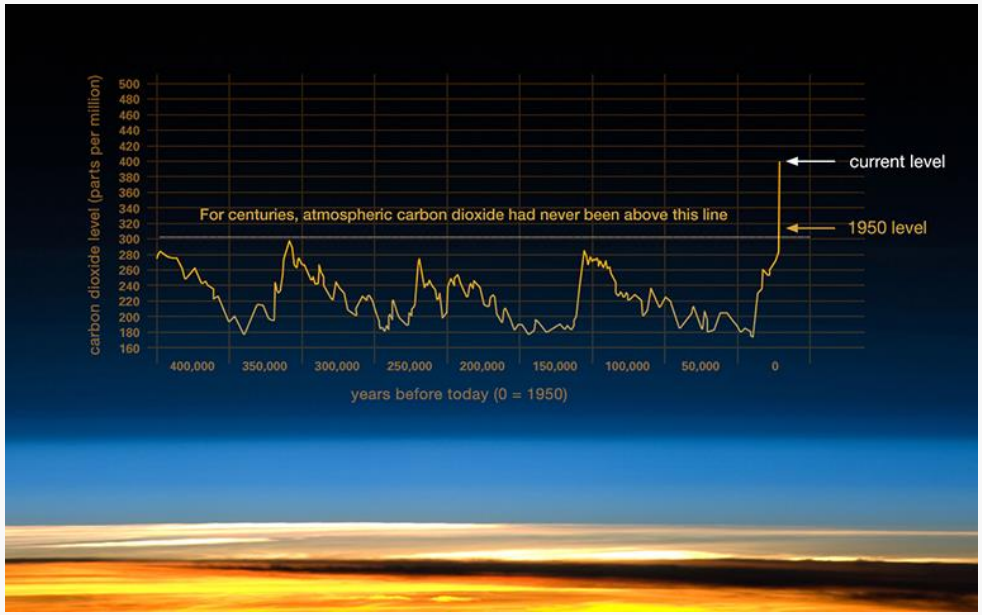
IMPATTO AMBIENTALE DEI SISTEMI ENERGETICI

- Produzione di CO_2 -

Corso di "PROGETTAZIONE DEI SISTEMI ENERGETICI"

Prof. Mauro Venturini

CO2 in Earth's atmosphere

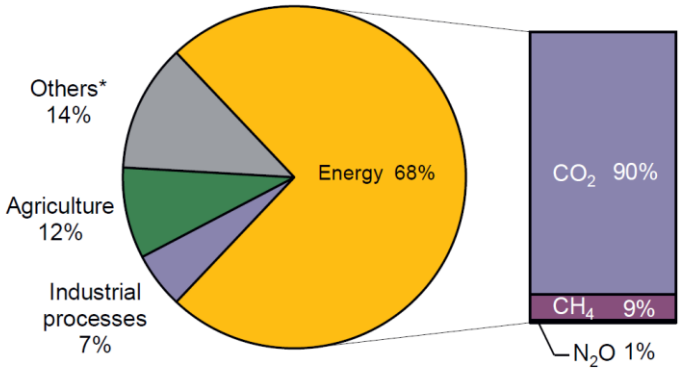


During ice ages, CO2 levels were around **200 ppm**, and during the warmer interglacial periods, they hovered around 280 ppm (see fluctuations in the graph).
In 2013, CO2 levels surpassed **400 ppm** for the first time in recorded history.
This recent relentless rise in CO2 shows a remarkably **constant relationship with fossil-fuel burning**, and can be well accounted for based on the simple premise that about 60 percent of fossil-fuel emissions stay in the air.

Source: https://climate.nasa.gov/climate_resources/24/

GHG emissions

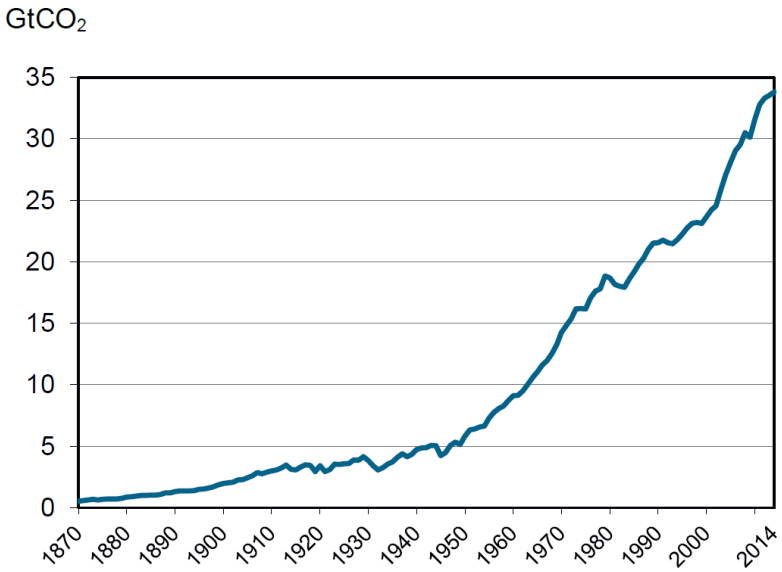
Figure 1. Estimated shares of global anthropogenic GHG, 2014



* Others include large-scale biomass burning, post-burn decay, peat decay, indirect N_2O emissions from non-agricultural emissions of NO_x and NH_3, Waste, and Solvent Use.

Source: based on IEA estimates for CO_2 from fuel combustion and EDGAR version 4.3.2 for CO_2, CH_4 and N_2O emissions and 4.2FT2010 for the F-gases; based on 100-year Global Warming Potential (GWP).

