Coal, pollution, and the challenge of valuing energy properly

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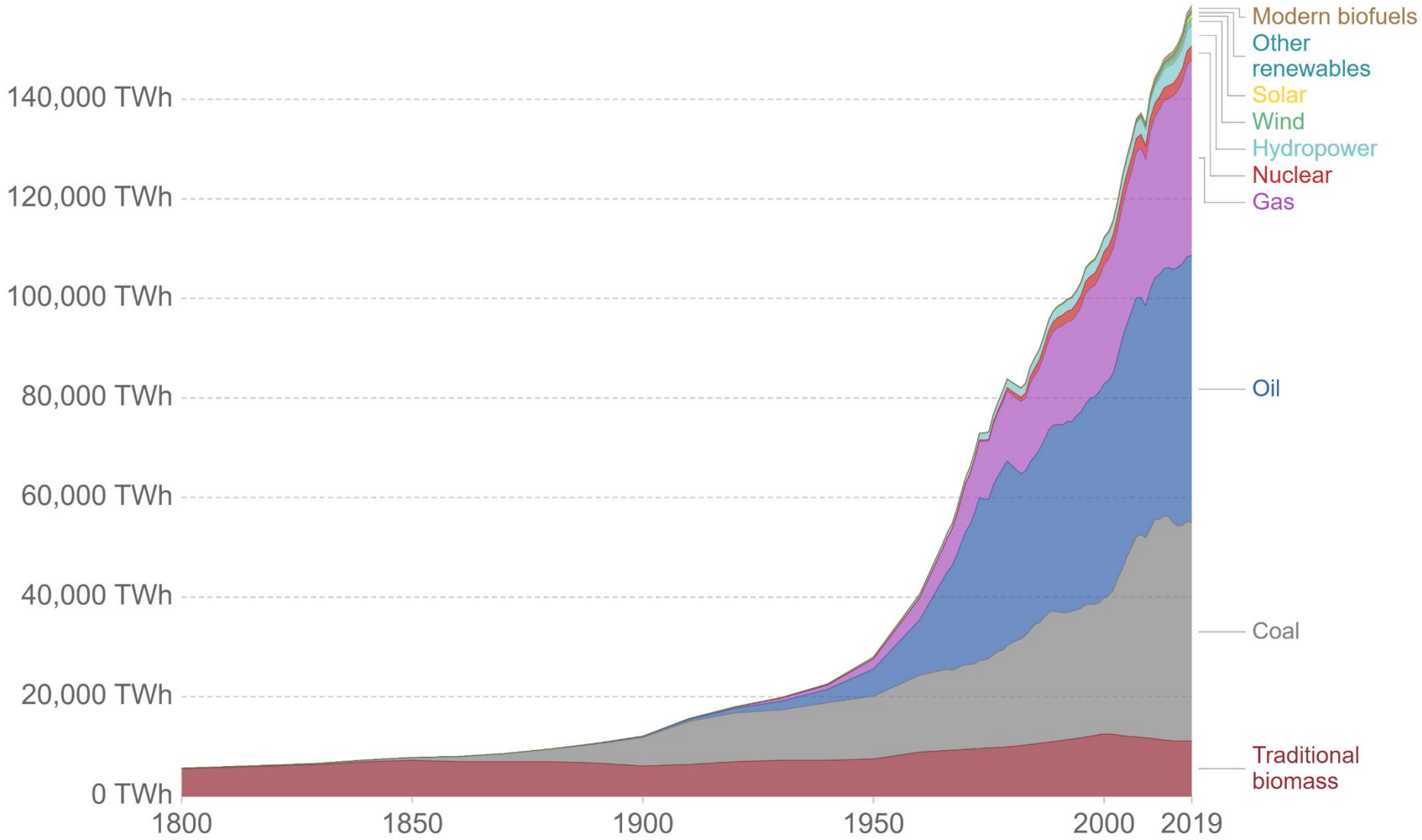
Global direct primary energy consumption

Direct primary energy consumption does not take account of inefficiencies in fossil fuel production.

