I

MONITORING THE ENVIRONMENTAL AND RESOURCE PRODUCTIVITY OF THE ECONOMY

A central element of green growth is the environmental and resource efficiency of production and consumption and its evolution over time and space, and across sectors. Understanding this evolution and the factors that drive these changes, is an essential ingredient in developing green growth policies.

Progress can be monitored by relating the use of environmental services in production (use of natural resources and materials, including energy, generation of pollutants and other residuals) to the output generated and by tracking decoupling in trends of production and environmental services. Decoupling at the national level can partly be explained by displacement effects - such as the substitution of goods or services produced domestically, and requiring high levels of environmental services, with imports - that don't necessarily imply decoupling at the global level. Such shortcomings in production based measures can be addressed by focusing on the evolution of efficiencies, or otherwise, in relation to consumption.

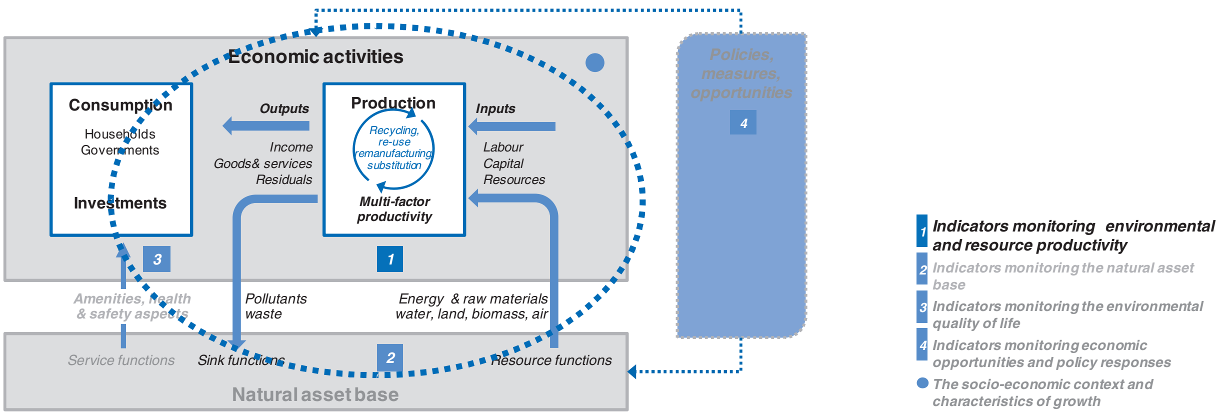
The main issues of importance to green growth include:

- **Carbon and energy productivity** that characterises among others interactions with the climate system and the global carbon cycle, and the environmental and economic efficiency with which energy resources are used in production and consumption, and that inform about the results of policies that promote low carbon technologies and cleaner energy.
- **Resource productivity** that characterises the environmental and economic efficiency with which natural resources and materials are used in production and consumption, and that informs about the results of policies and measures that promote resource productivity and sustainable materials management in all sectors. Important resources and materials include: mineral resources (metallic minerals, industrial minerals, construction minerals); biotic resources (food, feed, wood); water; and nutrients that reflect among others interactions with nutrient cycles and food production systems.

Other issues of importance include consumer behaviour, and household and government consumption patterns.

ENVIRONMENTAL AND RESOURCE PRODUCTIVITY

FRAMEWORK



PROPOSED INDICATORS

Theme	Proposed indicators	Type	R	S	M	Indicators presented here
Carbon & energy productivity	**1. CO_2 productivity**					
	1.1. Production-based CO_2 productivity GDP per unit of energy-related CO_2 emitted	M	1	1	S	☑
	1.2. Demand-based CO_2 productivity Real income per unit of energy-related CO_2 emitted	M	1	2	S/M	☑
	2. Energy productivity					
	2.1. Energy productivity (GDP per unit of TPES)	M	2	1	S	☑
	2.2. Energy intensity by sector (manufacturing, transport, households, services)	M	2	1	S/M	☑ selected countries & sectors
	2.3. Share of renewable energy in TPES, in electricity production	M	1	1	S	☑
Resource productivity	**3. Material productivity (non-energy)**					
	3.1. Demand based material productivity (comprehensive measure; original units in physical terms) related to real disposable income	M	1	3	M/L	–
	• Domestic material productivity (GDP/DMC) - Biotic materials (food, other biomass) - Abiotic materials (metallic minerals, industrial minerals)	P	1	2	S/M	☑
	3.2. Waste generation intensities and recovery ratios By sector, per unit of GDP or VA, per capita	M	1	1	M/L	☑ municipal waste
	3.3. Nutrient flows and balances (N,P)	M	1	3	L	–
	• Nutrient balances in agriculture (N, P) per agricultural land area and change in agricultural output	P	2	1	S/M	☑
	4. Water productivity VA per unit of water consumed, by sector (for agriculture: irrigation water per hectare irrigated)	M	1	1	M	–
Multi-factor productivity	**5. Multi-factor productivity reflecting environmental services** (comprehensive measure; original units in monetary terms)	M	1	2	M/L	–

Notes: see Annex page 139.

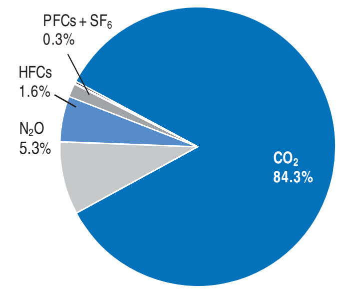
I.1 CO_2 PRODUCTIVITY

POLICY CONTEXT

The issue

Climate change is a major global issue that could have significant effects on green growth and sustainable development. Main concerns relate to effects of increasing atmospheric greenhouse gas (GHG) concentrations on global temperatures and the earth's climate, and the consequences for ecosystems, human settlements, agriculture and other socio-economic activities that could affect in turn global economic output.

Main drivers behind climate change and GHG emissions include fuel combustion in economic activities and by households. Major GHG include CO_2, CH_4, N_2O, PFCs, HFCs and SF_6. CO_2 from the combustion of fossil fuels and from biomass is a major contributor to GHG emissions and to the enhanced greenhouse effect. Accounting for over 80% of total GHG emissions it determines the overall trend and is a key factor in countries' ability to deal with climate change. National emissions are further affected by changes in the geography of global demand and supply with increasing trade flows and the relocation of carbon intensive production abroad.



Source: UNFCCC

Main challenges

The main challenges are to limit emissions of CO_2 and other GHG and to stabilise the concentration of GHG in the atmosphere at a level that would limit their adverse effects on the climate system.

With current climate change mitigation policies and the increasing industrialisation of emerging and developing economies, a business-as-usual approach will see global CO_2 and other GHG emissions continue to grow over the next few decades. Progress in stabilising the concentration of GHGs in the atmosphere therefore is dependent on the development of national and international strategies to further decouple CO_2 and other GHG emissions from economic growth. The increasing interdependencies of international production networks and supply chains, requires that such efforts are placed in a global context and build on a good understanding of carbon flows associated with international trade among countries and world regions.

Current policy measures are designed to mitigate GHG emissions by focusing on producers. However, reductions in national emissions can be achieved by offshoring domestic production and, thus, the related emissions. Evidence of decoupling in measures that focus on emissions per unit of GDP or per capita, therefore, may only reveal part of the story; hence the need to focus, in addition, on complementary measures that reflect the impact of consumption on emissions.

MONITORING PROGRESS THROUGH INDICATORS

Progress towards green growth can be assessed against the emission productivity of production and consumption and the level of decoupling achieved between CO2 and other GHG emissions and economic growth. This can further be related to domestic objectives and international commitments, and to changes in atmospheric concentrations of GHG.

The main international agreement is the United Nations Framework Convention on Climate Change (1992) and its 1997 Kyoto Protocol that established differentiated national or regional emission reduction or limitation targets for six GHG (CO_2, CH_4, N_2O, PFCs, HFCs and SF_6) for 2008-12 with 1990 as the reference year. Recent negotiations in Copenhagen and in Cancun led to progress on, inter alia, goals for emission reductions, including from developing countries; finance; adaptation and "Reducing Emissions from Deforestation and Degradation" (REDD).

I.1 CO_2 PRODUCTIVITY

Indicators of progress

The indicators presented here relate to CO_2 emissions from energy use (fossil fuel combustion). They include:

- Production based CO_2 productivity - GDP generated per unit of CO_2 emitted - and CO_2 intensities per capita for the period 1990 to 2008. The emissions presented here are gross direct emissions, emitted within the national territory and excluding bunkers, sinks and indirect effects. The CO_2 productivity of production informs about the relative decoupling between domestic production and carbon inputs. It also reflects other environmental issues, in particular emissions of greenhouse gases and air pollution that are correlated with the carbon intensity of economic production.
- Demand based CO_2 productivity – the real disposable income generated per unit of CO_2 emitted -for the period 1995 to 2005. Demand based emissions reflect the CO_2 emitted during all of the various stages of production of the goods and services consumed in domestic final demand, irrespective of where the stages of production occurred. Trends in emissions on this basis serve as a diagnostic complement to the more traditional production based measures.

Trends in GHG emissions are given as complements.

Interpretation

These indicators should be read in connection with other indicators and in particular on energy intensity and efficiency, on renewable energy, on energy prices and taxes, and carbon pricing.

Their interpretation should take into account the structure of countries' energy supply, the relative importance of fossil fuels and of renewable energy, trade patterns, as well as climatic factors.

Although the demand perspective is an important addition to the debate on global environmental issues, especially as a supplementary indicator that can explain movements in production based measures, some care is needed when considering the policy implications. The links between trade, economic growth and the environment are complex and policies need to weigh all of these factors together; especially the benefits of trade in enabling growth and development.

Measurability and data quality

Data on GHG emissions are reported annually to the Secretariat of the UNFCCC with 1990 as a base year (Annex I countries). Significant progress has been made with national GHG inventories, though data availability over longer periods remains best for CO_2 emissions from energy use.

Continued efforts are being done to further improve national GHG inventories, and in particular to better evaluate sinks and indirect effects and to calculate comparable net GHG emissions for all countries, including non Annex I countries. More needs to be done to monitor the effects of domestic demand and of the use of international transactions and flexible mechanisms of the Kyoto protocol on emissions outside the national territory.

The demand based estimates use macro approaches that assume homogeneity in production processes and imports within relatively aggregated industry groupings, meaning that they cannot differentiate between low and high emission companies allocated to the same sector; this limits the extent to which specific demand based policy measures can be developed. Continued efforts are needed to keep the methodologies and underlying data up to date.

See also *Notes and definitions*.

