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Energia e sviluppo sostenibile: il grande dilemma

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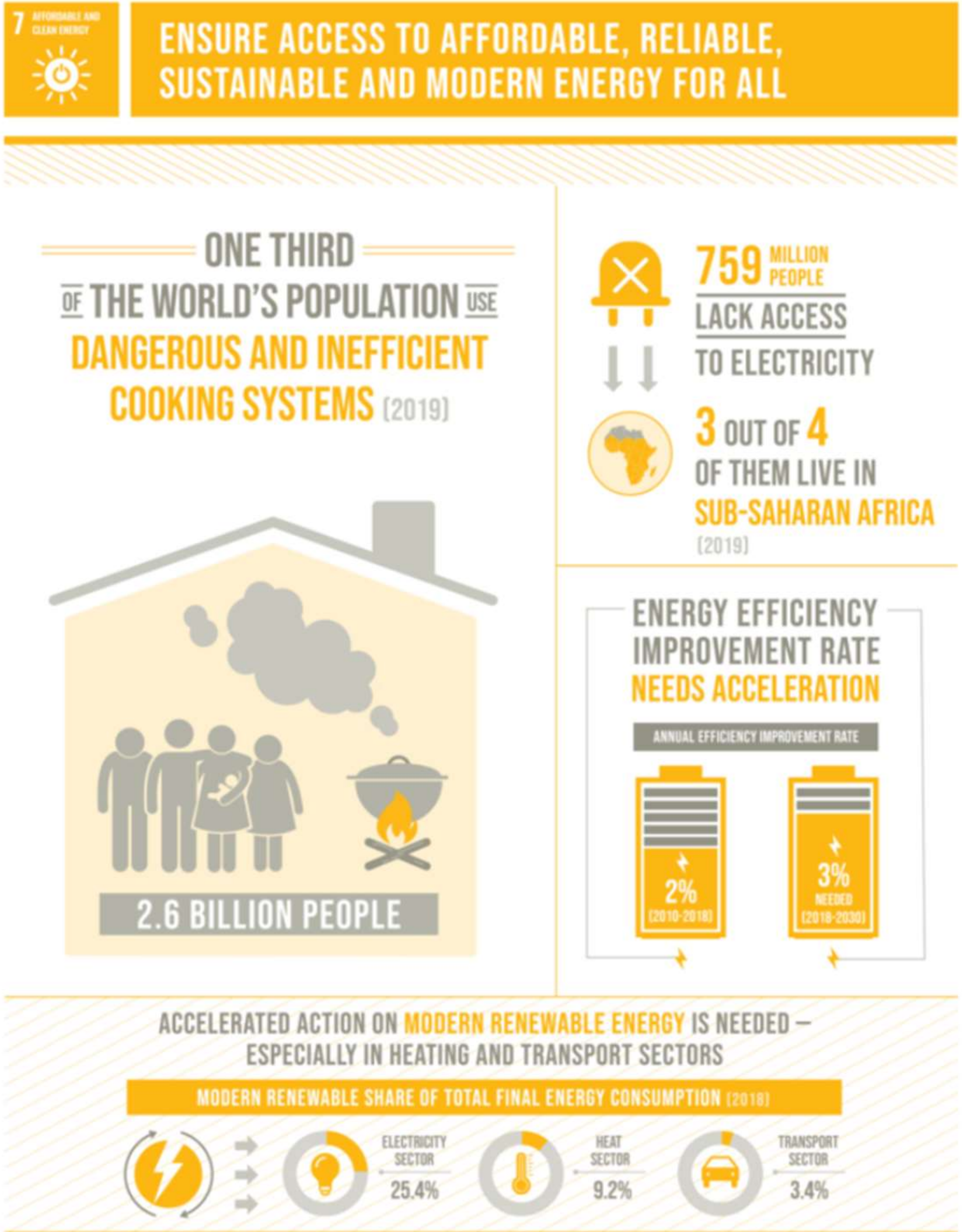
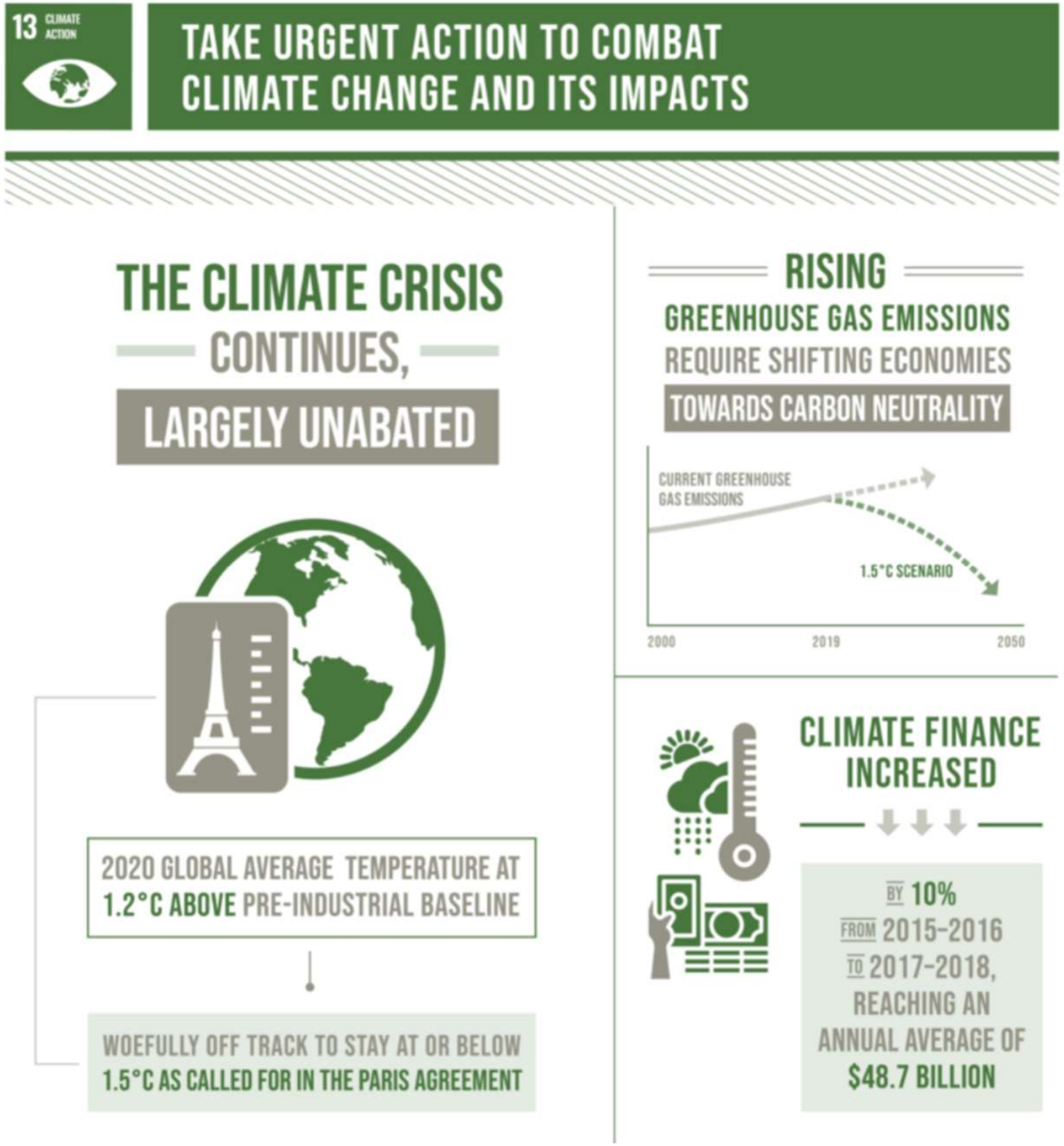
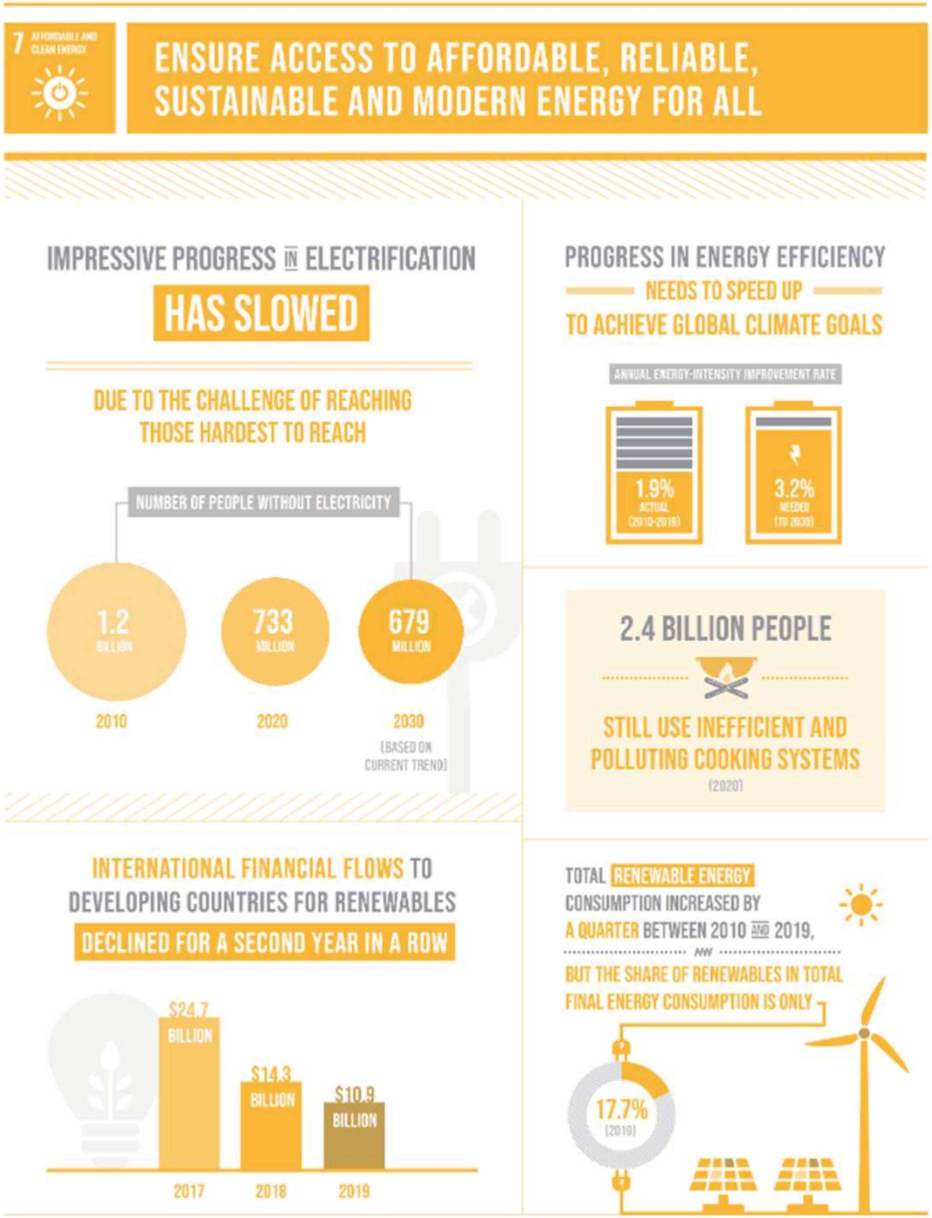
I DILEMMI DELLA TRANSIZIONE ENERGETICA

Il dilemma dell'energia nei SDG

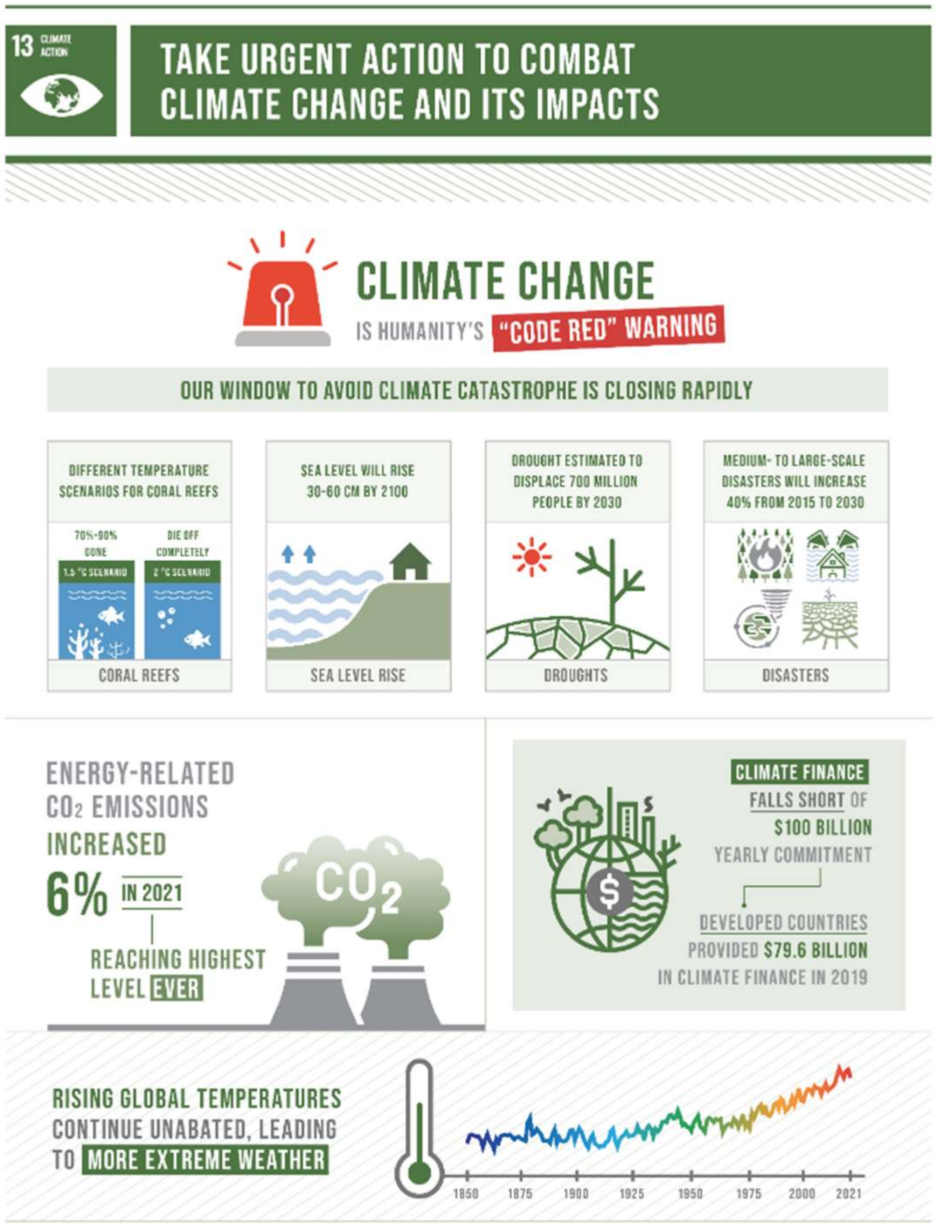




Il dilemma dell'energia nei SDG



THE SUSTAINABLE DEVELOPMENT GOALS REPORT 2022: UNSTATS.UN.ORG/SDGS/REPORT/2022/



THE SUSTAINABLE DEVELOPMENT GOALS REPORT 2022: UNSTATS.UN.ORG/SDGS/REPORT/2022/

SDG7: "Ensure access to affordable, reliable, sustainable and modern energy for all"

- 7.1: Ensure universal access to affordable, reliable and modern energy services
  - 7.1.1 - Proportion of population with access to electricity
  - 7.1.2 - Proportion of population with primary reliance on clean fuels and technology
- 7.2 - Increase substantially the share of renewable energy in the global energy mix
  - 7.2.1 - Renewable energy share in the total final energy consumption
- 7.3 - Double the global rate of improvement in energy efficiency
  - 7.3.1 - Energy intensity measured in terms of primary energy and GDP

SDG7: "Ensure access to affordable, reliable, sustainable and modern energy for all"

- 7.a - Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
  - 7.a.1 - International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems
- 7.b - Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support
  - 7.b.1 - Installed renewable energy-generating capacity in developing countries (in watts per capita)

Progressi significativi, ma obiettivi ancora lontani (2010-2021)

7.1.1. – Accesso globale passa da 83% a 91%; incremento tende a rallentare

7.1.2 - il 71% della popolazione mondiale ha accesso a sistemi di preparazione del cibo adeguati dal punto di vista sanitario (concentrati in Africa sub-Sahariana)