Our World in Data



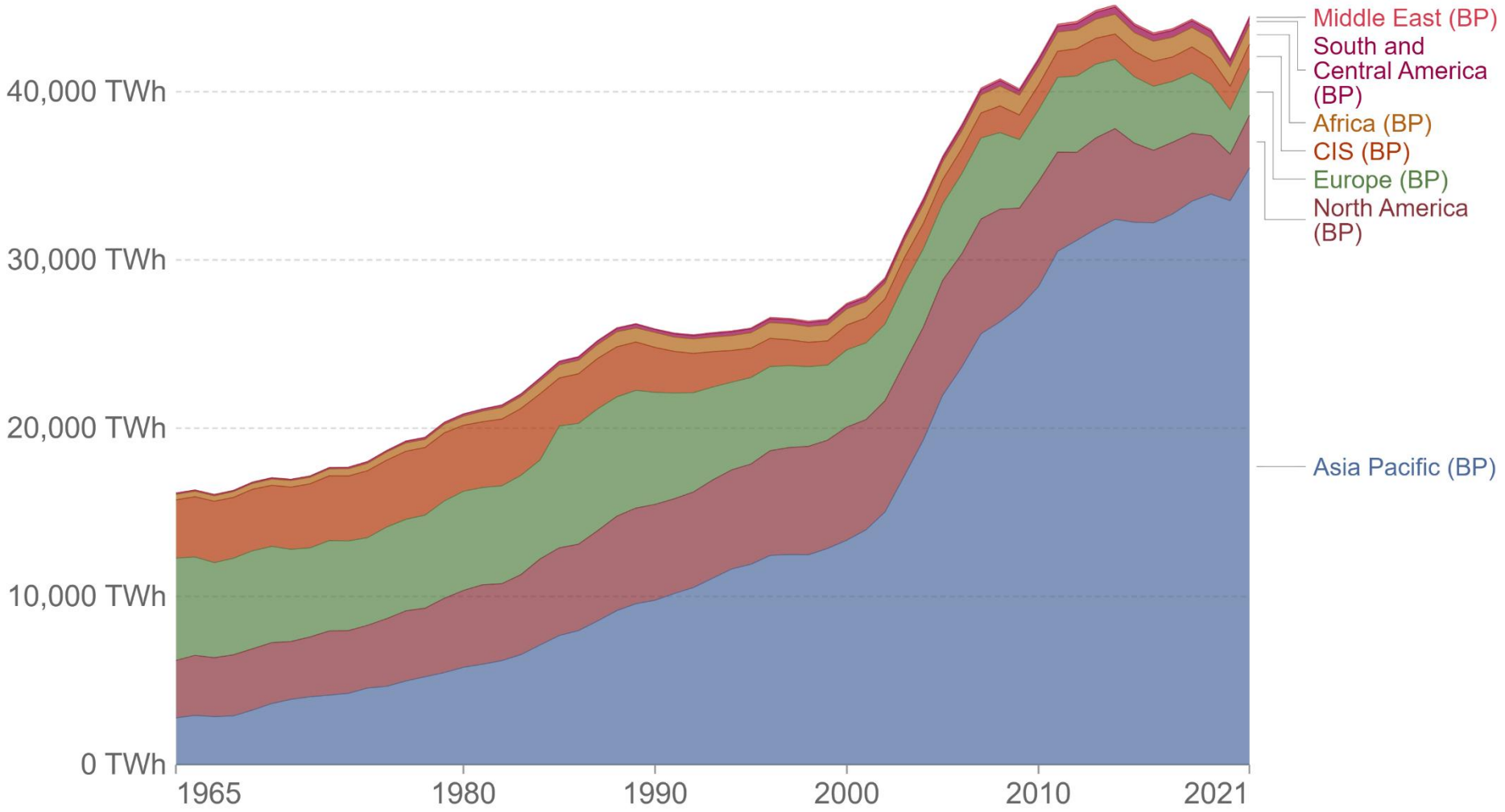
Source: Vaclav Smil (2017) and BP Statistical Review of World Energy

Coal and the first energy and environmental crisis

- Biomass crisis: wood depletion due to glass production.
- Glass dates back to 3000-3500 BCE; glass vases in 1500 BCE, Egypt & Mesopotamia.
- Production involves high-temperature melting requiring vast wood fuel.
- Wood also used for charcoal in metal smelting.
- Deforestation started in London, 1200, spread across the kingdom.
- By 1500s, metal smelting shifted to Ireland, Scotland, Wales.
- Jamestown, 1607: established partly for glass export to Britain.
- Ultimate solution: coal combustion, begun in England in the 13th century.

Coal consumption by region

Annual coal consumption, measured in equivalents of terawatt-hours (TWh) per year.



Source: Statistical Review of World Energy - BP (2022)

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Note: CIS (Commonwealth of Independent States) is an organization of ten post-Soviet republics in Eurasia following break-up of the Soviet Union.

Why do we still rely on coal?

- Abundance and distribution, large reserves.
- Cost.
- Existing infrastructure, technological familiarity, inertia.
- Energy density.
- Employment.
- Diversification.
- Lack of alternatives.
- Industrial proceses.

Environmental impacts

- Mining (opecast/surface mines and underground mines) – land use, water and air pollution, dust. Impact on biotops and landscape. Noise. Aestethical damages.
- Preparation for further processing – removal of impurities – acids, heavy metals, chemicals are released.
- Transport – dust from coal, transport-related pollution.
- Coal combustion – GHGs, primary pollutants, smog, acid rains.
- Solid waste – ash.

- Pollution - substances causing harm to ecosystems, human health, and well-being.