I.1 CO2 PRODUCTIVITY

MAIN TRENDS AND STRUCTURAL CHANGES IN PRODUCTION BASED EMISSIONS

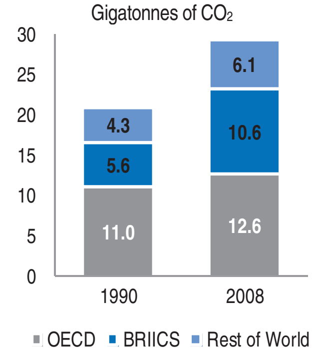
Relative decoupling

CO_2 and other GHG emissions are still growing in many countries, despite some progress achieved in decoupling domestic CO_2 emissions from GDP growth (relative decoupling), and improvements in energy efficiency.

Overall, CO_2 emissions from energy use have grown more slowly in OECD countries as a group than they have world-wide and in developing countries. This trend was emphasised in the recent years by the rapid economic growth of Asian countries and of the BRIICS.

Individual OECD countries' contributions to the greenhouse effect, and rates of progress towards stabilisation, vary significantly, regardless of whether they are considered in absolute numbers, per capita amounts, or through carbon productivity.

World CO_2 emissions
Gigatonnes of CO_2



Source: IEA.

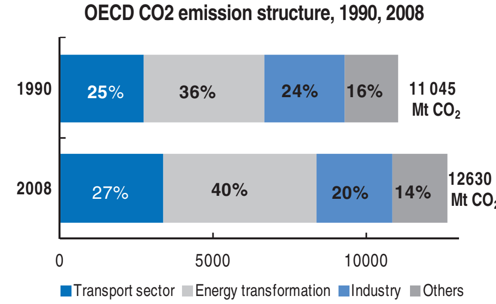
Important variations across countries

CO_2 emissions from energy use continue to grow, particularly in the OECD Asia-Pacific region and North America. This can be partly attributed to energy production and consumption patterns and trends, often combined with overall low energy prices. In OECD Europe, CO_2 emissions from energy use stay more or less stable due to changes in economic structures and energy supply mix, energy savings, implementation of policies and, in some countries, of decreases in economic activity.

Important variations across sectors

Disaggregating the emission estimates shows substantial variations within individual sectors. Between 1990 and 2008, the combined share of electricity and heat generation and transport has continued to grow and now represents more than two-thirds of the total (67%).

OECD CO2 emission structure, 1990, 2008



Source: IEA.

… AND IN DEMAND BASED EMISSIONS

Overall trends

Total emissions generated to satisfy domestic demand (final consumption plus investment) in OECD countries rose quicker than emissions related to production only. The converse holds in particular for large emerging economies. This reflects a host of factors, including trends in the international specialisation in production and relative comparative advantages of different countries. It should be emphasised here that the estimates obtained are not "leakage" estimates obtained from a model (replete with assumptions about how actors may react to a price change); these are estimates based on observed trends in production, consumption and trade patterns.

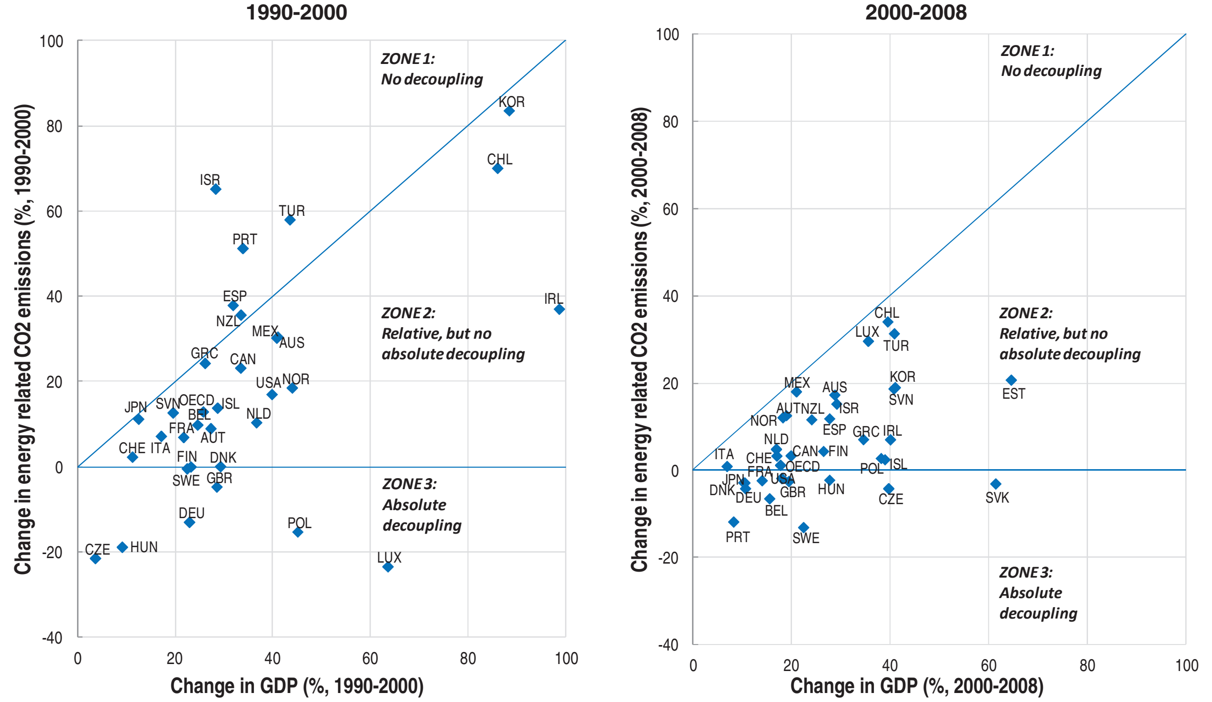
Important variations across world regions

The relative decoupling of demand-based emissions from income is much less prevalent than on production side, which can be partly explained by displacement of domestic production by imports. For example, in many OECD countries the increase in GDP per unit of CO_2 emitted is at least partly explained by imports of goods with a relatively high carbon footprint from other countries, notably China.

I.1 CO2 PRODUCTIVITY

DECOUPLING TRENDS: PRODUCTION BASED CO_2 EMISSIONS

Change in production-based CO2 emissions versus change in GDP, OECD countries



Source: OECD.

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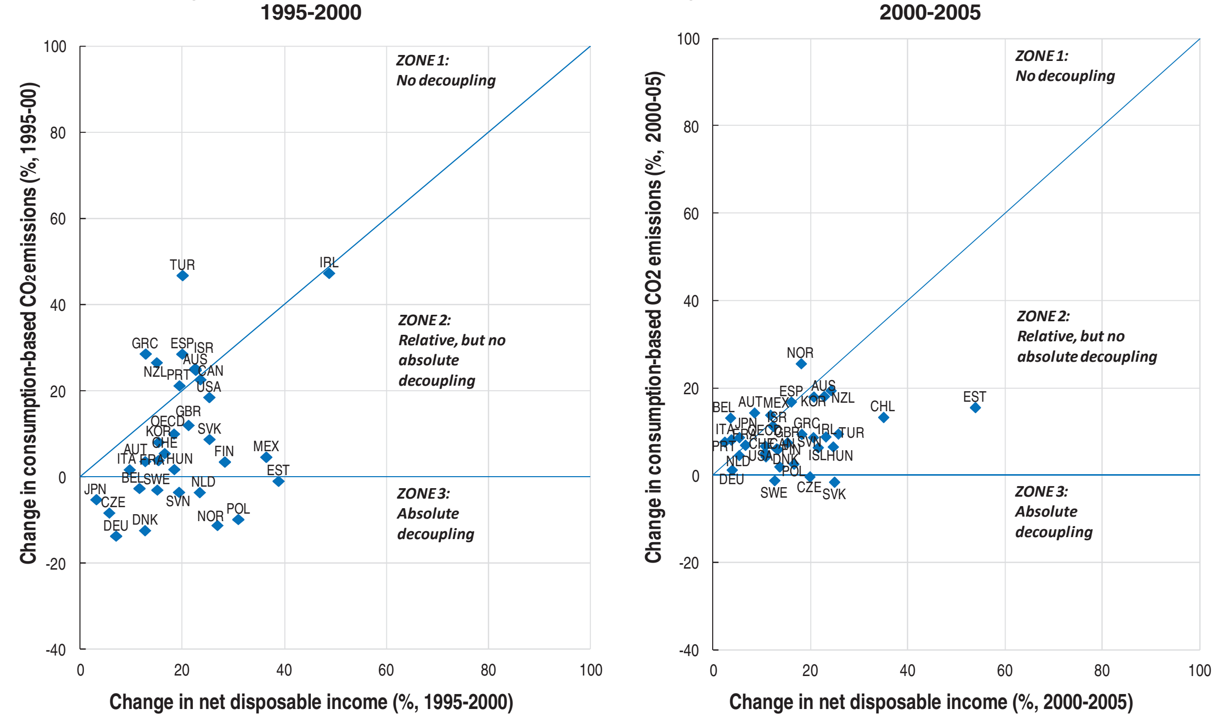
DECOUPLING TRENDS: DEMAND BASED CO_2 EMISSIONS

Change in demand-based CO2 emissions versus change in disposable income, OECD countries



Source: OECD

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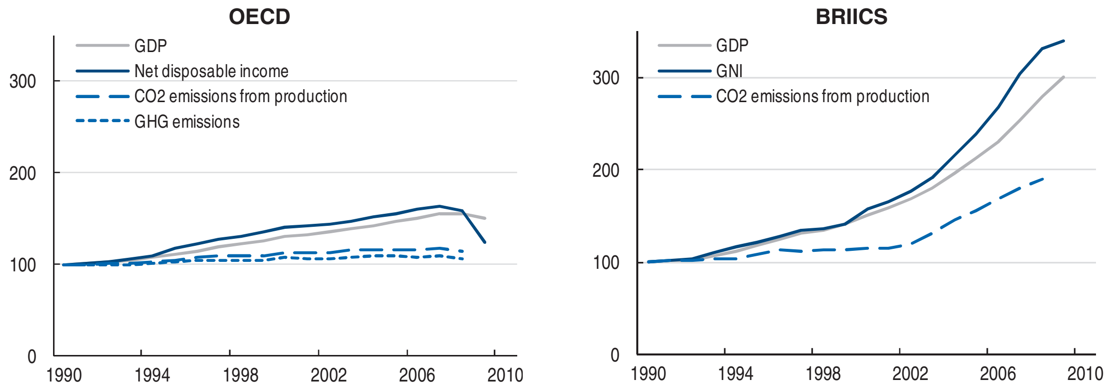
I.1 CO2 PRODUCTIVITY

DECOUPLING TRENDS: PRODUCTION BASED CO2 AND GHG EMISSIONS

CO_2 and GHG emissions versus GDP and real income, OECD, BRIICS, 1990-2008

Index 1990=100



* CO2: data refer to emissions from energy use (fossil fuel combustion).

Source: OECD, IEA, UNFCCC.