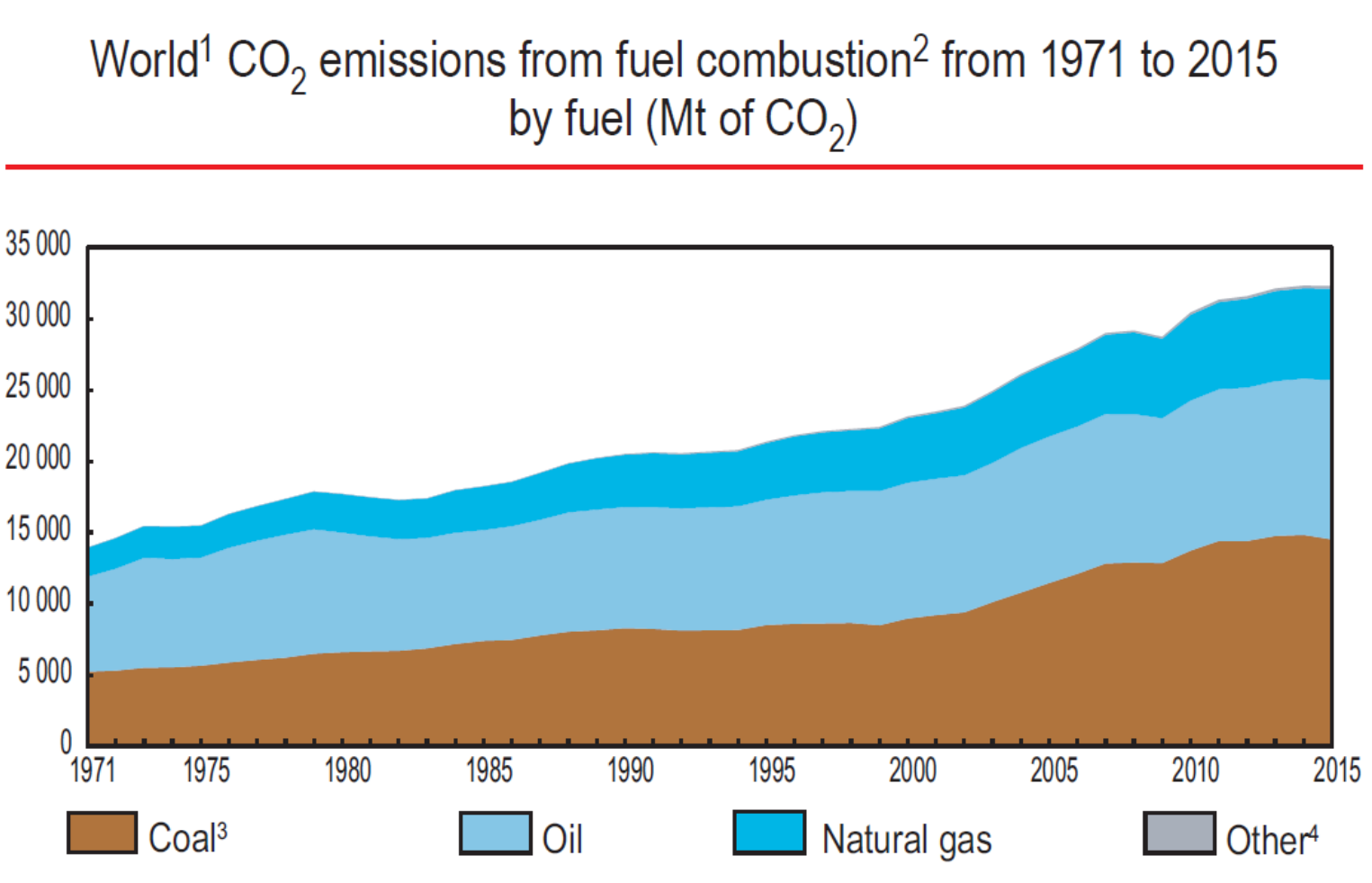
Figure 3. Trend in CO_2 emissions from fossil fuel combustion, 1870-2014



Source: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, Tenn., United States.