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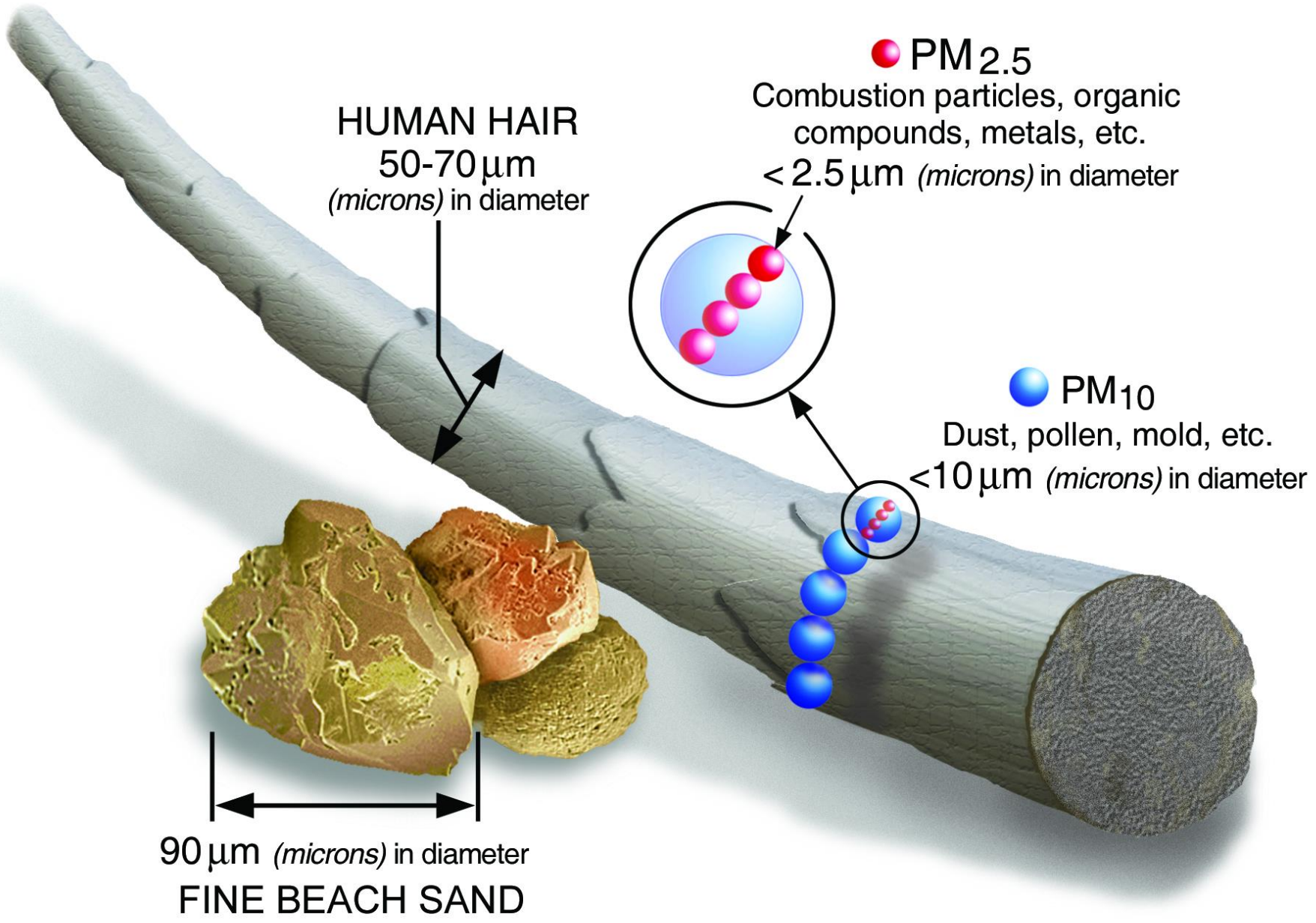
Particulate matter

- Combustion of biomass, dung, coal, industrial processes, wind erosion, atmospheric reactions of gases, transportation, abrasion.
- Coal, heavier oils (incl. diesel oil).
- PM_{10} inhalable particles, $PM_{2,5}$ (fine inhalable particles).
- Respiratory impacts include suspected asthma onset, exacerbation, COPD, stunted lung growth, and lung cancer. Cardiovascular effects encompass arrhythmias, heart attacks, and heart failure. Also linked to ischemic stroke in the nervous system.


HUMAN HAIR
50-70 µm
(microns) in diameter
PM2.5
Combustion particles, organic
compounds, metals, etc.
< 2.5 µm (microns) in diameter
PM10
Dust, pollen, mold, etc.
<10 µm (microns) in diameter
90 µm (microns) in diameter
FINE BEACH SAND

Sulphur

- Combustion of sulfur-containing fuels (coal).
- Sulphur dioxide (SO_2).
- Affects respiratory and lung functions, exacerbates asthma and bronchitis, increases susceptibility to respiratory infections, irritates eyes, worsens cardiac conditions, and raises ischemic stroke risk
- Contributes to acid rains. Impact on aquatic life, etc.

1) $2SO_2 + O_2 \rightarrow 2SO_3$ (Sulfur trioxide) $SO_3 + H_2O \rightarrow H_2SO_4$ (Sulfuric acid).

2) London smog (Smoke and fog, typically in winter (combination with inversion). SO_2 + PM (soot) + vater vapour = transport of gaseous matters of smog to the lungs).