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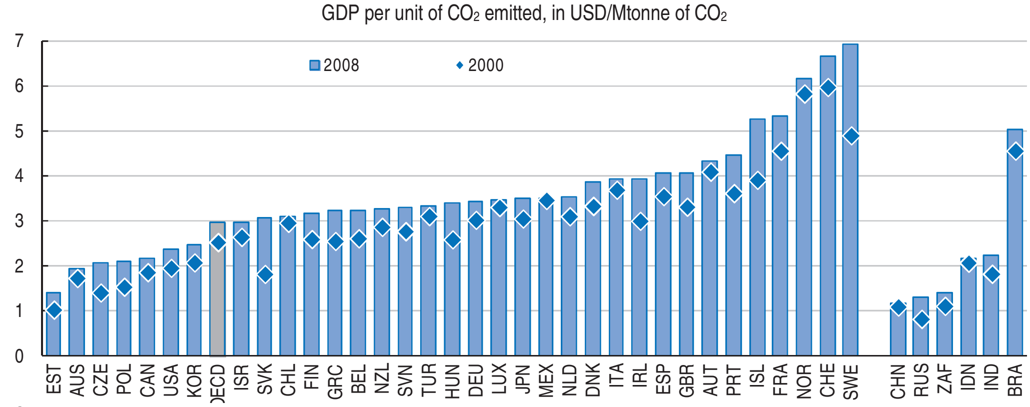
PRODUCTION BASED CO_2 PRODUCTIVITY AND INTENSITY

Energy related CO_2 emission productivity, OECD countries, BRIICS, 2000, 2008

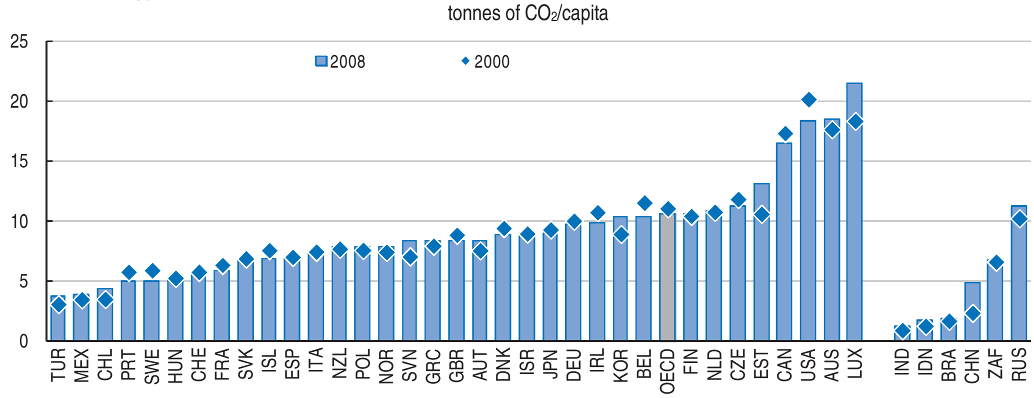
GDP per unit of CO_2 emitted, in USD/Mtonne of CO_2



Source: OECD, IEA.

Energy related CO_2 emission intensities per capita, OECD countries, BRIICS, 2000, 2008

tonnes of CO_2/capita



Source: OECD, IEA.

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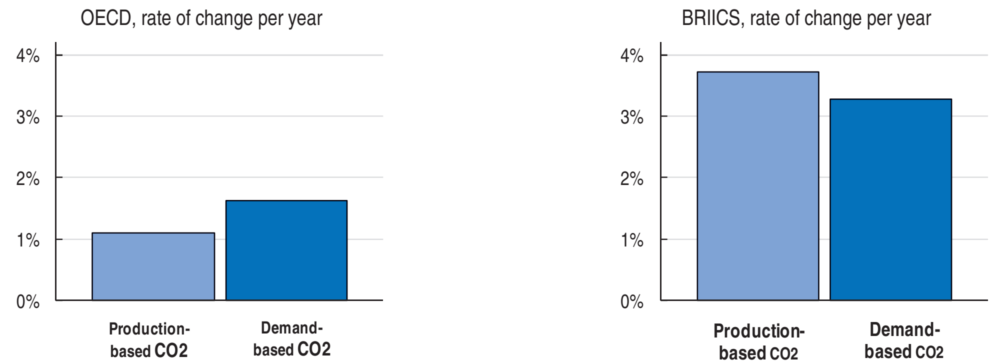
I.1 CO2 PRODUCTIVITY

PRODUCTION VERSUS DEMAND BASED EMISSIONS

Change in production- and demand-based CO_2 emissions, OECD, BRIICS, 1995-2005



Source: OECD, IEA

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Notes and definitions

Production-based CO2 emissions from fuel combustion

Emissions calculated using IEA energy databases and the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. The estimates are affected by the quality of the underlying energy data. For example, some countries, both OECD and non-OECD, have trouble reporting information on bunker fuels and incorrectly define bunkers as fuel used abroad by their own ships and planes. Since emissions from bunkers are excluded from the national totals, this affects the comparability of the estimates across countries. On the other hand, since these estimates have been made using the same method and emission factors for all countries, in general, the comparability across countries is quite good.

The very high per capita emissions of Luxembourg result, to a large degree, from the lower taxation of gasoline and diesel oil compared to neighbouring countries. The price differential attracts drivers from Belgium, France and Germany, as well as transiting freight, to refuel in the country. As emissions are calculated based on fuel deliveries, Luxembourg is accountable for emissions from the totality of those sales.

Demand-based CO_2 emissions and Carbon embodied in trade

The estimates of CO2 emissions embodied in final domestic demand are calculated by the OECD using a combination of input-output tables, bilateral trade data and production based CO2 emissions, described above. The approach uses the bilateral trade data in conjunction with national input-output tables for 47 countries - responsible for 95% of global GDP and over 85% of global CO_2 emissions (with an input-output table modelled for the Rest of the World) – to create a global input-output table that shows trade flows in goods and services between countries. This provides a framework that can be used to allocate the flows of CO_2 emitted in producing a product to the final purchaser of that product; irrespective of how many intermediate processes and countries the product passes through before arriving with its final purchaser. Emissions from bunkers and fugitive emissions from fuel extraction are excluded.

Gross domestic product and net disposable income

Real gross domestic product (GDP, expenditure approach) and net national disposable income for the OECD countries are for comparative purposes expressed in constant US$ prices at PPPs (base year 2000). The aggregate volumes for real GDP and gross national income for BRIIC countries (i.e. Brazil, Russian Federation, India, Indonesia, China) are in constant US$ prices at PPPs (base year 2005).

Sources

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Further information

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I.2 ENERGY PRODUCTIVITY AND RENEWABLES

POLICY CONTEXT

The issue

Energy is a major component of the economy, both as a sector in itself and as a factor input to all other economic activities. The structure of a country's energy supply and the intensity of its energy use, along with changes over time, are key determinants of the environmental performance and the sustainability of economic development, and hence of green growth.

Energy production and use have environmental effects that differ greatly by energy source. Main concerns relate to the effects on greenhouse gas emissions and on local and regional air pollution. Other effects involve water quality, land use, risks related to the nuclear fuel cycle and risks related to the extraction, transport and use of fossil fuels. The use of renewable energy sources, and of low-carbon and clean fuel technologies plays an important role in addressing climate change, as well as other challenges such as energy security.

Main challenges

The main challenge is to further decouple energy use and related emissions from economic growth, through improvements in energy efficiency and through the development and use of cleaner fuels. This requires the use of a mix of instruments including extended reliance on economic instruments.

MONITORING PROGRESS THROUGH INDICATORS

Progress towards green growth can be assessed against the energy productivity of the economy and against domestic objectives such as energy intensity or energy efficiency targets, and targets concerning the share of renewable energy sources. Progress can further be assessed against international environmental commitments that have direct implications for domestic energy policies and strategies (e.g. UNFCCC).

Indicators of progress

The indicators presented here relate to:

- Energy productivity and energy intensity by sector (manufacturing, freight transport, passenger transport). Energy productivity, expressed as GDP per unit of total primary energy supply (TPES), and intensities per capita, may reflect, at least partly, efforts to improve energy efficiency and to reduce carbon and other atmospheric emissions. They also reflect structural and climatic factors (see "*Interpretation*" below). The structure of energy supply is given as a complement.
- Share of renewables in TPES and in electricity production. The energy mix, i.e. the structure of energy supply, in terms of primary energy source as a % of TPES or of total electricity generation is closely related to consumption and production patterns and to environmental effects. Renewables are also used in heat generation. Main sources of renewable energy are combustible renewables (mainly wood) and waste, hydro, geothermal, wind and solar energy.

Interpretation

These indicators should be read in connection with other indicators and in particular with indicators on CO_2 productivity and intensities, on R&D and patents related to energy efficiency and renewable energy, on energy prices and taxes for households and industry, and on carbon pricing. They should further be complemented with information on energy-related air and water emissions and waste generation.

When interpreting these indicators, it should be kept in mind that energy productivity and intensities reflect structural and climatic factors as well as changes in energy efficiency, and should not be used to assess how efficient the use of energy is in a country.

- The energy productivity of an economy is a measure of how much national revenue is generated for each unit of energy used.

I.2 ENERGY PRODUCTIVITY AND RENEWABLES

- Efficiency is a contributing factor in productivity, but many other elements – often more significant – need also be considered. These include: the structure of the economy (presence of large energy-consuming industries, for instance); the size of the country (higher demand from the transport sector); the climate (higher demand for heating or cooling).

Cross country comparisons need to take into account countries' endowment in different types of energy resources.

Measurability and data quality

Data on total energy supply and consumption are available from international sources (IEA) for all OECD countries and other countries in the world. Efforts are being made by the IEA to further develop appropriate measures of energy efficiency and to improve the mandatory reporting of energy efficiency-related data.

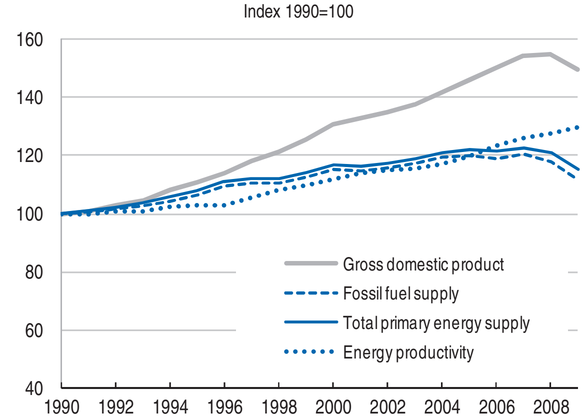
MAIN TRENDS AND STRUCTURAL CHANGES

Relative decoupling

While some decoupling of environmental effects from growth in energy use has been achieved, results to date are insufficient and the environmental implications of increasing energy use remain a major issue in most OECD countries. Progress in per capita terms has been slow, reflecting an overall increase in energy supply and increasing energy demands for transport activities.

Total primary energy supply versus GDP, OECD, 1990-2009

Index 1990=100



Source: OECD, IEA.