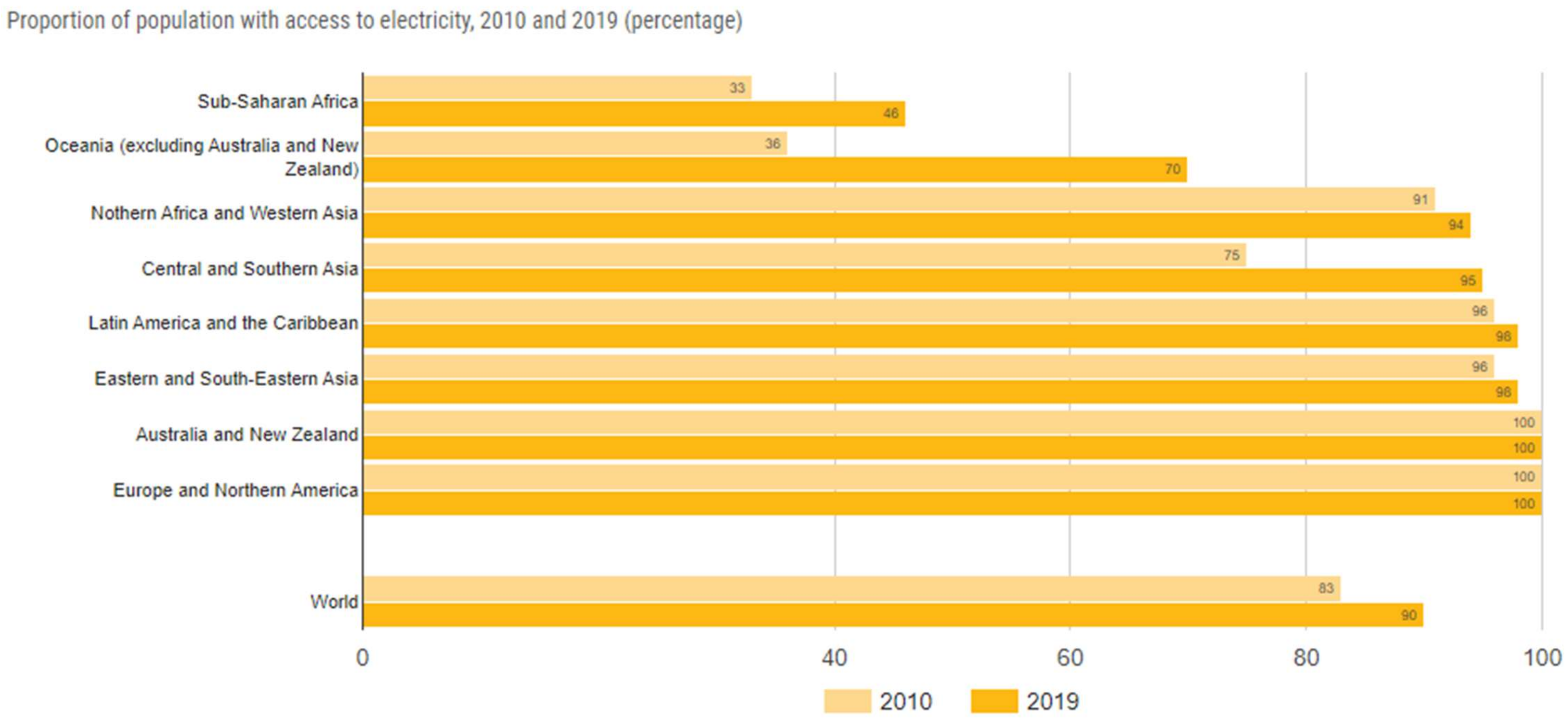
7.2.1 – La quota delle energie rinnovabili passa dal 16,4 al 19,1%; per la maggior parte, nei paesi poveri «energia rinnovabile» significa biomasse povere

7.3.1 – L'intensità energetica del PIL diminuisce leggermente da 5,6 MJ/$ a 4,8 MJ/$; miglioramenti tendono a rallentare

7.a.1 – Finanziamenti ai PVS raggiungono i 14 B$, ma sono diminuiti dal 2017 al 2021 (10,8 B$)

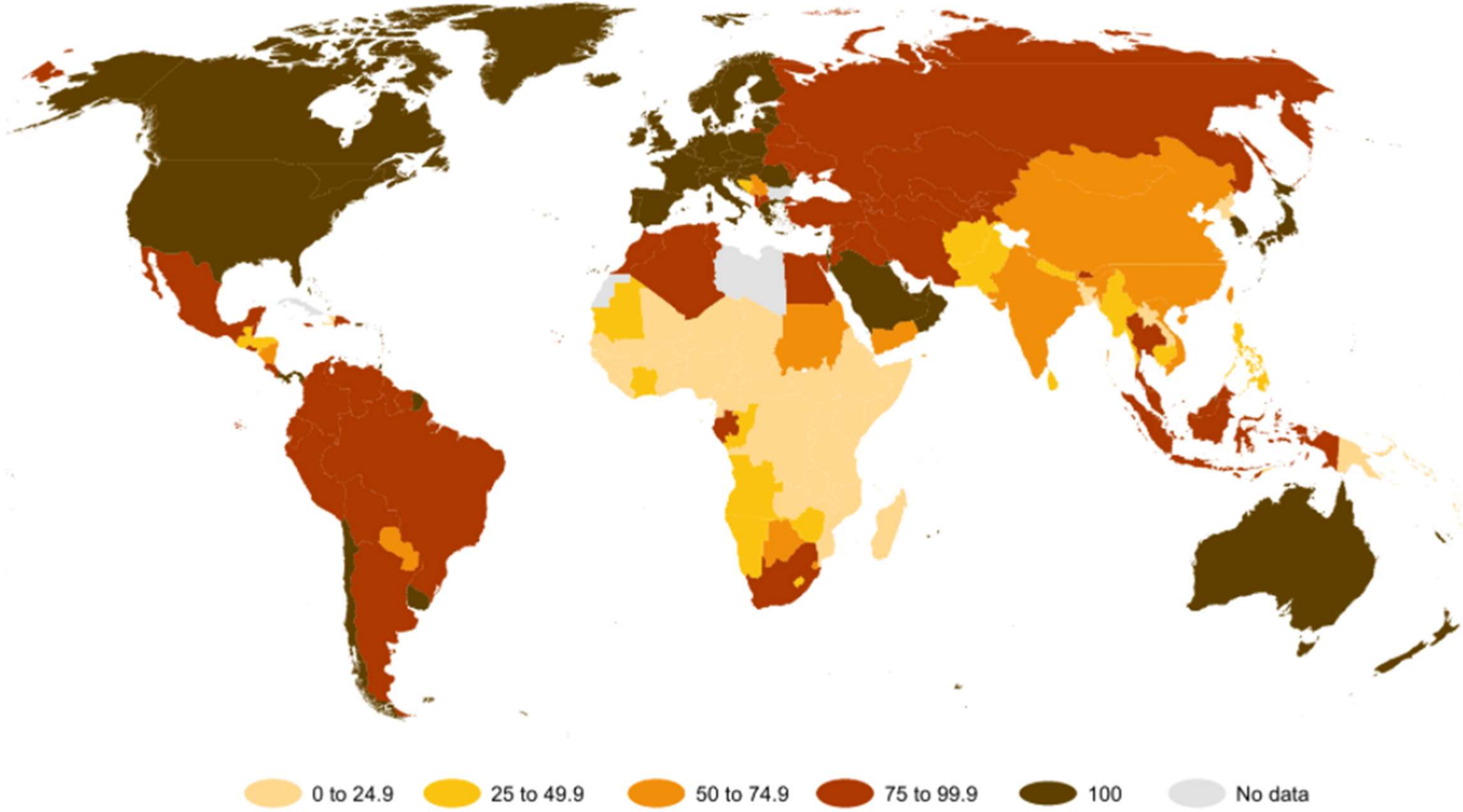
7.a.2 – Espansione della capacità di generazione da FER maggiore della crescita della popolazione, ma in diminuzione dal 2018 al 2019; accelerazione negli anni successivi, ma non nei paesi più poveri

7.1.1 Accesso all'elettricità (%)



7.1.2 - Accesso a sistemi di cottura del cibo adeguati dal punto di vista sanitario (%)

Share of the population with access to clean cooking systems, 2019 (percentage)



SDG13:
“Take urgent action to combat climate change and its impacts”

- 13.1 - Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
  - 13.1.1 - Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
  - 13.1.2 - Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030
  - 13.1.3 - Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
- 13.2 - Integrate climate change measures into national policies, strategies and planning
  - 13.2.1 - Number of countries with nationally determined contributions, long-term strategies, national adaptation plans and adaptation communications, as reported to the secretariat of the UN Framework Convention on CC
  - 13.2.2 - Total greenhouse gas emissions per year
- 13.3 - Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning
  - 13.3.1 - Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment)

SDG13: “Take urgent action to combat climate change and its impacts”

- 13.a - Implement the commitment undertaken by developed-country parties to the UN Framework Convention on CC to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible
  - 13.a.1 - Amounts provided and mobilized in US$ per year in relation to the continued existing collective mobilization goal of the $100 billion commitment through to 2025
- 13.b - Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities
  - 13.b.1 - Number of least developed countries and small island developing States with nationally determined contributions, long-term strategies, national adaptation plans and adaptation communications, as reported to the secretariat of the United Nations Framework Convention on Climate Change

Progressi significativi, ma obiettivi ancora lontani (2010-2021)

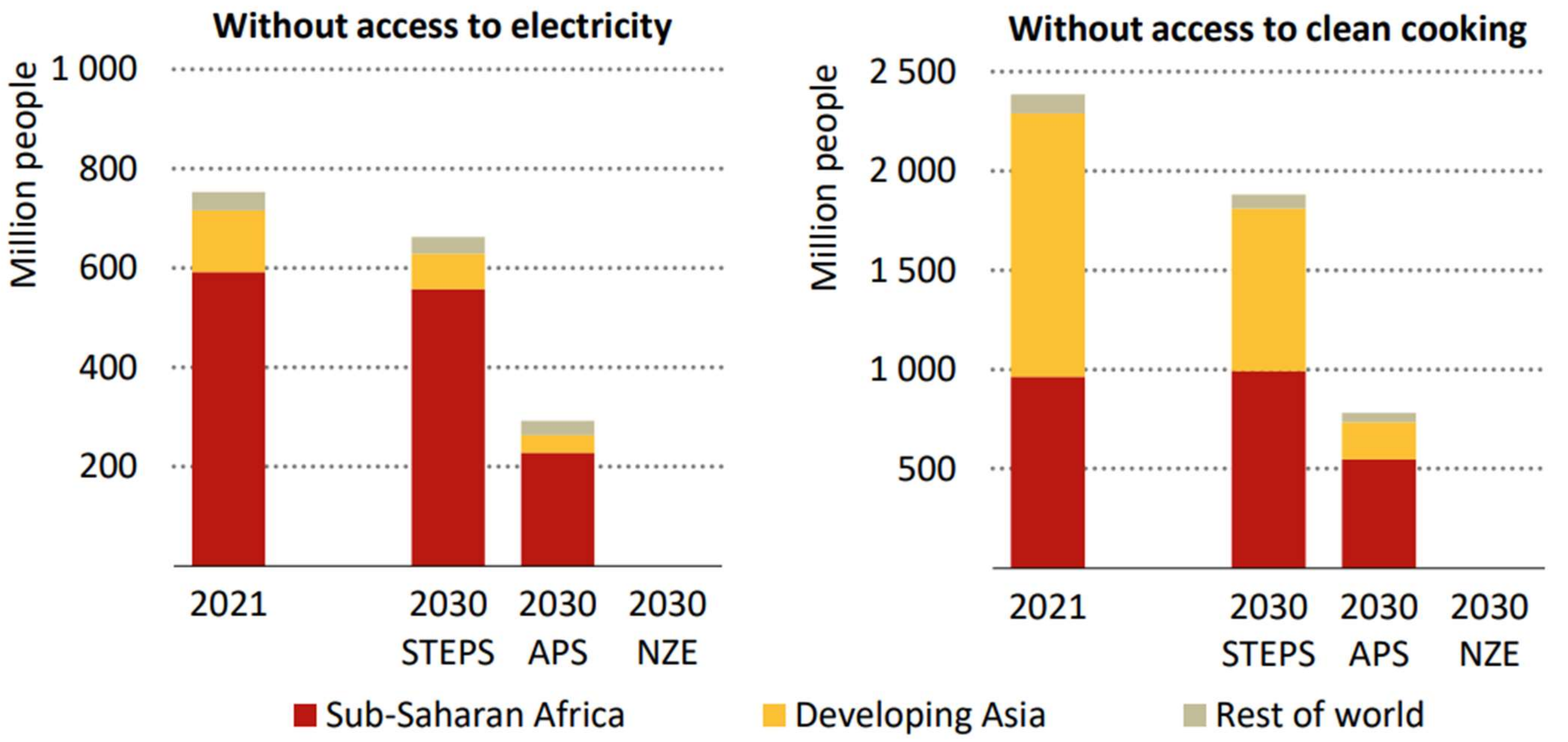
13.1.2 The number of deaths and missing persons due to disasters per 100,000 population has steadily decreased from 1.64 during 2005-2015 to 0.86 during 2012-2021. The average disaster mortality stood at 47,337 in absolute terms in 2015-2021. However, the number of persons affected by disasters per 100,000 people rose from 1,198 during 2005-2015 to 2,113 during 2012-2021. The number of countries with national strategies for disaster risk reduction has increased from 55 in 2015 to 126 by the end of 2021. Based on this, a total of 118 countries have reported having some level of policy coherence with other global frameworks, such as the 2030 Agenda and the Paris Agreement.

13.2 Global temperatures have already hit 1.1°C, rising due to increasing global greenhouse gas emissions, which reached record highs in 2021. Real-time data from 2022 show emissions continuing an upward trajectory. Instead of decreasing emissions as required by the target to limit warming, carbon dioxide levels increased from 2020 to 2021 at a rate higher than the average annual growth rate of the last decade and is already 149% higher than pre-industrial levels. Projected cumulative future CO2 emissions over the lifetime of existing and currently planned fossil fuel infrastructure exceed the total cumulative net CO2 emissions in pathways that limit warming to 1.5°C (>50%) with no or limited overshoot.

13.3 – An analysis of 100 national curriculum frameworks reveals that nearly half (47%) do not mention climate change. In 2021, despite 95% of teachers recognizing the importance of teaching about climate change severity, only one-third are capable of effectively explaining its effects in their region. Additionally, 70% of young people can only describe the broad principles of climate change in 2022.