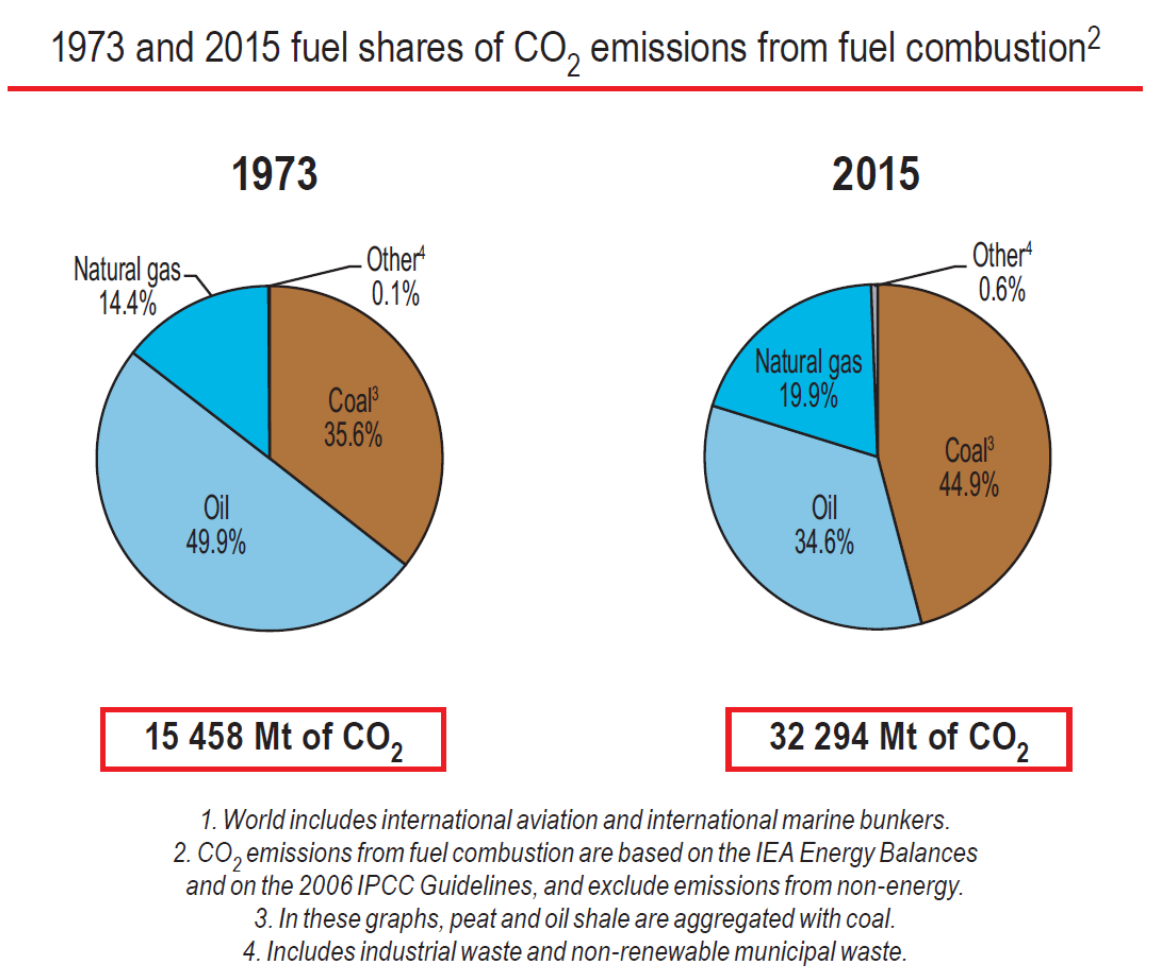
Source: http://www.iea.org/

CO2 emissions



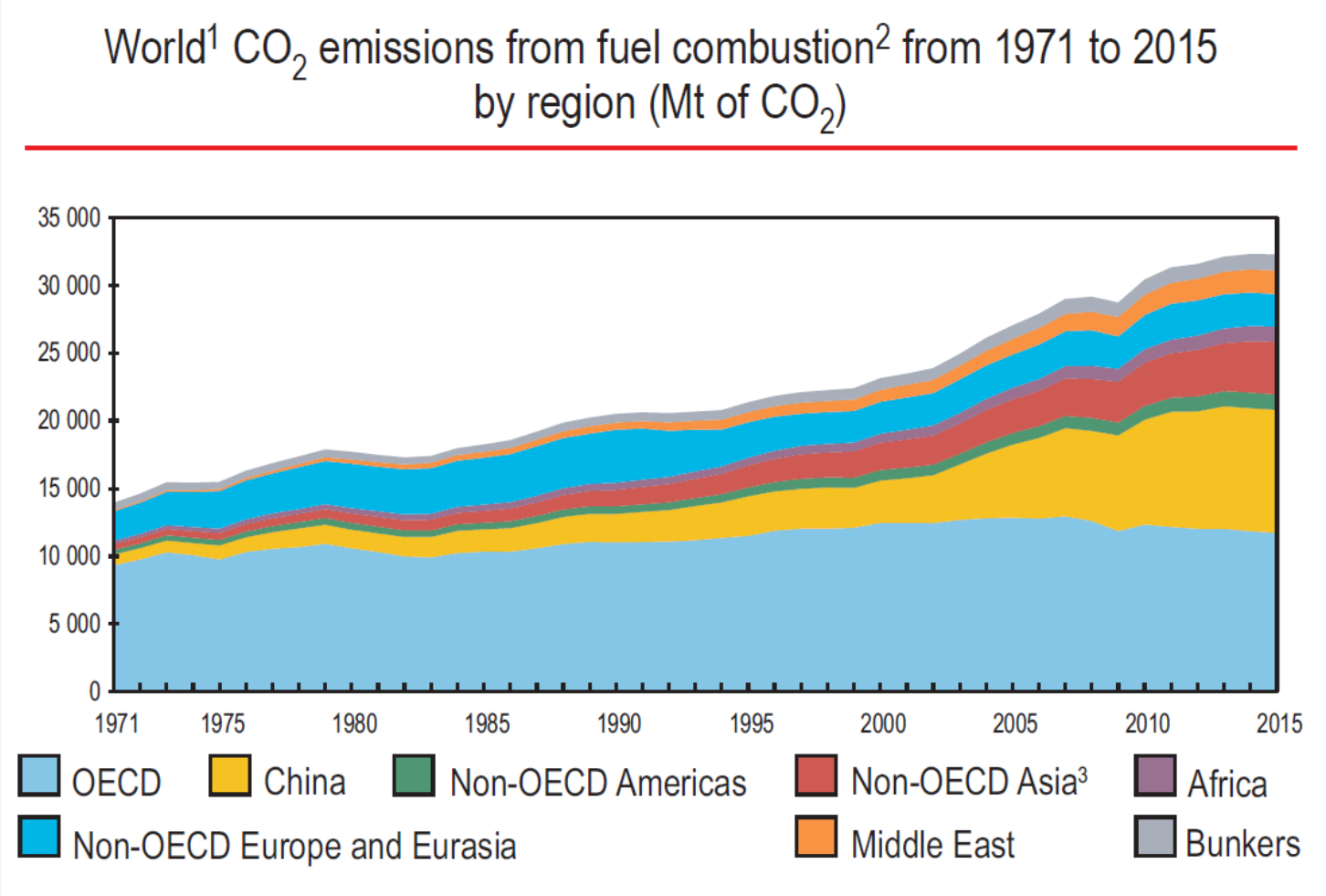
Source: http://www.iea.org/

CO2 emissions



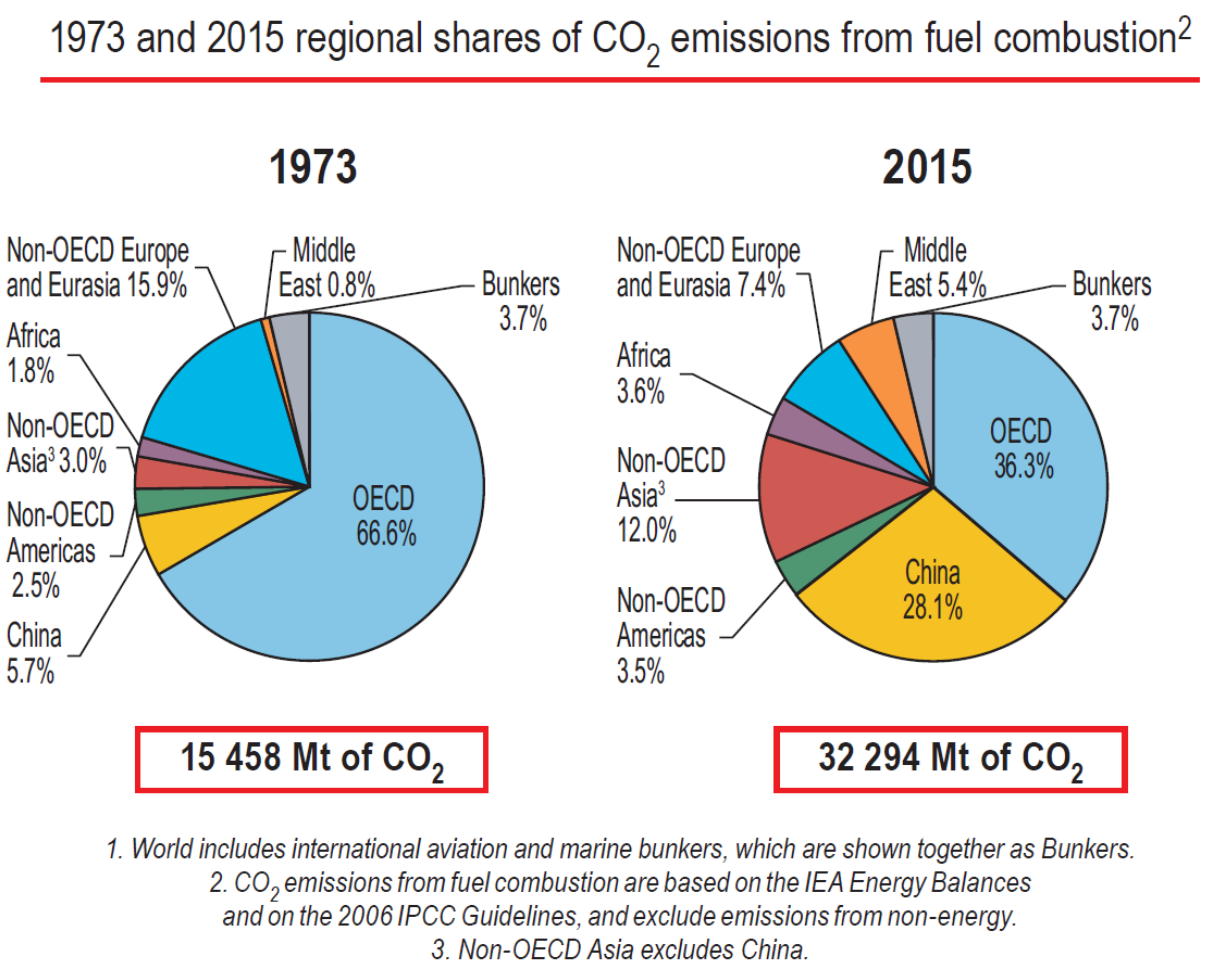
Source: http://www.iea.org/

CO2 emissions



Source: http://www.iea.org/

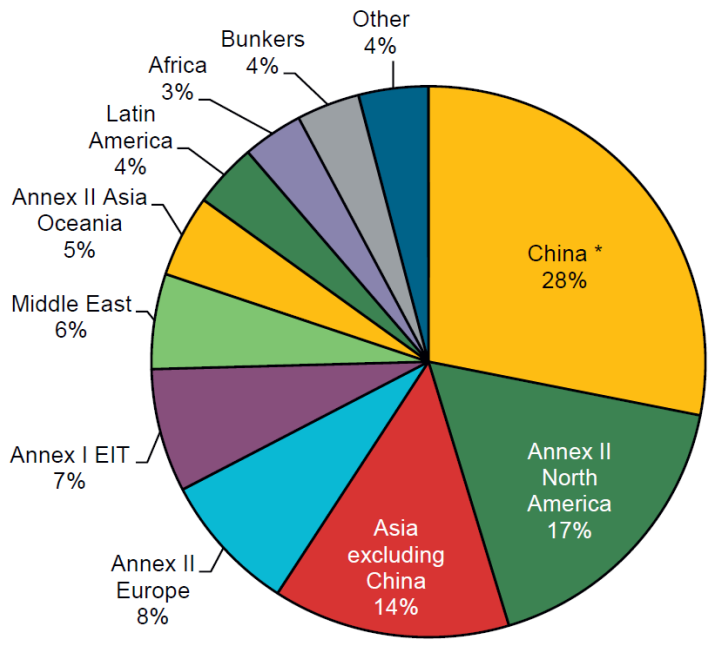
CO2 emissions



Source: http://www.iea.org/

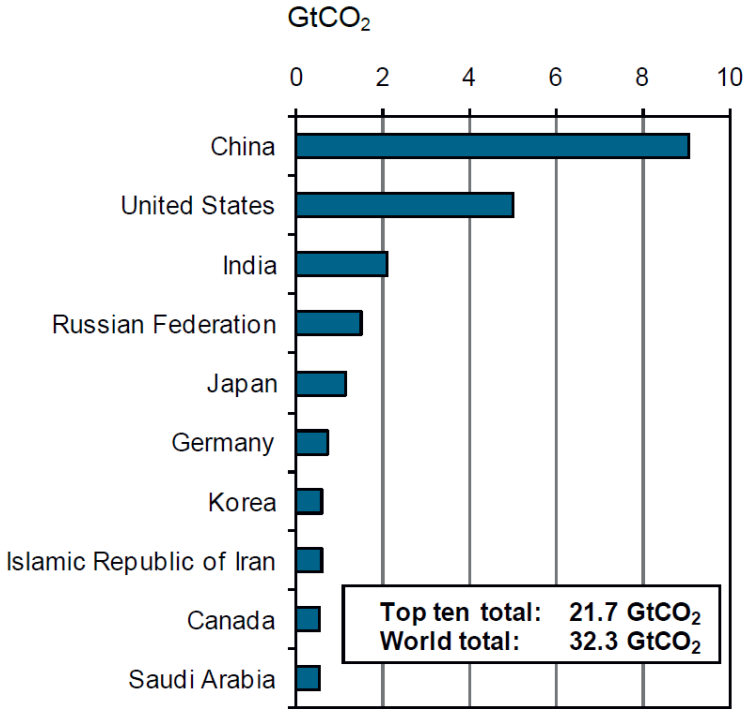
CO2 emissions

Figure 8. CO_2 emissions by region, 2015



* China includes Hong Kong, China.

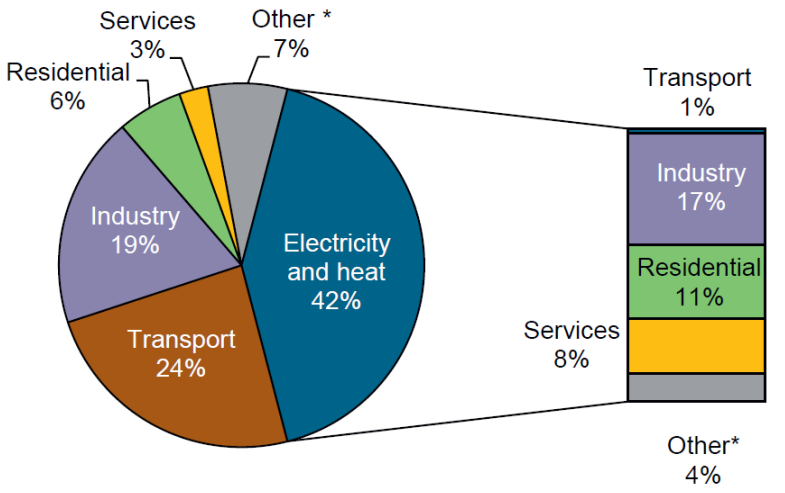
Figure 9. Top ten emitting countries, 2015



Source: http://www.iea.org/

CO2 emissions

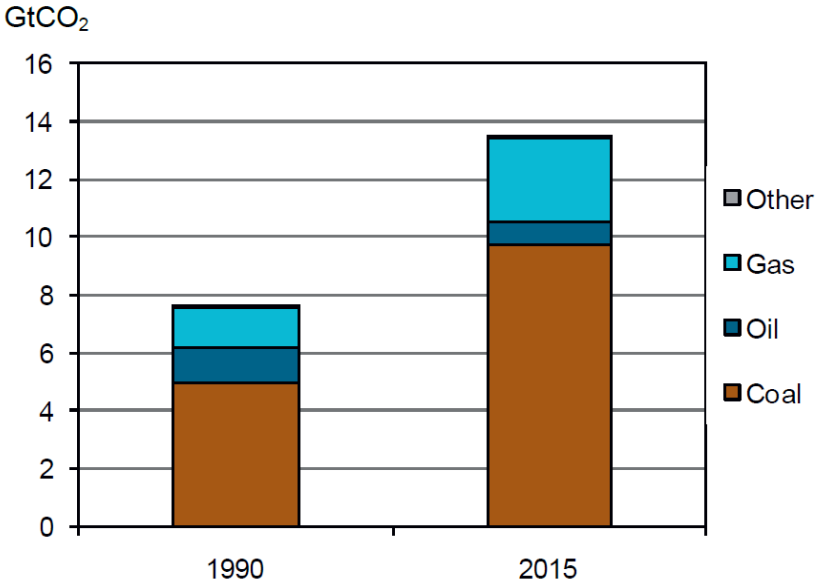
Figure 10. World CO_2 emissions from fuel combustion by sector, 2015