Important variations across countries and world regions

During the past two decades, energy productivity has generally increased in the OECD, but at a slower pace than during the 1980s. While in the first half of the 1990s, energy productivity did not improve in most countries, due to decreasing prices for energy resources (oil, gas, etc.), it improved slightly as of the second half of the 1990s as a consequence of structural changes in the economy, energy conservation measures, and in some countries decreases in economic activity.

Variations in energy productivity and intensity among OECD countries are wide and depend on national economic structure, geography (e.g. climate), energy policies and prices, and countries' endowment in different types of energy resources.

Important variations in the fuel mix

The supply structure varies considerably among countries. It is influenced by demand from industry, transport and households, by national energy policies and by national and international energy prices. During the 1990s, growth in total primary energy supply was accompanied by changes in the fuel mix: the shares of solid fuels and oil fell, while those of gas and other sources, including renewable energy sources, rose.

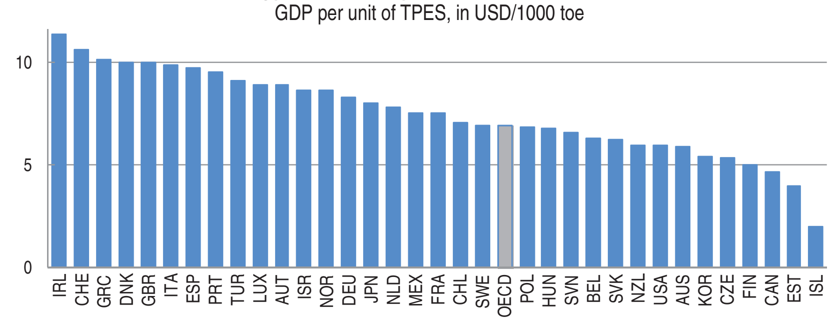
Energy end-use intensities

In the residential sector, there is still ample room for further efficiency gains. However, it is worth noting that differences in future demographic and income trends across OECD countries could spur the efficiency gains as measured in relative terms per capita or income levels. Space heating still accounts for more than half of household energy consumption in OECD countries; however the share of appliances is quickly growing.

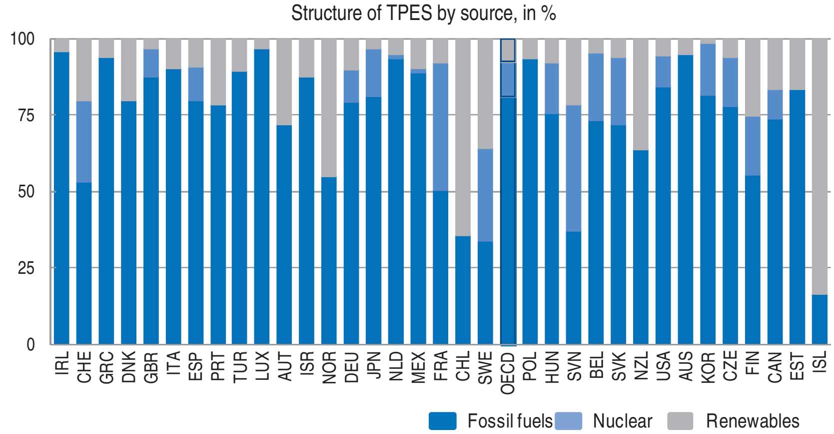
I.2 ENERGY PRODUCTIVITY AND RENEWABLES

ENERGY PRODUCTIVITY AND STRUCTURE

Energy productivity, OECD countries, 2009
GDP per unit of TPES, in USD/1000 toe



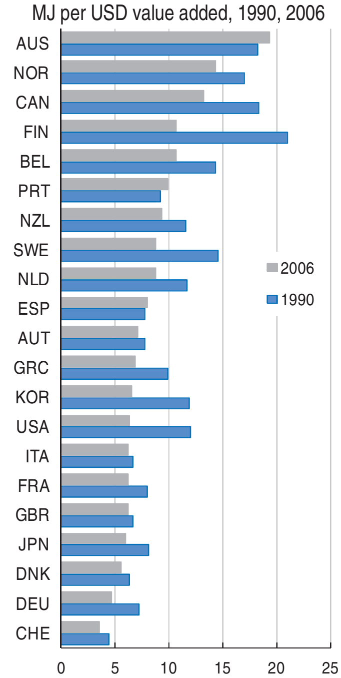
Energy mix, OECD countries, 2009
Structure of TPES by source, in %



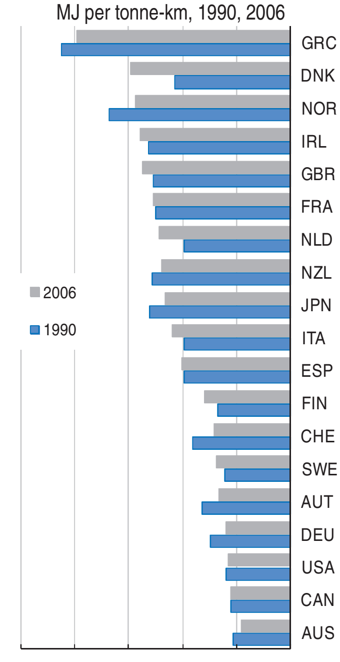
Source: OECD, IEA.

ENERGY INTENSITIES BY END-USE OR SECTOR

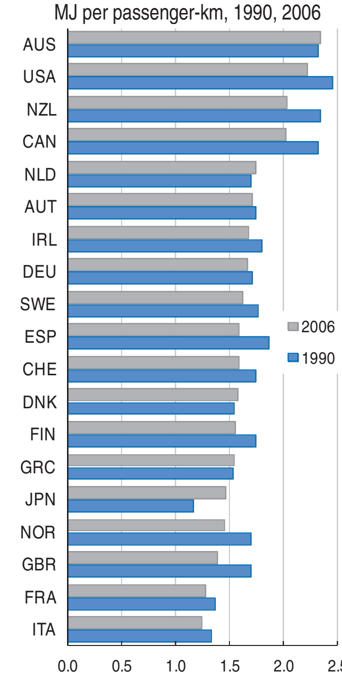
Manufacturing energy intensity
MJ per USD value added, 1990, 2006



Freight transport energy intensity
MJ per tonne-km, 1990, 2006



Passenger transport energy intensity
MJ per passenger-km, 1990, 2006

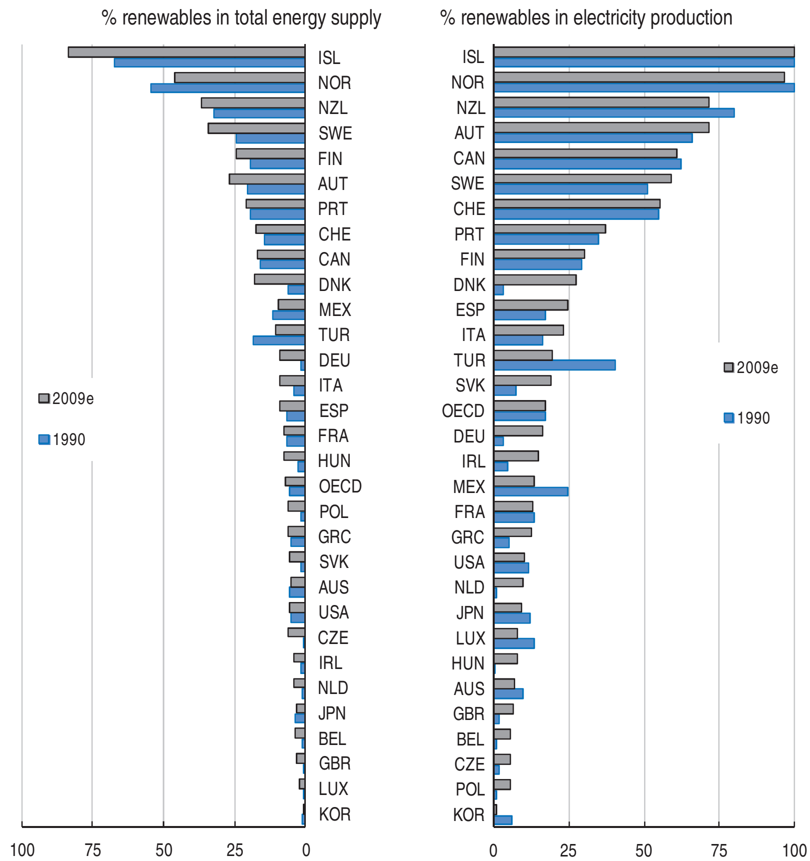


Source: IEA Scoreboard.

I.2 ENERGY PRODUCTIVITY AND RENEWABLES

SHARE OF RENEWABLE ENERGY

Share of renewable energy in energy use, OECD countries, 1990, 2009



Source: OECD-IEA.

Some increase in the share of renewables

Several OECD countries have made progress in promoting renewables in their energy mixes. Overall, the share of renewable energy has remained relatively stable for the OECD and accounts for about 7% of total supply, with a slight increase in recent years reflecting the growing role of bioenergy, liquid biofuels and wind in some countries. Biomass and hydro still represent the largest shares. Many obstacles remain and greater efforts are needed in terms of implementation of effective policies and technology improvement.

Despite the growth of electricity generation from renewable sources in absolute terms since 1990, its share in total electricity generation decreased for the OECD as a whole until 2001. During this period growth of renewables did not keep pace with growth of electricity generation from fossil fuels and nuclear. Since 2001 the trend is reversing: renewable electricity shares have been slightly increasing (reaching 17% in 2009), mainly thanks to government policies supporting the deployment of wind – and, to lesser extent, of biomass and solar.

The challenge in electricity generation is essentially about improving the cost-effectiveness of existing low-carbon technologies and putting in place the policies that enable their deployment. Because new capital investments in more energy-efficient technologies usually represent only a small fraction of the total capital stock, the gains from new technologies will only be gradual (see section on *technology & innovation*).

I.2 ENERGY PRODUCTIVITY AND RENEWABLES

Notes and definitions

Total primary energy supply and productivity

Total primary energy supply (TPES) equals production plus imports minus exports minus international marine and aviation bunkers plus or minus stock changes. The world total, international marine and aviation bunkers are not subtracted from TPES. Energy productivity is calculated as the amount of revenue (GDP here) generated per unit of energy used (TPES here).

Energy use by sector and end-use

These indicators, developed from an updated and expanded IEA database, describe energy use across three main end-use sectors in IEA countries: manufacturing (in megajoule per USD of value added), passenger transport (in megajoule per passenger-km) and freight transport (in megajoule per tonne-km). These indicators make it possible to examine how changes in energy efficiency, economic structure, income, prices and fuel mix have affected recent trends in energy use and CO_2 emissions.

Share of renewable energy sources in TPES and in electricity generation

Renewables include hydro, geothermal, solar, wind, tide/wave/ocean energy, as well as combustible renewables and waste.