13.a – According to the OECD, total climate finance provided and mobilised by developed countries for developing countries amounted to $83.3 billion in 2020, a 4% increase from 2019, but still short of the $100 billion target. Climate finance remains primarily targeted to mitigation; however, and adaptation finance continues to lag, with international finance flows to developing countries 5-10 times below estimated needs

Figure 1.7 ▹ **Number of people without access to electricity and clean cooking by scenario, 2021 and 2030**



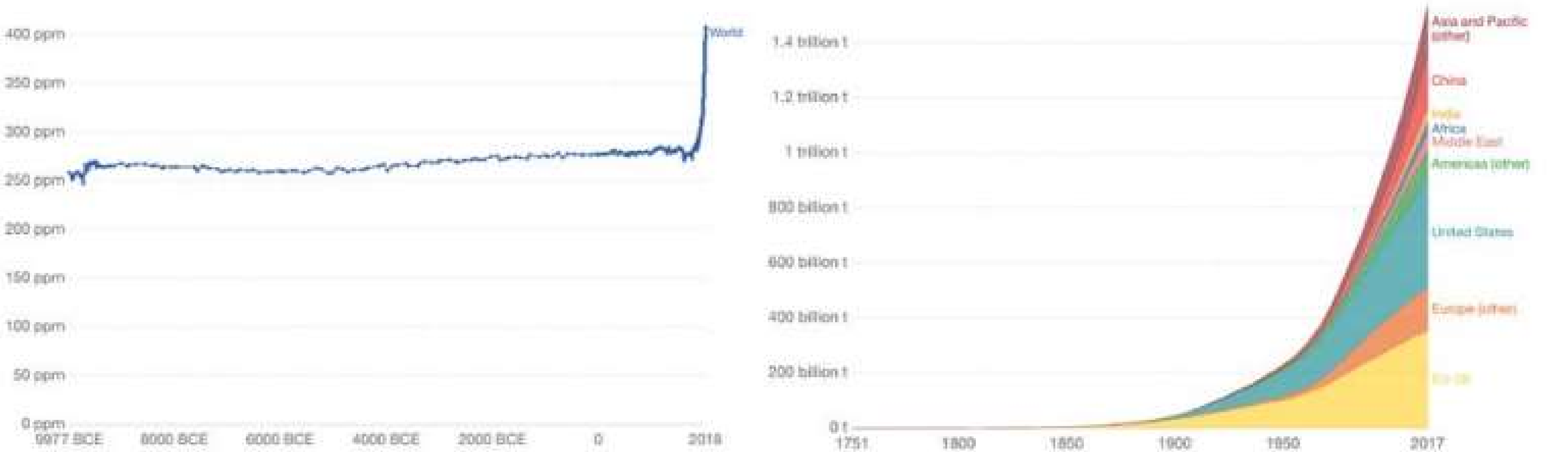
Well-formulated national strategies and international support are vital to regain momentum on improving energy access after Covid-19 and today's high energy prices

Notes: Sub-Saharan Africa excludes South Africa. STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Source: IEA, World Energy Outlook 2022

Concentrazione di CO_2 in atmosfera ed emissioni di CO_2 di origine antropica

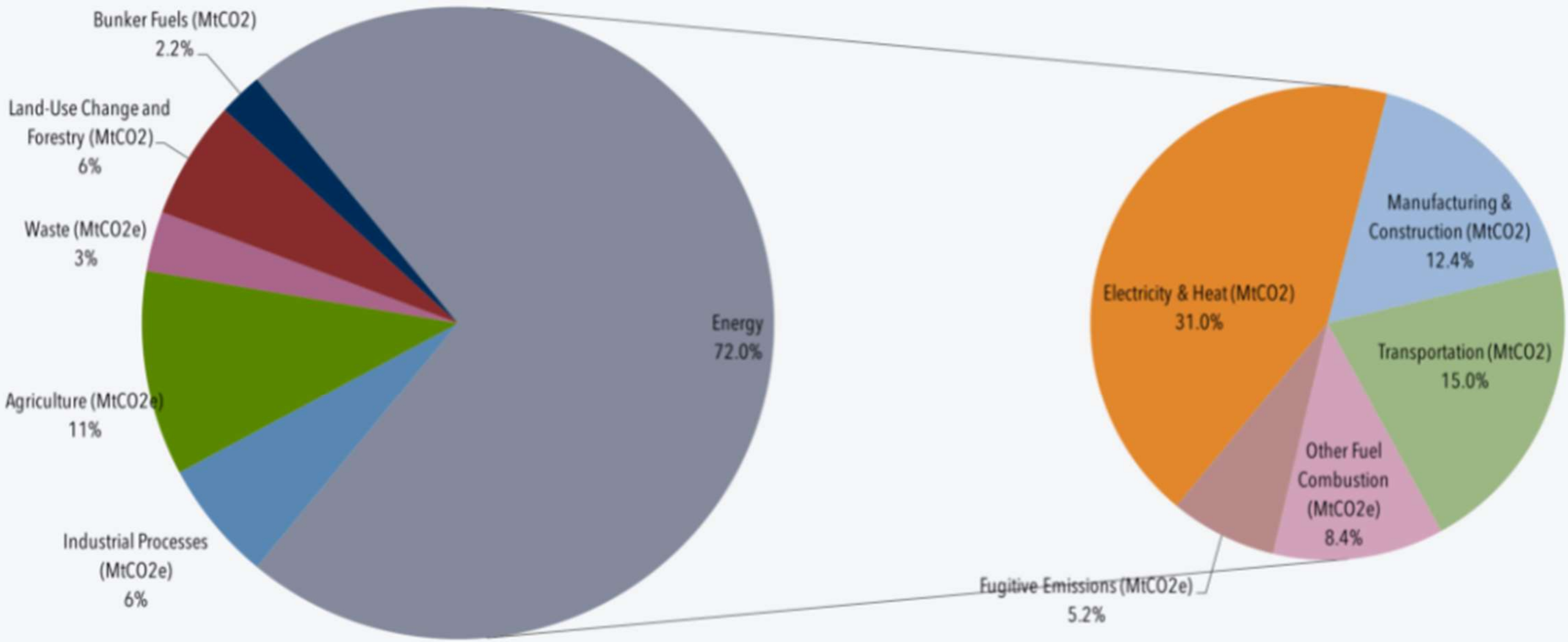
Evolution of atmospheric CO_2 concentration — Graph 1



Atmospheric CO_2 concentration over the past 12 millennia, measured in parts per million (left-hand panel); and annual total CO_2 emissions by world region since 1751 (right-hand panel).

Sources: Bereiter et al. (2015), NOAA, www.esrl.noaa.gov/gmd/ccgg/trends/data.html; Carbon Dioxide Information Analysis Center, http://cdiac.ornl.gov; and Global Carbon Project (2018). Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

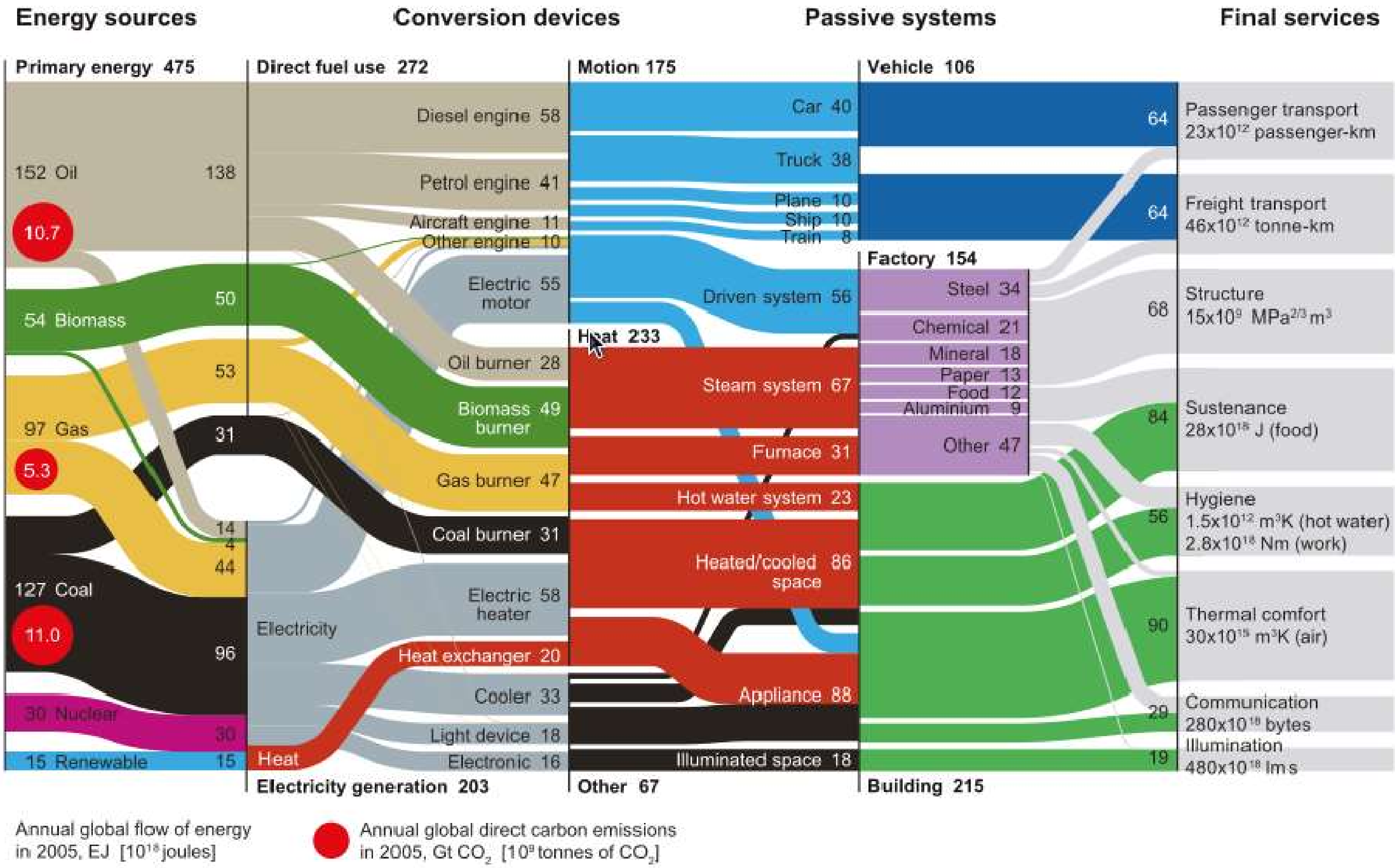
Global man-made CO2 emissions by source



NOTES

Globally, the primary sources of greenhouse gas emissions are electricity and heat (31%), agriculture (11%), transportation (15%), forestry (6%) and manufacturing (12%). Energy production of all types accounts for 72 percent of all emissions.

L’ENERGIA FINO A OGGI


Energy sources
Conversion devices
Passive systems
Final services
Primary energy 475
Direct fuel use 272
Motion 175
Vehicle 106
152 Oil
138
10.7
54 Biomass
50
53
97 Gas
5.3
31
14
4
44
127 Coal
11.0
96
30 Nuclear
30
15 Renewable
15
Diesel engine 58
Petrol engine 41
Aircraft engine 11
Other engine 10
Electric motor 55
Oil burner 28
Biomass burner 49
Gas burner 47
Coal burner 31
Electricity
Electric heater 58
Heat exchanger 20
Cooler 33
Light device 18
Electronic 16
Heat
Electricity generation 203
Car 40
Truck 38
Plane 10
Ship 10
Train 8
Driven system 56
Heat 233
Steam system 67
Furnace 31
Hot water system 23
Heated/cooled space 86
Appliance 88
Illuminated space 18
Other 67
Factory 154
Steel 34
Chemical 21
Mineral 18
Paper 13
Food 12
Aluminium 9
Other 47
Building 215
64
64
68
84
56
90
29
19
Passenger transport
23x10¹² passenger-km
Freight transport
46x10¹² tonne-km
Structure
15x10⁹ MPa²/³ m³
Sustenance
28x10¹⁸ J (food)
Hygiene
1.5x10¹² m³K (hot water)
2.8x10¹⁸ Nm (work)
Thermal comfort
30x10¹⁵ m³K (air)
Communication
280x10¹⁸ bytes
Illumination
480x10¹⁸ lm s
Annual global flow of energy in 2005, EJ [10¹⁸ joules]
Annual global direct carbon emissions in 2005, Gt CO₂ [10⁹ tonnes of CO₂]

Il consumo di energia nella storia dell'umanità

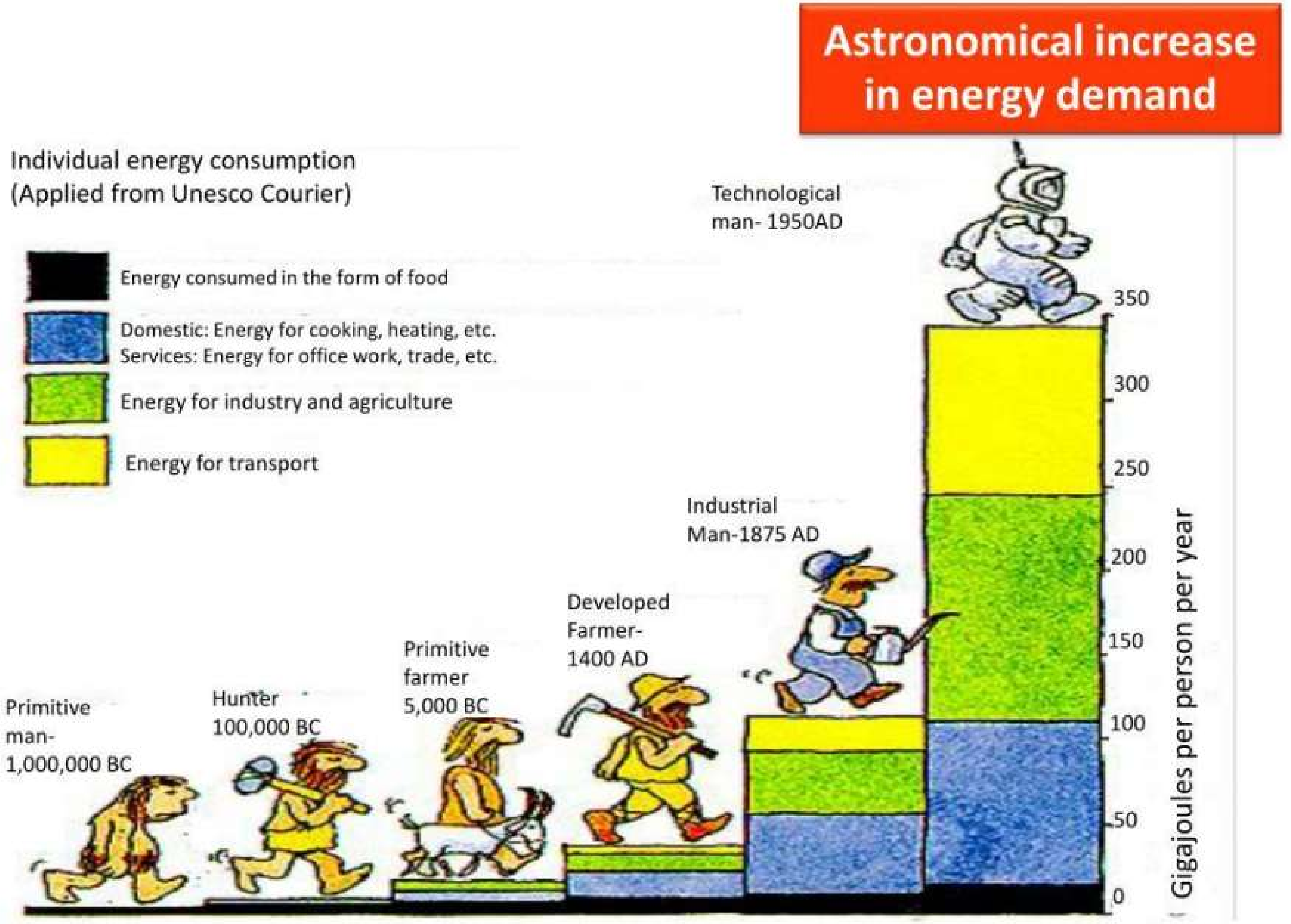
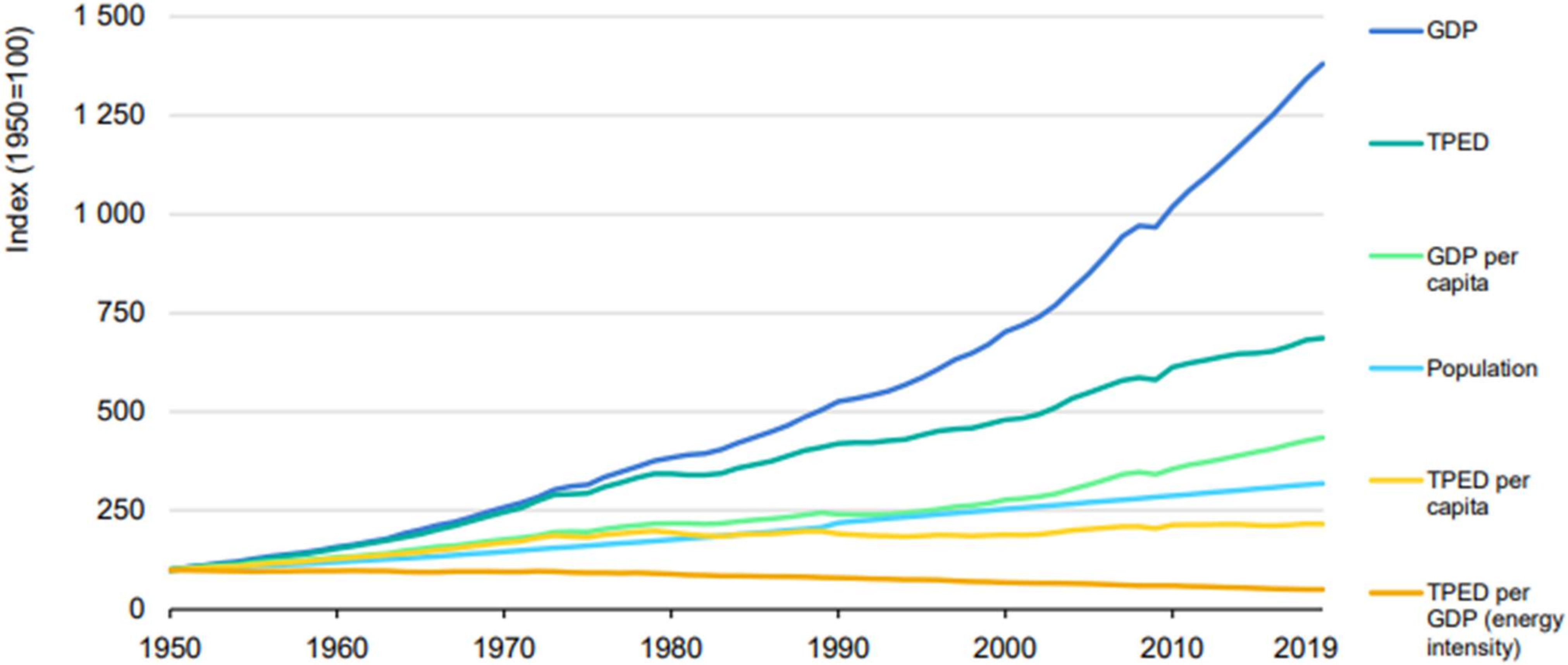


