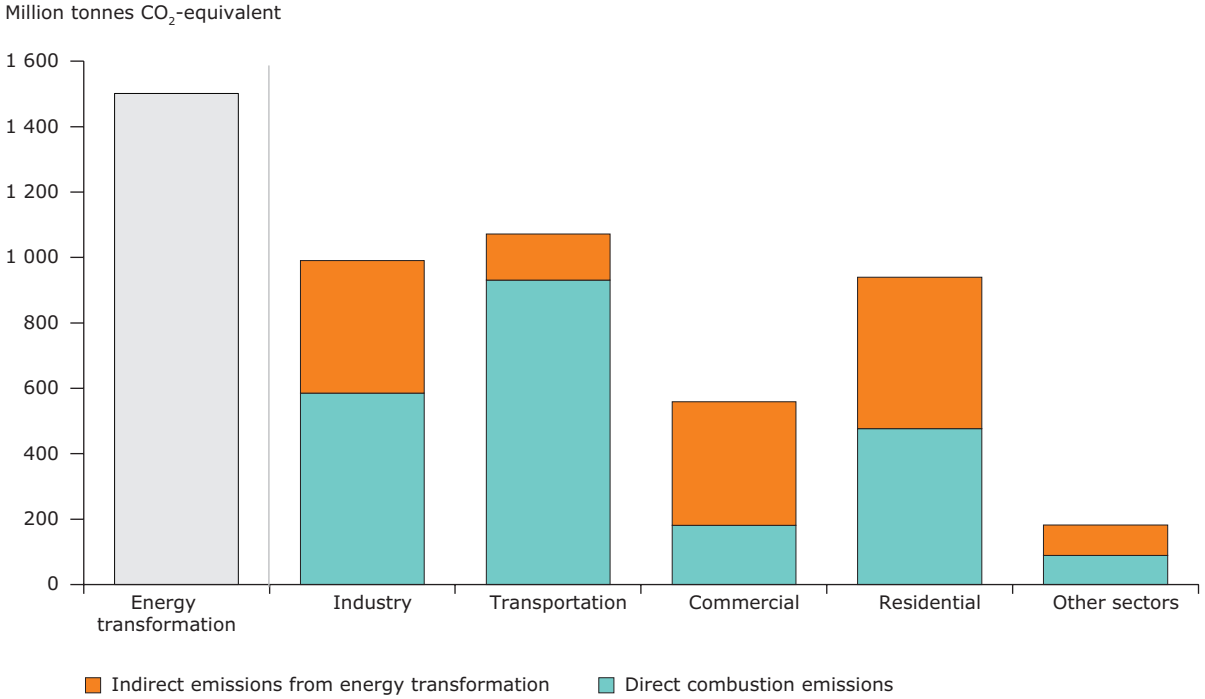
As explained above, the model to estimate end-use emissions is restricted to the energy sector as defined for reporting purposes under UNFCCC (i.e. energy combustion and fugitive emissions). Much of the sector is regulated by the EU ETS (e.g. combustion installations). The 'energy' subsectors which are outside the scope of the EU ETS broadly include direct combustion emissions from residential and commercial buildings, as well as transportation (excluding electric trains). Thus, while direct emissions from households, for example, are generally excluded from the EU ETS, indirect emissions from the electricity and heat supplied to households fall within the scope of the EU ETS.

Results by end use for 2010

Figure ES.1 shows the indirect emissions from energy transformation and the direct combustion emissions by main energy-consuming sector in million tonnes of CO_2-equivalent. The heights of the bars depict the total end-use GHG emissions in that sector. Energy transformation on the left side of the chart is shown in white to reflect that all emissions (including fugitives) are allocated to the end-use sectors.

Figure ES.2 presents the same information in an alternative way, and in relation to total energy-related GHG emissions in 2010. The height of the line in each sector (in red) is the sum of direct and indirect GHG emissions in that sector.