Geothermal is the energy available as heat emitted from within the earth's crust, usually in the form of hot water or steam. It can be used directly as heat for district heating, agriculture, etc., or to produce electricity. Unless the actual efficiency of the geothermal process is known, the quantity of geothermal energy entering electricity generation is inferred from the electricity production at geothermal plants assuming an average thermal efficiency of 10%.

Solar includes solar thermal and solar photovoltaic (PV). The quantities of solar PV entering electricity generation are equal to the electrical energy generated. Direct use of solar thermal heat is also included.

Tide, wave and ocean represents the mechanical energy deriving from tidal movement, wave motion or ocean current and exploited for electricity generation. The quantities entering electricity generation are equal to the electrical energy generated.

Wind represents the kinetic energy of wind exploited for electricity generation in wind turbines. The quantities entering electricity generation are equal to the electrical energy generated.

Combustible renewables and waste comprises solid biomass, liquid biomass, biogas, industrial waste and municipal waste. Biomass is defined as any plant matter used directly as fuel or converted into fuels (*e.g.* charcoal) or electricity and/or heat. Included here are wood, vegetal waste (including wood waste and crops used for energy production), ethanol, animal materials and/or wastes, and sulfite lyes (i.e. black liquor). Municipal waste comprises wastes produced by the residential and commercial and public service sectors (which are collected by local authorities for disposal in a central location for the production of heat and/or power).

N.B. The methodology used to calculate the TPES correspondent to a given amount of final energy has important implications on the respective share of each contributing energy source. This is particularly true for calculation of the shares of renewable energy sources. The IEA Secretariat uses the "physical energy content" methodology to calculate TPES. For combustibles, TPES is based on the net calorific value of the fuels. For other sources, the IEA assumes an efficiency of 10% for geothermal electricity, 33% for nuclear, 50% for geothermal heat and 100% for hydro, wind and solar PV. As a result, for the same amount of electricity produced, the TPES calculated for combustible renewables will be several times higher than the TPES for hydro, wind or solar PV.

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I.3 RESOURCE PRODUCTIVITY: MATERIAL PRODUCTIVITY

POLICY CONTEXT

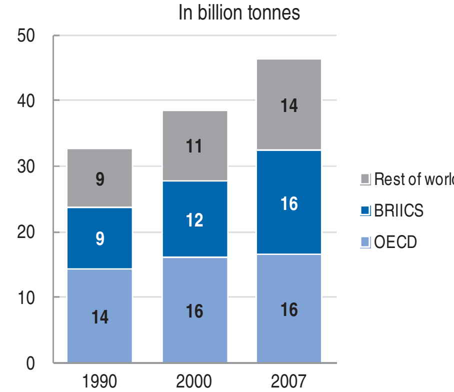
The issue

Economic growth is generally accompanied by growing demand for raw materials, energy and other natural resources with consequences on market prices and on trade flows of these resources.

Worldwide use of virtually every significant material has been rising over many years, causing recurrent concerns about shortages of natural resource stocks, the security of supply of energy and other materials, and the environmental effectiveness of their use. At the same time, the amount of waste generated by economic activity has been rising in line with growing global demand for raw materials. Despite achievements in waste recycling and some relative decoupling of waste generation from economic growth, many valuable materials contained in waste continue to be disposed of and are potentially lost for the economy. This affects both the efficiency of material use and environmental quality in terms of land use, water and air pollution, and greenhouse gas emissions.

OECD countries represent one third of the world extraction of non-energy materials

In billion tonnes



Source: SERI.

The use of materials from natural resources and the attendant production and consumption processes have many economic, social and environmental consequences that often extend beyond the borders of single countries or regions. Ensuring that the flows of materials are managed in an effective and sound way through the economic system is thus critical, not only from an environmental perspective but also from an economic and trade perspective. From an economic perspective, the manner in which materials are used and managed affects (i) short-term costs and long-term economic sustainability; (ii) the supply of strategically important materials; and (iii) the productivity of economic activities and industrial sectors.

Main challenges

The main challenge is to improve resource productivity and ensure that materials are managed well and used efficiently at all stages of their life-cycle (extraction, transposition, transportation, consumption, and disposal) so as to avoid waste of resources, and reduce the associated negative environmental impacts. Resource productivity has an impact on the production process and on economic growth through impacts on capital stocks, and through impacts on costs, especially in resource-intensive industries. Improving resource productivity will also help reduce demand pressures on primary natural resource stocks and increase the long term availability (and quality) of resources for everyone.

Improving resource productivity and ensuring sustainable materials management requires integrated life-cycle based waste, materials and product policies, such as circular economy or 3R related initiatives, and the use of instruments aimed at stimulating technological change. It also implies internalising the costs of waste management into prices of consumer goods and of waste management services; and ensuring greater cost-effectiveness and full public involvement in designing measures.

I.3 RESOURCE PRODUCTIVITY: MATERIAL PRODUCTIVITY

MONITORING PROGRESS THROUGH INDICATORS

Progress towards green growth can be in part assessed against changes in the extraction of resources and domestic consumption of materials, and in the associated material productivity. These indicators complement existing productivity measures and hence facilitate the analysis related to economic output (value added) per amount of material resources used.

Indicators of progress

The indicators presented here relate to:

- Material extraction, i.e. domestic extraction "used" (DEU), expressed in absolute terms, and related changes for individual material groups and for aggregates. The focus is on non-energy materials.
- Material consumption, i.e. domestic material consumption (DMC), expressed in absolute terms, and related productivity ratios for individual material groups and for aggregates. Productivity is expressed as the amount of economic output generated for a unit of materials consumed. The focus is on non-energy materials.

Trends in municipal waste generated are given as a complement. While municipal waste is only one part of total waste generated, its management represents more than one third of the public sector's financial efforts to abate and control pollution.

Interpretation

These indicators should be read with information on commodity prices, flows of secondary raw materials and recovery ratios, waste management practices and costs, and consumption levels and patterns. Cross-country comparisons should also take into account countries' endowments in natural resources and the structure of their economy.

When interpreting these indicators, it should be kept in mind that they are first approximations of potential environmental pressure; more information is needed to describe the actual pressure.

Measurability and data quality

Material flows: A considerable amount of work on MFA has been carried out in the past decade, much of it focusing on the development of methodologies and the necessary "spade work" to set up accounts required for calculating material flow (MF) indicators. More needs to be done to:

- Capture flows that do not enter the economy as transactions, but that are relevant from an environmental point of view.
- Monitor physical trade flows by origin and destination.
- Measure indirect flows (domestic and trade related) and develop common conversion factors and coefficients.
- Monitor flows of secondary raw materials (recycled, reused) and of recyclable materials.
- Develop methods to assess the environmental impacts of materials use.
- Provide industry-level and material-specific information to indicate opportunities for improved performance and efficiency gains.

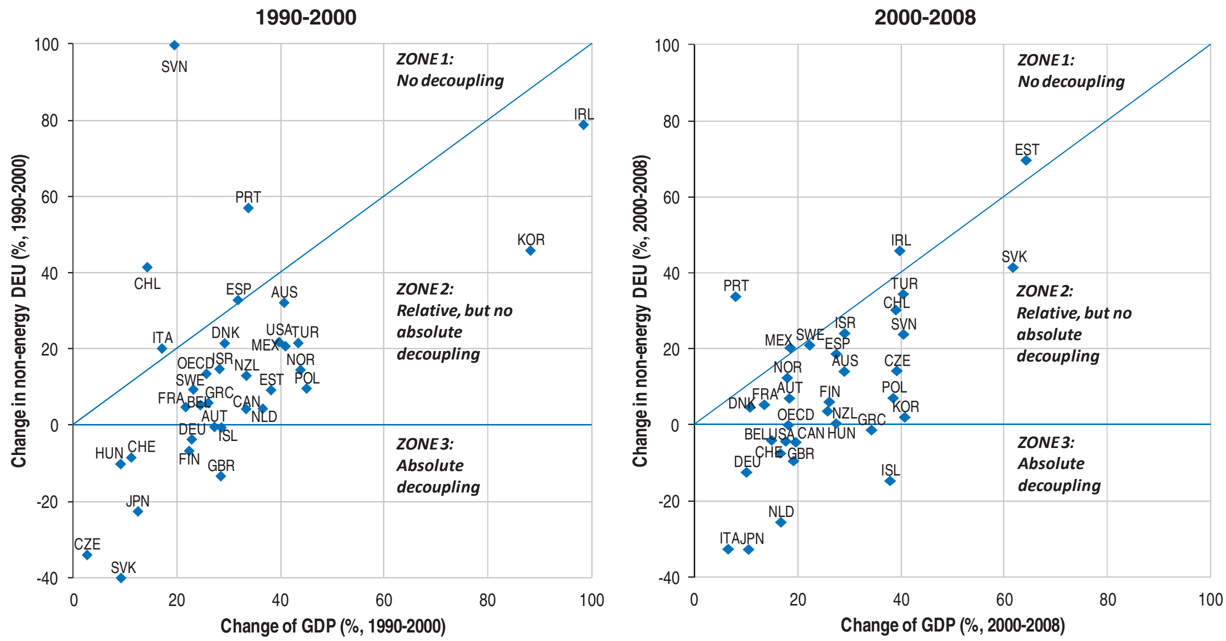
Waste: Despite considerable progress, data on waste generation and disposal remains weak in many countries. Further efforts are needed to:

- Ensure an appropriate monitoring of all waste flows and of related management practices.
- Improve the international comparability of the data.
- Fill data gaps with respect to waste prevention measures and other measures related to the 3Rs (reduce, reuse, recycle).

I.3 RESOURCE PRODUCTIVITY: MATERIAL PRODUCTIVITY

DECOUPLING TRENDS: MATERIAL EXTRACTION

Non-energy material extraction versus GDP, OECD countries, 1990-2008



Source: OECD Material Flow Database.