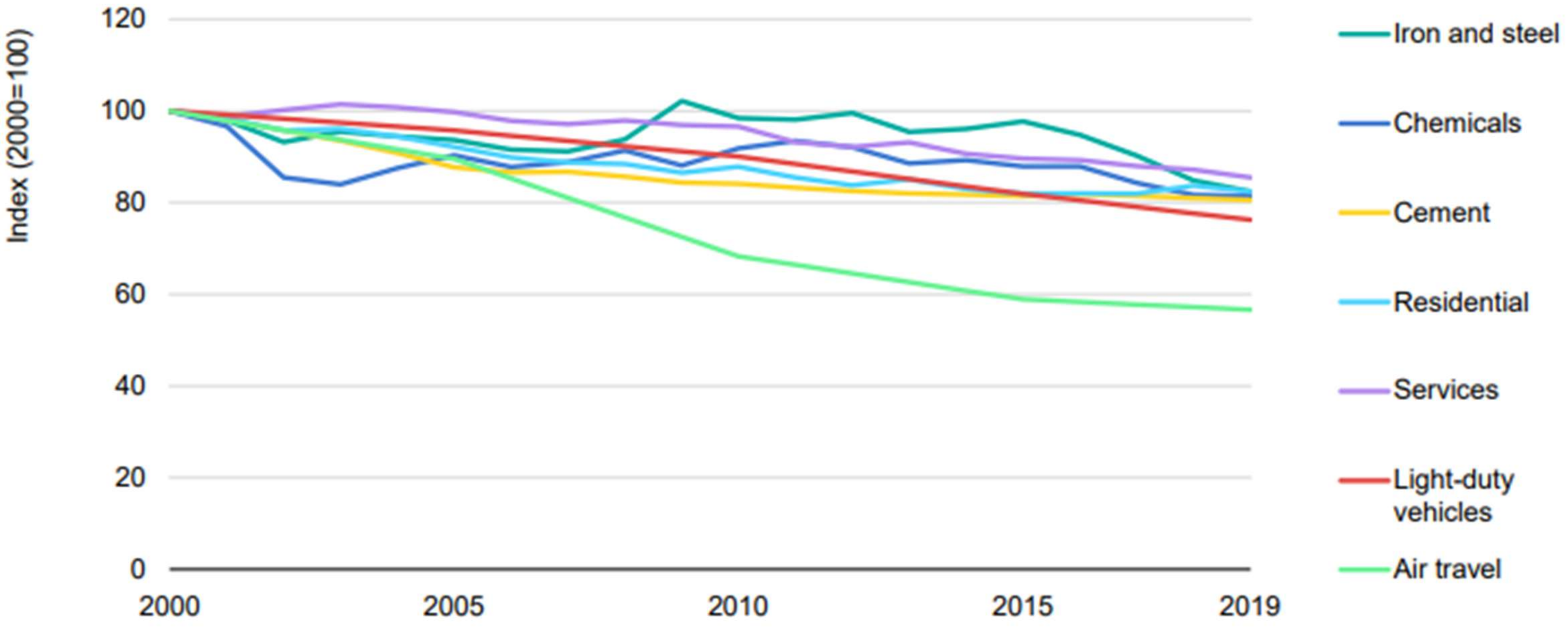
Figure 1.1 Global total primary energy demand, population and GDP, 1950-2019



Note: TPED = total primary energy demand.

Energy demand has historically been driven by GDP and population, reaching a sevenfold increase from 1950.

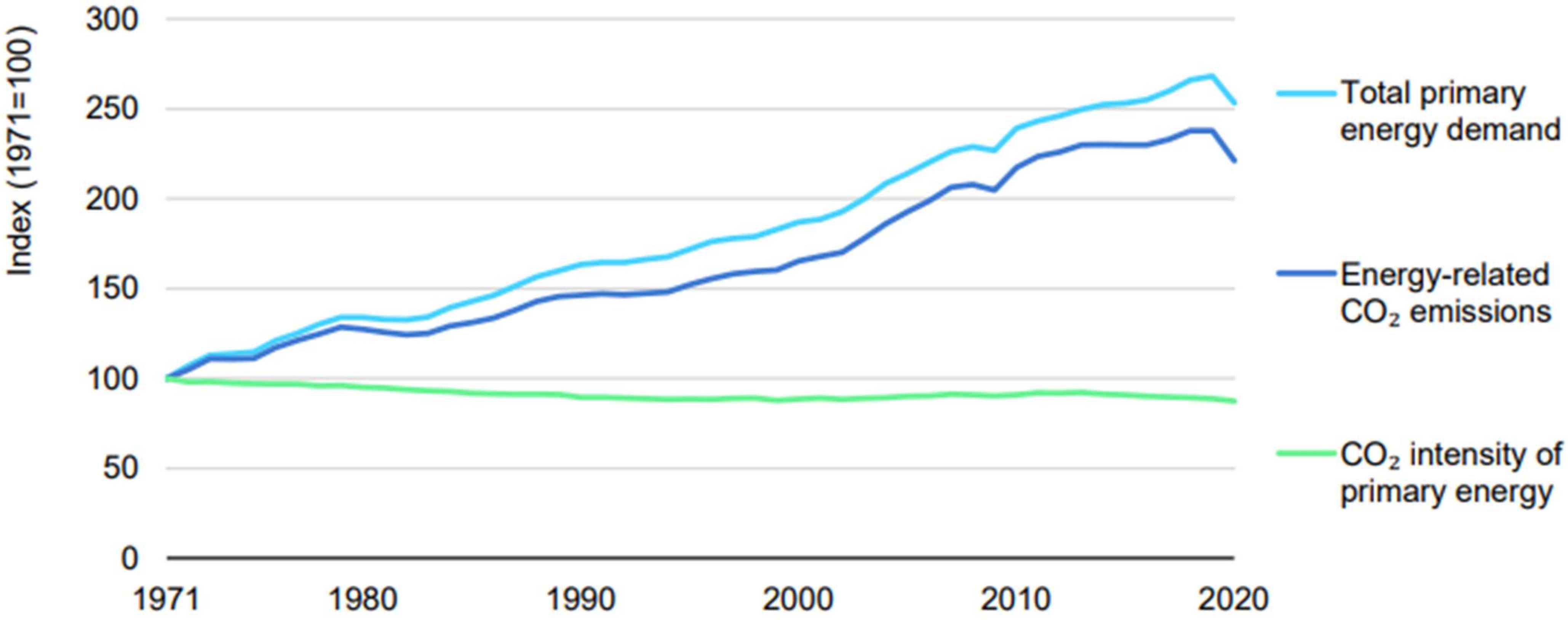
Figure 1.6 Global average energy intensity in selected end-use sectors, 2000-19



Notes: Intensity is measured as energy use per dollar of value added in the industry and services sectors; per tonne of steel in the iron and steel sub-sectors; per tonne of primary chemicals in the chemical and petrochemical sub-sectors; per tonne of clinker in the cement sub-sector; per square metre of floor space in the residential sector; and per passenger kilometre in the transport sector. Cement here refers to the energy intensity of clinker, which is the most energy-intensive portion of cement production and where energy-efficient equipment changes can have the largest effect.

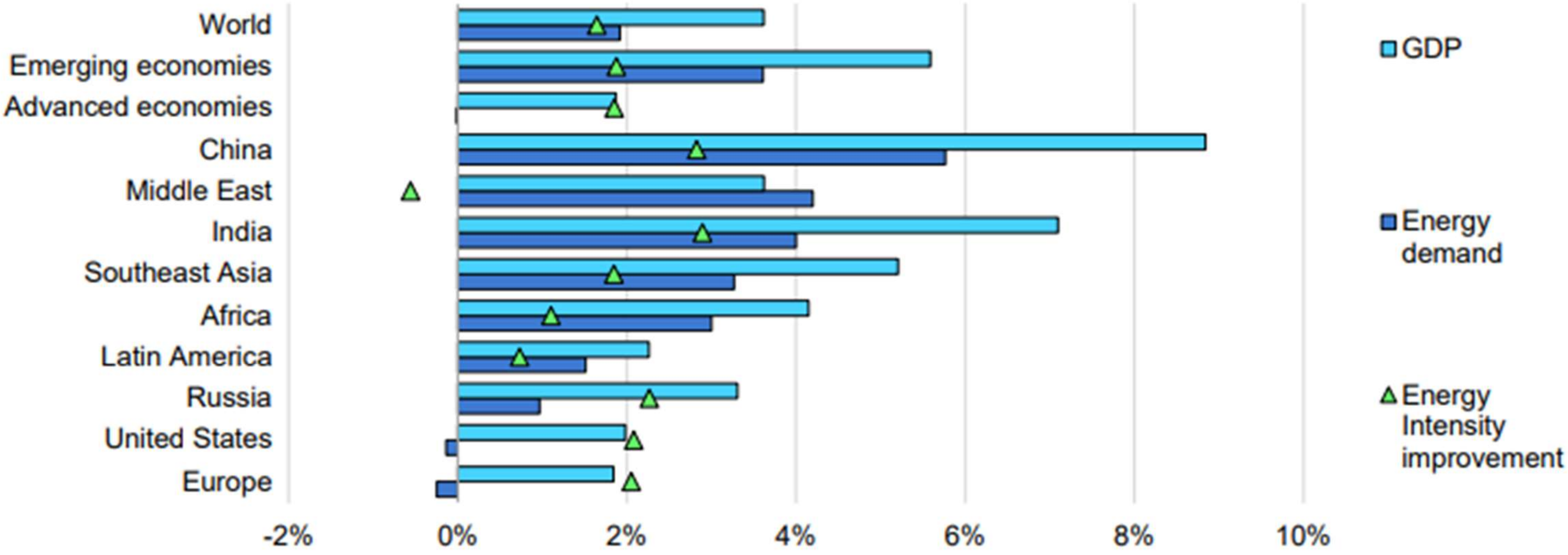
Improvements in energy intensity over two decades are diminishing in some sectors reflecting structural shifts in economies and weakening efficiency policy efforts, particularly for performance standards.

Figure 1.8 Global primary energy demand and energy-related CO_2 emissions, 1971-2020



Energy-related CO_2 emissions generally have risen with energy demand since the 1970s; the Covid-19 is set to cause the largest decline in annual emissions over that period.

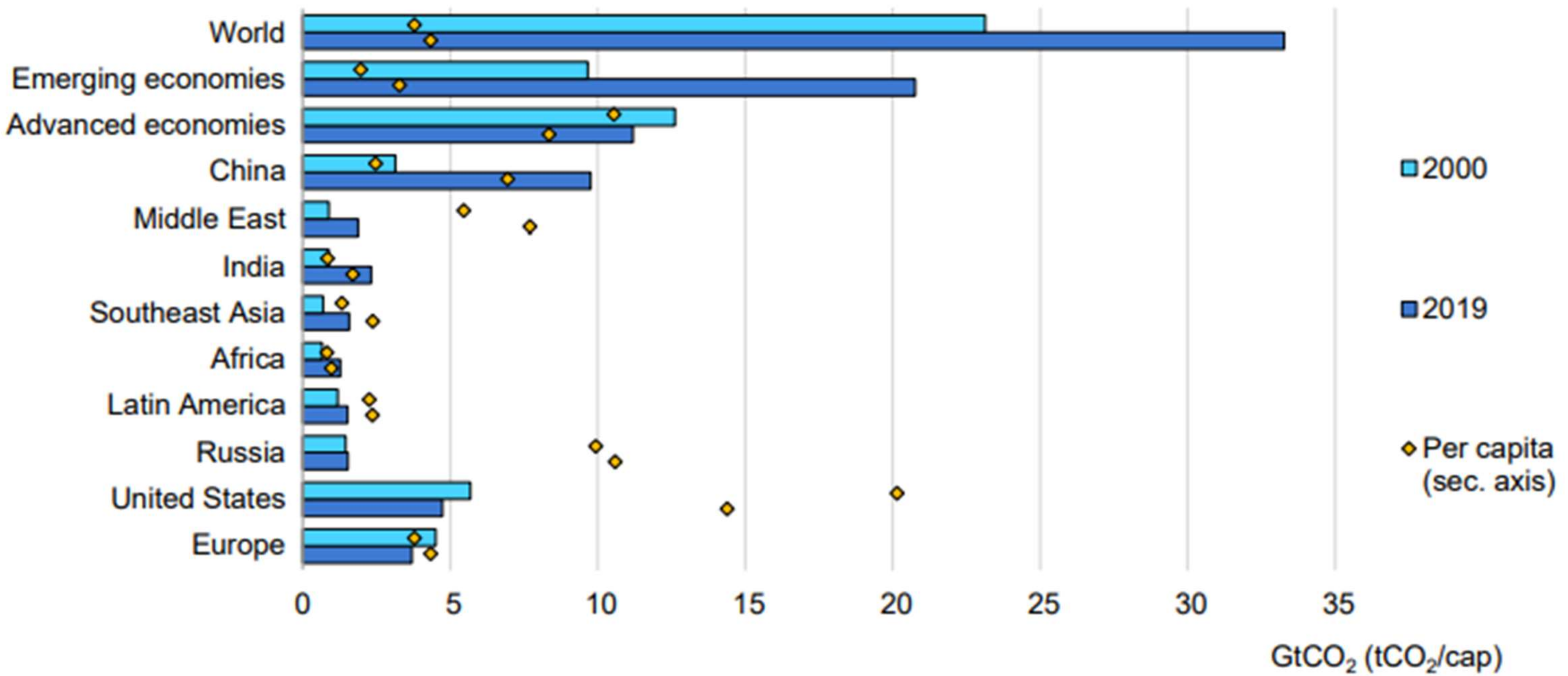
Figure 1.2 Annual change in GDP, total primary energy demand and energy intensity in selected countries/regions, 2000-19



Note: Energy intensity is measured as total primary energy demand per unit of GDP. GDP is measured in PPP terms.

Energy intensity of the global economy improved on average by 1.6% per year due to structural changes, saturation effects and efficiency gains.

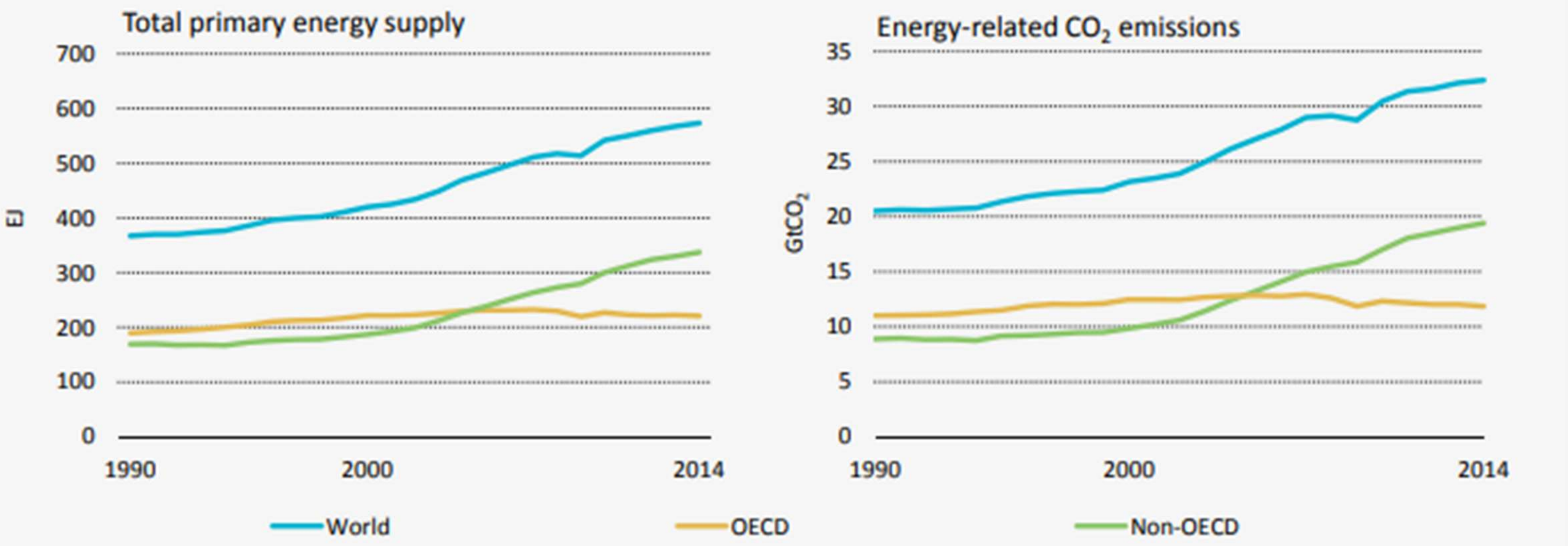
Figure 1.10 Global energy-related CO_2 emissions by region



Note: tCO_2/cap = tonnes of carbon dioxide per capita.