Figure ES.1 End-use greenhouse gas emissions from energy use in EU-27 in 2010

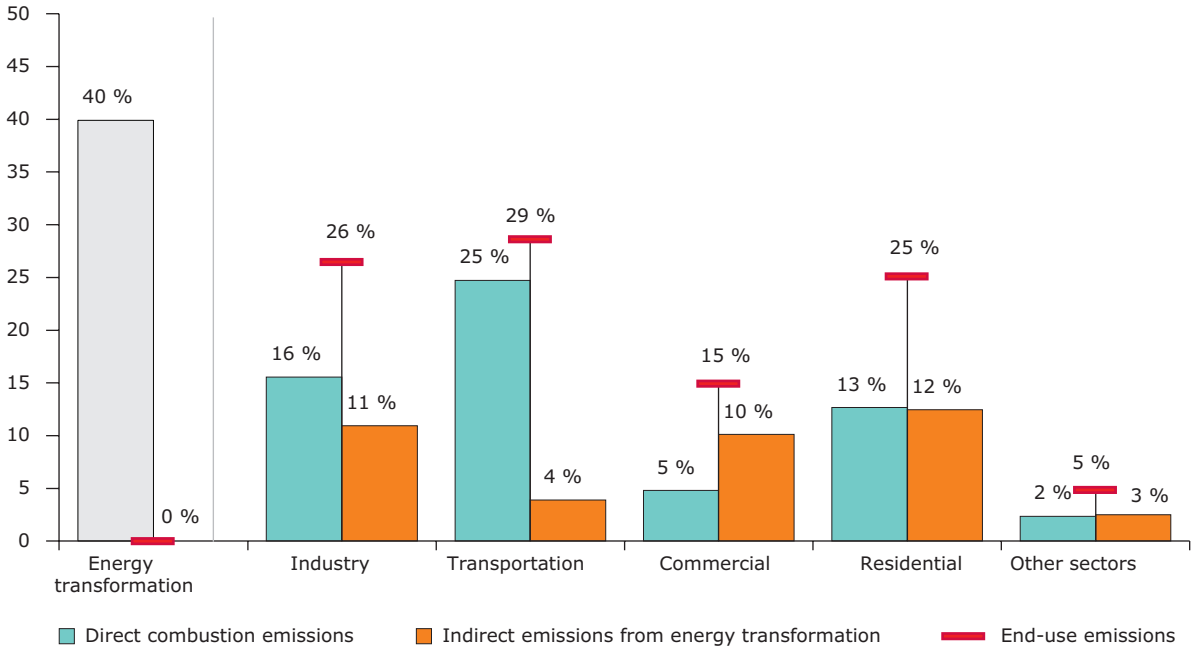


Note: The sum of direct and indirect emissions equals end-use emissions. The total indirect emissions allocated to end users in a country can be smaller than the direct emissions from fuel transformation in that country if some of the indirect emissions are allocated to exports and international bunkers. The indirect emissions allocated to end users including exports and bunkers equal the direct emissions from fuel transformation plus the indirect emissions associated with energy imported from other countries. The indirect emissions arising from energy supplied from countries outside the EU are assumed to be zero. 'Other sectors' includes emissions from agriculture, forestry and fishing as well as the net (indirect) emissions from energy trade. The emissions shown in the chart are only representative of the EU as a whole. Country-specific data are available in Annex 2 of the main report.

Source: EEA, 2012.

Figure ES.2 End-use greenhouse gas emissions from energy use in EU-27 in 2010

% of GHG emissions from the energy sector



Note: The sum of direct and indirect emissions equals end-use emissions. The total indirect emissions allocated to end users in a country can be smaller than the direct emissions from fuel transformation in that country if some of the indirect emissions are allocated to exports and international bunkers. The indirect emissions allocated to end users including exports and bunkers equal the direct emissions from fuel transformation plus the indirect emissions associated with energy imported from other countries. The indirect emissions arising from energy supplied from countries outside the EU are assumed to be zero. 'Other sectors' includes emissions from agriculture, forestry and fishing as well as the net (indirect) emissions from energy trade. The shares shown in the chart are only representative of the EU as a whole. Country-specific data are available in Annex 2 of the main report.

Source: EEA, 2012.

Energy industries and fugitive emissions accounted for 40 % of energy-related GHG emissions in the EU-27 in 2010. In the commercial and residential sectors indirect emissions from heat and electricity generation in thermal stations are larger than the direct (inventory) combustion emissions attributed to these sectors. This is by and large because of the electricity supplied by thermal stations to these two sectors. The remaining difference is accounted for by distributed heat from district heating and CHP plants. In transport, particularly, direct emissions account for the bulk of emissions in the sector, with a significantly lower share of indirect emissions from petroleum refining and electricity for railways, for example. 'Other sectors' include the indirect emissions from imports and exports of energy between countries (e.g. electricity trade). For some EU Member States there is a larger effect, which highlights the relative importance of trade in energy flows in these countries. These effects can also vary significantly from year to year.