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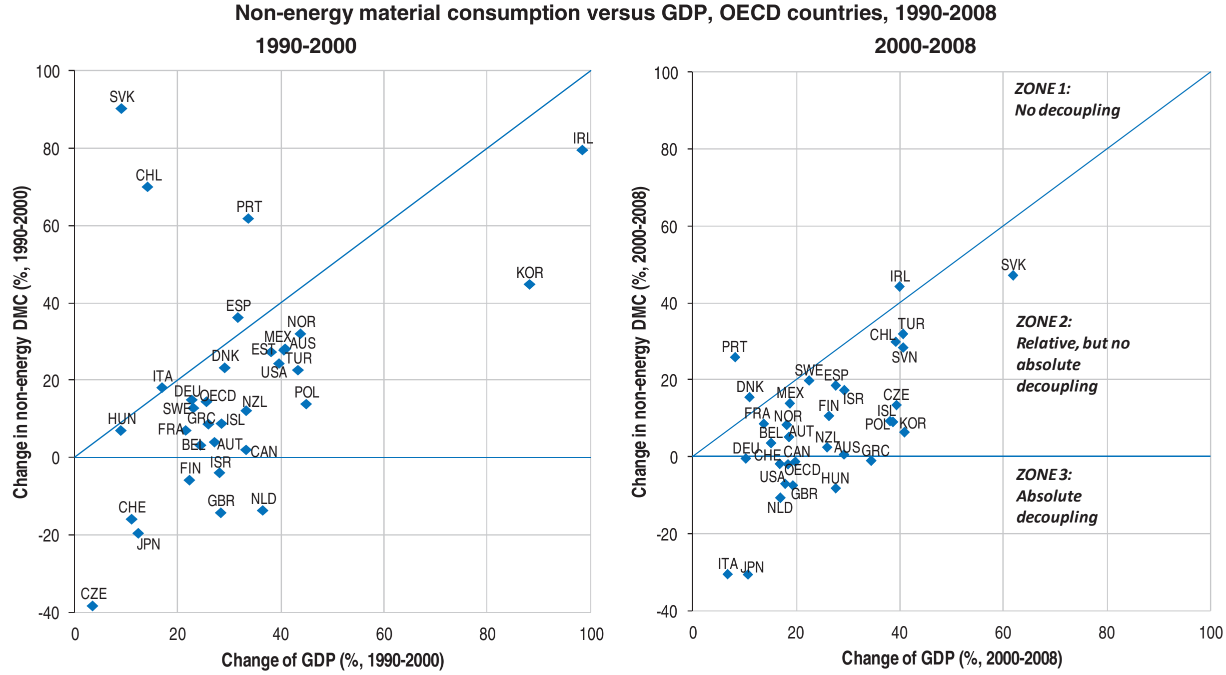
DECOUPLING TRENDS: MATERIAL CONSUMPTION

Non-energy material consumption versus GDP, OECD countries, 1990-2008



Note: Not presented in the chart is Slovenia, its DMC increased by 108% and GDP by 20% from 1990 to 2000.

Source: OECD Material Flow Database.

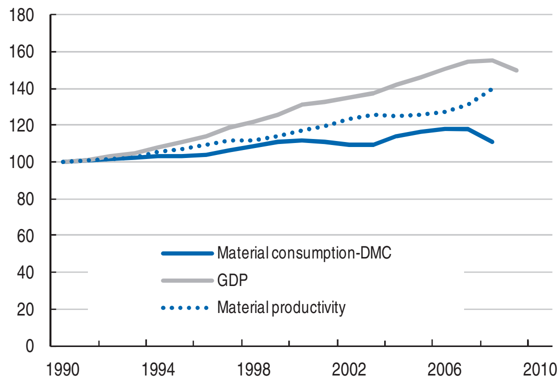
Note: Not presented in the chart is Estonia; its DMC increased by 140% and GDP by 64% from 2000 to 2008.

StatLink http://dx.doi.org/10.1787/888932425422

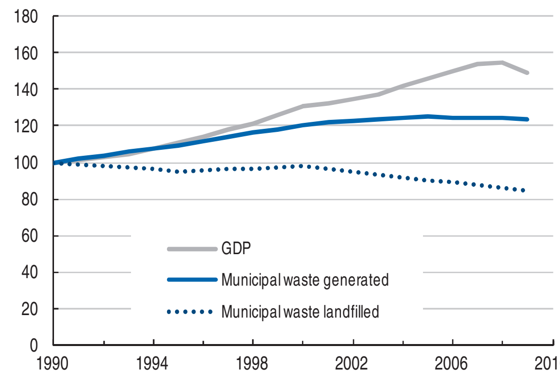
I.3 RESOURCE PRODUCTIVITY: MATERIAL PRODUCTIVITY

DECOUPLING TRENDS: MATERIAL CONSUMPTION AND WASTE

Domestic material consumption versus GDP, OECD, 1990-2009
Index 1990=100



Municipal waste generation versus GDP, OECD 1990-2009
Index 1990=100

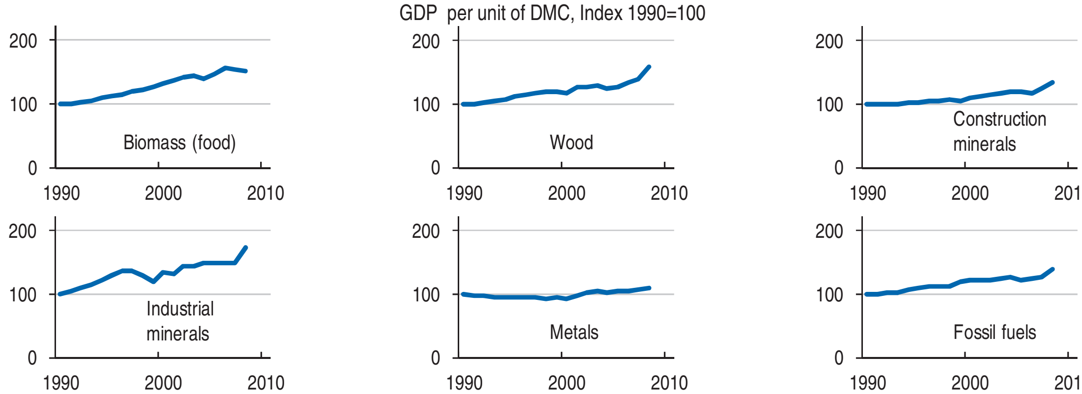


Source: OECD Material Flow database; OECD Environmental Data.

StatLink http://dx.doi.org/10.1787/888932425441

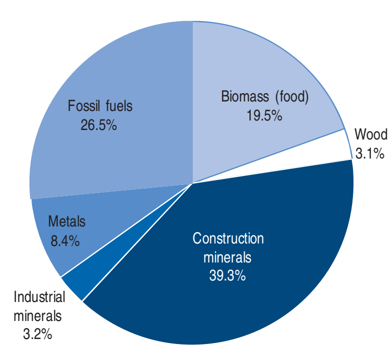
MATERIAL PRODUCTIVITY BY GROUP AND MATERIALS MIX

Material productivity by material group, OECD
GDP per unit of DMC, Index 1990=100



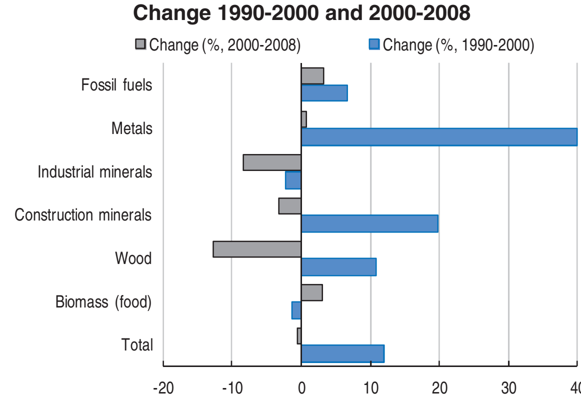
Composition of domestic material consumption (DMC) and change since 1990, OECD

State 2008



Source: OECD Material Flow database

Change 1990-2000 and 2000-2008



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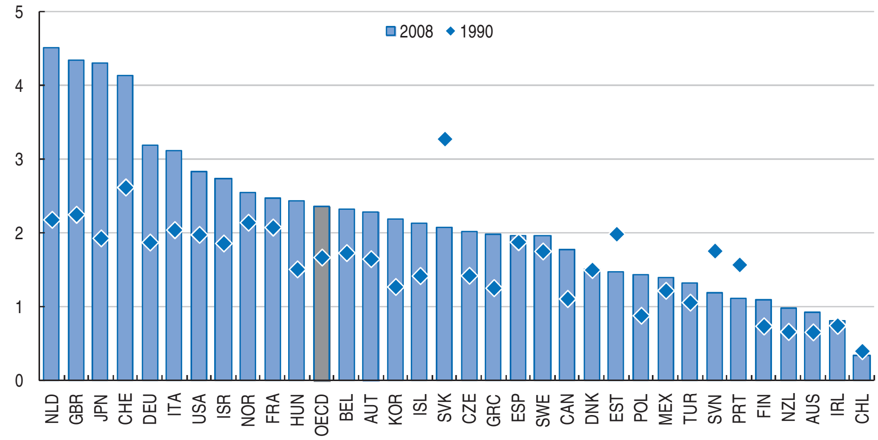
I.3 RESOURCE PRODUCTIVITY: MATERIAL PRODUCTIVITY

DOMESTIC MATERIAL PRODUCTIVITY

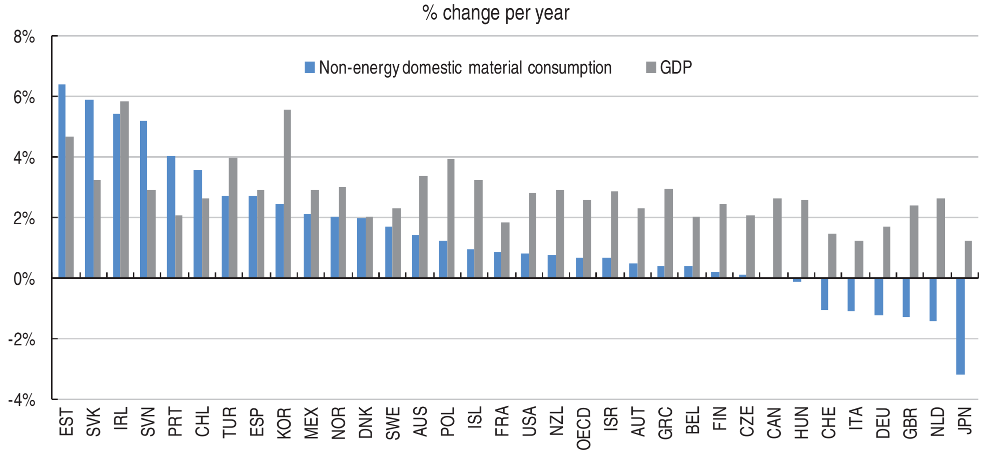
Non-energy domestic material productivity, OECD countries, 1990, 2008

GDP per unit of domestic material consumption (DMC), in USD/1000 tonnes



Change in non-energy domestic material consumption (DMC) and GDP, OECD countries, 1990-2008

% change per year



Source: OECD Material Flow database

StatLink http://dx.doi.org/10.1787/888932425479

MAIN TRENDS

Continued growth in consumption

Since 1990 the extraction and consumption of raw materials has continued to expand in OECD countries, although growth has slowed significantly compared to the previous decade. Abiotic materials (i.e. minerals, metals, fossil energy carriers) account for a dominant and growing share of consumption thanks in large part to strong growth in the consumption of construction minerals, which dominate the material mix. In 2008 abiotic materials represented nearly 80% of consumption with biotic materials (i.e. food, feed, wood and wood fibre) making up slightly over 20%.