Carbon monoxide (CO)

- Incomplete (insufficient oxygen) combustion of fuels (and other carbon-containing materials, such as tobacco or wood).
- Mobile sources (cars, trucks, boats, aircraft etc.), fires, industrial processes, stationary combustion.
- Toxic due to hemoglobin binding, blocking oxygen to tissues. Causes visual issues, decreased work and learning capacity, reduced manual skills, and difficulty with complex tasks.

Nitrogen oxides (NOx)

- Combustion of fuels. Mobile sources (transportation), stationary sources, industry, fires.
- Asthma development (suspected), asthma exacerbation, COPD, stunted lung development; cardiac arrhythmias, ischemic stroke.
- Reacts with VOCs in sunlight to form ground- level ozone.
- Increases an amount of nitrogen in soil and country – change of diversity. In aquasystems causes eutrophication. Increases acidity of soil and water.

Photochemical smog

- NO_2 + solar energy → NO+O; O+O_2 → O_3
- Ozone – bronchial constriction, coughing, wheezing, respiratory irritation, eye irritation, decreased crop yields, retars plant growth, damages plastics…

Heavy metals and other pollutants

- Nickel, mercury, arsen, chromium, cadmium, lead, florine, chlorine…

Emissions	**Amount of pollutants (in tons per 1TWh – 1000MW plant for 1000hrs)**
SO_2	2600
NO_x	2800

Representative 1000MW coal power plant = 6 million tons of CO_2 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).

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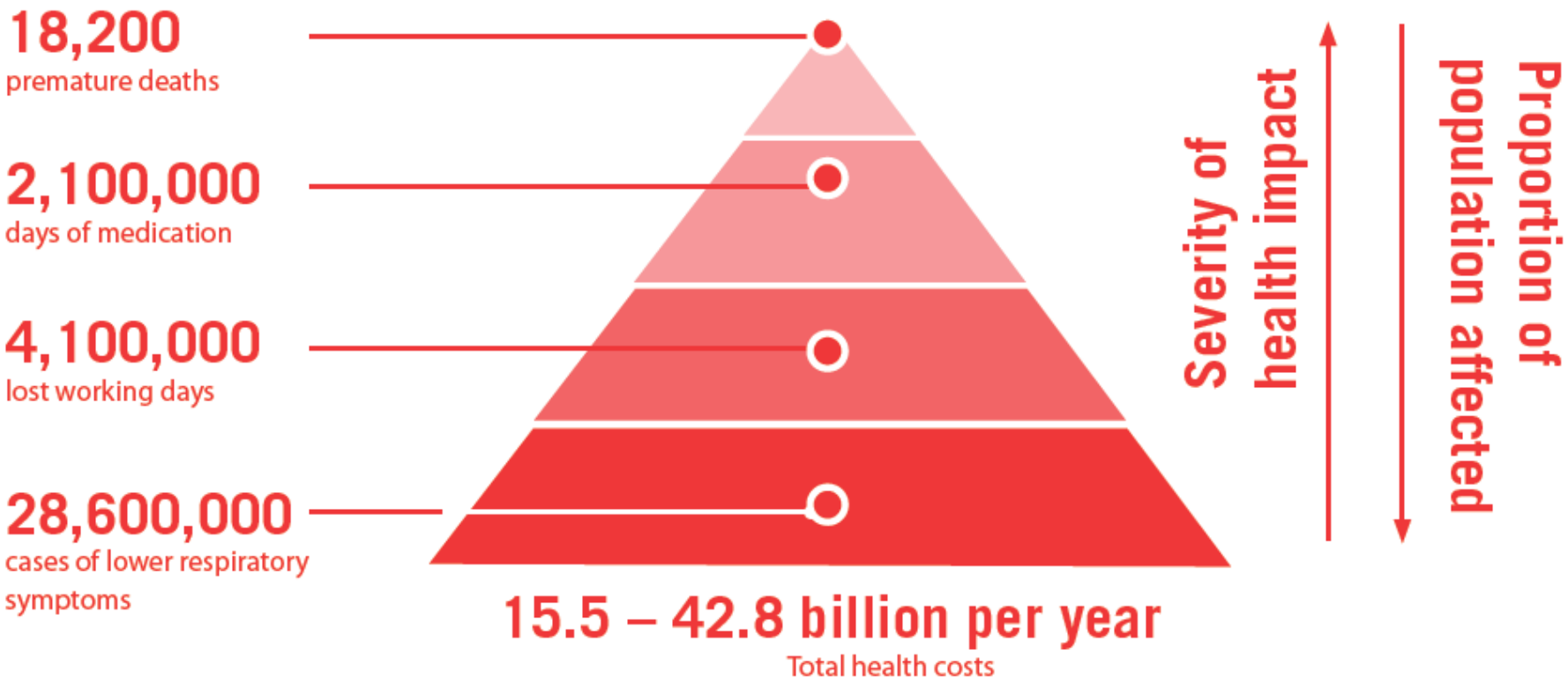
Health impacts of coal combustion



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

Costs

- Who is currently covering the costs of these damages to the environment and individuals, and who should rightfully bear these expenses?