Figures ES.1 and ES.2 portray the emissions shares across sectors from the final demand side at one point in time, i.e. 2010. It should be stressed these shares only apply to the EU as a whole and very different pictures emerge for different countries. This shows for example that the vast majority of transport emissions (with the exception of electric railways) are by and large direct emissions which are covered by the ESD.

The dynamics of how end-use emissions evolve over time are even more relevant. The progressive development of electric vehicles should result in a redistribution of the emission shares in transport across the EU ETS and the ESD. GHG emission savings will depend on whether transport demand continues growing, outpacing any environmental benefits, and whether the fuel mix for electricity generation is more carbon friendly than combustion engines using mainly diesel and/or gasoline. Improvements in the efficiency of electricity

transformation should also contribute to further emissions reductions.

How have end-use GHG emissions changed between 2009 and 2010?

Total GHG emissions (excluding land use, land-use change and forestry (LULUCF)) in the EU increased in 2010 after five consecutive years of emission reductions, starting in 2004. With the exception of road transportation, all the main sectors increased their GHG emissions in 2010. Energy combustion (i.e. the production and consumption of energy by all sectors, including transport) accounted for over 90 % of the net increase in EU GHG emissions in 2010.

The increase in emissions in 2010 was partly driven by the economic recovery from the 2009 recession in many European countries, which had itself caused substantial emission reductions in 2008 and 2009 in all Member States. In 2010, the winter was also colder than in the previous year, leading to increased demand for heating and higher emissions from the residential and commercial sectors. The continued strong increase in renewable energy use and the improved carbon intensity of fossil fuels — underpinned by strong gas consumption — prevented the increase in GHG emissions from being higher.

Figure ES.3 (top) shows the evolution of indirect GHG emissions, estimated by reallocating GHG emissions from energy industries and fugitives. Figure ES.3 (middle) shows the trends in direct GHG emissions as reported to UNFCCC, while excluding emissions from the energy transformation sector. Figure ES.3 (bottom) shows total energy-related GHG emissions, including both indirect and direct emissions from the charts above.

In 2010, GHG emissions increased in the transformation sector (energy industries, including fugitives), and particularly in heat and electricity production. Emissions from gas and coal more than offset lower emissions from liquid fuels in the sector. The use of biomass for heat and power also increased strongly in 2010 and continued the upward trend observed since 1990.

On an end-use basis, GHG emission increases in industry accounted for about half (40 % direct and 10 % indirect) of all energy-related GHG emission increases in 2010. Within industry, the bulk of the increase in emissions was accounted for by the iron and steel sector, driven by higher industrial activity and an increase in crude steel production. GHG inventories for 2010, the 2010 energy balances and the verified 2010 emissions from the EU ETS published last year all confirm significantly higher energy use and emissions in industry — predominantly in iron and steel. Overall, the sectors covered by the EU ETS increased their emissions more in 2010 than the non-trading sectors (i.e. those outside the EU ETS). Most of the biggest industrial installations are part of the EU ETS, and higher industrial activity during 2010, after the strong contraction in 2009, appears to have led to a sharper increase in final energy demand and emissions in these sectors.

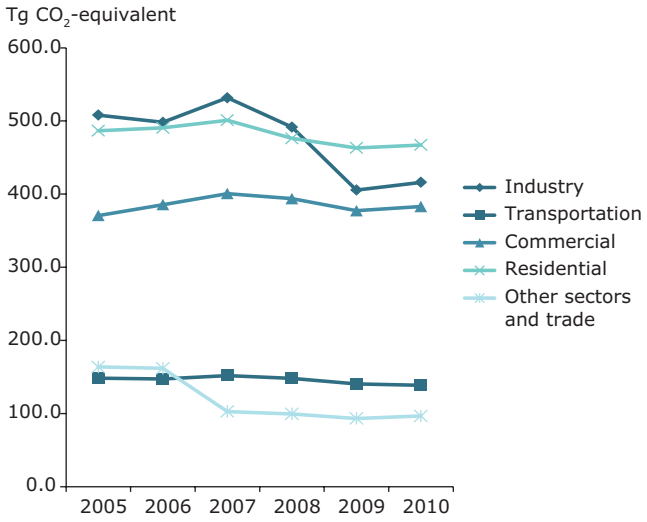
The second largest contributor to higher emissions in the EU on an end-user basis in 2010 was the residential sector, accounting for about 39 % (35 % direct and 4 % indirect) of all energy-related GHG emission increases in 2010. The winter in Europe in 2010 was colder than in 2009, resulting in greater household demand for heating and higher GHG emissions. Part of this heating is supplied via distributed systems from district heating and CHP thermal stations. The primary energy to generate distributed heat (mainly from coal and gas) is reported under 'public electricity and heat production' in GHG inventories, which generally falls under the EU ETS. Eurostat's energy balances confirm a very significant increase in derived heat in EU-27 households during 2010. Higher final electricity consumption of the residential sector also explains why emissions increased significantly compared to 2009. The other part of the heating consists of non-distributed heat, which is generated directly by households. Non-distributed heat (mainly from gas and biomass) is reported under the residential sector in GHG inventories. More than two thirds of the increase in direct emissions from households in 2010 was accounted for by higher gas use.

