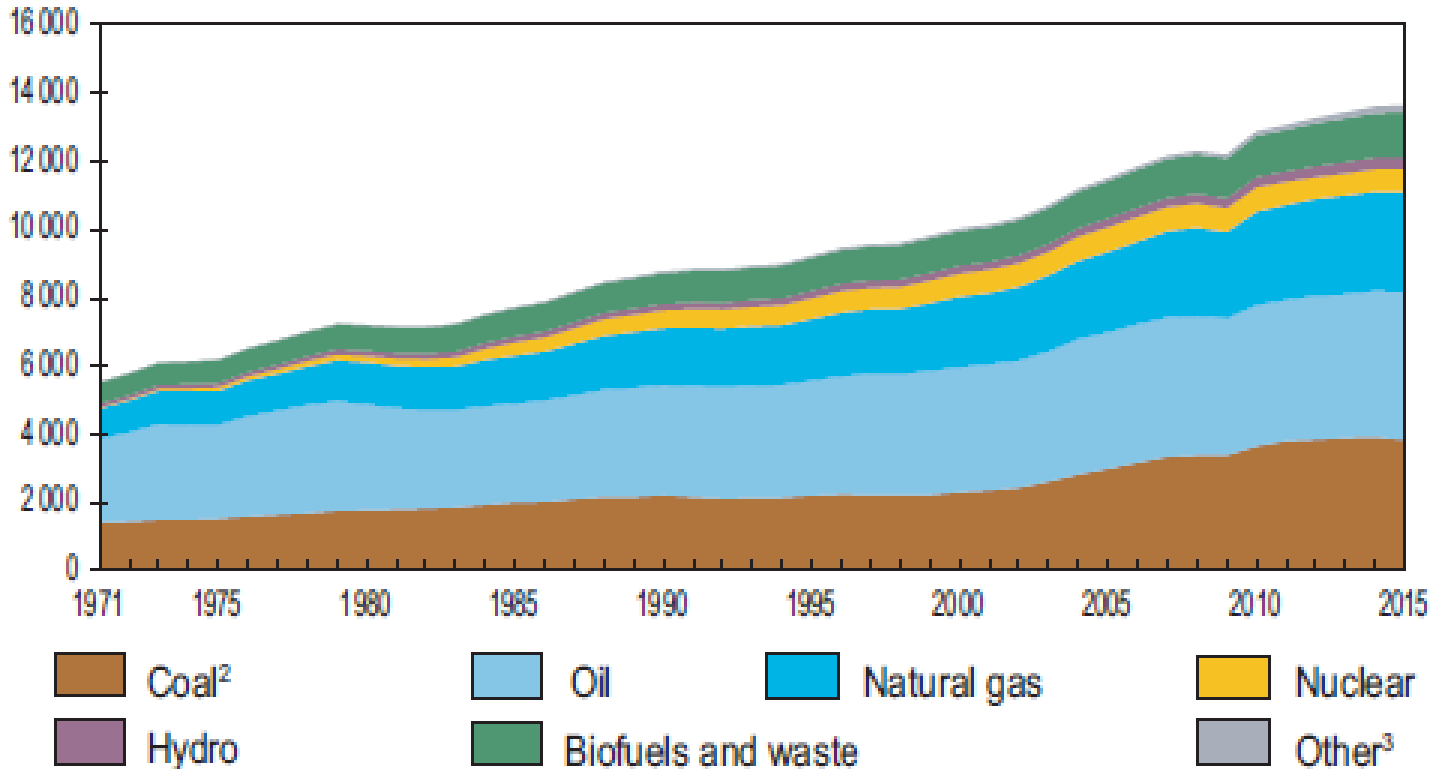


# Coal and externalities

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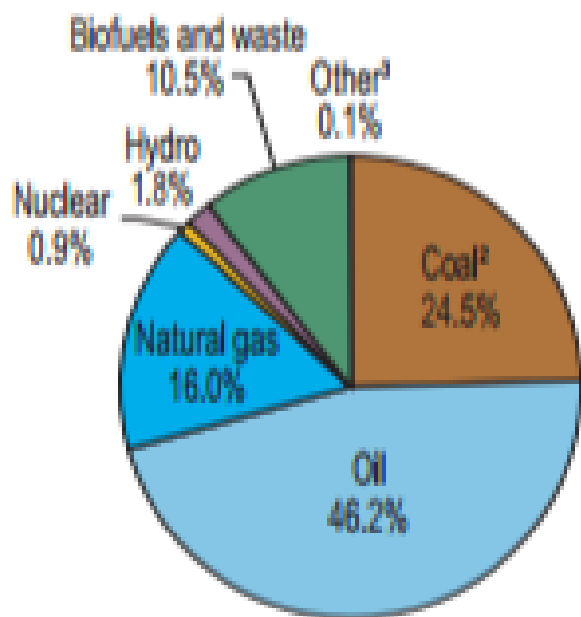
# World total primary energy supply by fuel



*Note: Peat and oil shale aggregated with coal.*

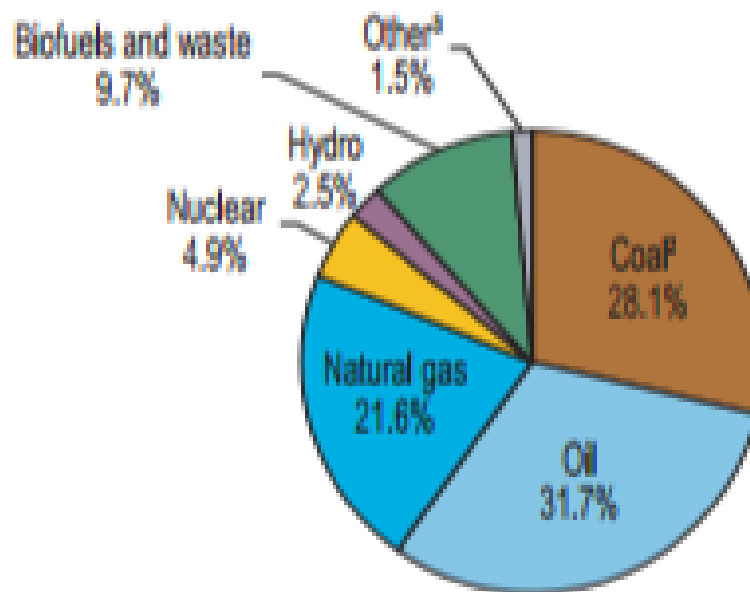
# World total primary energy supply by fuel