- Should the situation remain as it is or be altered?
- If altered, in what manner?
- What actions should be taken?
- Who should bear the expenses for these actions, if introduced?

- Coal fired power plant; industry; local people; local government; people from neighbouring city.

CO_2 emissions by fuel type

Fuel Type	CO2 Emissions (kg/GJ)
Anthracite	98.1
Bituminous	88.3
Lignite	92.5
Diesel fuel and heating oil	69.2
Gasoline	67.5
Propane	59.7
Natural gas	50.2

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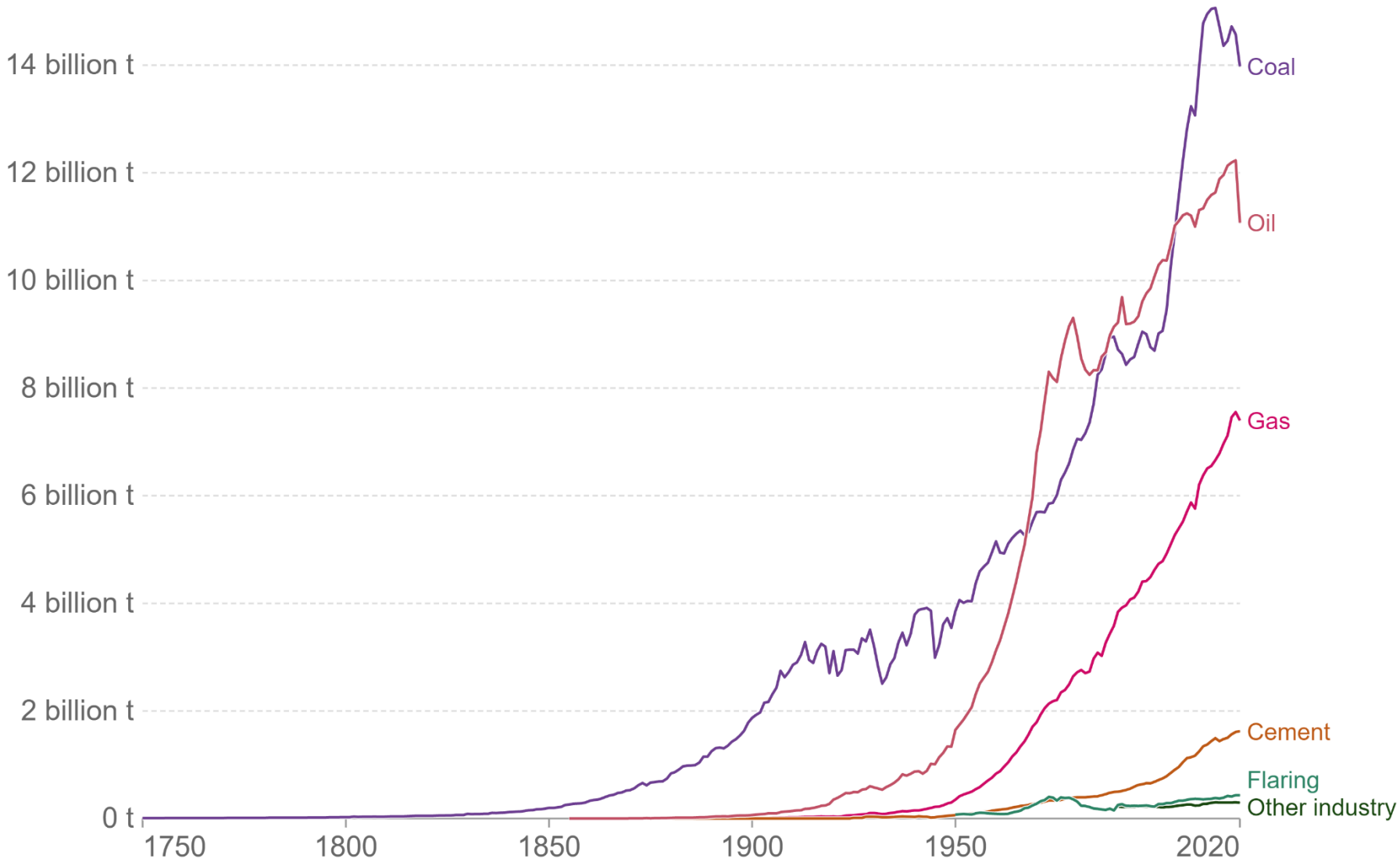
CO_2 emissions by fuel, World