End-user emissions in the commercial sector accounted for 13 % of the total increase in energy-related GHG emissions in 2010 — split roughly the same between indirect and direct emissions. As with the residential sector, higher heat demand due to the colder winter and increased electricity consumption explain the increase in emissions in this sector in 2010.

GHG emissions did fall in some sectors between 2009 and 2010. Road transport emissions continued to decline in 2010 due to lower gasoline emissions. This was despite the recovery in diesel emissions after two consecutive years of decline. To a lesser extent, increased use of biofuels, lower emissions

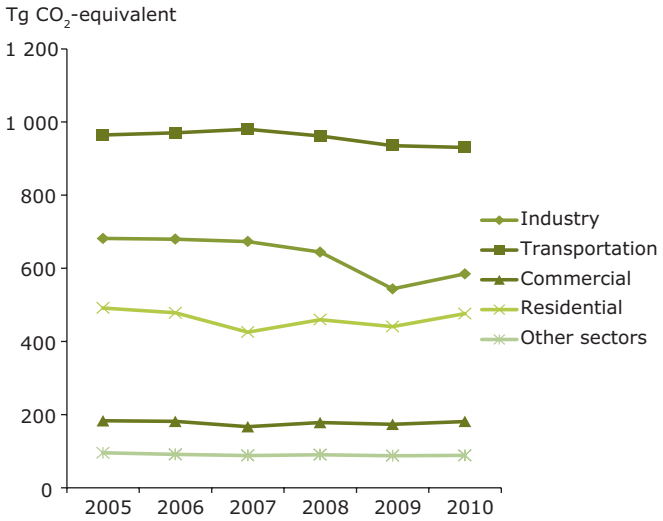
Figure ES.3 Trends in direct and indirect GHG emissions by end-use sector in EU-27, 2005-2010

Indirect GHG emissions by sector, 2005–2010



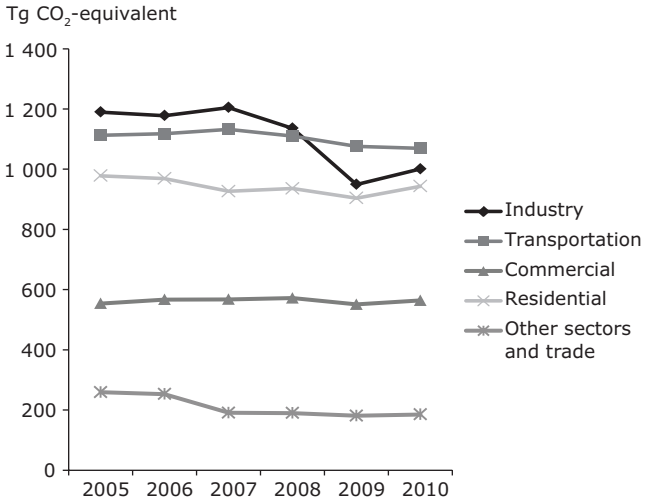
Sector	Contribution to the total reduction in energy-related emissions, 2009/2010
	Indirect emissions
Industry	10.4 %
Transportation	– 1.9 %
Commercial	5.7 %
Residential	4.0 %
Other sectors and trade	3.2 %
Indirect emissions (all sectors)	21.3 %

Direct GHG emissions by sector, 2005–2010



Sector	Contribution to the total reduction in energy-related emissions, 2009/2010
	Direct emissions
Industry	40.3 %
Transportation	– 4.6 %
Commercial	7.5 %
Residential	34.7 %
Other sectors	0.8 %
Direct emissions (all sectors)	78.7 %

Total (direct + indirect) GHG emissions by sector, 2005–2010



Sector	% of the total absolute reduction in energy-related emissions, 2009/2010
	Total emissions
Industry	50.7 %
Transportation	– 6.6 %
Commercial	13.1 %
Residential	38.7 %
Other sectors and trade	4.0 %
Total direct and indirect emissions (all sectors) in Tg CO_2-equivalents	102

from refining of oil products for transportation, and lower indirect emissions from electric railways also contributed to the lower road transport emissions in 2010.