Emissions have started to fall in most advanced economies as a result of a slowdown in primary energy demand, a switch to clean energy and gains in efficiency, but they are still rising almost everywhere else.

Figure 1.2. Total primary energy supply and CO_2 emissions

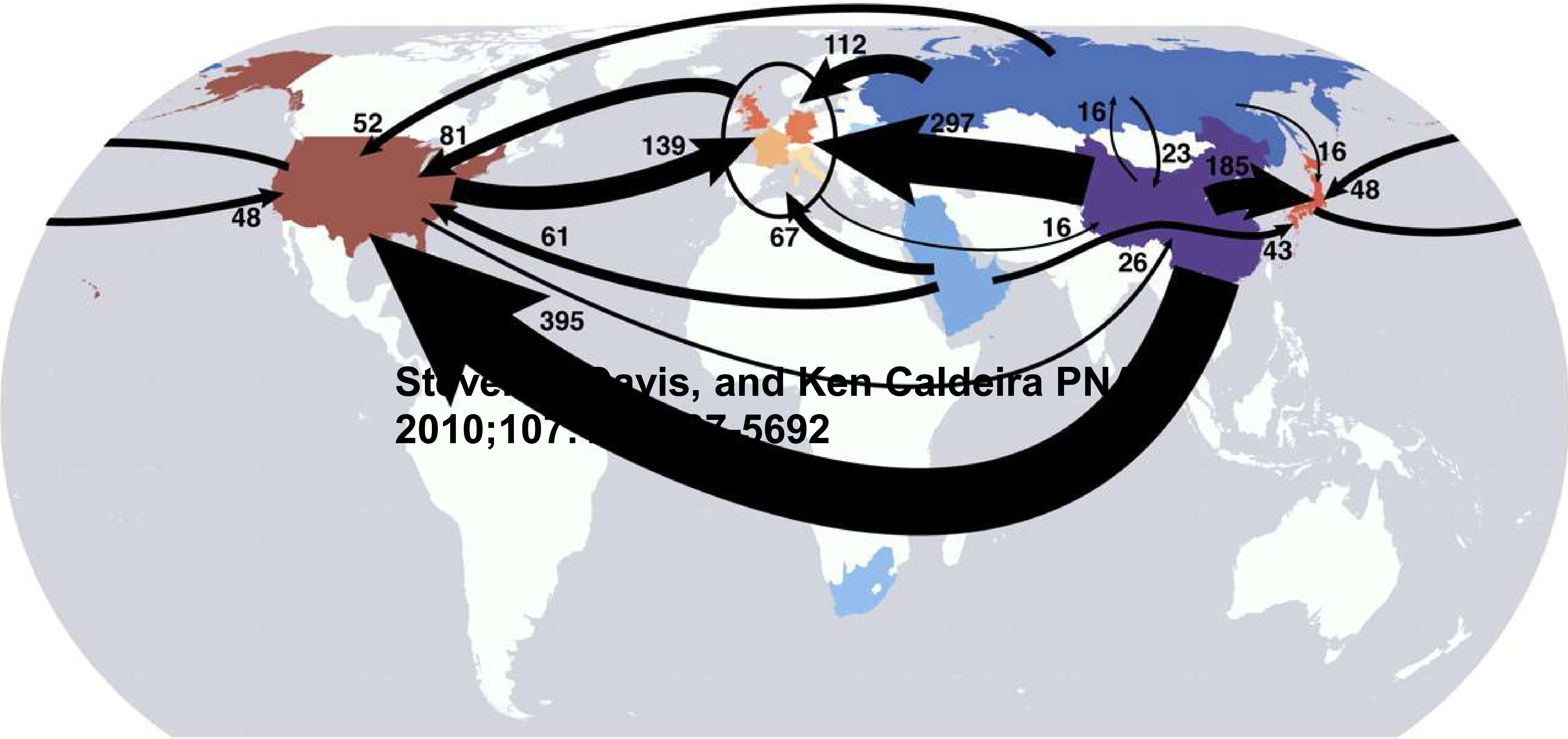


Source: IEA (2016h), *World Energy Statistics and Balances*; IEA (2016i), *CO_2 Emissions from Fuel Combustion*.

Key point *Recent global trends in primary energy supply and energy-related CO_2 emissions have been driven by growth in non-OECD economies.*

Le emissioni si sono stabilizzate nei paesi OECD ma crescono in modo sensibile al di fuori
Attenzione a come si contabilizzano le emissioni! OECD ha esternalizzato le produzioni nei paesi emergenti; andrebbero considerate le emissioni importate («embedded»)

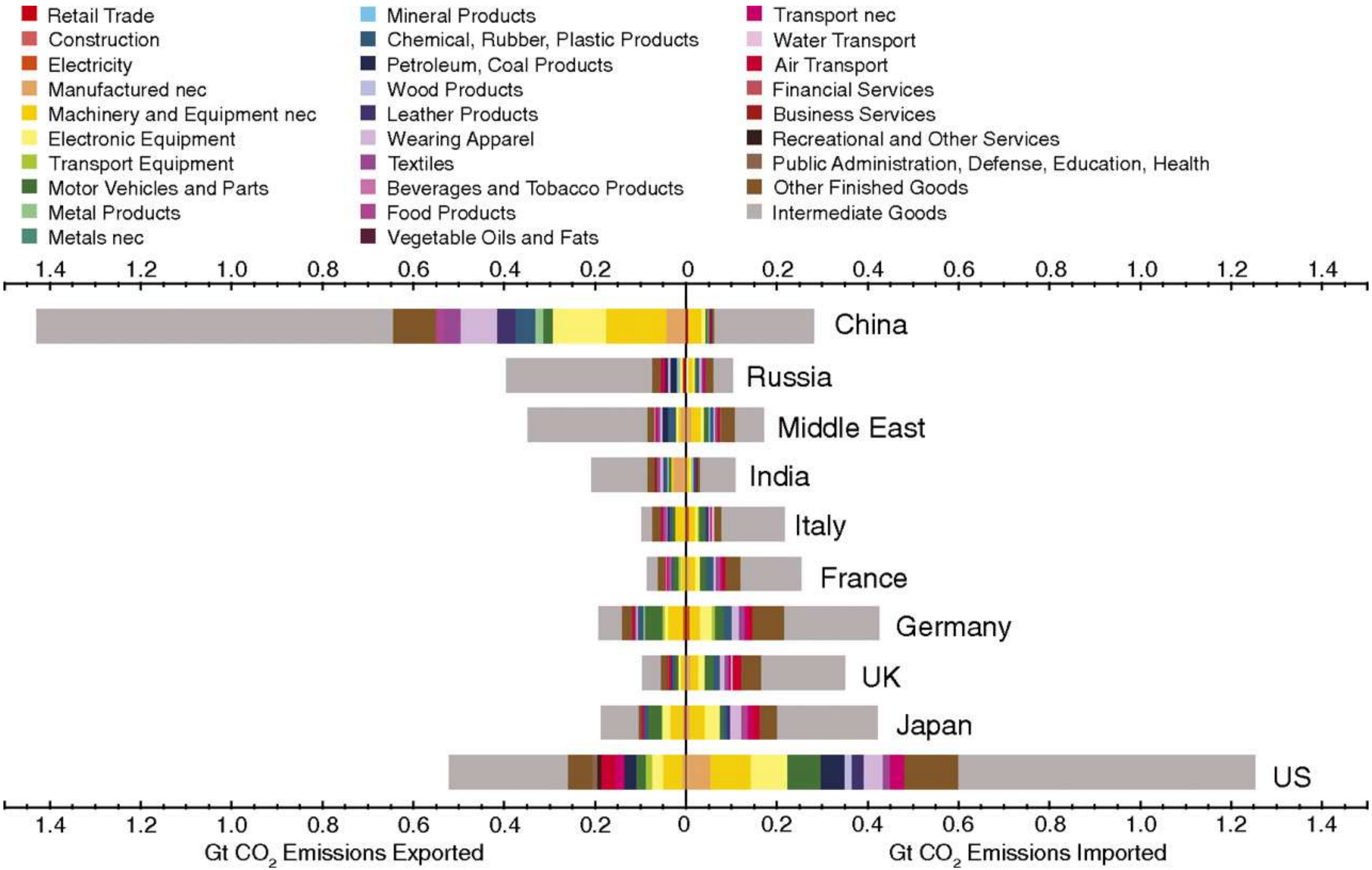
Flussi internazionali di CO2 incorporati nei beni scambiati sul mercato (Mt/anno)



Dominant net exporting countries (blue)
Dominant net importing countries (red)

Source: Davis and Caldeira PNAS 2010;107:12:5687-5692

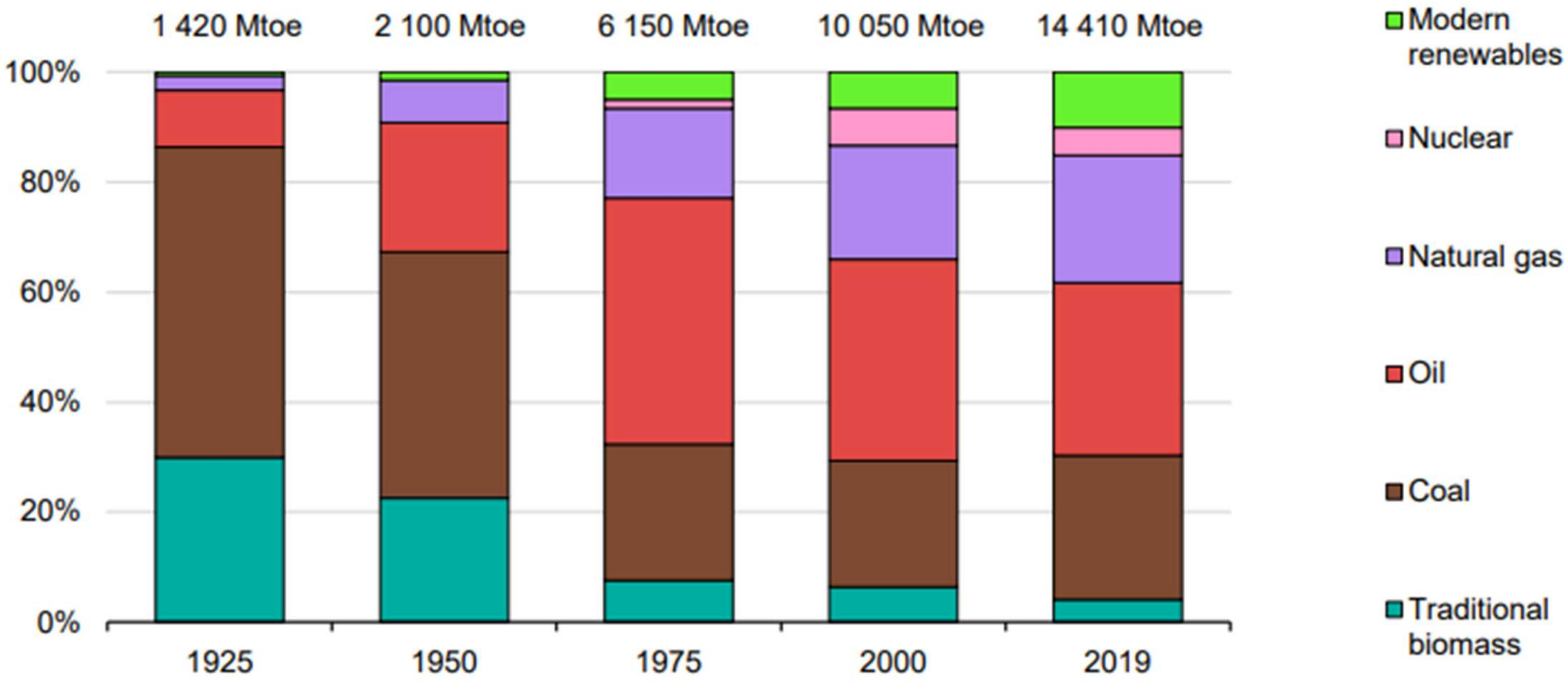
Balance of CO2 emissions embodied in imports and exports of the largest net importing/exporting countries (and Middle East region).



Steven J. Davis, and Ken Caldeira PNAS 2010;107:12:5687-5692

La robe no jè di cui che la fâs,
ma di cui che la gjolt!

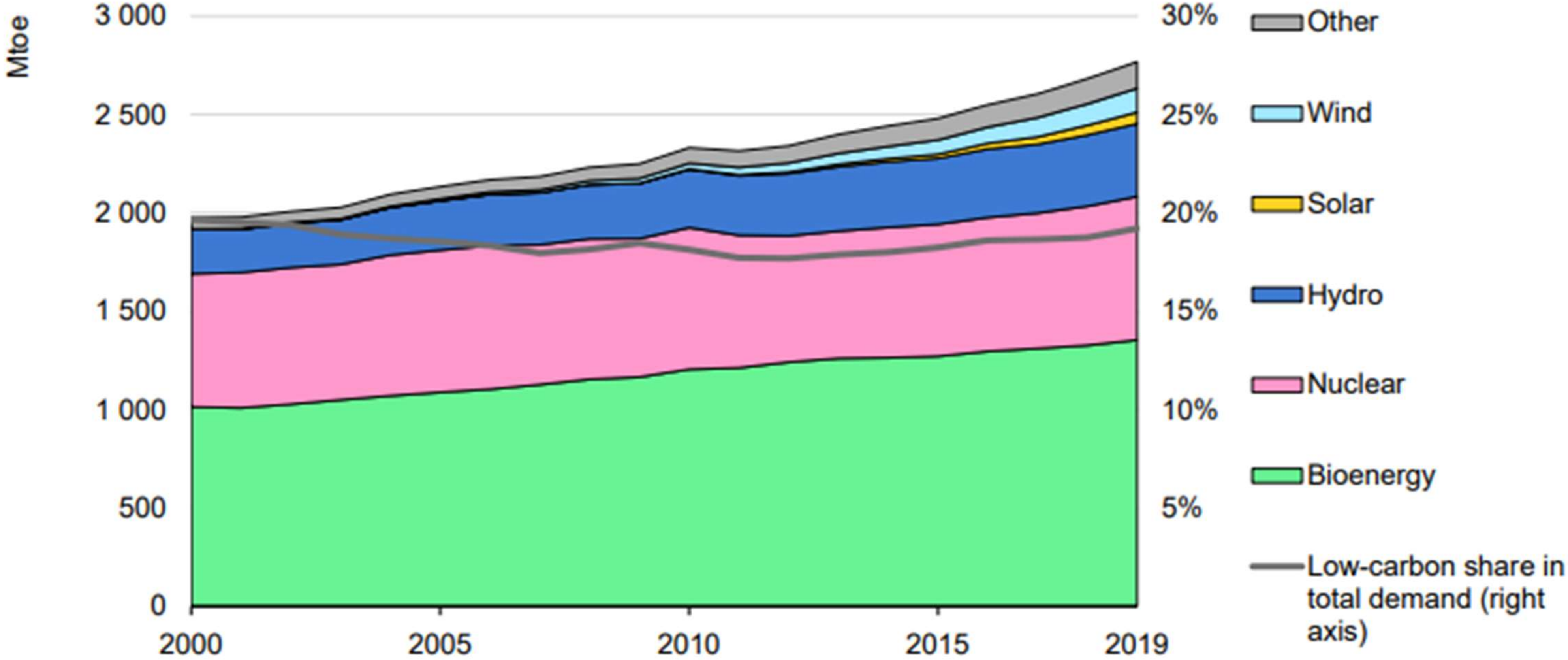
Figure 1.3 Global primary energy demand by fuel, 1925-2019



Note: Modern renewables includes all uses of renewable energy with the exception of traditional use of solid biomass.

Coal and traditional biomass have declined over the last century while first oil and then gas, nuclear power and renewables emerged in successive waves. Since 2000 the share of oil and nuclear has declined while that of coal has increased.