Material consumption in OECD countries reached almost 22 Gt in 2008 meaning that the average person living in an OECD country consumed 18t of raw materials per year or roughly 50 kg of materials per day. Notwithstanding wide variation in per capita consumption level between member countries, people living in OECD countries, on average, consume significantly more than those in non-OECD countries. In 2007, per capita consumption in OECD economies was more than double the world average and three times greater than in non-OECD economies.

Excluding the fossil energy carriers from the material composition, non-energy domestic material consumption grew by 13% between 1990 and 2008.

I.3 RESOURCE PRODUCTIVITY: MATERIAL PRODUCTIVITY

Relative decoupling

The efficiency which with individual OECD countries use raw materials varies significantly, regardless of whether considered in absolute numbers, per capita amounts, or in terms of productivity. Although growing in absolute terms, progress has been made in decoupling material consumption from economic growth in relative terms. Material productivity in OECD economies is improving as more economic output (i.e. GDP) is being generated for each unit of raw material consumed. From 1990 to 2008, the non-energy material productivity of OECD economies increased from 1.7 USD/kg (constant 2005 PPP) to 2.3 USD/kg due to strong economic growth that outpaced growth in material consumption

These trends reflect to a certain degree efficiency gains in production processes, but other factors have to be taken into account, such as changes in the materials mix and substitution of domestic production by imports of intermediate and final goods.

Relative decoupling has been witnessed across all major material groups, but some absolute decoupling has also occurred for industrial minerals and metals in recent years. This trend is promising given growing supply security concerns and the amount of unused materials and waste associated with mining activities. Another pressing challenge remains fossil energy carriers, where a significantly lower degree of decoupling has taken place, given their importance for energy security and climate change (see section on *energy productivity and renewables*).

Notes and definitions

Material extraction

The most commonly used material extraction indicator is domestic extraction used (DEU). DEU measures the flows of materials that originate from the environment and that physically enter the economic system for further processing or direct consumption (they are "used" by the economy). They are converted into or incorporated in products in one way or the other, and are usually of economic value.

Material consumption

Domestic material consumption measures the total amount of materials used in an economy and is calculated as domestic extraction (used materials) minus export plus imports. Internationally comparable data are not available for individual non-OECD economies, only estimated values for the world aggregate.
Decoupling trends (scatter graph): For the following countries the period 1990-2000 refers to: 1996-2000 for Chile and Slovenia; 1991-2000 for Hungary; and 1995-2000 for Estonia and Israel.

All data on materials: The OECD total does not include Luxembourg.

Municipal waste

Municipal waste is waste collected by or on behalf of municipalities. It includes waste originating from households, commercial activities, office buildings, institutions such as schools and government buildings, and small businesses that dispose of waste at the same facilities used for municipally collected household waste. Household waste is waste generated by the domestic activity of households. It includes mixed household waste, bulky waste and separately collected waste. National definitions may differ.

Sources

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- SERI (Sustainable Europe Research Institute) online portal for worldwide data on global resource extraction: www.materialflows.net .Portal set up and administrated by SERI in cooperation with the Wuppertal Institute for Climate, Environment, Energy.

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I.4 RESOURCE PRODUCTIVITY: NUTRIENT BALANCES

POLICY CONTEXT

The issue

The sustainability of agro-food systems is at the centre of green growth considerations. Main concerns relate to food security, to the flows of potentially polluting nutrients (nitrogen, phosphorous) from excessive commercial fertiliser use and intensive livestock farming, and to pesticides residues that may leach into surface water and groundwater, and may enter the food chain.

Agriculture's environmental effects can be negative or positive. They depend on the scale, type and intensity of farming as well as on agro-ecological and physical factors, climate and weather, and on policy, economic and market developments. Farming can lead to deterioration in soil, water and air quality, and to loss of natural habitats and biodiversity. These environmental changes can in turn have implications for the level of agricultural production and food supply, and limit the sustainable development of agriculture. Farming can also provide sinks for greenhouse gases, contribute to conserving biodiversity and landscapes, and help prevent floods and landslides.

Main challenges

The main challenge is to progressively decrease the negative impacts and increase the positive environmental benefits associated with agricultural production so that ecosystem functions can be maintained and food security ensured for the world's growing population.

This implies improving the productivity and sustainability of agro-food systems, for example through the reduction of waste in supply chains, better management of fisheries, attention to land management practices, and to minimise pollution discharges from agriculture, such as better management of nutrients (fertilisers and livestock manure), and addressing agricultural support policies linked to production that can encourage the intensity of production beyond that which would occur in the absence of these policies. More efficient management of food systems is also a key ingredient in stemming the rate of biodiversity loss in the world.

MONITORING PROGRESS THROUGH INDICATORS

Progress towards green growth can, in part, be assessed against changes in agricultural nutrient balances and related intensities. Nutrient balances are an indication of the level of potential environmental pressures from nutrients on natural assets, in particular soil, water and air. For instance, soil fertility can decline in the case of a nutrient deficit or for a nutrient surplus there is a risk of polluting soil, air, and water (eutrophication).

Indicators of progress

The indicators presented here relate to agricultural nutrient balances. They include:

- Agricultural nutrient intensity related to changes in agricultural output, expressed as changes in the nitrogen (N) and phosphorus (P) balance per ha of agricultural land versus changes in agricultural production.
- Nitrogen and phosphorus surplus intensities, expressed as the N and P balance per ha of agricultural land.

Interpretation

When interpreting these indicators it should be noted that they describe potential environmental pressures, and may hide important sub-national variations. More information is needed to describe the actual pressure. They should be read together with information on agricultural land use and farm management approaches.

Cross-country comparisons of change in nutrient surplus intensities over time should take into account the absolute intensity levels during the reference period.

It should also be noted that these indicators reflect nutrient balances from agriculture only, and do not consider nutrient balances from other food production systems such as fisheries or total nitrogen cycles in an economy.

I.4 RESOURCE PRODUCTIVITY: NUTRIENT BALANCES

Measurability and data quality

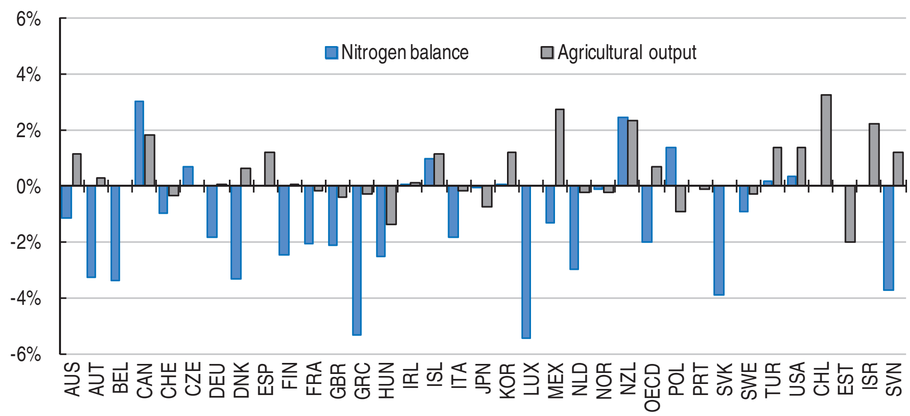
OECD data on nitrogen and phosphorus balances are available for 30 OECD countries until 2008. A comparable measure of agricultural output is available as an index number from the FAO. Improvements to the underlying methodology, nutrient conversion coefficients and primary data is currently being undertaken by OECD countries in cooperation with Eurostat and FAO as the nutrient balances are revised and updated.

In the long term, nutrient balances should also take into account nutrient losses through erosion, as well as nutrient inputs and outputs from other sources and economic activities.

NUTRIENT INTENSITIES: NITROGEN

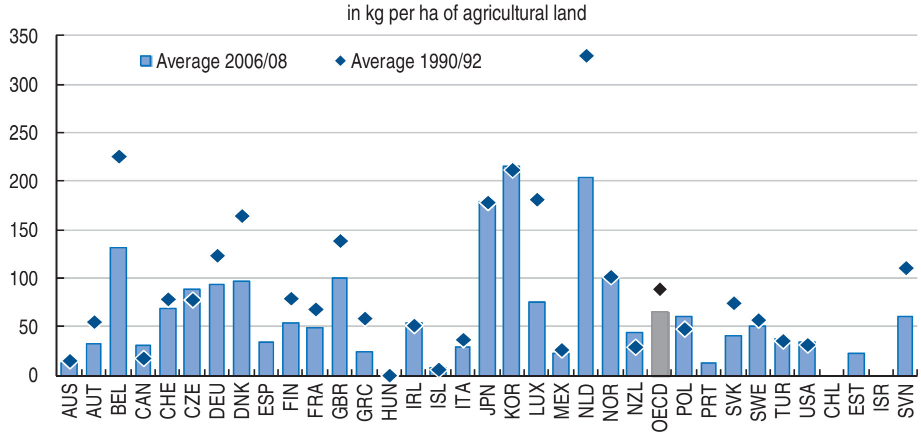
Change in nitrogen balance and agricultural output, OECD countries, 1990-2008

% change per year



Nitrogen surplus intensities, OECD countries, 1990/92 and 2006/08

in kg per ha of agricultural land



Source: OECD Agri-environmental indicators, Eurostat.

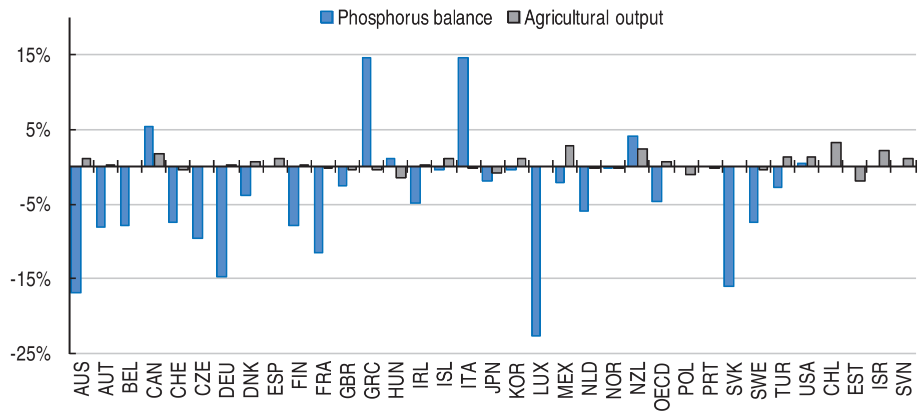
StatLink http://dx.doi.org/10.1787/888932425498

I.4 RESOURCE PRODUCTIVITY: NUTRIENT BALANCES

NUTRIENT INTENSITIES: PHOSPHOROUS

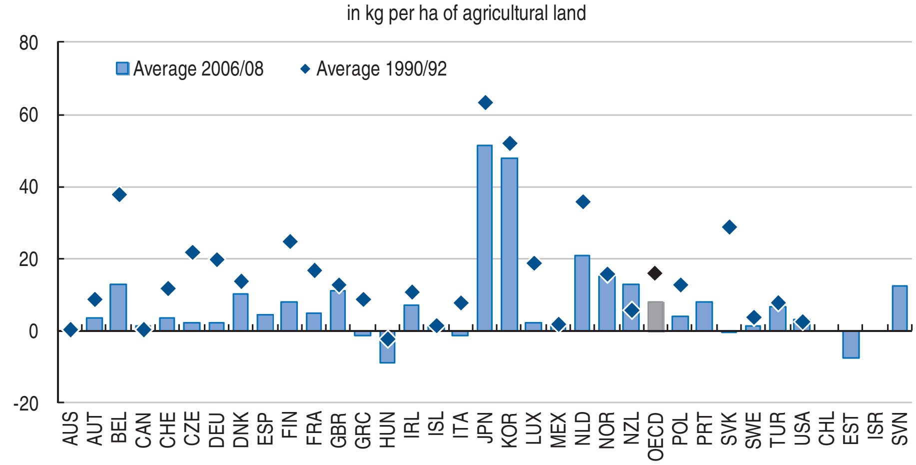
Change in phosphorous balance and agricultural output, OECD countries, 1990-2008

% change per year



Phosphorous surplus intensities, OECD countries, 1990/92 and 2006/08

in kg per ha of agricultural land



Source: OECD Agri-environmental indicators, Eurostat.