While tracking indirect emissions from energy transformation industries is not directly suited to monitoring overall GHG emission targets, the method to reallocate indirect emissions to the end users can help increase the transparency of how reductions in energy use in households and other sectors affect overall emission reductions at the level of that sector (direct and indirect). In this way, Member States could better assess which additional policies/measures may be needed to reduce emissions in these sectors to meet their overall emission targets. These additional measures could, for example, include specific sectoral policies as well as overall improvements in energy efficiency, carbon intensity and higher shares of renewables, to mention but a few.

End-use air pollutant emissions: SO_x and NO_x

Emissions of nitrogen oxides (NO_x) and sulphur oxides (SO_x) influence climate change indirectly. NO_x is a precursor substance for ground-level ozone which is itself a GHG. SO_x emissions can contribute to forming microscopic particles (aerosols), which can reflect sunlight back out into space and also affect cloud formation. Both NO_x and SO_x are reported at an aggregate level to the UNFCCC annually as part of the Parties' official GHG submissions. In addition, emissions from these substances are reported to the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (LRTAP) and to the EU's National Emission Ceilings Directive. Most NO_x emissions are direct emissions from the transportation sector, whereas most SO_x emissions are indirect emissions from energy industries. As with GHG, the same end-user methodology has been applied to NO_x and SO_x and the results are shown in Annex 4 of the main report.

How were end-use emissions calculated?

There is no perfect match between the sectoral classification used in GHG inventories submitted to the UNFCCC and the energy balances because of different reporting requirements. Energy industries (CRF 1.A.1) and fugitive emissions (CRF 1.B) could be thought of as the equivalent of the transformation sector in the energy balances. However, the GHG inventory does not allocate emissions from energy industries to the end users of the final energy (households, transport, agriculture, industry and services). In the energy balances, primary energy is transformed (by combustion or mechanical means) to useful energy (e.g. heat, electricity or gasoline/diesel) which is then allocated to these sectors. Thus, one should not compare GHG inventory emissions directly with final energy consumption from the energy balances ([3]).

The conceptual model to reallocate emissions from energy transformation industries to the end users is based on the *UK end-user model* ([4]). The model reallocates emissions from the energy transformation industries (power stations, refineries, coal mining, solid smokeless fuel production, gas production and town gas production) to the end users.

Refineries, the coal industry and the gas production industry are supplied with a small part of the public electricity produced. The refineries supply oil to the power stations and the coal industry. The coal industry supplies coal to the power stations. The gas industry supplies gas to the power stations. CO_2 and other GHGs are emitted by each of these source categories. Each of the source sectors thus produces both direct and indirect emissions. It is not possible to allocate emissions directly from all producers to

([3]) To give one example: the electricity and heat used by households and services which are reported as final energy consumption in the energy balances also include the energy supplied/distributed from conventional thermal stations. Under UNFCCC reporting, GHG emissions from households and services are estimated from direct combustion activities and exclude indirect emissions from energy transformation industries. The same is true for other energy-consuming sectors such as industry, agriculture and transportation. Emissions arising from the transformation of primary fuels in thermal power stations to produce heat and electricity for the final users of energy (e.g. households, services, transportation, industry and agriculture) are reported under public electricity and heat production. Other energy transformation industries include petroleum refining, coal mining, and oil and gas extraction. Fugitive emissions are also linked to the production, processing, transmission, storage and use of fuels (e.g. flaring of natural gases at oil and gas production facilities).

([4]) The *UK end-user model* has been used by policymakers in the United Kingdom to understand the interactions between the energy transformation industries and their effect on GHG emissions in the United Kingdom. In addition, the model has been used to improve the analysis of energy efficiency and GHG emissions in the Devolved Administrations of the United Kingdom by taking account of electricity transfers between the Devolved Administrations.