The graph also shows allocation of electricity and heat to end-use sectors.

* Other includes agriculture/forestry, fishing, energy industries other than electricity and heat generation, and other emissions not specified elsewhere.

Figure 11. CO_2 emissions from electricity and heat generation*, 1990-2015



* Refers to main activity producers and autoproducers of electricity and heat.

Source: http://www.iea.org/

Annex I countries

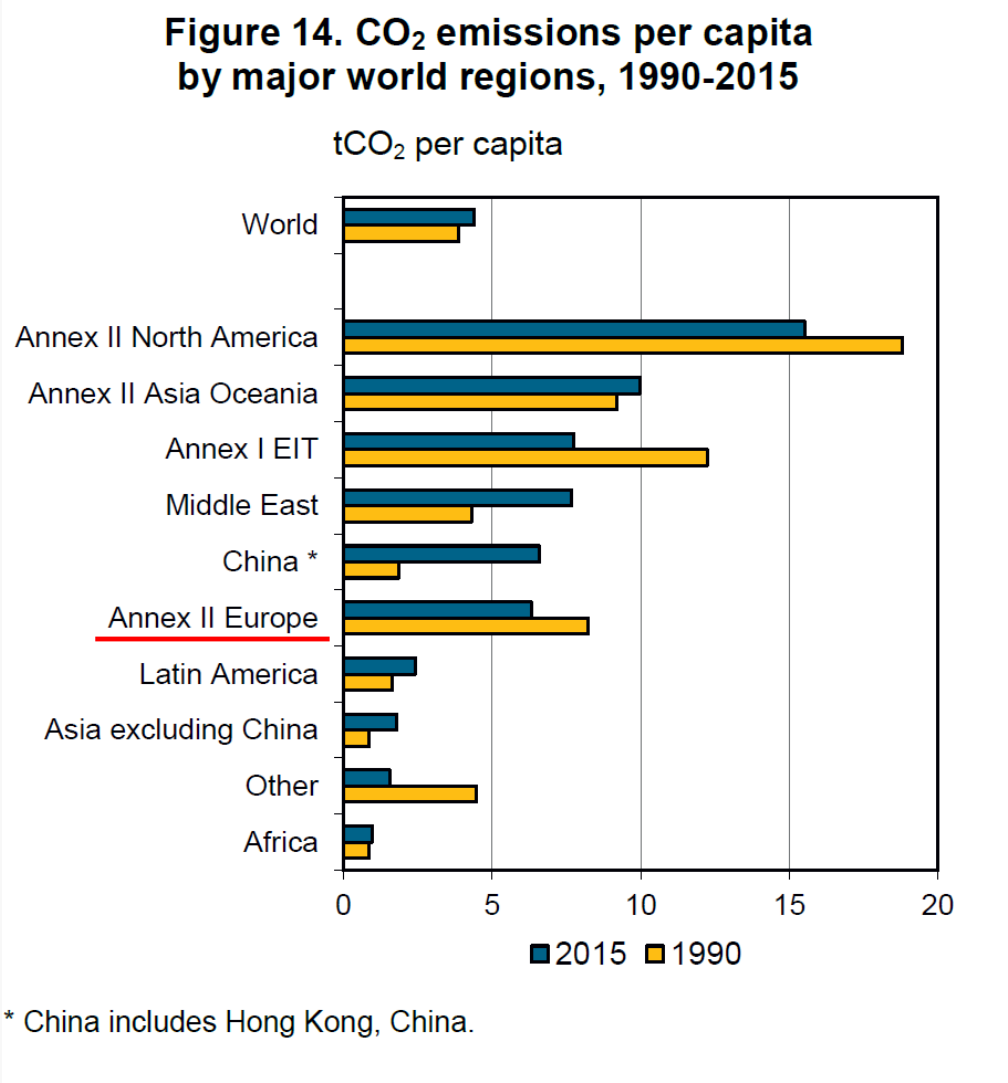
Annex I
Australia
Austria
Belarus **
Belgium
Bulgaria
Canada
Croatia **
Cyprus
Czech Republic **
Denmark
Estonia
European Union
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy **
Japan
Latvia
Liechtenstein **
Lithuania
Luxembourg
Malta
Monaco **