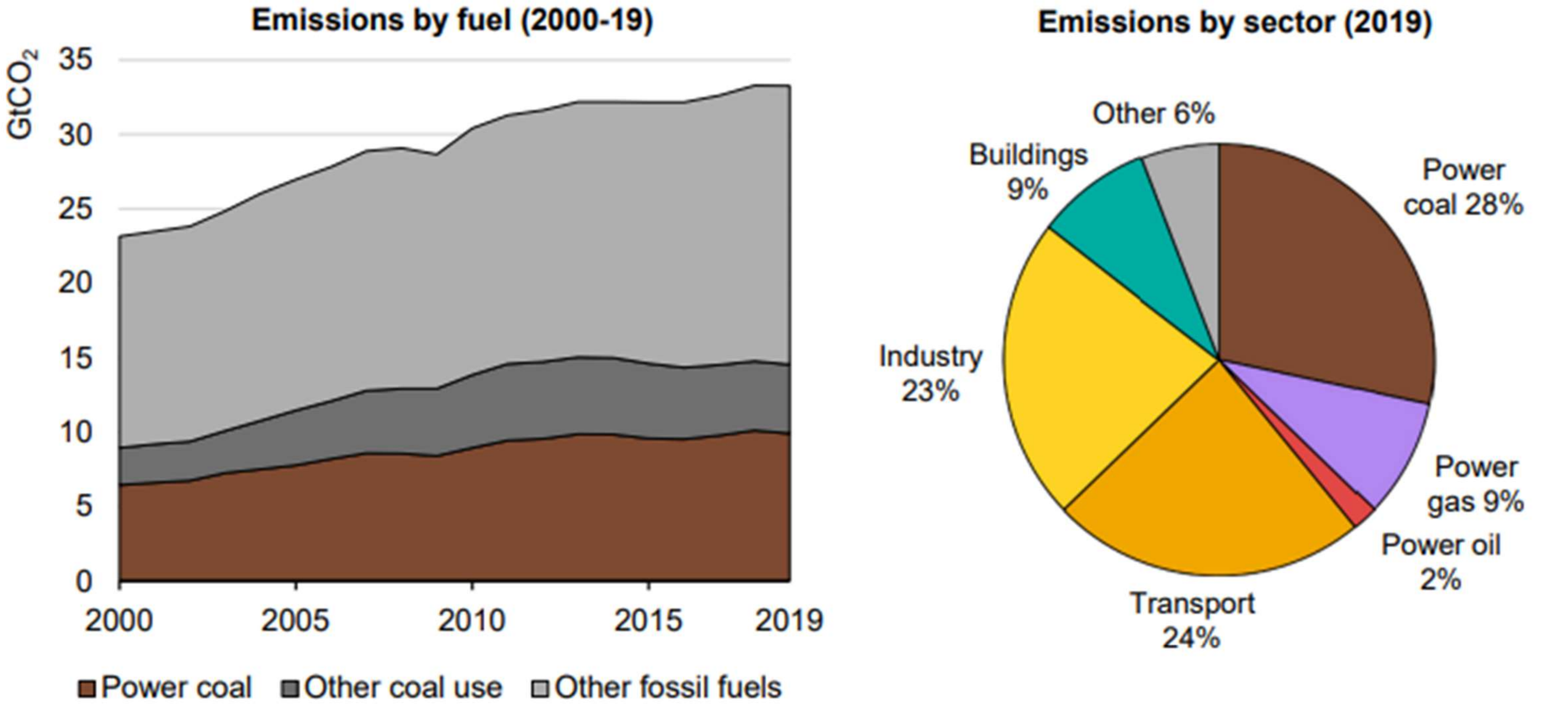
Figure 1.4 Primary demand for low-carbon energy sources, 2000-19



Notes: Mtoe = million tonnes of oil equivalent. Other includes geothermal and marine energy.

Bioenergy remains the single largest category of renewables, though solar PV and wind power have increased the fastest in recent years.

Figure 1.9 Global energy-related CO_2 emissions by fuel (left) and sector (right), 2000-19



Power generation, where coal use is increasingly concentrated, is the biggest emitter of CO_2 worldwide, accounting for about 40% of total emissions.

L’ENERGIA OGGI E DOMANI NEL WORLD ENERGY OUTLOOK (IEA)

Russia's invasion of Ukraine has sparked a global energy crisis

- **The world is in the midst of its first global energy crisis – a shock of unprecedented breadth and complexity.**
  - Pressures in markets predated Russia's invasion of Ukraine, but Russia's actions have turned a rapid economic recovery from the pandemic – which strained all manner of global supply chains, including energy – into full-blown energy turmoil.
  - Russia has been by far the world's largest exporter of fossil fuels, but its curtailments of natural gas supply to Europe and European sanctions on imports of oil and coal from Russia are severing one of the main arteries of global energy trade.
  - All fuels are affected, but gas markets are the epicentre as Russia seeks leverage by exposing consumers to higher energy bills and supply shortages.
- **Prices for spot purchases of natural gas have reached levels never seen before, regularly exceeding the equivalent of USD 250 for a barrel of oil.**
  - Coal prices have also hit record levels, while oil rose well above USD 100 per barrel in mid-2022 before falling back.
  - High gas and coal prices account for 90% of the upward pressure on electricity costs around the world.
  - To offset shortfalls in Russian gas supply, Europe is set to import an extra 50 billion cubic metres (bcm) of liquefied natural gas (LNG) in 2022 compared with the previous year.
  - This has been eased by lower demand from China, where gas use was held back by lockdowns and subdued economic growth, but higher European LNG demand has diverted gas away from other importers in Asia.

Russia’s invasion of Ukraine has sparked a global energy crisis

- **The crisis has stoked inflationary pressures and created a looming risk of recession, as well as a huge USD 2 trillion windfall for fossil fuel producers above their 2021 net income.**
  - Higher energy prices are also increasing food insecurity in many developing economies, with the heaviest burden falling on poorer households where a larger share of income is spent on energy and food.
  - Some 75 million people who recently gained access to electricity are likely to lose the ability to pay for it, meaning that for the first time since we started tracking it, the total number of people worldwide without electricity access has started to rise.
  - And almost 100 million people may be pushed back into reliance on firewood for cooking instead of cleaner, healthier solutions.
- **Faced with energy shortfalls and high prices, governments have so far committed well over USD 500 billion, mainly in advanced economies, to shield consumers from the immediate impacts.**
  - They have rushed to try and secure alternative fuel supplies and ensure adequate gas storage.
  - Other short-term actions have included increasing oil- and coal-fired electricity generation, extending the lifetimes of some nuclear power plants, and accelerating the flow of new renewables projects.
  - Demand-side measures have generally received less attention, but greater efficiency is an essential part of the short- and longer-term response.

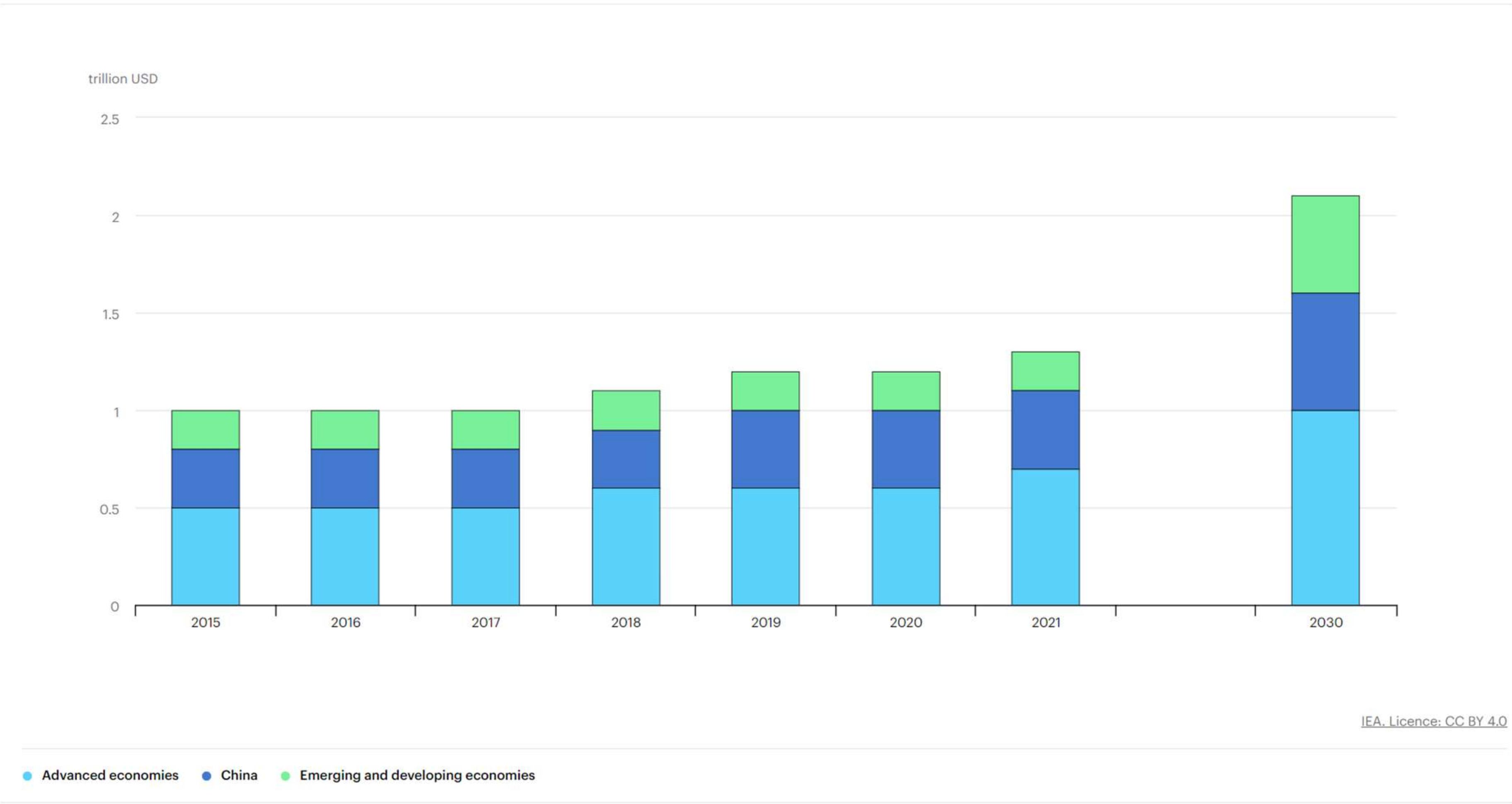
Is the crisis a boost, or a setback, for energy transitions?

- **With energy markets remaining extremely vulnerable, today's energy shock is a reminder of the fragility and unsustainability of our current energy system.**
    - A key question for policy makers, and for this *Outlook*, is whether the crisis will be a setback for clean energy transitions or will catalyse faster action.
    - Climate policies and net zero commitments were blamed in some quarters for contributing to the run-up in energy prices, but there is scant evidence for this.
    - In the most affected regions, higher shares of renewables were correlated with lower electricity prices, and more efficient homes and electrified heat have provided an important buffer for some – but far from enough – consumers.
- **Times of crisis put the spotlight on governments, and on how they react.**
    - Alongside short-term measures, many governments are now taking longer-term steps: some seeking to increase or diversify oil and gas supply; many looking to accelerate structural change.
    - The three scenarios explored in this *World Energy Outlook* (WEO) are differentiated primarily by the assumptions made on government policies.
    - The **Stated Policies Scenario (STEPS)** shows the trajectory implied by today's policy settings.
    - The **Announced Pledges Scenario (APS)** assumes that all aspirational targets announced by governments are met on time and in full, including their long-term net zero and energy access goals.
    - The **Net Zero Emissions by 2050 (NZE) Scenario** maps out a way to achieve a 1.5 °C stabilisation in the rise in global average temperatures, alongside universal access to modern energy by 2030.

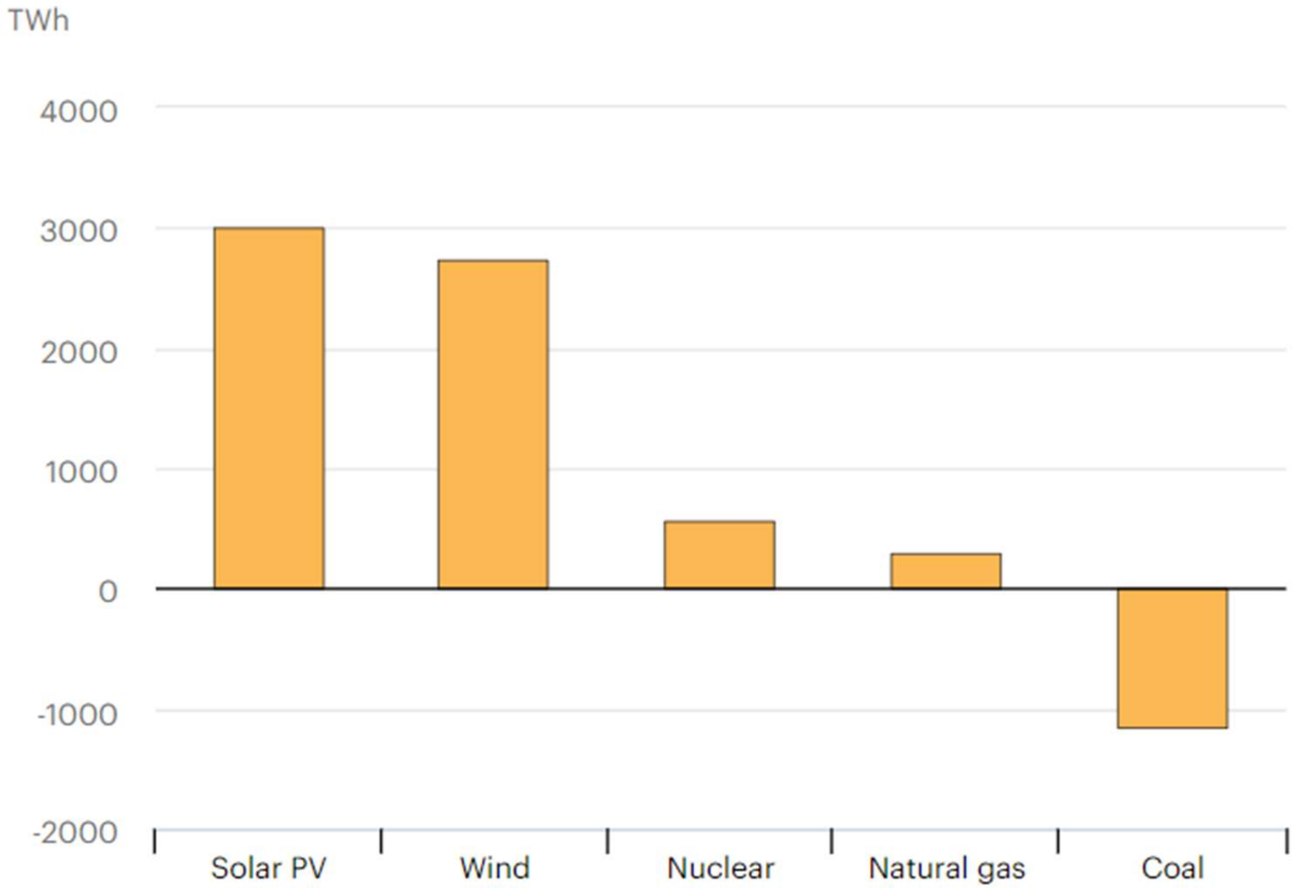
Policy responses are fast-tracking the emergence of a clean energy economy

- **New policies in major energy markets help propel annual clean energy investment to more than USD 2 trillion by 2030 in the STEPS, a rise of more than 50% from today.**
  - Clean energy becomes a huge opportunity for growth and jobs, and a major arena for international economic competition.
  - By 2030, thanks in large part to the US Inflation Reduction Act, annual solar and wind capacity additions in the United States grow two-and-a-half-times over today's levels, while electric car sales are seven times larger. New targets continue to spur the massive build-out of clean energy in China, meaning that its coal and oil consumption both peak before the end of this decade.
  - Faster deployment of renewables and efficiency improvements in the European Union bring down EU natural gas and oil demand by 20% this decade, and coal demand by 50%, a push given additional urgency by the need to find new sources of economic and industrial advantage beyond Russian gas.
  - Japan's Green Transformation (GX) programme provides a major funding boost for technologies including nuclear, low-emissions hydrogen and ammonia, while Korea is also looking to increase the share of nuclear and renewables in its energy mix.
  - India makes further progress towards its domestic renewable capacity target of 500 gigawatts (GW) in 2030, and renewables meet nearly two-thirds of the country's rapidly rising demand for electricity.
- **As markets rebalance, renewables, supported by nuclear power, see sustained gains; the upside for coal from today's crisis is temporary.**
  - The increase in renewable electricity generation is sufficiently fast to outpace growth in total electricity generation, driving down the contribution of fossil fuels for power.
  - The crisis briefly pushes up utilisation rates for existing coal-fired assets, but does not bring higher investment in new ones.
  - Strengthened policies, a subdued economic outlook and high near-term prices combine to moderate overall energy demand growth. Increases come primarily from India, Southeast Asia, Africa and the Middle East.
  - However, the rise in China's energy use, which has been such an important driver for global energy trends over the past two decades, slows and then halts altogether before 2030 as China shifts to a more services-orientated economy.
- **International energy trade undergoes a profound reorientation in the 2020s as countries adjust to the rupture of Russia-Europe flows, which is assumed to be permanent**.
  - Not all Russian flows displaced from Europe find a new home in other markets, bringing down Russian production and global supply.
  - Crude oil and product markets, especially diesel, face a turbulent period as EU bans on Russian imports kick in. Natural gas takes longer to adjust.
  - The upcoming northern hemisphere winter promises to be a perilous moment for gas markets and a testing time for EU solidarity – and the winter of 2023-24 could be even tougher.
  - Major new additions to LNG supply – mainly from North America, Qatar and Africa – arrive only around the mid-2020s.
  - Competition for available cargoes is fierce in the meantime as Chinese import demand picks up again.