1973



6 101 Mtoe

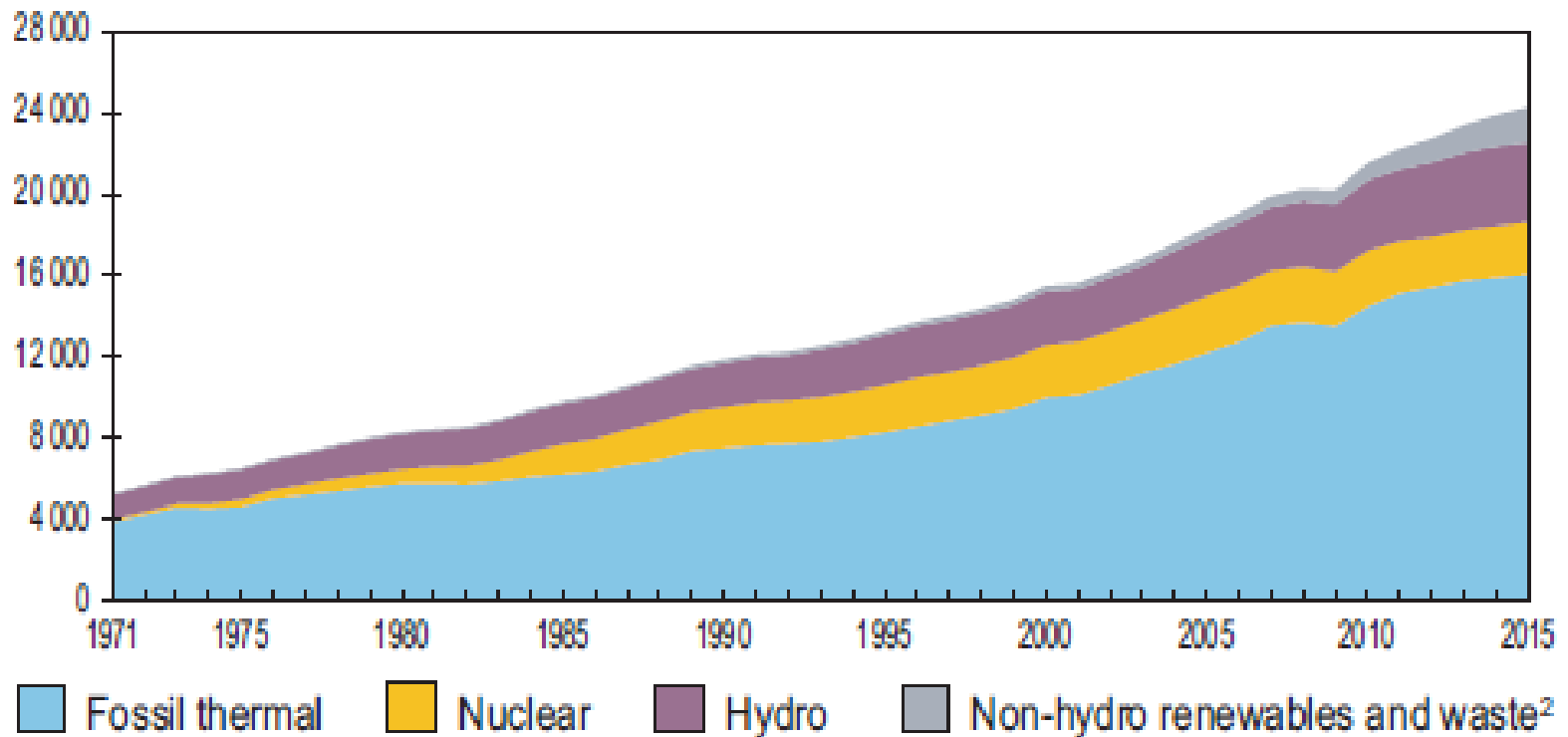
2015



13 647 Mtoe

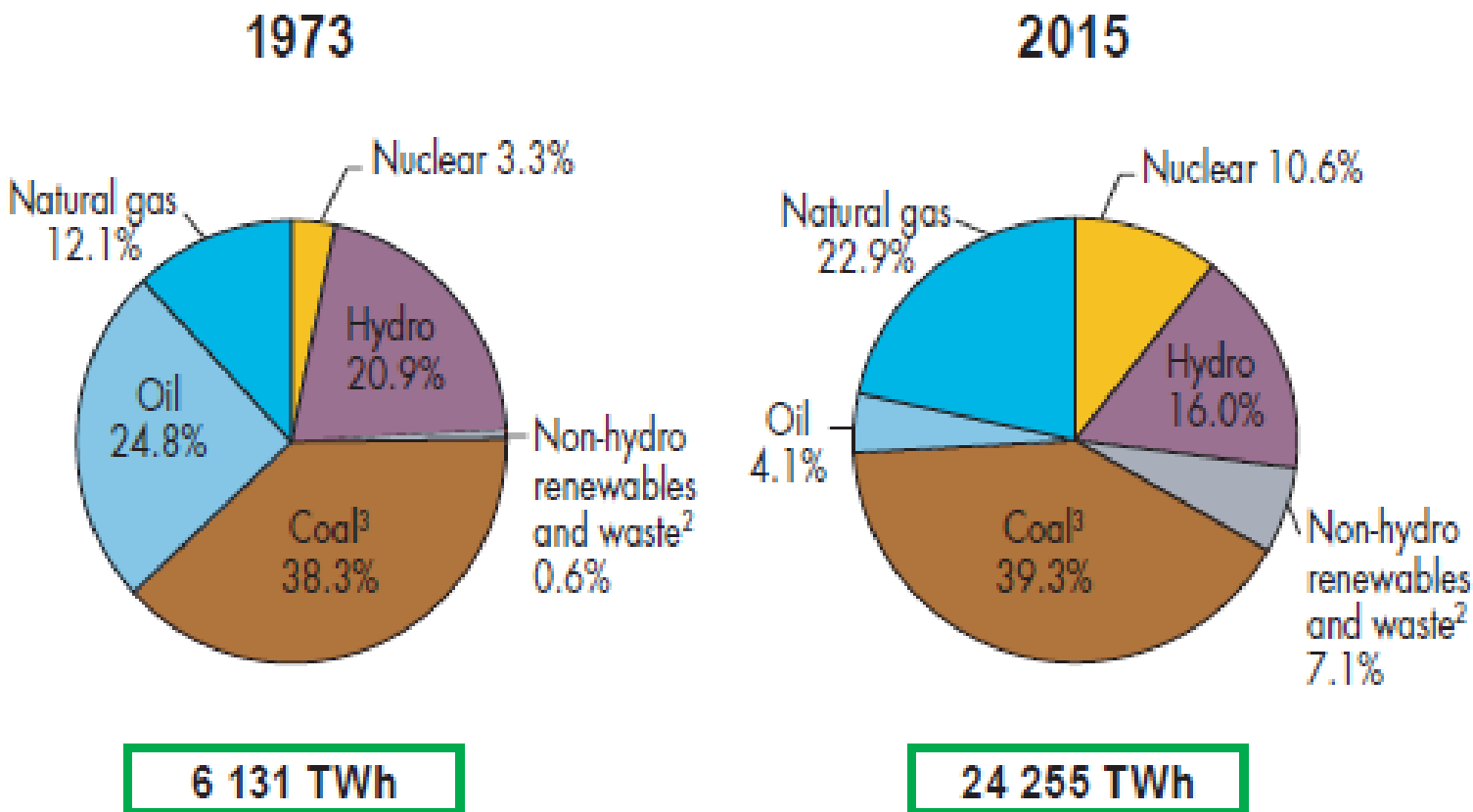
*Note: Peat and oil shale aggregated with coal.*