	Netherlands
	New Zealand
	Norway
	Poland
	Portugal
	Romania
	Russian Federation **
	Slovakia **
	Slovenia **
	Spain
	Sweden
	Switzerland
	Turkey **
	Ukraine **
	United Kingdom of Great Britain and Northern Ireland
	United States of America

** Party for which there is a specific COP and/or CMP decision

Source: http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php

CO2 emissions



CO2 emissions per capita
Annex II Europe

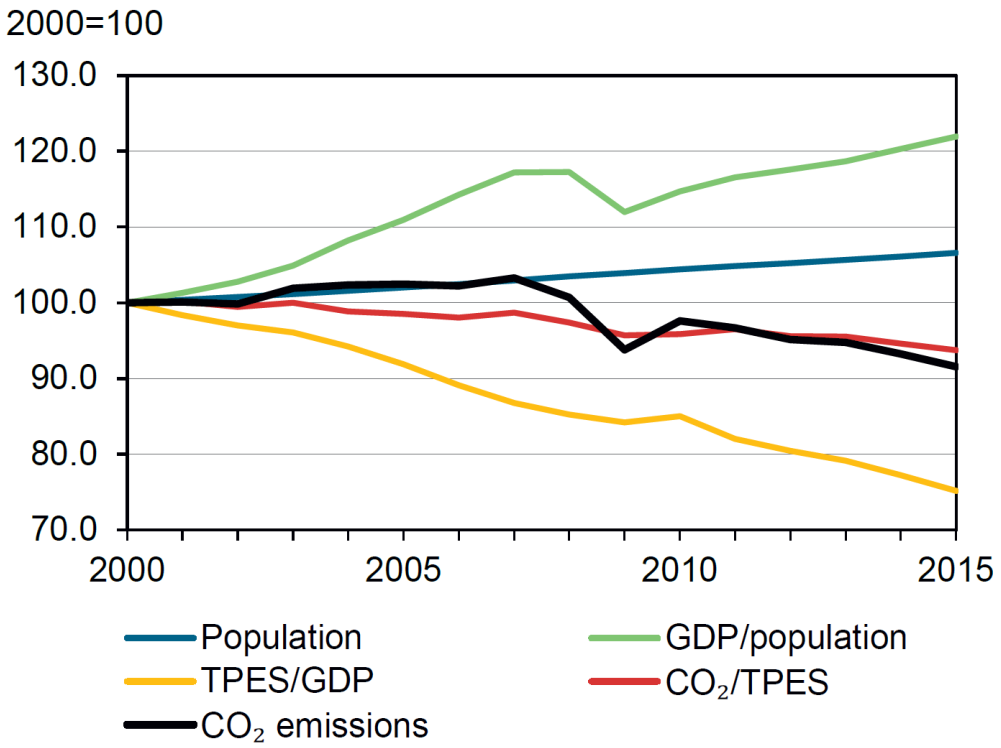
Year 2015
6.3 t_CO2

Year 1990
8.3 t_CO2

Source: http://www.iea.org/

CO2 emissions

Figure 17. Annex I CO_2 emissions and drivers (Kaya decomposition)[14], 2000-2015



- TPES = total primary energy supply
- CO2/TPES = tonnes of CO2 per terajoule

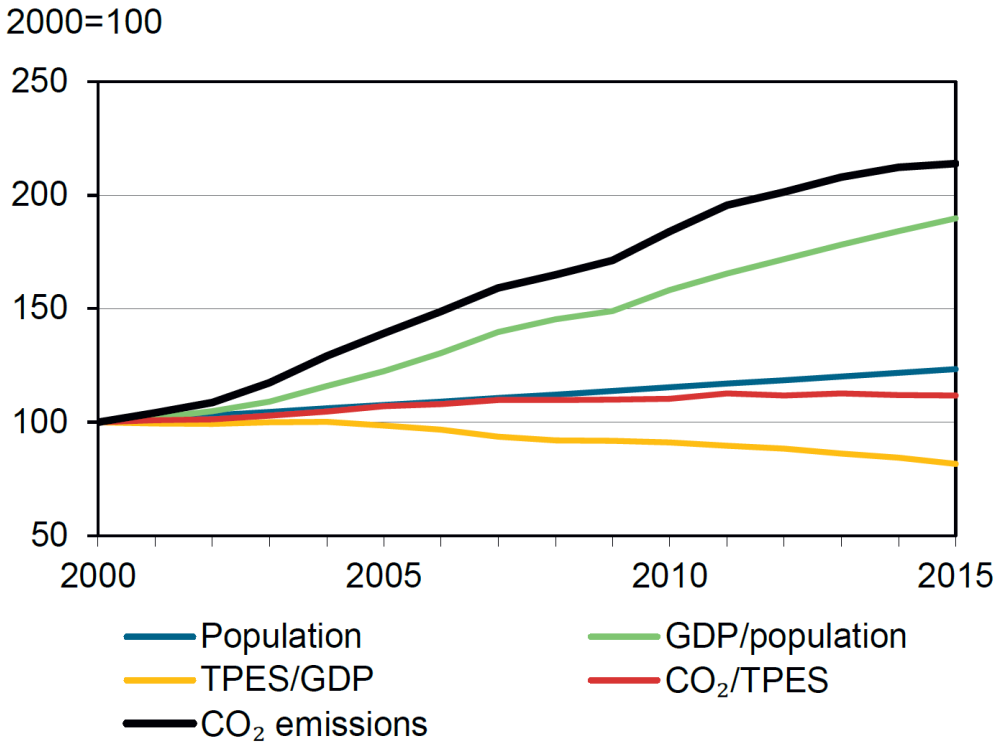
On a global level, CO2 emissions grew by 40% between 2000 and 2015.
Globally, economic growth partially decoupled from energy use, as energy intensity decreased by 21% over the period. However, with a practically unchanged carbon intensity of the energy mix, the combined growth in population (20%) and in per capita GDP (43%) led to a significant increase in global CO2 emissions between 2000 and 2015.
However, due to differences in levels of economic, demographic and technological development and growth, emissions evolved at different rates in Annex I and non-Annex I countries and regions.