Source: Global Carbon Project

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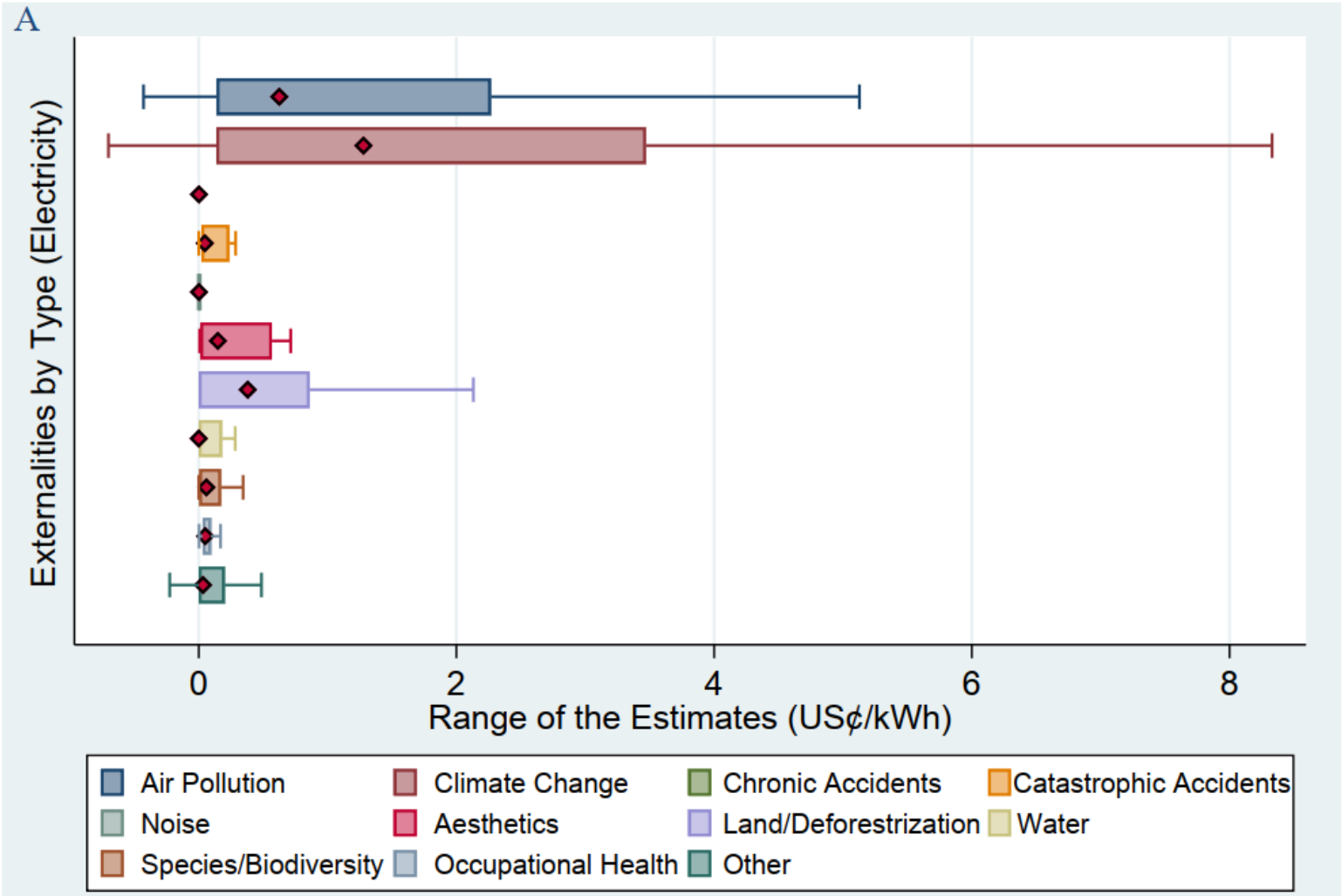

Fig. 5. The negative externalities by type associated with electricity supply (top panel) and transport (bottom panel) adjusted to US$2018, ¢/kWh and ¢/km. The range of the monetized estimates is broad. Because of the large standard deviation of aesthetics, air pollution, and congestion, the severity of externalities is changed if we apply mean values instead of the median. In terms of mean, the most severe externality with electricity is aesthetics, followed by air pollution, climate change, and degradation. For transport, the mean value indicates congestion as the most costly externality like the median, but air pollution takes second place, followed by accidents, noise, and land degradation. Note: The left end denotes minimum and the right end maximum in the box-and-whisker plots. The red dot means the median, and the left and right end of the box represent the first and third quartiles, respectively.

Source: Sovacool, B.K.; Kim, J.; Yang, M.(2021): The hidden costs of energy and mobility: A global meta-analysis and research synthesisi of elektricity and transport externalities, ERSS.