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MAIN TRENDS

Some decoupling

For many OECD countries, nutrient surpluses (the potential transfer of nutrients to soil, water and air) relative to changes in agricultural output declined, signalling a process of relative decoupling of agricultural production from N/P-related environmental pressure.

… and important variations across countries

This reflects both improvements in nutrient use efficiency and the reduction in agricultural output. There are, however, sizable variations within and between countries in terms of the intensity and trends of nutrient surpluses.

The absolute pressure on the environment (measured as the intensity of nitrogen and phosphorus surpluses per hectare) remains high in a number of countries.

… and within countries.

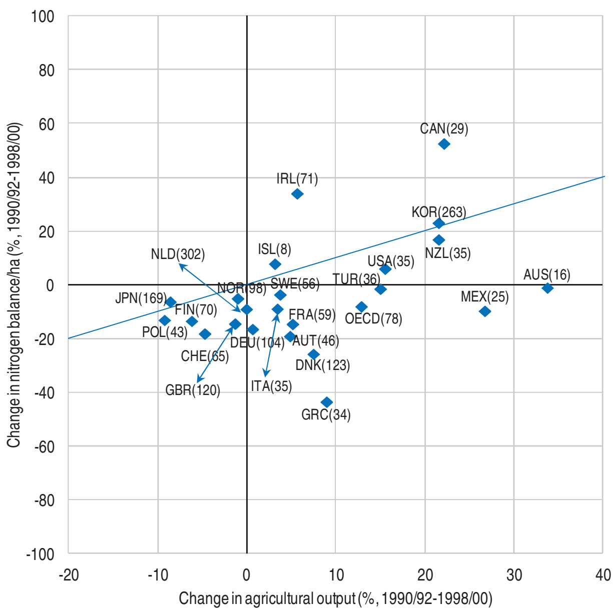
In most countries there is considerable variation in the level and trends of regional nutrient balance surpluses around national average values. Regional variations are explained by the spatial distribution of intensive livestock farming and cropping systems that require high nutrient inputs, such as maize and rice relative to wheat and oilseeds.

I.4 RESOURCE PRODUCTIVITY: NUTRIENT BALANCES

DECOUPLING TRENDS: NITROGEN AND PHOSPHOROUS

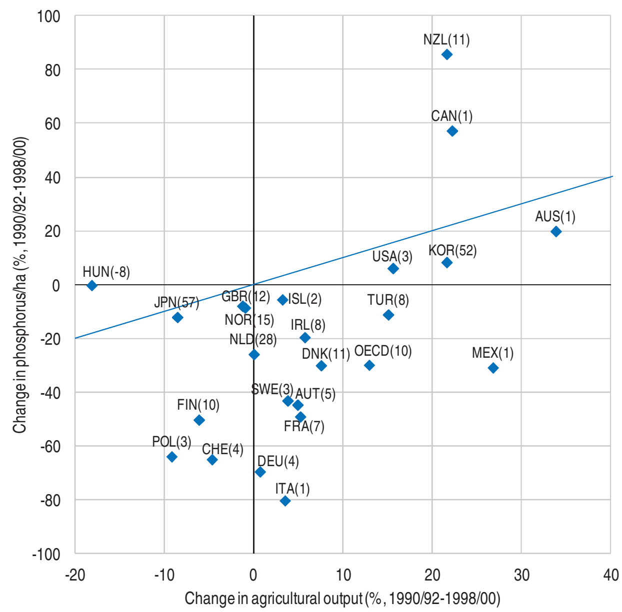
Nitrogen balance versus agricultural output

1990/92-1998/2000

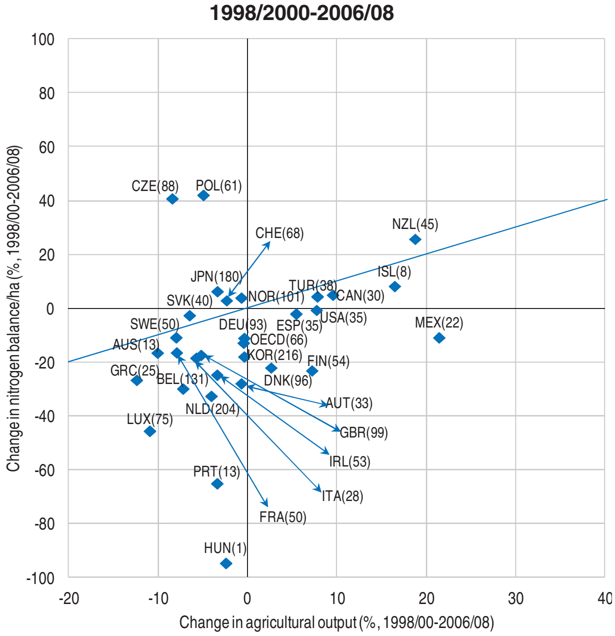


Phosphorous balance versus agricultural output

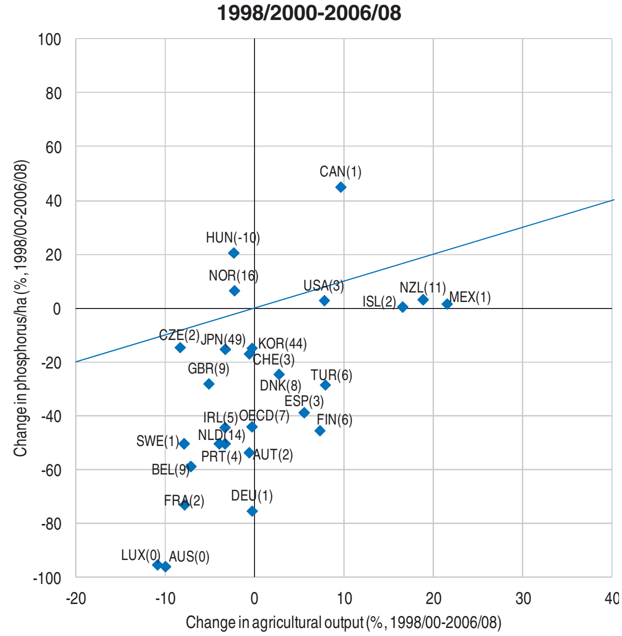
1990/92-1998/2000



1998/2000-2006/08



1998/2000-2006/08



The values in brackets indicate the average nitrogen and phosphorous balance (kg/ha) in 1998/2000 and 2006/08 respectively. A 3-year average is considered to smooth the influence of natural events (such as drought and floods) on agricultural production over time.

Source: OECD Agri-environmental indicators, Eurostat.

StatLink http://dx.doi.org/10.1787/888932425536

I.4 RESOURCE PRODUCTIVITY: NUTRIENT BALANCES

Notes and definitions

Agricultural nutrient balances

Agricultural nutrient balances are calculated as the difference between the total quantity of nutrient inputs entering an agricultural system (mainly fertilisers and livestock manure), and the quantity of nutrient outputs leaving the system (mainly uptake of nutrients by crops and grassland).

The gross nitrogen and phosphorous balances

The gross nutrient balances are calculated as the difference between the total quantity of nutrient inputs entering an agricultural system, and the quantity of nutrient outputs leaving the system. This calculation can be used as a proxy to reveal the status of environmental pressures, such as declining soil fertility in the case of a nutrient deficit, or for a nutrient surplus the risk of polluting soil, water and air.

The nutrient balance indicator is expressed in terms of kilograms of nutrient surplus (deficit) per hectare of agricultural land per annum to facilitate the comparison of the relative intensity of nutrients in agricultural systems between countries. The nutrient balances are also expressed in terms of changes in the physical quantities of nutrient surpluses (deficits) to indicate the trend and level of potential physical pressure of nutrient surpluses into the environment. The spatial variations in nutrient balances are usually explained by regional differences in farming systems, differing climates and types of soil, farming types and crops types, and also varying topography across the agricultural regions.

Scatter graphs:

The values in brackets indicate the average **nitrogen** balance (kg/ha) in 1998/2000 and 2006/2008 respectively. The OECD area excludes Chile, Estonia, Israel. A 3-year average is considered to address the short-term variability in the agricultural output, except for the United Kingdom for which the data are available only for 1990 in 1990/92 average and 2000 in 1998/2000 average, and Slovenia for which the data on phosphorus are not available before 1992 and for nitrogen before 1995. There are no data available on nitrogen balances in the period 1990/92 for Portugal and Spain. The nitrogen balance increased by 1100% from 1 to 12 kg/ha for Hungary between 1990/92-1998/00 and since it is an outlier it is not included in the OECD average.

The values in brackets indicate the average **phosphorus** balance (kg/ha) in 1998/2000 and 2006/2008 respectively. The OECD area excludes Chile, Estonia, Israel. A 3-year average is considered to address the short-term variability in the agricultural output, except for the United Kingdom for which the data are available only for 1990 in 1990/92 average and 2000 in 1998/2000 average, and Slovenia for which the data on phosphorus are not available before 1992 and for nitrogen before 1995. There are no data available on phosphorus balances in the period 1990/92 for Portugal and Spain. The phosphorus balance decreased by 433% from 1.0 to -3.3 kg/ha for Italy, decreased by 400% from 0.3 to -1.0 kg/ha for Slovakia, and increased by 175% from 2.7 to 7.3 kg/ha for Poland between, and increased by 133% for Greece between 1998/00-2006/08 while decreased by 118% between 1990/92-1998/00 (not presented in the graph).

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