In Annex I countries as a whole, CO2 emissions in 2015 were actually 8% lower than in 2000. Significant decoupling of energy consumption from economic activity (TPES/GDP: -25%) acted to decrease emissions but per-capita economic output grew (GDP/population: +22%), as did population (+7%), however, the energy sector's carbon intensity (CO2/TPES) declined mildly (-6%).

Source: http://www.iea.org/

CO2 emissions

Figure 18. Non-Annex I CO_2 emissions and drivers (Kaya decomposition)[14], 1990-2015



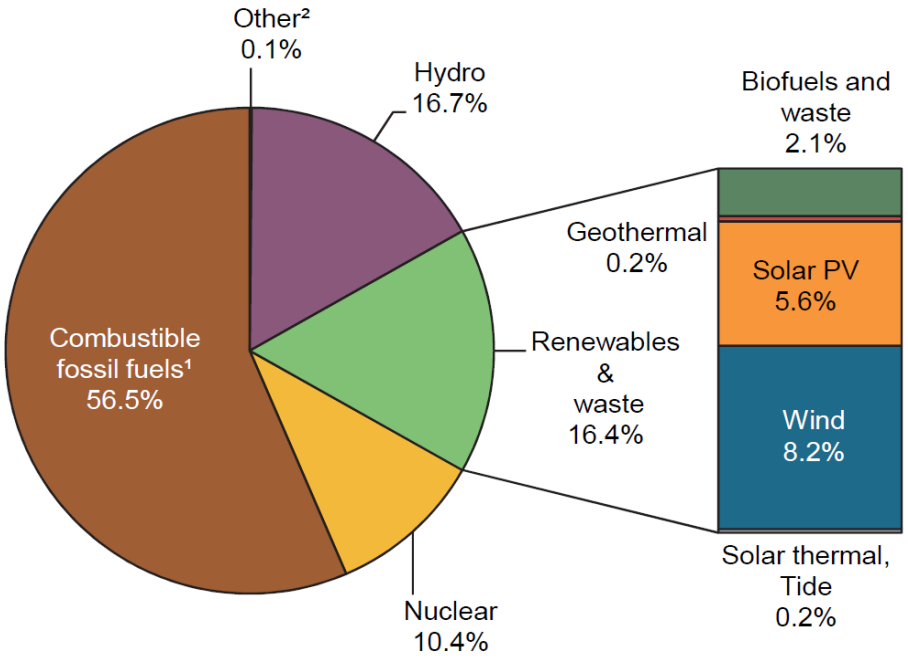
- TPES = total primary energy supply
- CO2/TPES = tonnes of CO2 per terajoule

By contrast, emissions in non-Annex I countries doubled over the same period, as very strong growth in per-capita economic output (+90%) combined with population growth (+23%). The CO2 intensity of the energy mix also increased (CO2/TPES: +12%), mainly due to higher coal consumption in larger countries. However, a significant decrease in the energy intensity of the economic output (TPES/GDP: -18%) tempered those increases.

Source: http://www.iea.org/

OECD generating capacity in 2015

Figure 18: OECD generating capacity 2015



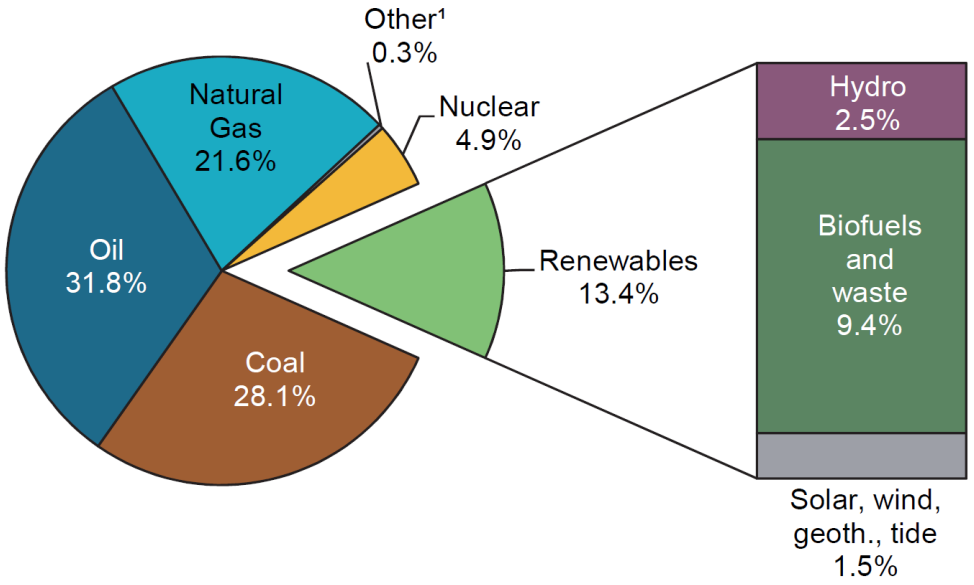
1. The capacities of plants which co-fire biofuels and waste with fossil fuels (e.g. solid biofuels that are co-fired with coal) are included under the dominant fuel.
2. Other: fuel cells, waste/chemical heat.

Note: Totals in graphs might not add up due to rounding.

Source: http://www.iea.org/

Fuel shares in 2015

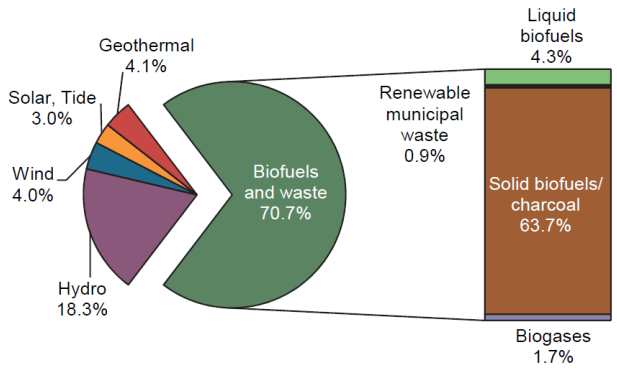
Figure 1: 2015 fuel shares in world total primary energy supply



1. Other includes non-renewable wastes and other sources not included elsewhere such as fuel cells.

Note: Totals in graphs might not add up due to rounding.

Figure 2: 2015 product shares in world renewable energy supply



Note: Totals in graphs might not add up due to rounding.