# World electricity generation by source (TWh)

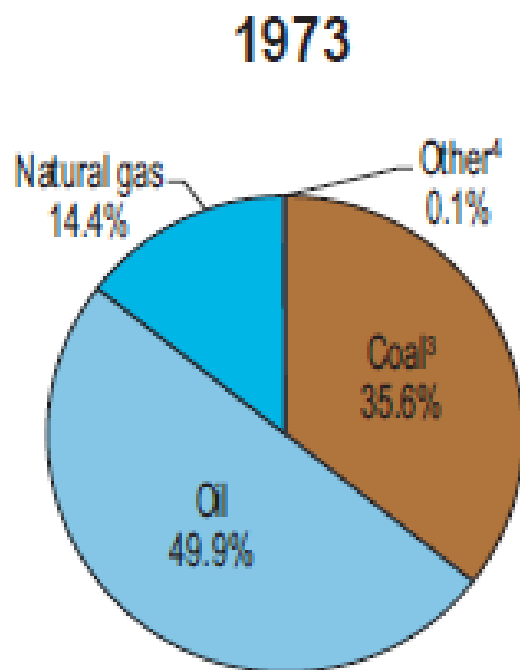


*Note: Peat and oil shale aggregated with coal.*

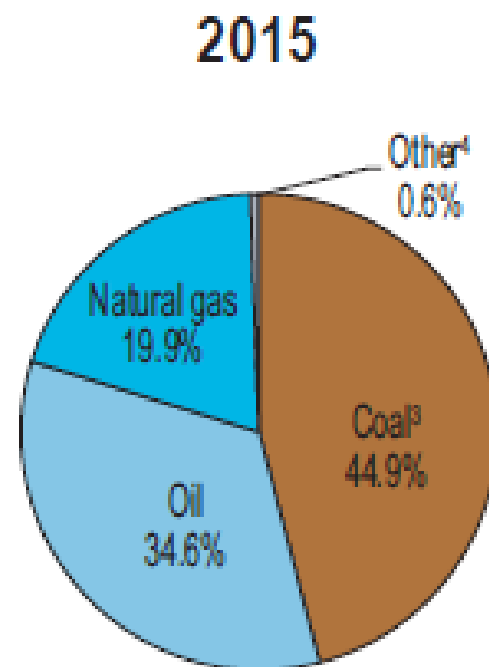
# World electricity generation by source (TWh)