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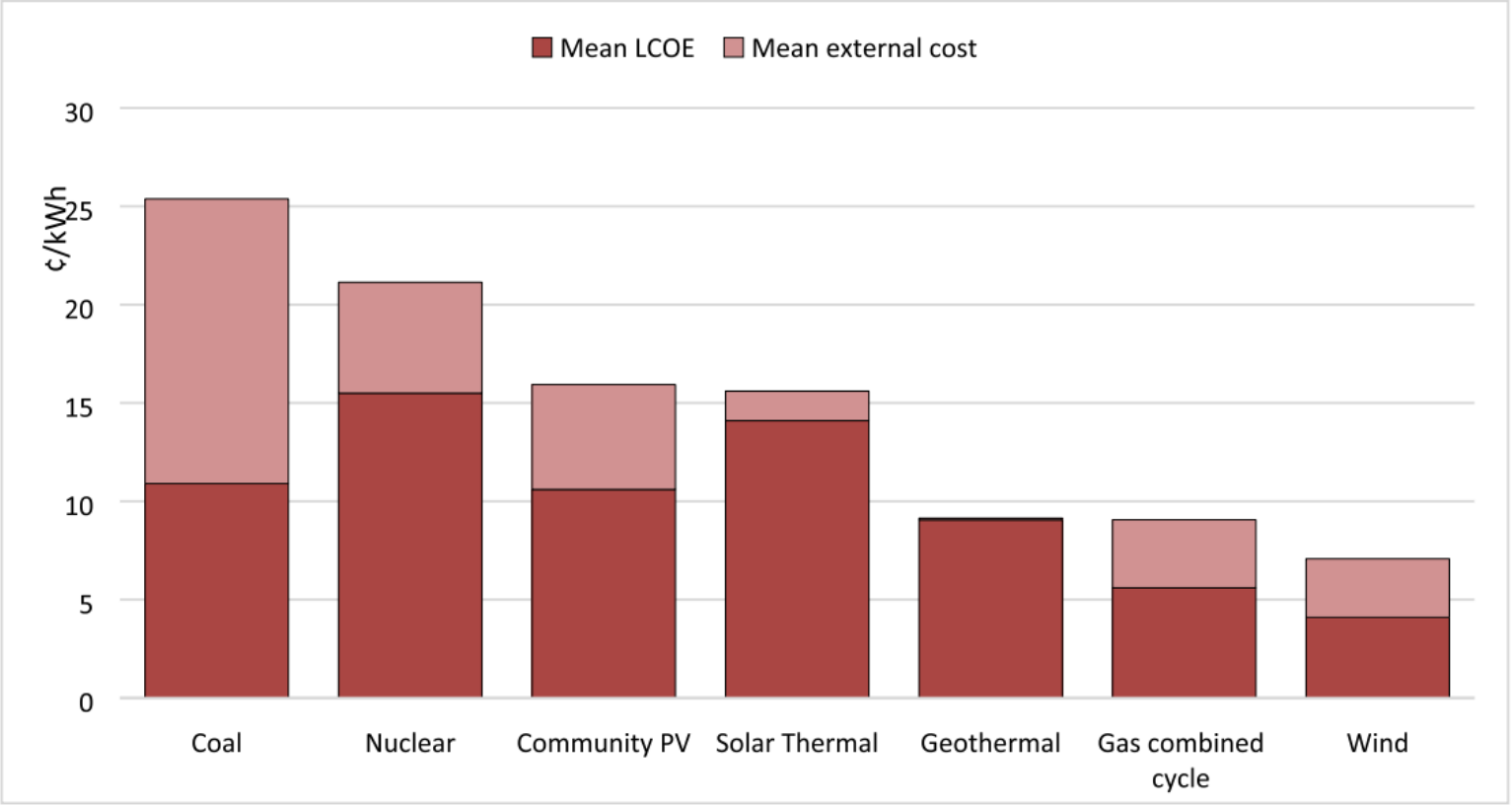

Fig. 9. Estimating the total social cost of electricity systems (LCOE + mean externality cost in US$2018 cents per kWh). From a purely LCOE standpoint, using mean average numbers from Lazard's, then the lowest merit order for energy systems is wind (7.1 ¢/kWh), gas (9 ¢/kWh), and geothermal (9.1 ¢/kWh). Solar PV and thermal falls in the middle around 15 ¢/kWh, Coal (25.4 ¢/kWh) and nuclear (21.1 ¢/kWh) become uneconomical and the two most expensive forms of energy on the market. Including their social costs rules them practically out of the portfolio. Note that some sources of electricity, such as hydropower, bioenergy or waste, are not included in Lazard's estimations and are therefore not represented in the diagram.

Source: Sovacool, B.K.; Kim, J.; Yang, M.(2021): The hidden costs of energy and mobility: A global meta-analysis and research synthesisi of electricity and transport externalities, ERSS.

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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.

Coal subsidies

Type of Subsidy	Description	Examples
Direct Financial Support	Financial incentives provided directly to coal producers or consumers.	Grants and special funds for exploration or mining; Direct payments to coal companies, subsidies for coal consumption.
Indirect Financial Support	Financial benefits not directly provided as cash but which reduce costs.	Tax breaks like special deductions; Loan guarantees for coal companies; Price supports or minimum purchase guarantees.
Infrastructure Support	Investments in infrastructure that indirectly support coal production or use.	Development of railroads or ports for coal transport; Funding R&D projects for coal technologies.
Regulatory Benefits	Measures that reduce regulatory burdens on the coal industry.	Relaxation of environmental regulations; Providing coal mining rights on public lands at below-market rates.
Trade and Foreign Aid	Measures that promote coal trade or international coal projects.	Export credits to facilitate coal exports; Foreign aid for coal power plant development in other countries.
External Costs	Costs not borne by coal companies but instead by the public or environment.	Not fully accounting for costs related to environmental degradation or health issues caused by coal; recultivation of mining areas.; social schemes for miners;