Source: http://www.iea.org/

Renewables and waste

Figure 3: Average annual growth rates of world renewables supply from 1990 to 2015

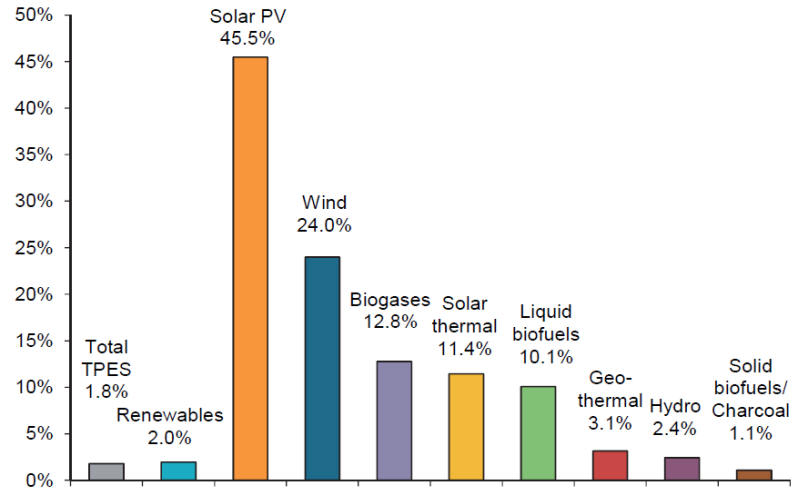
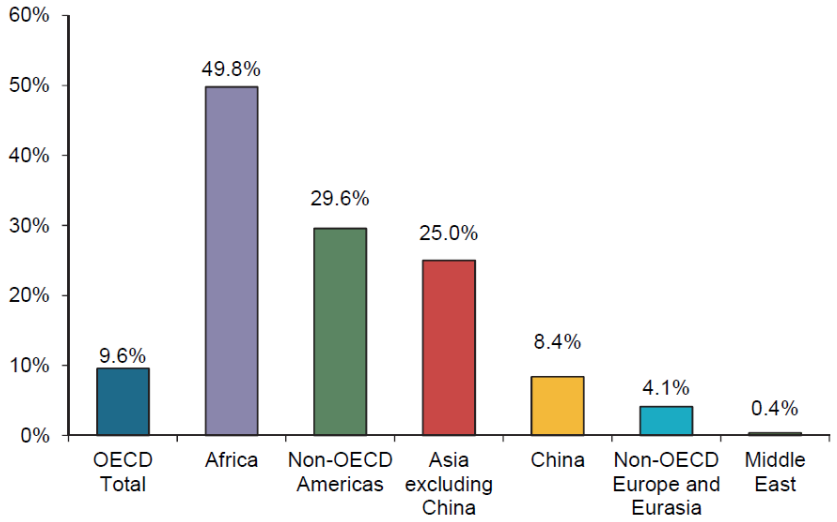


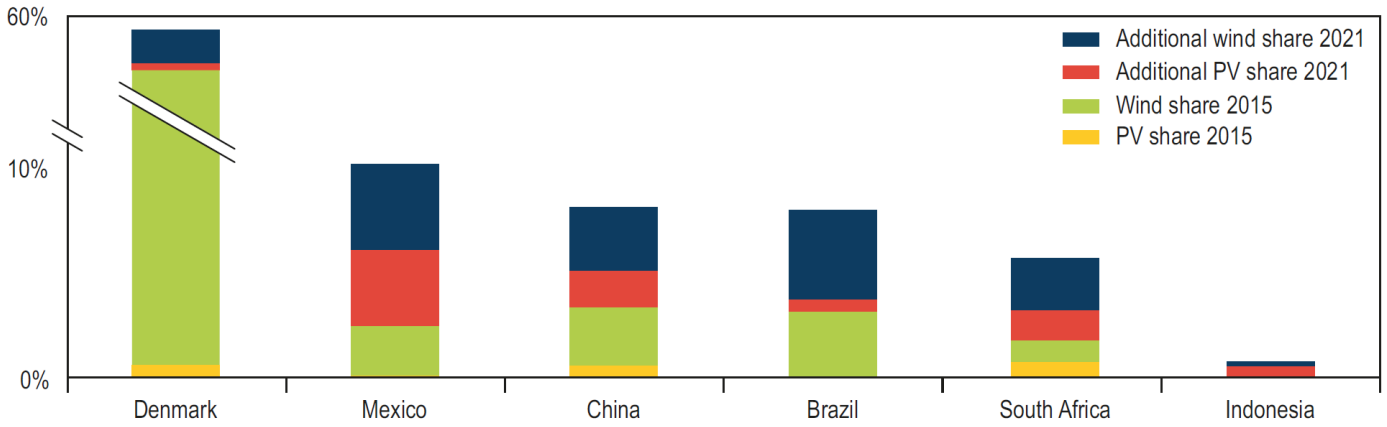
Figure 5: 2015 shares of renewables of regional total primary energy supply



Source: http://www.iea.org/

Renewables and waste

Figure ES.1 • Current and forecasted share of VRE generation for case study countries.



Source: Adapted from IEA (2016a), *Medium-Term Renewable Energy Market Report 2016*.

Key point • Mexico, China and Brazil are expected to double their VRE share to reach about 10% of annual generation by 2021; South Africa is forecasted to triple its VRE share, reaching 6%; Denmark grows to reach 60% and Indonesia hardly taps into its VRE potential.

Variable renewable energy (VRE) is a renewable energy source that is non-dispatchable due to its fluctuating nature, like wind power and solar power, as opposed to a controllable renewable energy source such as hydroelectricity, or biomass, or a relatively constant source such as geothermal power or run-of-the-river hydroelectricity.

Source: http://www.iea.org/

General Energy Policy (Italy)

Key data (2015 estimated)

Energy production: 35.5 Mtoe (biofuels and waste 32.2%, oil 15.9%, natural gas 15.6%, geothermal 15.4%, hydro 10.6%, solar 6.6%, wind 3.6%, coal 0.1%), +17.7% since 2005

TPES: 150.7 Mtoe (natural gas 36.7%, oil 34.2%, biofuels and waste 9.7%, coal 8.2%, geothermal 3.6%, electricity net imports 2.6%, hydro 2.5%, solar 1.6%, wind 0.8%), -19.1% since 2005

TPES per capita: 2.5 toe (IEA average: 4.5 toe)

TPES per GDP: 0.08 toe/USD 1 000 PPP (IEA average: 0.11 toe/USD 1 000 PPP)

Electricity generation: 280.7 TWh (natural gas 38.3%, coal 16.6%, hydro 15.6%, solar 9.3%, biofuels and waste 7.8%, wind 5.2%, oil 4.8%, geothermal 2.2%), -5.4% since 2005

Electricity and heat generation per capita: 5.6 MWh (IEA average: 9.9 MWh)

Table 2.1 National 2020 target and estimated trajectory of energy from renewable sources

	2005	2010	2015	2020
RES heating and cooling	2.8%	6.53%	10.09%	17.09%
RES electricity	16.29%	18.71%	22.39%	26.39%
RES transport	0.87%	3.5%	6.63%	10.17%
Overall share of RES	4.92%	8.05%	11.24%	17%

Source: Italy's National Renewable Energy Action Plan in line with Directive 2009/28/EC.