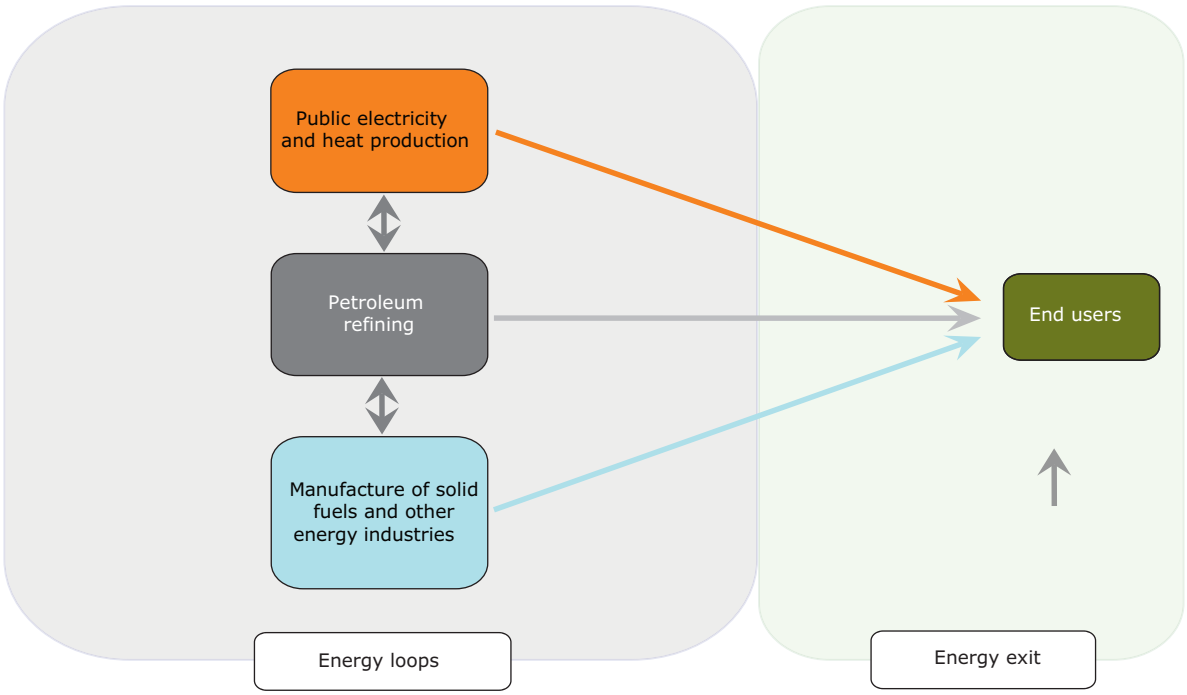
their end users, and the reallocation of emissions thus requires the development of a conceptual model that takes account of feedback loops between energy producers. In this way, all the emissions from the energy producers, including heat production, are reallocated. These feedback loops are illustrated in Figure ES.4.

There are two streams of data used in the allocation of energy-related GHG emissions to end users. The first one is the GHG inventory of the EU — an annual submission of national GHG inventories of Annex I Parties under the UNFCCC and the Kyoto Protocol, which the EEA compiles on behalf of the European Commission. The second data source is the annual energy balances reported to Eurostat under the Energy Statistics Regulation. In both cases there are well established QA/QC processes to ensure the highest possible quality of the emissions and energy estimates, respectively. Differences remain between both sets of data: between fuel/activity data in GHG inventories and energy data in the energy balances, for example. Under the Energy Statistics Regulation, EU Member States are expected to ensure a high degree of consistency between the energy balances reported to Eurostat and the activity data reported under the UNFCCC. The main mismatch occurs at a more detailed sectoral level due to different reporting requirements and/or practices. The treatment of non-energy use, particularly in industrial sectors, can be a source of inconsistencies between the energy balances and national GHG inventories.

The end-user approach is internally consistent at EU level as all emissions from energy-producing industries are reallocated to the final users using the energy balances as the distributing tool. The starting point is the emissions (EEA GHG data viewer) which are then reallocated using energy flows in the energy balance (Eurostat). The allocation of indirect emissions depends on the fuel mix in the energy balance. This means emissions factors are not an input to the model but can be derived from the model.