# CO<sub>2</sub> emissions by fuel



**15 458 Mt of CO<sub>2</sub>**

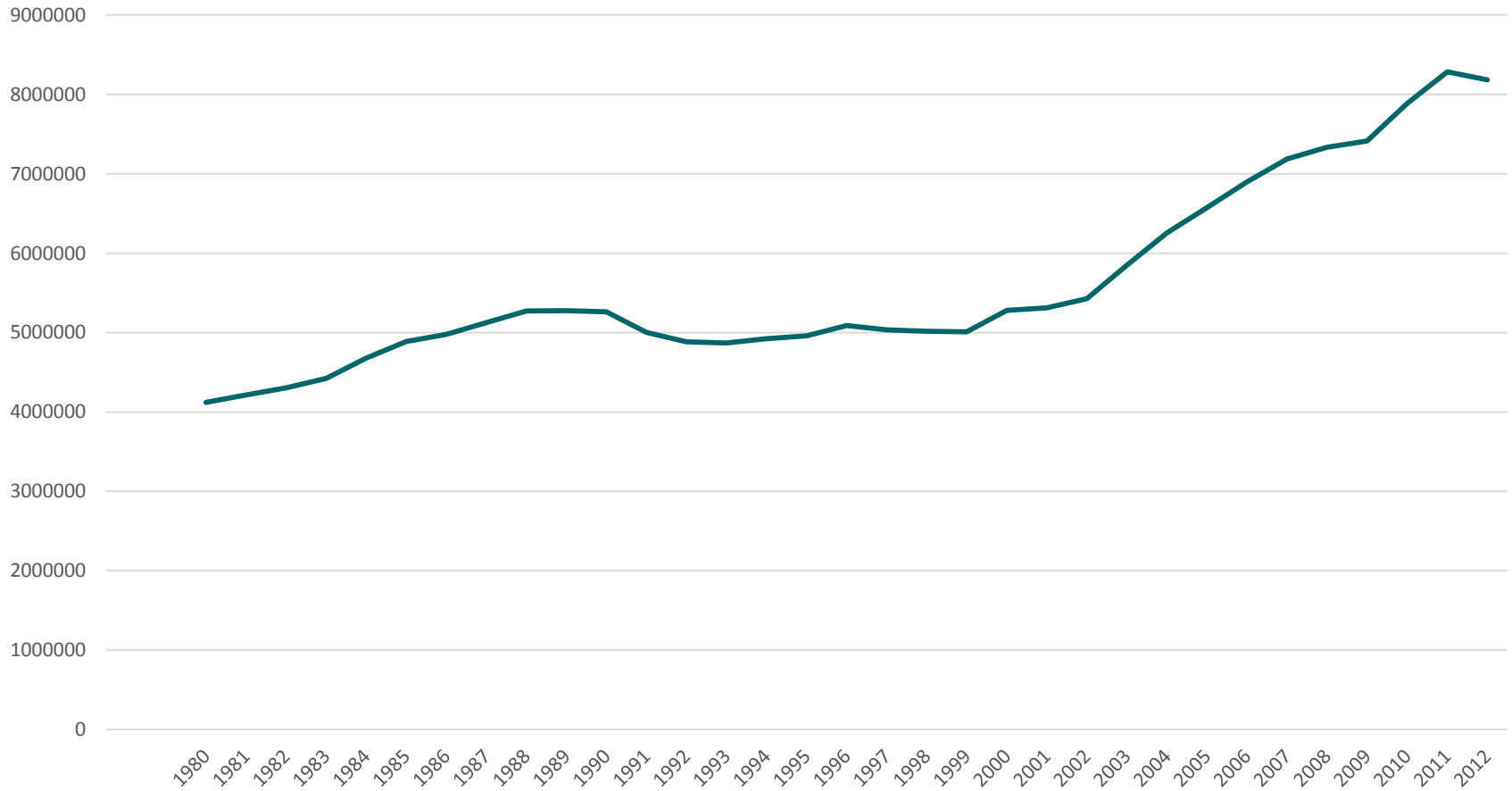


**32 294 Mt of CO<sub>2</sub>**

## CO<sub>2</sub> emissions by fuel (pounds of CO<sub>2</sub>/MBtu)

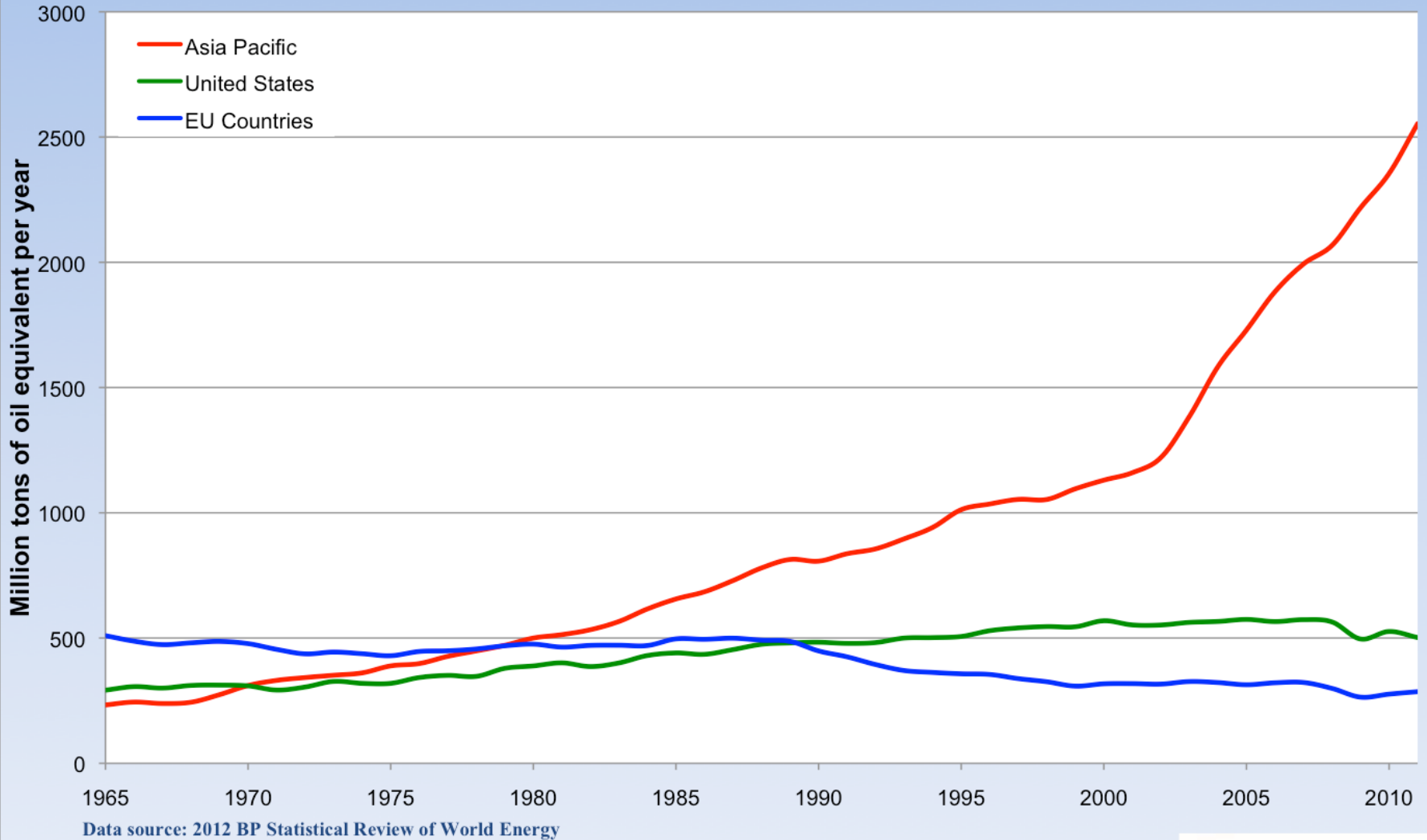
Coal (anthracite)	228.6
Coal (bituminous)	205.7
Coal (lignite)	215.4
Coal (subbituminous)	214.3
Diesel fuel and heating oil	161.3
Gasoline (without ethanol)	157.2
Propane	139.0
Natural gas	117.0

# World consumption of coal (thousands of short tons, EIA)





# Coal Consumption 1965-2011

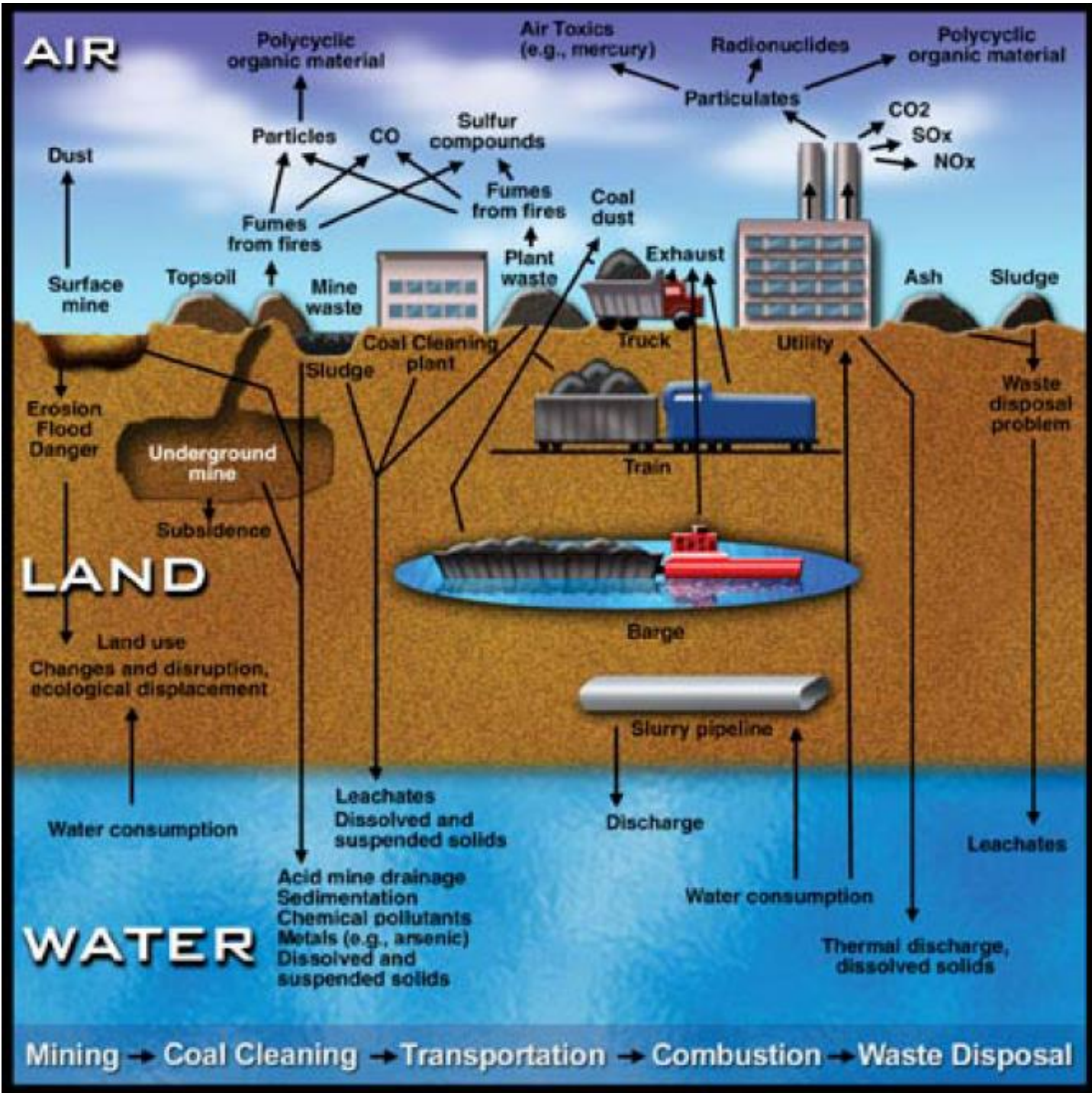


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# History of coal usage

- The first known depleted coal mine Fu Shun in China in 1000 BC. 300 BC Theophrastus described combustion of coal in Greece. Romans used coal in 400 BC.
- Coal substituted wood (charcoal) in glass and metal production – first energy revolution.
- Deforestation of London surroundings in 1200, by 1500 production moved to Ireland, Scotland, Wales.
- Coal depletion at Newcastle upon Tyne – spreading the mining activities across the country.
- 1352 coal first internationally traded commodity.
- Start of industrial revolution, steam engine, production of steel, coke.
- In navy shift from sails to steam.
- In 1910 coal represented 60% of world energy mix, declining between world wars.