Source: http://www.iea.org/

CO2 emissions (Italy)

Key data (2014 provisional)

GHG emissions without LULUCF*: 418.6 $MtCO_2$-eq, -19.8% from 1990 to 2014

GHG emissions with LULUFC*: 392.0 $MtCO_2$-eq, -24.0% from 1990 to 2014

2008-12 target: -6.5% since 1990; **actual reduction:** -4.5% since 1990

CO_2 emissions from fuel combustion: 319.7 $MtCO_2$, -17.9% since 1990

CO_2 emissions by fuel: oil 45.5%, natural gas 36.7%, coal 16.2%, other 1.6%

CO_2 emissions by sector: power generation 32.3%, transport 33.0%, residential 13.1%, industry 11.2%, commercial and other services, including agriculture and fishing 7.1%, other energy industries 3.2%

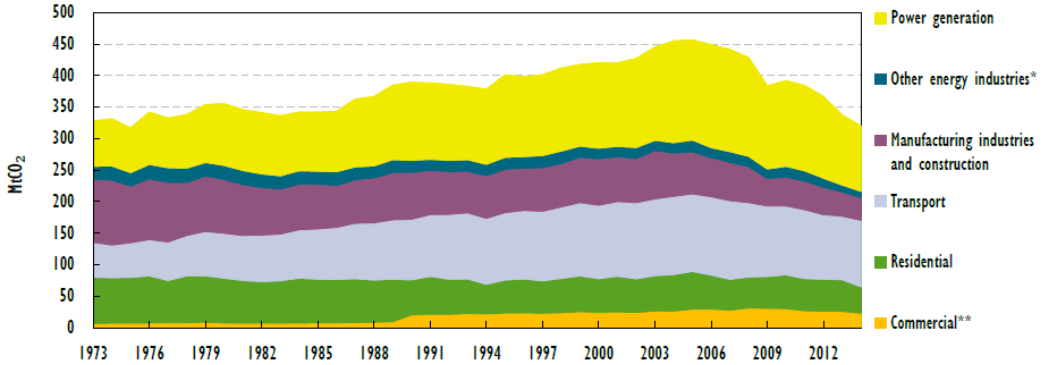
* Source: UNFCCC, 2016.

- LULUCF = land use, land-use change and forestry

Source: http://www.iea.org/

CO2 emissions (Italy)

Figure 3.1 CO_2 emissions by sector, 1973-2014

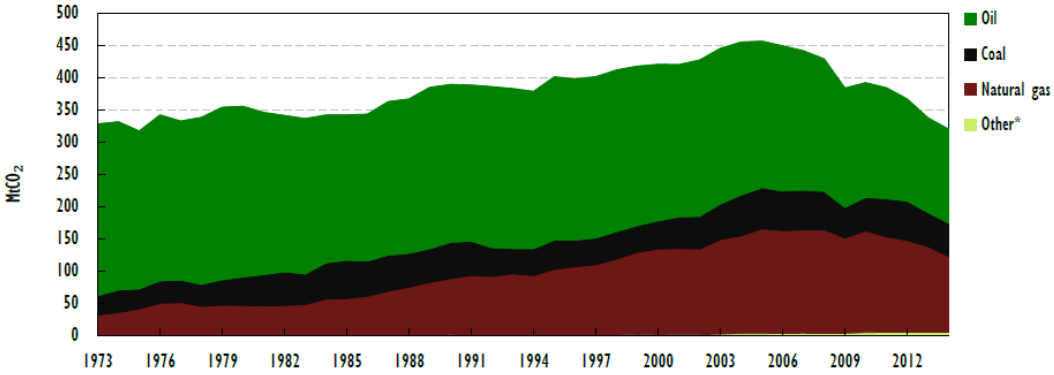


* *Other energy industries* includes other transformations and energy own-use.

** *Commercial* includes commercial and public services, agriculture/forestry and fishing.

Source: IEA (2016a), *CO_2 Emissions from Fuel Combustion 2016*, www.iea.org/statistics/.

Figure 3.2 CO_2 emissions by fuel, 1973-2014



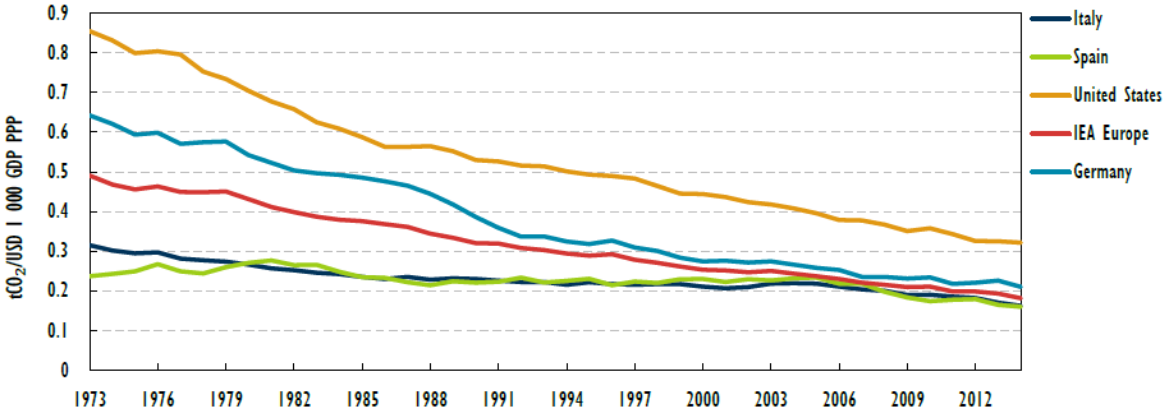
* *Other* includes industrial waste and non-renewable municipal waste.

Source: IEA (2016a), *CO_2 Emissions from Fuel Combustion 2016*, www.iea.org/statistics/.

Source: http://www.iea.org/

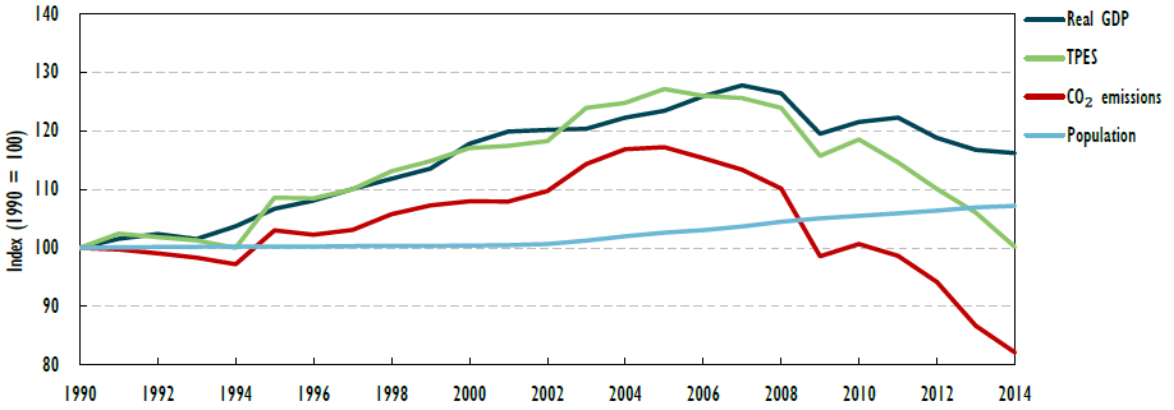
CO2 emissions (Italy)

Figure 3.3 Energy-related CO_2 emissions per unit of GDP in Italy and in other selected IEA member countries, 1973-2014



Source: IEA (2016a), *CO_2 Emissions from Fuel Combustion 2016*, www.iea.org/statistics/.

Figure 3.4 CO_2 emissions and its main drivers in Italy, 1990-2014



Sources: IEA (2016a), *CO_2 Emissions from Fuel Combustion 2016*, www.iea.org/statistics/; IEA (2016b), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

Source: http://www.iea.org/

CO2 emissions from fossil fuel plants

Emissioni di CO_2 per i principali combustibili fossili.

Combustibile (valori medi)	% C, in peso	LHV, MJ/kg	kg di CO_2 per kg_f	kg di CO_2 per MJ_{th}	kg di CO_2 per MJ_{el}
Gas naturale	75	48	2.75	0.0573	0.099 (η=58%)
Olio combustibile	88	42	3.23	0.0769	0.175 (η=44%)
Carbone	62	24	2.27	0.0946	0.215 (η=44%)

Source: Lozza G., 2016, "Turbine a gas e cicli combinati", Edizioni Esculapio (3a edizione).