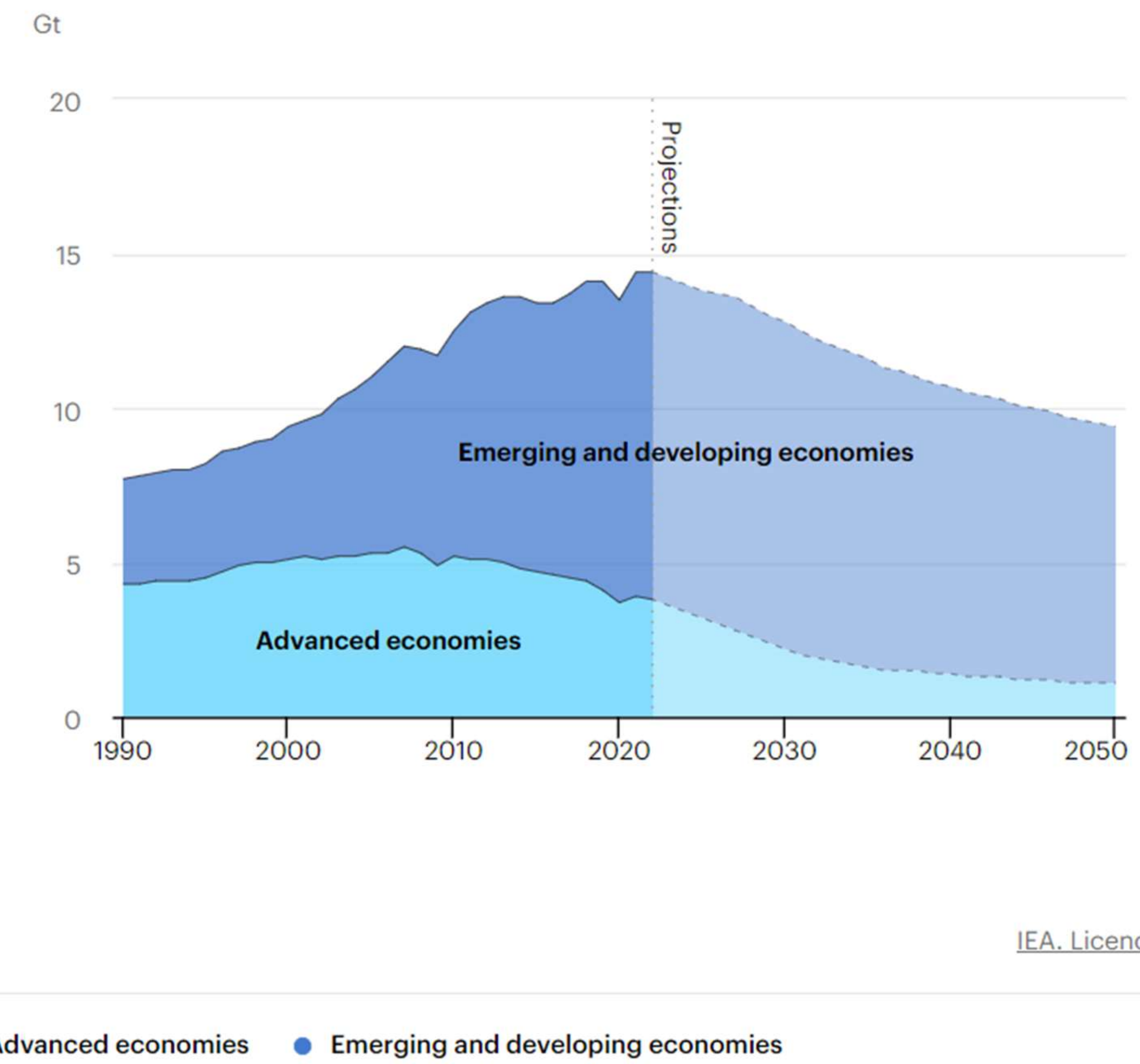
Clean energy investment in the Stated Policies Scenario, 2015-2030



Change in electricity generation in the Stated Policies Scenario between 2021 and 2030



Power sector CO2 emissions, 1990-2050



Today's stronger policy settings bring a fossil fuel peak into view

- **For the first time, a *WEO* scenario based on prevailing policy settings has global demand for each of the fossil fuels exhibiting a peak or plateau**
  - In the STEPS, coal use falls back within the next few years, natural gas demand reaches a plateau by the end of the decade, and rising sales of electric vehicles (EVs) mean that oil demand levels off in the mid-2030s before ebbing slightly to mid-century.
  - Total demand for fossil fuels declines steadily from the mid-2020s by around 2 exajoules per year on average to 2050, an annual reduction roughly equivalent to the lifetime output of a large oil field.
- **Global fossil fuel use has risen alongside GDP since the start of the Industrial Revolution in the 18th century: putting this rise into reverse while continuing to expand the global economy will be a pivotal moment in energy history.**
  - The share of fossil fuels in the global energy mix has been stubbornly high, at around 80%, for decades. By 2030 in the STEPS, this share falls below 75%, and to just above 60% by 2050.
  - A high point for global energy-related CO2 emissions is reached in the STEPS in 2025, at 37 billion tonnes (Gt) per year, and they fall back to 32 Gt by 2050.
  - This would be associated with a rise of around 2.5 °C in global average temperatures by 2100. This is a better outcome than projected a few years ago: renewed policy momentum and technology gains made since 2015 have shaved around 1 °C off the long-term temperature rise.
  - However, a reduction of only 13% in annual CO2 emissions to 2050 in the STEPS is far from enough to avoid severe impacts from a changing climate.
- **Full achievement of all climate pledges would move the world towards safer ground, but there is still a large gap between today's ambitions and a 1.5 °C stabilisation**.
  - In the APS, a near-term peak in annual emissions is followed by a faster decline to 12 Gt by 2050.
  - This is a bigger reduction than in the *WEO-2021* APS, reflecting the additional pledges that have been made over the past year, notably by India and Indonesia.
  - If implemented on time and in full, these additional national commitments – as well as sectoral commitments for specific industries and company targets (considered for the first time in this year's APS) – keep the temperature rise in the APS in 2100 at around 1.7 °C.
  - However, it is easier to make pledges than to implement them and, even if they are achieved, there is still considerably further to go to align with the NZE Scenario, which achieves the 1.5 °C outcome by reducing annual emissions to 23 Gt by 2030 and to net zero by 2050.

Fossil fuel demand in the Stated Policies Scenario, 1900-2050

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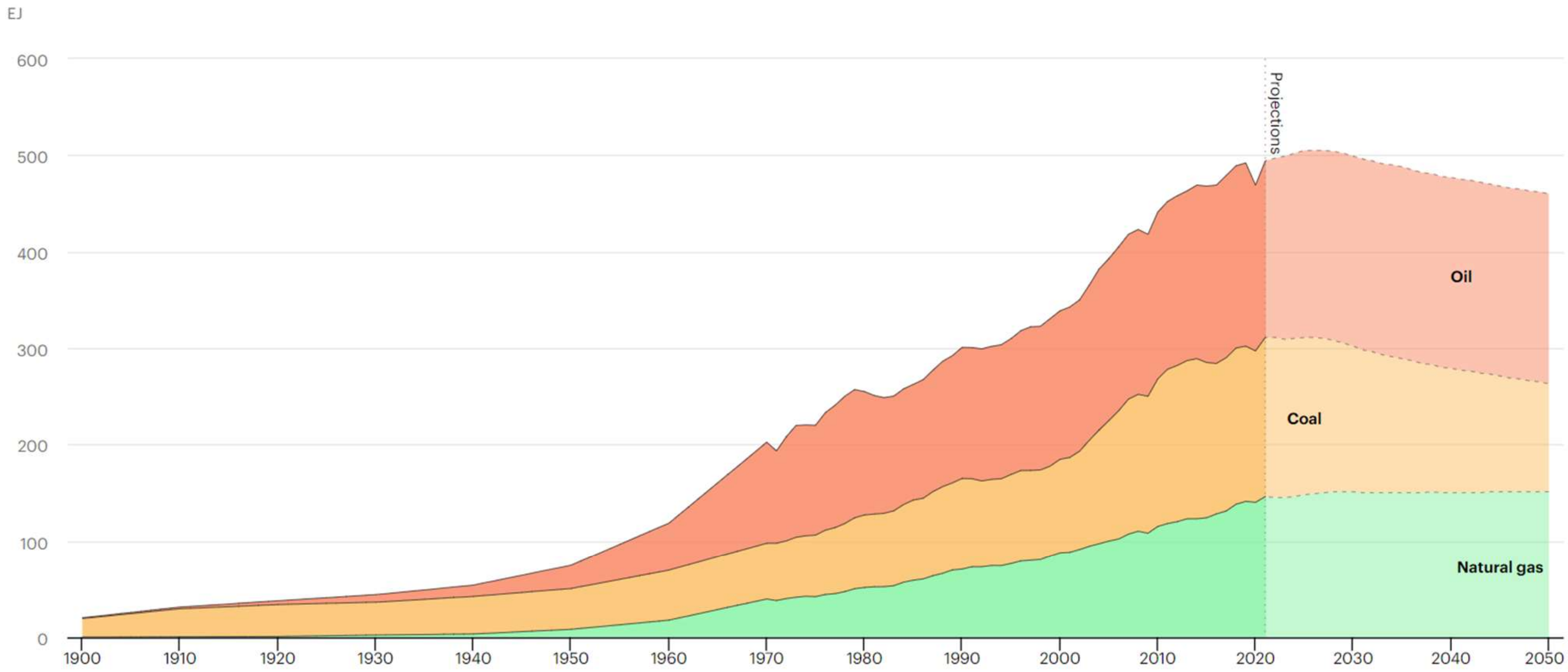

Natural gas Coal Oil

Global energy related CO2 emissions by scenario, 1990-2050

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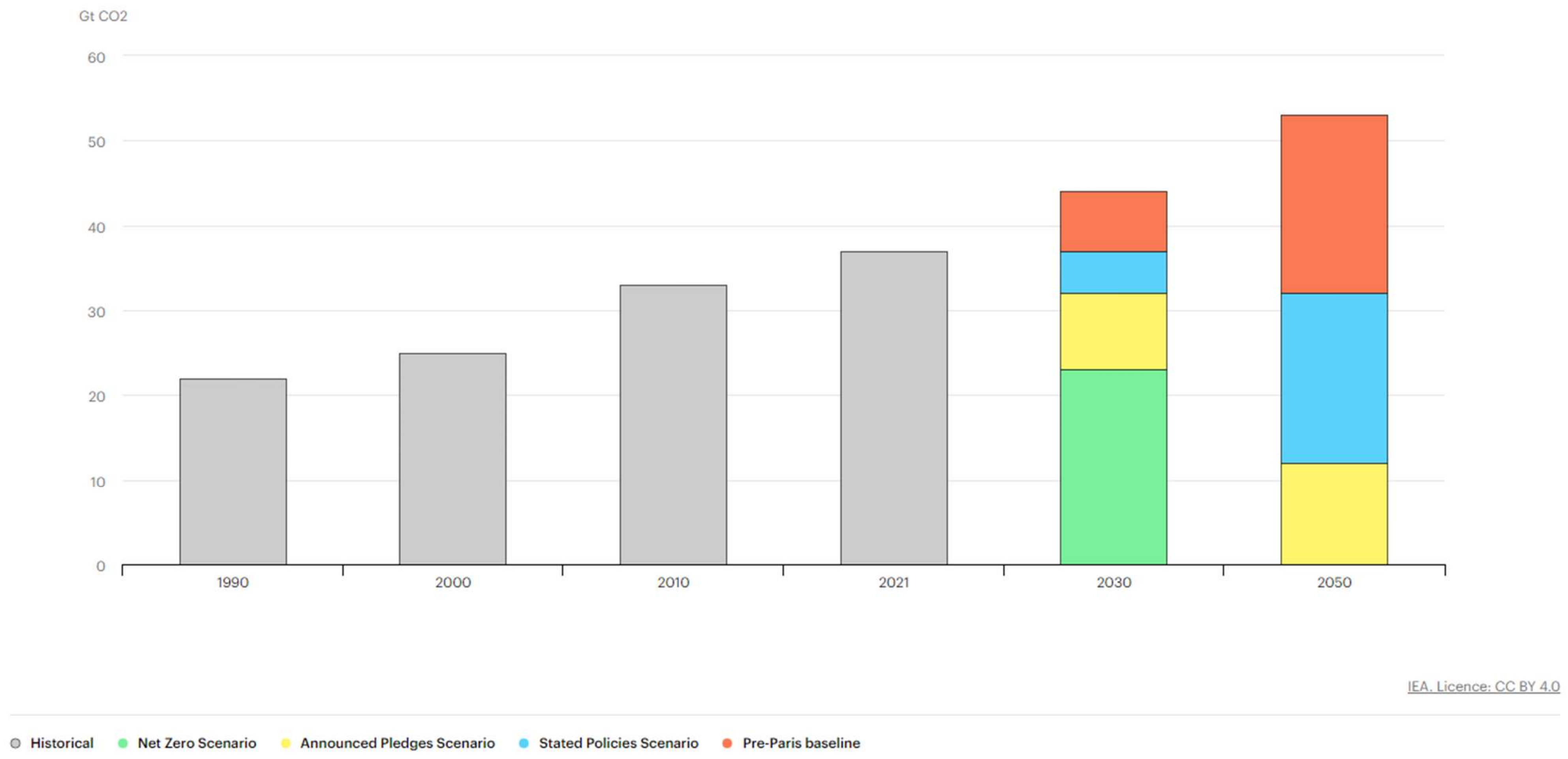
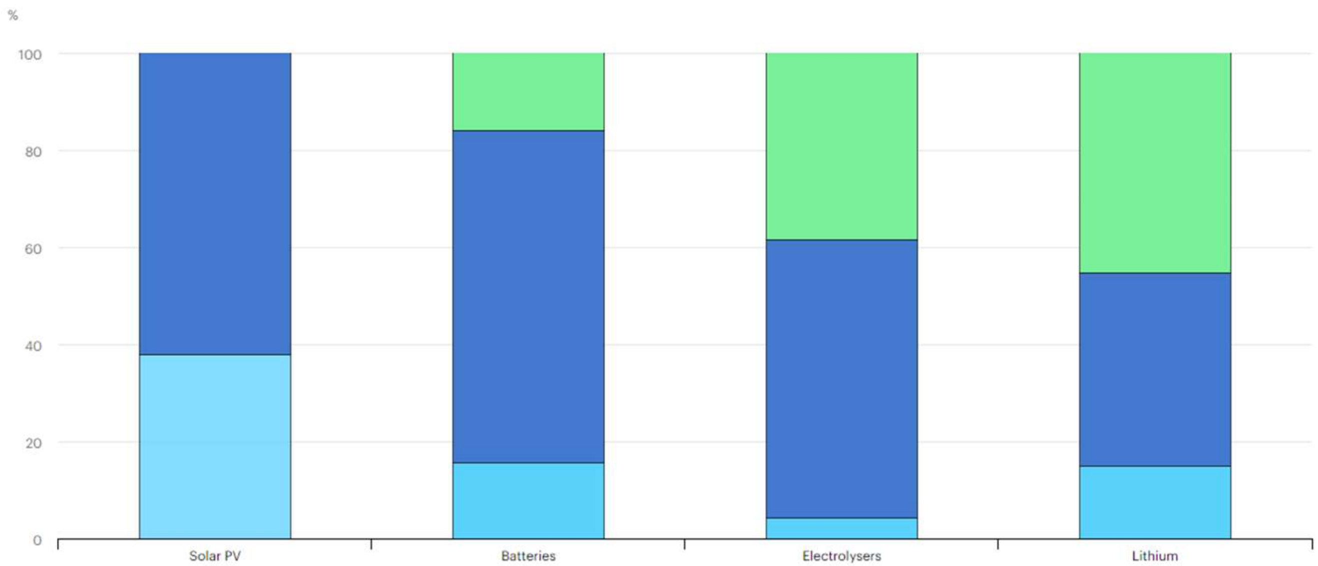