# Environmental impacts

- Mining (opencast/surface mines) – land use, water and air pollution, dust. Impact on biotops and landscape. Noise. Aesthetical damages.
- Preparation for further processing – removal of impurities – acids, heavy metals, chemicals are released.
- Transport – dust from coal, transport-related pollution.
- Workers – exposition to the dust and chemicals, mining risks.
- Coal combustion – GHG, primary pollutants, smog, acid rains.
- Solid waste – ash.

# Air pollutants and their effects

Name	Source	Effects (esp. on human)
Particulate matter (PM)	Combustion, industrial processes, wind erosion, atmospheric reactions of gases, transport	Respiratory: asthma development (suspected), asthma exacerbation, chronic obstructive pulmonary disease, stunted lung development (PM <sub>2.5</sub> ), lung cancer; Cardiovascular: cardiac arrhythmias, acute myocardial infarction, congestive heart failure (PM <sub>2.5</sub> ). Nervous system: ischemic stroke.
Volatile organic compounds (VOC)	Incomplete combustion of fossil fuels, evaporation of solvents and gasoline, emission from plants	Organic chemicals in varied forms (eg. benzene, chlorofluorocarbons...). Carcinogenic, ozone formation
Carbon monoxide (CO)	Incomplete combustion of fuels	Poisonous because of ability to bind to hemoglobin and block oxygen delivery to tissues. Visual impairment, reduced work capacity, reduced manual dexterity, poor learning ability, difficulty in performing complex tasks.

# Air pollutants and their effects

Name	Source	Effects (esp. on human)
Nitrogen oxides (NO <sub>x</sub> )	Combustion of fuels	<p>Asthma development (suspected), asthma exacerbation, chronic obstructive pulmonary disease, stunted lung development; cardiac arrhythmias, ischemic stroke.</p> <p>Reacts with VOCs in sunlight to form ground-level ozone</p> <p>Increases an amount of nitrogen in soil and country – change of diversity. In aquasystems causes eutrophication. Increases acidity of soil and water.</p>
Sulfur oxides (SO <sub>x</sub> )	Combustion of sulfur-containing fuels (coal)	<p>Can affect respiratory system and lung functions, aggravation of asthma and chronic bronchitis, make people more prone to infections of the respiratory tract; irritation of eyes; cardiac disease aggravated; ischemic stroke risk. Contributes acid rain.</p>
Other elements		<p>Nickel, mercury, arsen, chromium, cadmium, lead, fluorine, chlorine</p>

# Secondary pollution

- London smog
  - Smoke and fog, typically in winter (combination with inversion).  $\text{SO}_2$  + PM (soot) + water vapour = transport of gaseous matters of smog to the lungs.
  - <http://www.youtube.com/watch?v=bSlwGIapFJI>
- Photochemical smog
  - Primary pollutants ( $\text{NO}_x$  + Volatile Organic Compounds created during fossil fuel combustion) interacts under the influence of sunlight = ozone  $\text{O}_3$  plus other pollutants.
  - Ozone – bronchial constriction, coughing, wheezing, respiratory irritation, eye irritation, decreased crop yields, retards plant growth, damages plastics...
- Acid rains
  - Acidic rains caused by emissions of sulfur dioxide and nitrogen oxide = with water produce acids.

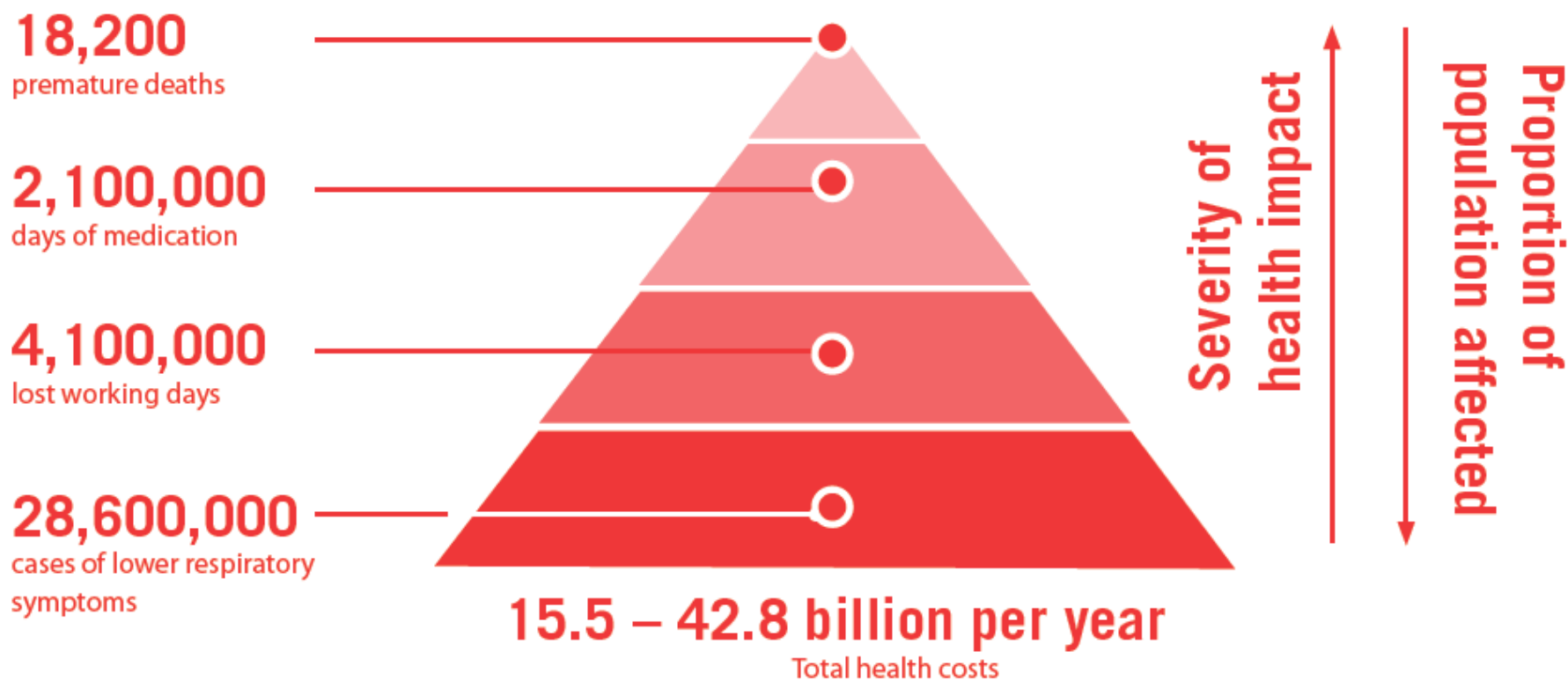
Emissions	Amount of pollutants (in tons per 1TWh – 1000MW plant for 1000hrs)
SO <sub>2</sub>	2600
NO <sub>x</sub>	2800

Representative 1000MW coal power plant = 6 million tons of CO<sub>2</sub> per year = equivalent of 2 million cars. Plus 2 670 000 tons of ash.