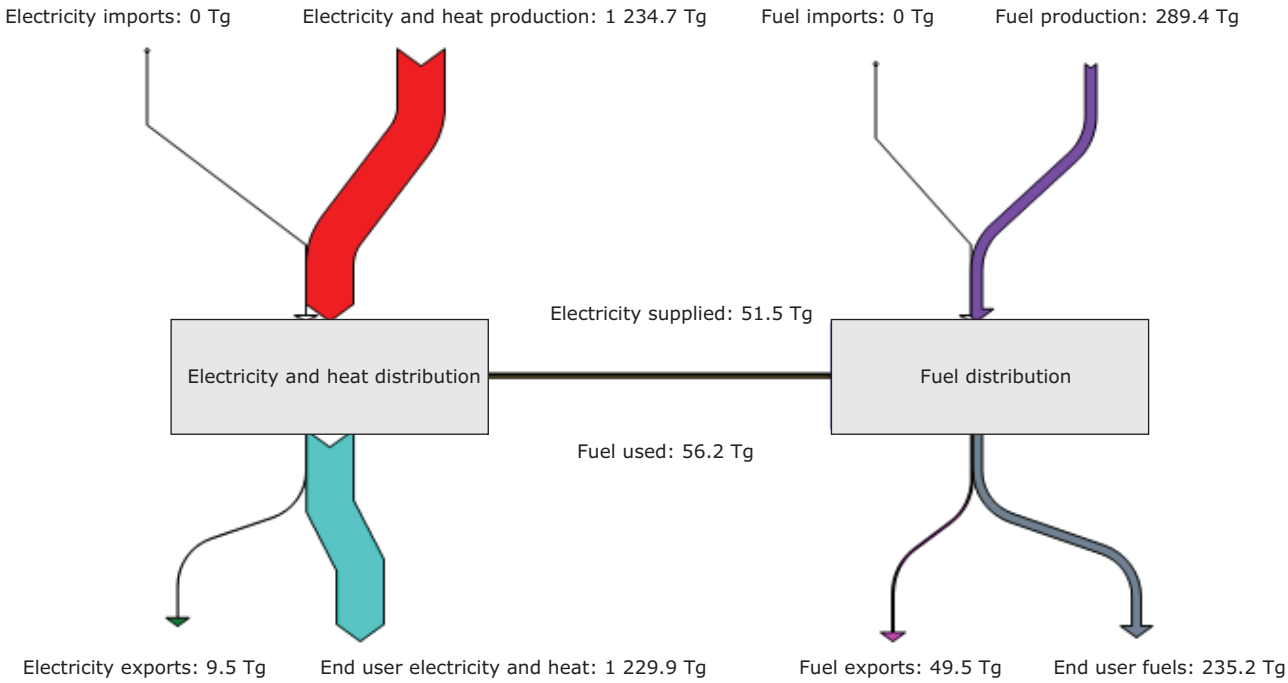
Figure ES.5 and ES.6 show the results of the end-user methodology for the EEA member countries ([5]). Details by country are shown in Annex 3 of the main report. Figure ES.5 shows the

Figure ES.4 Energy flows in the end-user model



([5]) EEA member countries include the 27 Member States of the EU, the four members of the European Free Trade Association (EFTA) and Turkey. GHG data were not available for Turkey at the time of production of this report. Eurostat's energy balances are not available for Iceland or Liechtenstein. Therefore, the EEA aggregate referred to in this report includes the EU-27 Member States, plus Norway and Switzerland.

Figure ES.5 Direct GHG emissions from energy transformation in EEA member countries, 2010