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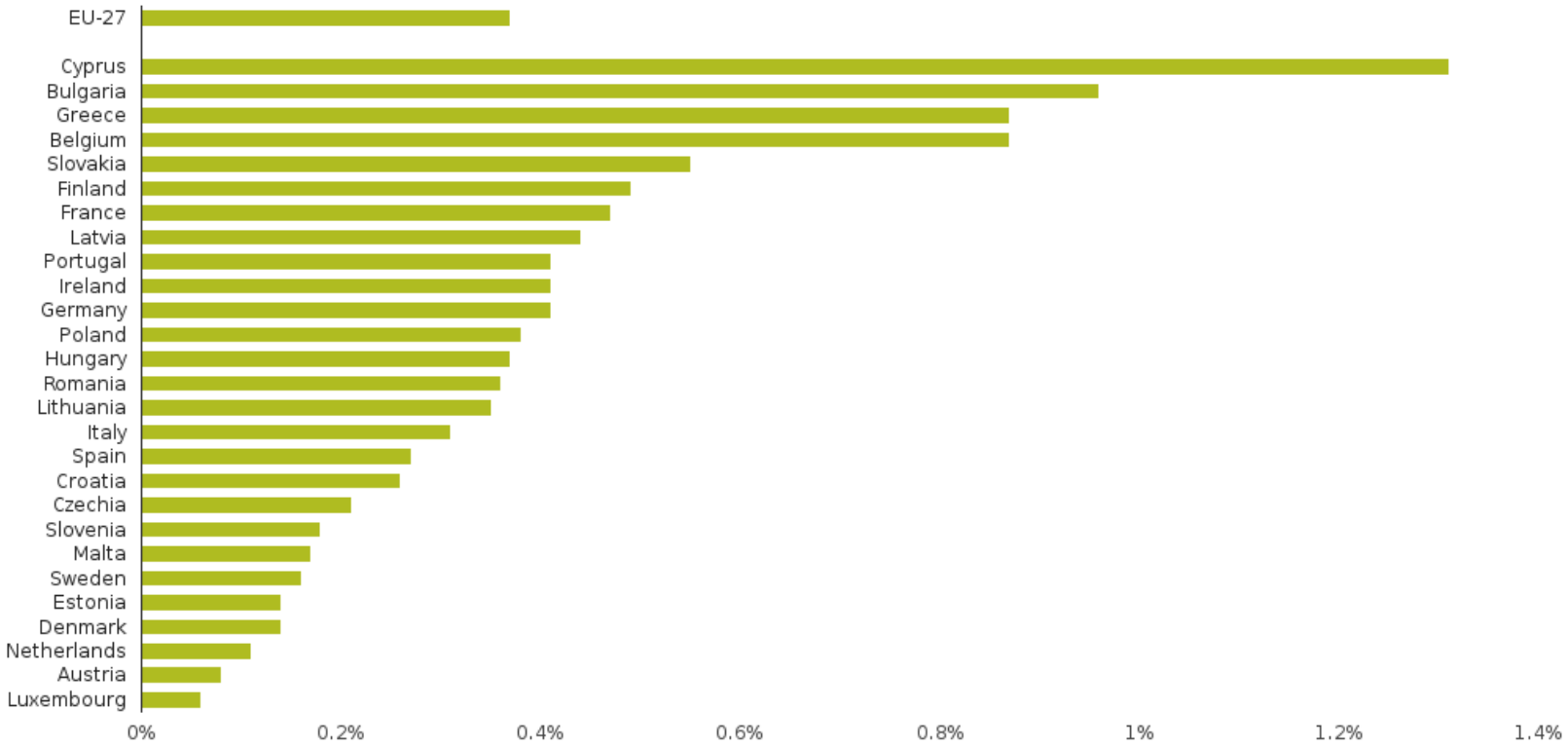
Chart — Fossil fuel subsidies as a share of national gross domestic products, 2020



Note

Units: Percentage of Gross Domestic Product (GDP)

More informationData sources:

The data from dataset 1 (Fossil fuel subsidies) was received by EEA in disaggregated form and corresponds to the aggregated fossil fuel subsidy figure of the EU presented in figure 3 of the '2022 Report on Energy Subsidies in the EU' published by the EC (COM 642final).

More informationData sources:

Fossil fuel subsidies provided by European Commission

GDP and main components (output, expenditure and income) [NAMA_10_GDP__custom_3489075] provided by Statistical Office of the European Union (Eurostat)

Problems with pricing of energy

- Problem is twofold:
  - fuels aren't priced based on their true costs,
  - they aren't equitably priced in relation to one another.
- By overlooking externalities and providing financial and other forms of support, consumption is raised inefficiently.
- This results in excessive and often inappropriate energy consumption.

- So why don't we abolish subsidies and enforce the payment of externalities?

Sources

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