In CR production of around 40 TWh of electricity from coal, installed capacity around 11 700 MW. (2014).



# Health impacts of coal combustion

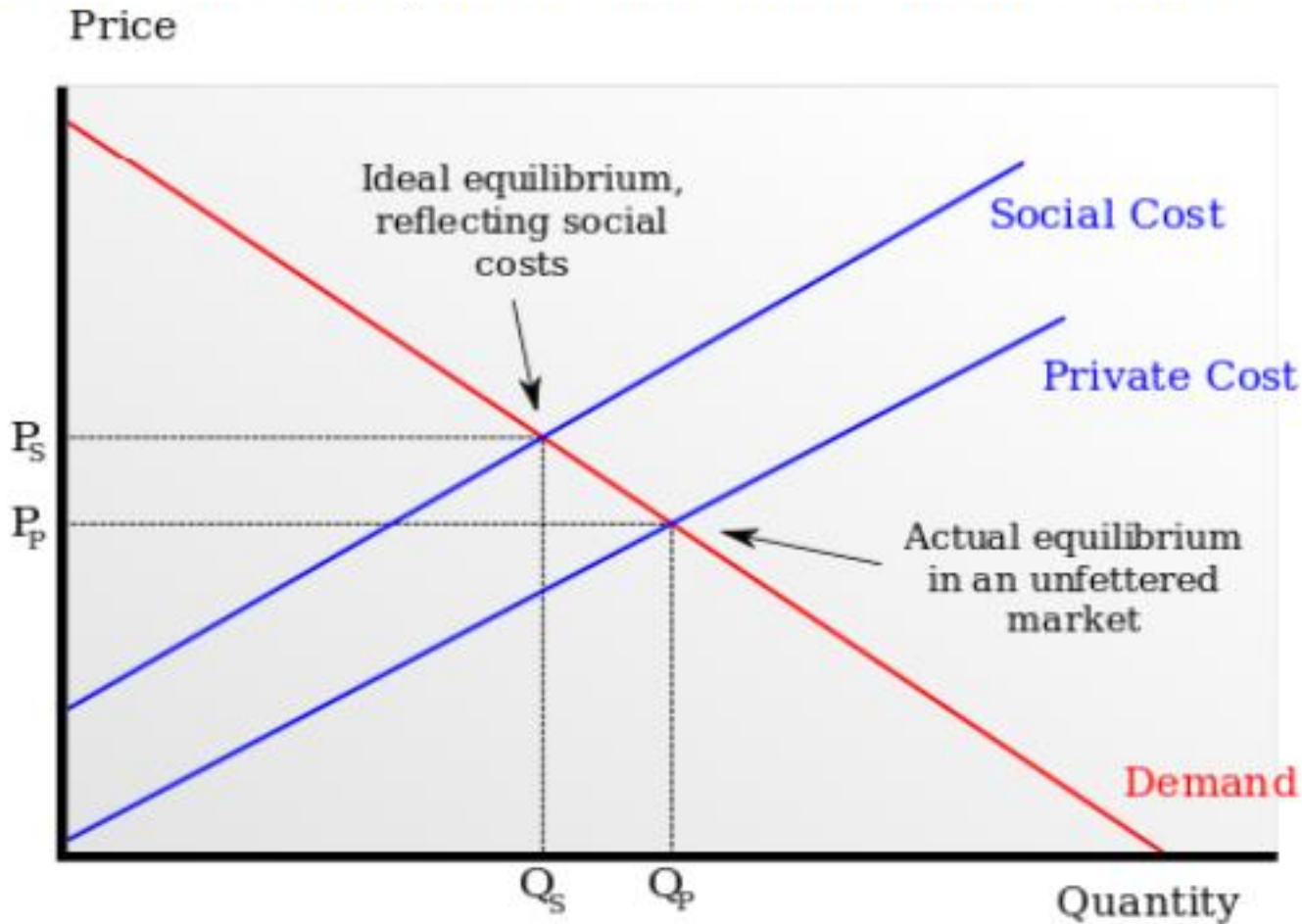


Annual health impacts caused by coal power plants in the EU (27 countries)

# Externalities

- Who is paying for these damages to ecosystems and human health?
  - Reduction in life expectancy – respiratory and heart illnesses, cancers...
  - Degradation of buildings
  - Reduction of crop yields
  - Global warming
  - Ecosystem loss and degradation...