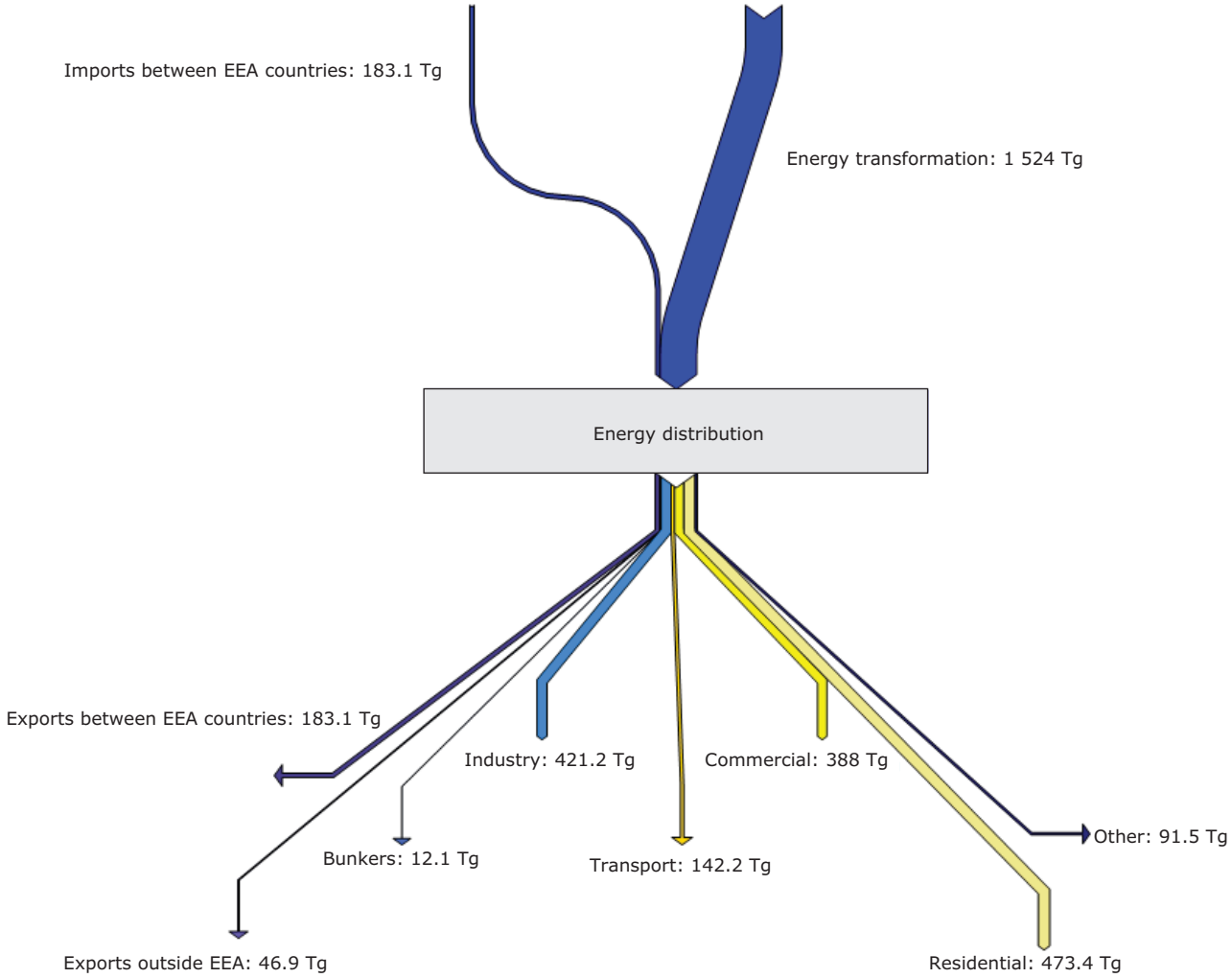


GHG emissions associated with energy flows within the energy transformation sector. Figure ES.6 shows the 'indirect' GHG emissions associated with the distribution of energy flows to the end-user sectors.

The end-user model also takes into account energy trade flows between countries to allocate emissions to the final users. This is because electricity, oil products, natural gas and solid fuels produced in one country may be exported to other countries. Thus, the net exported indirect emissions by country may be different from zero for countries with significant energy trade flows with other countries. The indirect emissions allocated to end users including exports and bunkers equal the direct emissions from fuel transformation plus the indirect emissions associated with energy imported from other countries.

A country can both import and export fuels and the implied emissions factors for imports and exports are not generally the same because of different fuel mixes across countries. To guarantee the internal consistency in the model, the redistribution of indirect emissions across countries is based on the fuel mix of the exporting country. For example, if country A exports electricity to country B, then country B is allocated a fraction of country A's emissions based on the fuel mix in country A. Also, indirect emissions from refining oil products in one country would be allocated to end users in other countries in proportion to the energy content of the fuel supplied. Thus, the derived emissions factors for the allocation of indirect emissions to the end users in the importing country are based on the exporting country fuel mix and transformation efficiency. See Chapters 2 and 3 in the main report for more information.

Figure ES.6 Indirect GHG emissions from energy distribution by end-user sector in EEA member countries, 2010



For more information:

Annual European Union greenhouse gas inventory 1990–2010 and inventory report 2012
http://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2012.

EEA greenhouse gas — data viewer
http://www.eea.europa.eu/pressroom/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

EEA Climate change publications
http://www.eea.europa.eu/themes/climate/publications.

Eurostat energy balances
http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database.

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