# Externalities



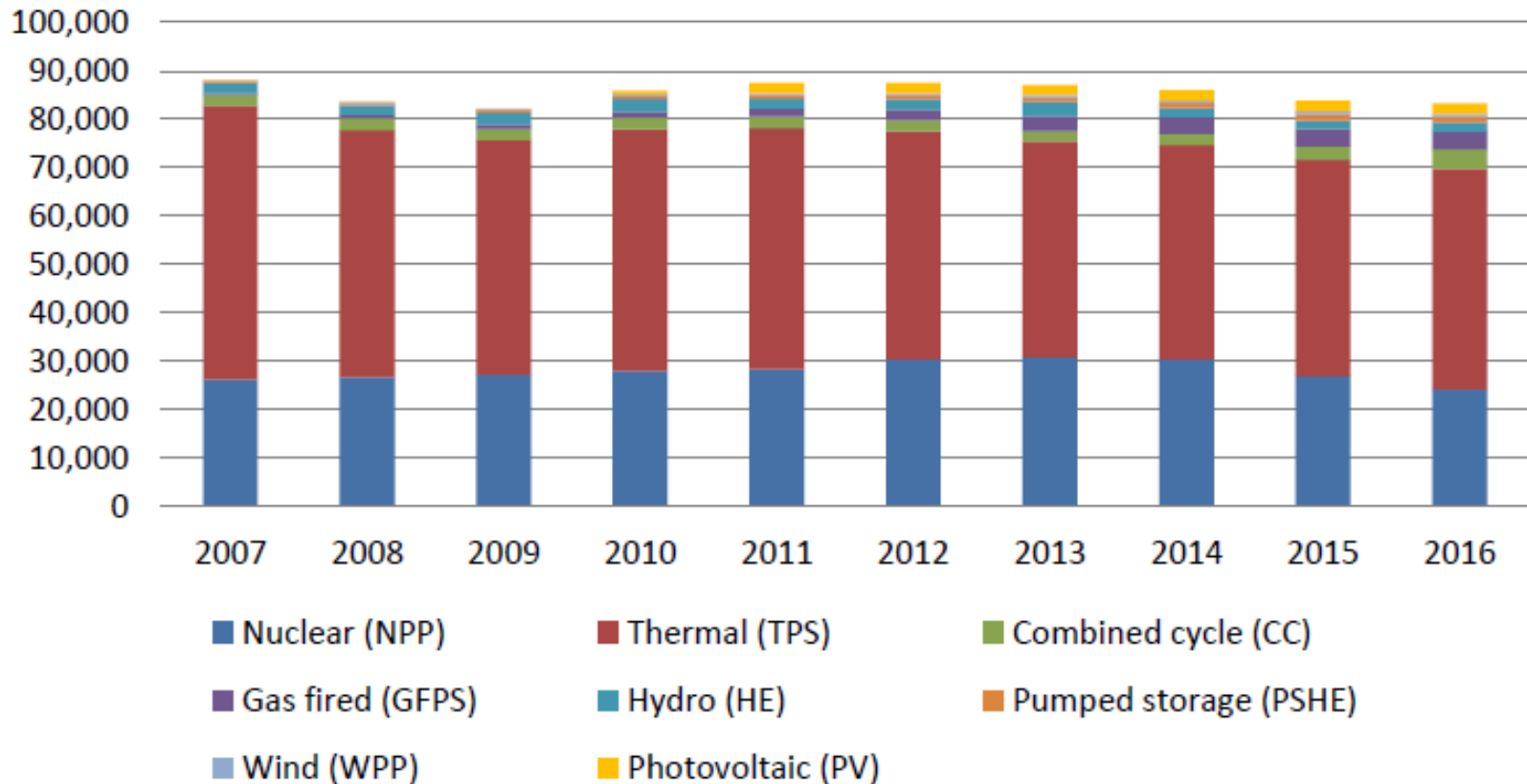
# Externality

- A consequence of an economic activity that is experienced by unrelated third parties. An externality can be either positive or negative.
  - (Pigouvian) taxes/subsidies
  - Command and control solution
  - Ownership rights

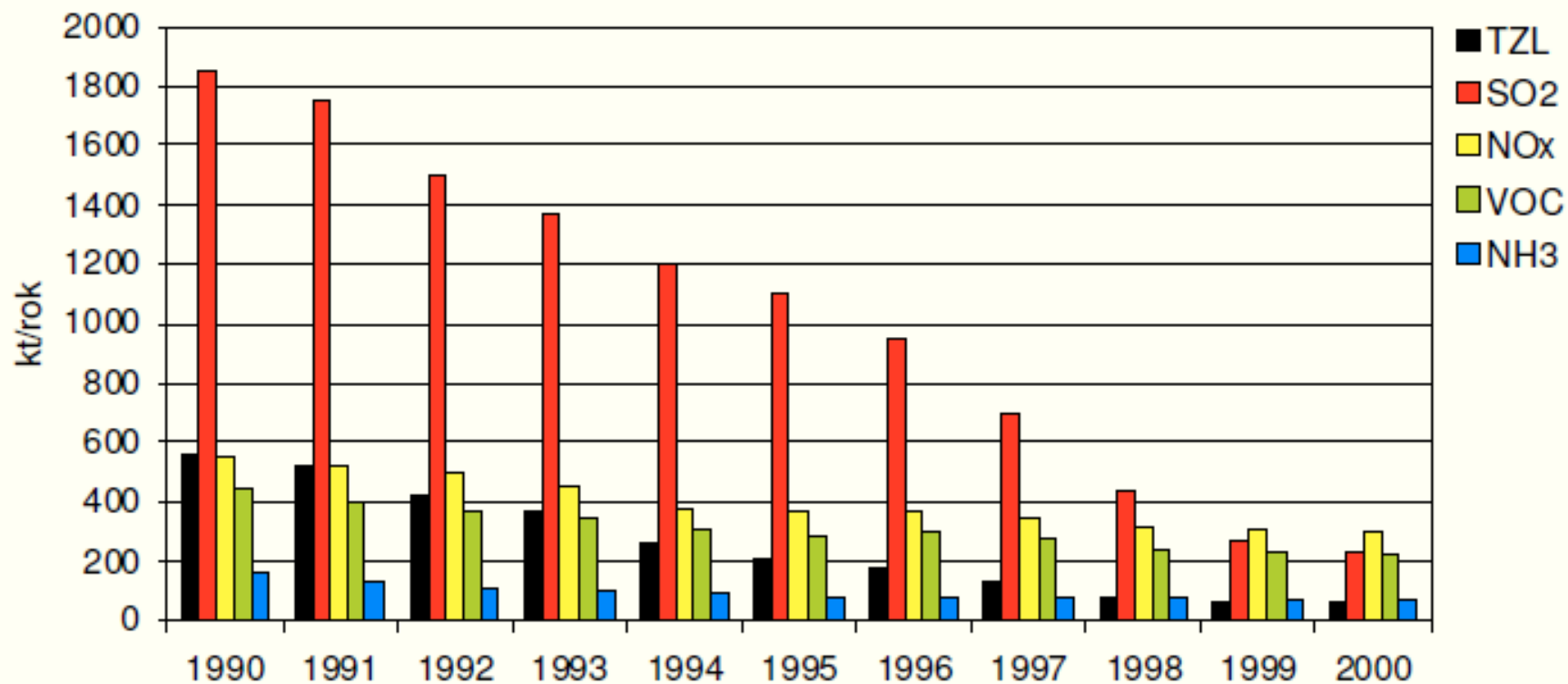
# Coase theorem

- If trade in an externality is possible and there are sufficiently low transaction costs, bargaining will lead to an efficient outcome regardless of the initial allocation of property.
- Uneffective if:
  - there are many affected parties, so it is expensive to coordinate the necessary contracts for the sale of property rights.
  - one person can block the sale, regardless of the costs actually imposed on them.
  - enforcement of the contract is too expensive, such as the costs of court proceedings if there is a breach of contract.
  - the costs of monitoring the offending behavior are high

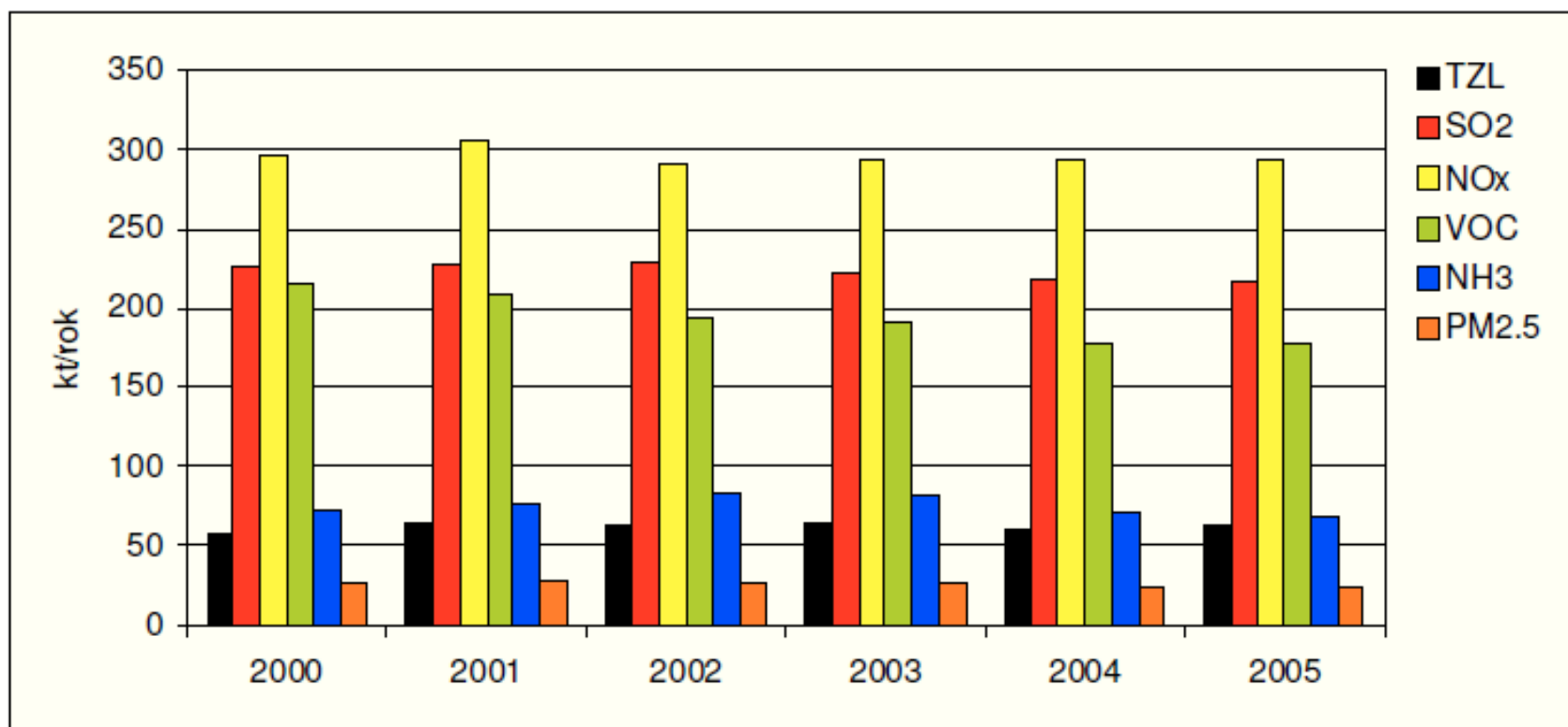
# Gross electricity generation in the Czech Republic (GWh)



# Situation in the Czech Republic



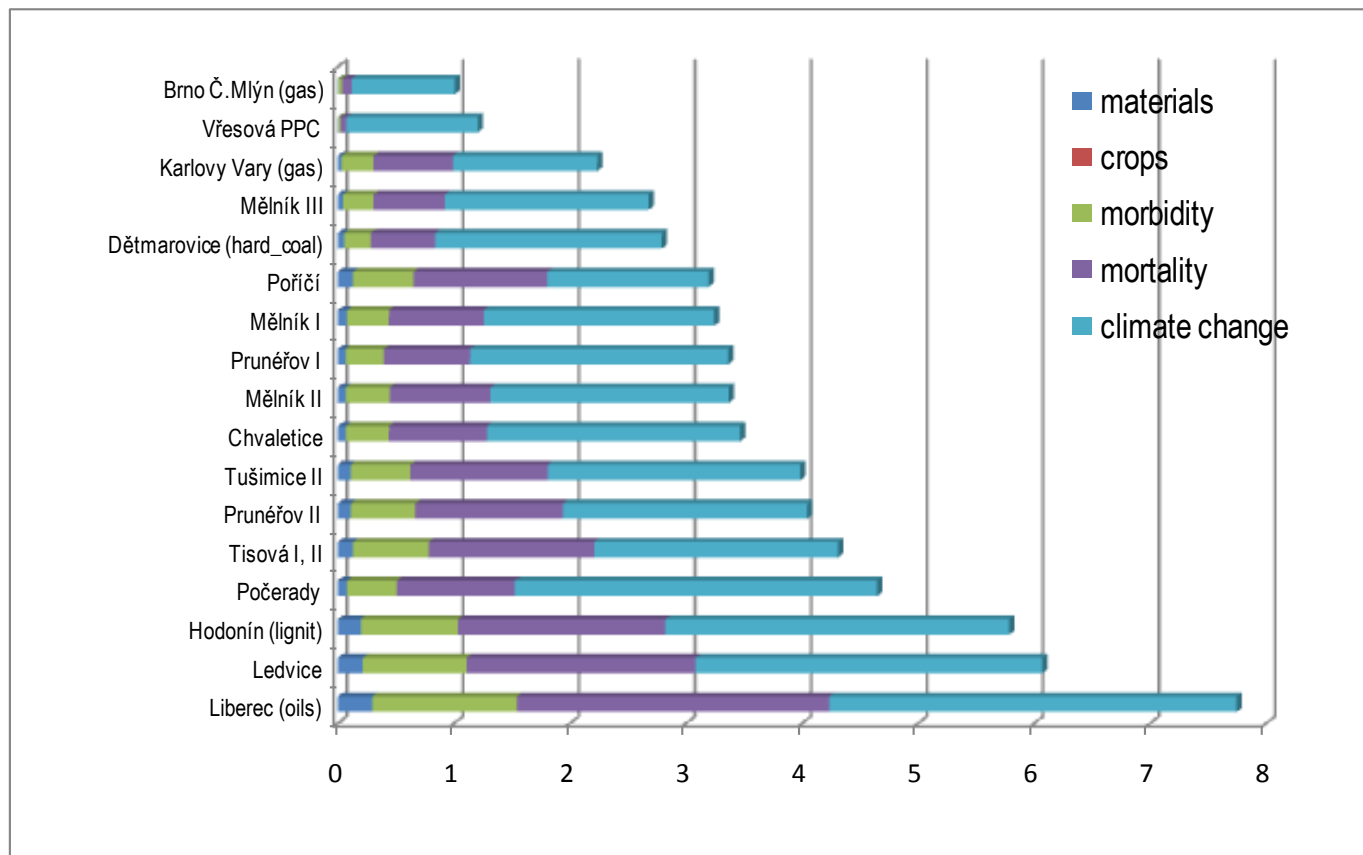
# Situation in the Czech Republic





# Externalities of electricity production

In €cents/kWh for selected energy sources in 2003 (Price of electricity in 2003  
– 1-2 €cents/kWh)



# Solution of the 'coal problem'?

- Source substitution.
- Higher efficiency of coal combustion.
- Reduction of coal pollutants during the process.
- CCS

# Sources

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- Sourcewatch.org – External costs of coal
- Ecofys: Subsidies and costs of EU energy, 2014
- Ščastný, M.; Melichar, J.: External Cost of Fossil And Non-fossil Energy Systems: The Case of the Czech Republic, 2007