Announced manufacturing capacity compared with Net Zero Scenario deployment, 2030

Open



- Capacity in 2021
- Announced capacity in 2030
- Needed to match NZE deployment in 2030

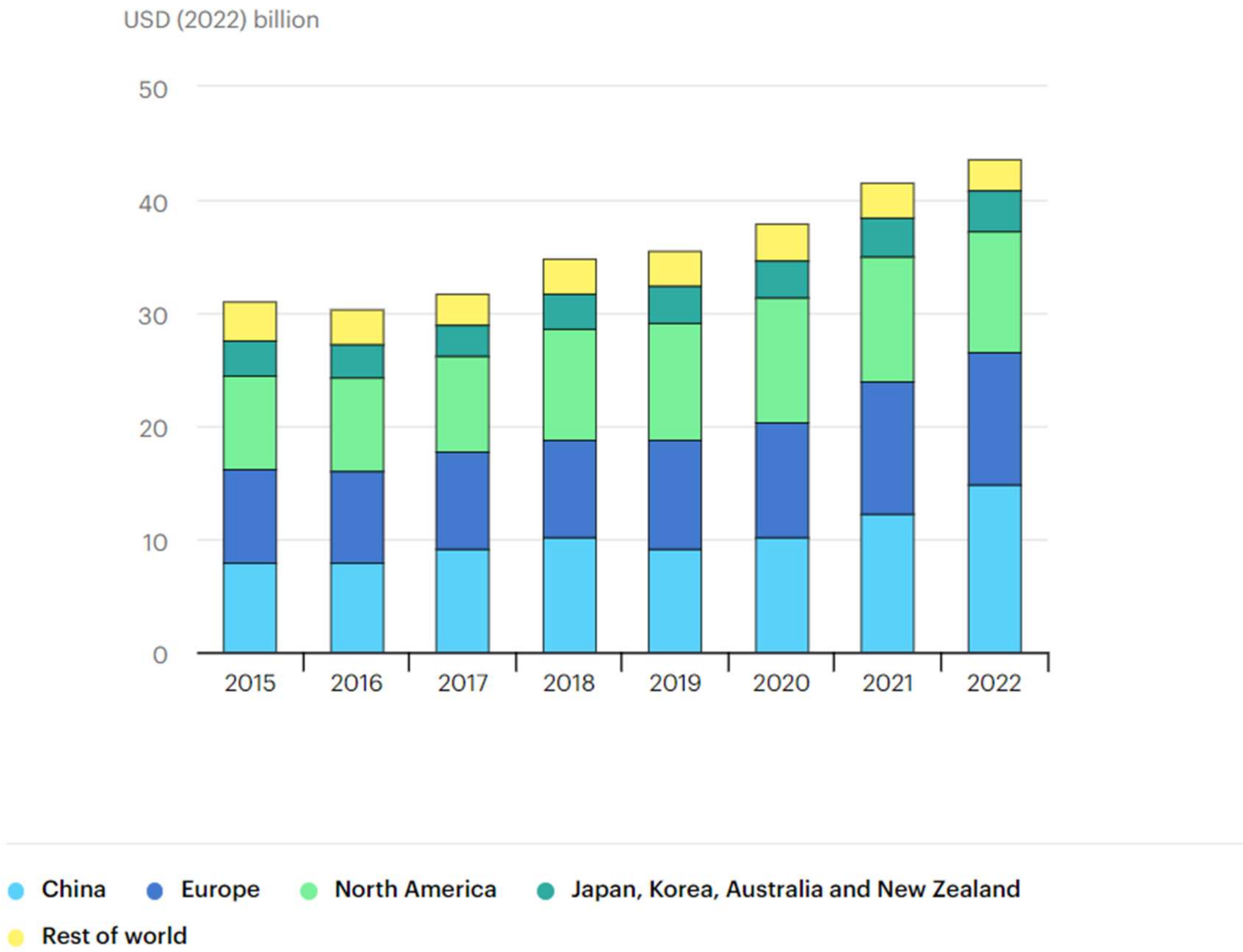
Efficiency and clean fuels get a competitive boost

- **Today's high energy prices underscore the benefits of greater energy efficiency and are prompting behavioural and technology changes in some countries to reduce energy use**
    - Efficiency measures can have dramatic effects – today's light bulbs are at least four times more efficient than those on sale two decades ago – but much more remains to be done.
    - Demand for cooling needs to be a particularly focus for policy makers, as it makes the second-largest contribution to the overall rise in global electricity demand over the coming decades (after EVs).
    - Many air conditioners used today are subject only to weak efficiency standards and one-fifth of electricity demand for cooling in emerging and developing economies is not covered by any standards at all. In the STEPS, cooling demand in emerging and developing economies rises by 2 800 terawatt-hours to 2050, which is the equivalent of adding another European Union to today's global electricity demand.
    - This growth is reduced by half in the APS because of tighter efficiency standards and better building design and insulation – and by half again in the NZE Scenario.
- **Concerns about fuel prices, energy security and emissions – bolstered by stronger policy support – are brightening the prospects for many low-emissions fuels**
    - Investment in low-emissions gases is set to rise sharply in the coming years. In the APS, global low-emissions hydrogen production rises from very low levels today to reach over 30 million tonnes (Mt) per year in 2030, equivalent to over 100 bcm of natural gas (although not all low-emissions hydrogen would replace natural gas).
    - Much of this is produced close to the point of use, but there is growing momentum behind international trade in hydrogen and hydrogen-based fuels.
    - Projects representing a potential 12 Mt of export capacity are in various stages of planning, although these are more numerous and more advanced than corresponding projects to underpin import infrastructure and demand.
    - Carbon capture, utilisation and storage projects are also advancing more rapidly than before, spurred by greater policy support to aid industrial decarbonisation, to produce low- or lower-emissions fuels, and to allow for direct air capture projects that remove carbon from the atmosphere.

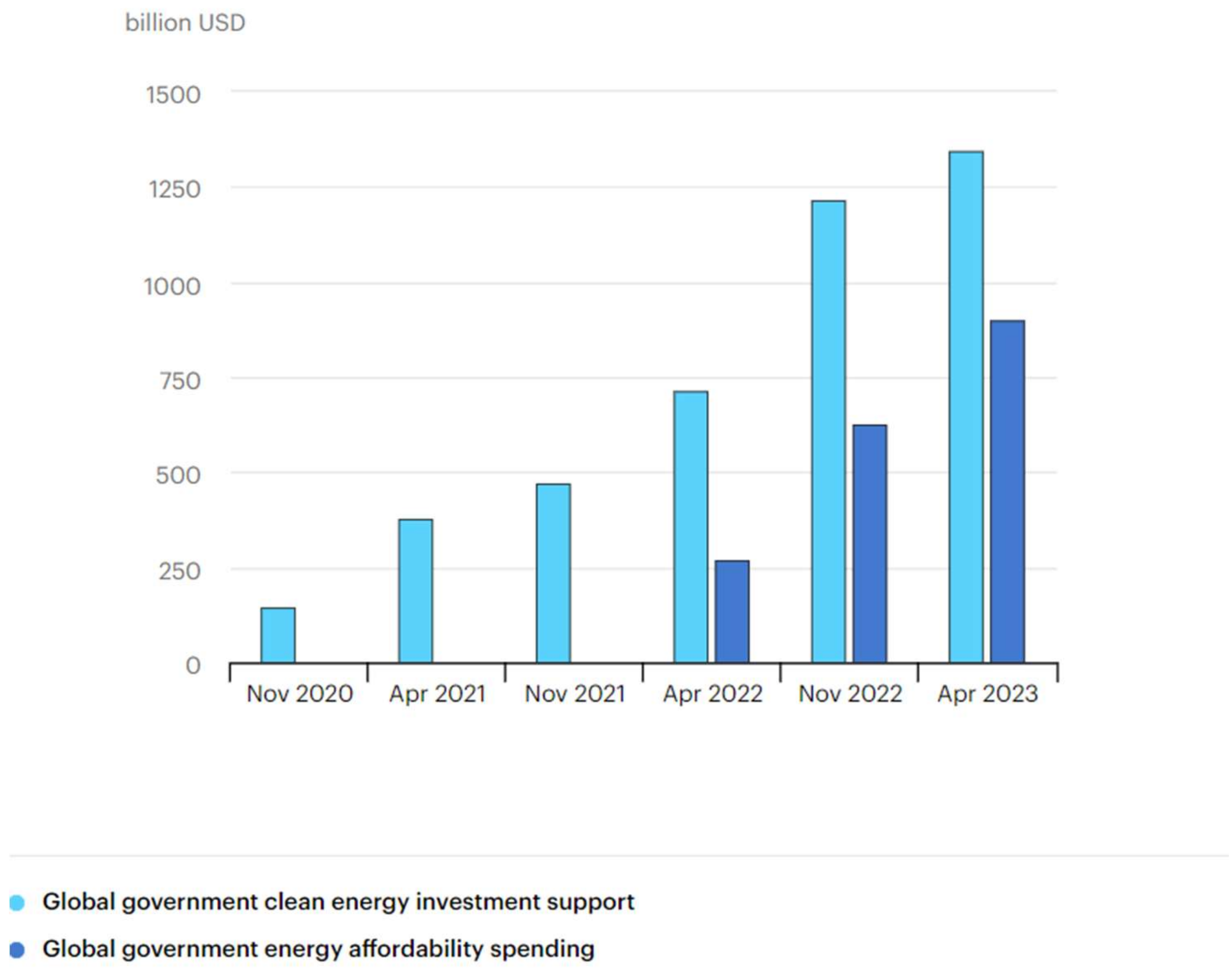
But rapid transitions ultimately depend on investment

- **A huge increase in energy investment is essential to reduce the risks of future price spikes and volatility, and to get on track for net zero emissions by 2050.**
  - From USD 1.3 trillion today, clean energy investment rises above USD 2 trillion by 2030 in the STEPS, but it would have to be above USD 4 trillion by the same date in the NZE Scenario, highlighting the need to attract new investors to the energy sector.
  - Governments should take the lead and provide strong strategic direction, but the investments required are far beyond the reaches of public finance. It is vital to harness the vast resources of markets and incentivise private actors to play their part.
  - Today, for every USD 1 spent globally on fossil fuels, USD 1.5 is spent on clean energy technologies.
  - By 2030, in the NZE Scenario, every USD 1 spent on fossil fuels is outmatched by USD 5 on clean energy supply and another USD 4 on efficiency and end-uses.
- **Shortfalls in clean energy investment are largest in emerging and developing economies, a worrying signal given their rapid projected growth in demand for energy services**.
  - If China is excluded, then the amount being invested in clean energy each year in emerging and developing economies has remained flat since the Paris Agreement was concluded in 2015.
  - The cost of capital for a solar PV plant in 2021 in key emerging economies was between two- and three-times higher than in advanced economies and China. Today's rising borrowing costs could exacerbate the financing challenges facing such projects, despite their favourable underlying costs.
  - A renewed international effort is needed to step up climate finance and tackle the various economy-wide or project-specific risks that deter investors.
  - There is immense value in broad national transition strategies such as the Just Energy Transition Partnerships with Indonesia, South Africa and other countries, that integrate international support and ambitious national policy actions while also providing safeguards for energy security and the social consequences of change.
- **The speed at which investors react to broad and credible transition frameworks depends in practice on a host of more granular issues**.
  - Supply chains are fragile, and infrastructure and skilled labour are not always available.
  - Permitting provisions and deadlines are often complex and time-consuming.
  - Clear procedures for project approval, supported by adequate administrative capacity, are vital to accelerate the flow of viable, investable projects – both for clean energy supply as well as for efficiency and electrification.
  - Our analysis finds that permitting and construction of a single overhead electricity transmission line can take up to 13 years, with some of the longest lead times in advanced economies.
  - Developing new deposits of critical minerals has historically taken over 16 years on average, with 12 years spent lining up all aspects of permitting and financing and 4-5 years for construction.

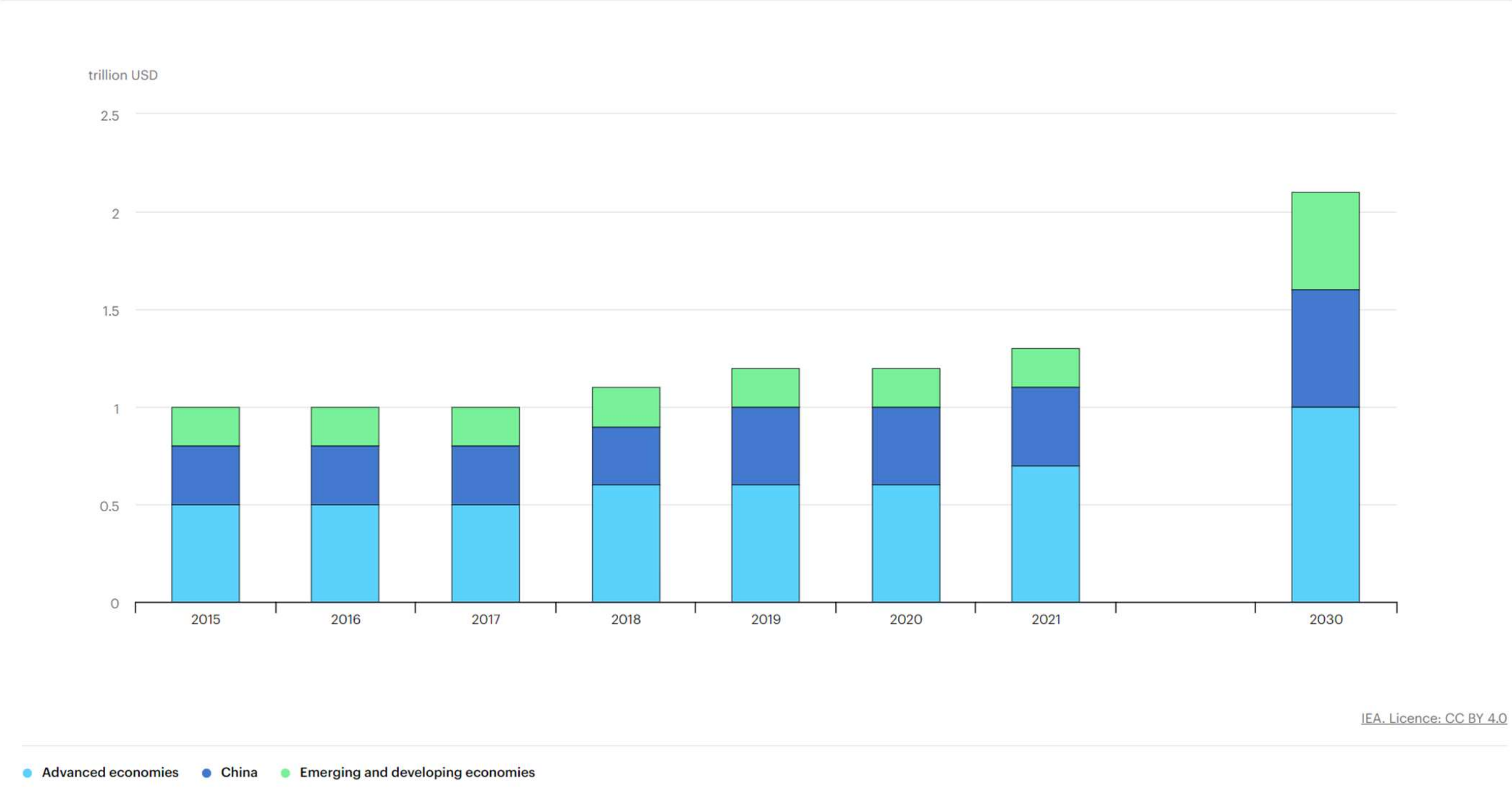
Global public energy RD&D budget, 2015-2022



Govmt spending for clean energy investment support and crisis-related short-term consumer energy affordability measures, Q2 2023



Clean energy investment in the Stated Policies Scenario, 2015-2030



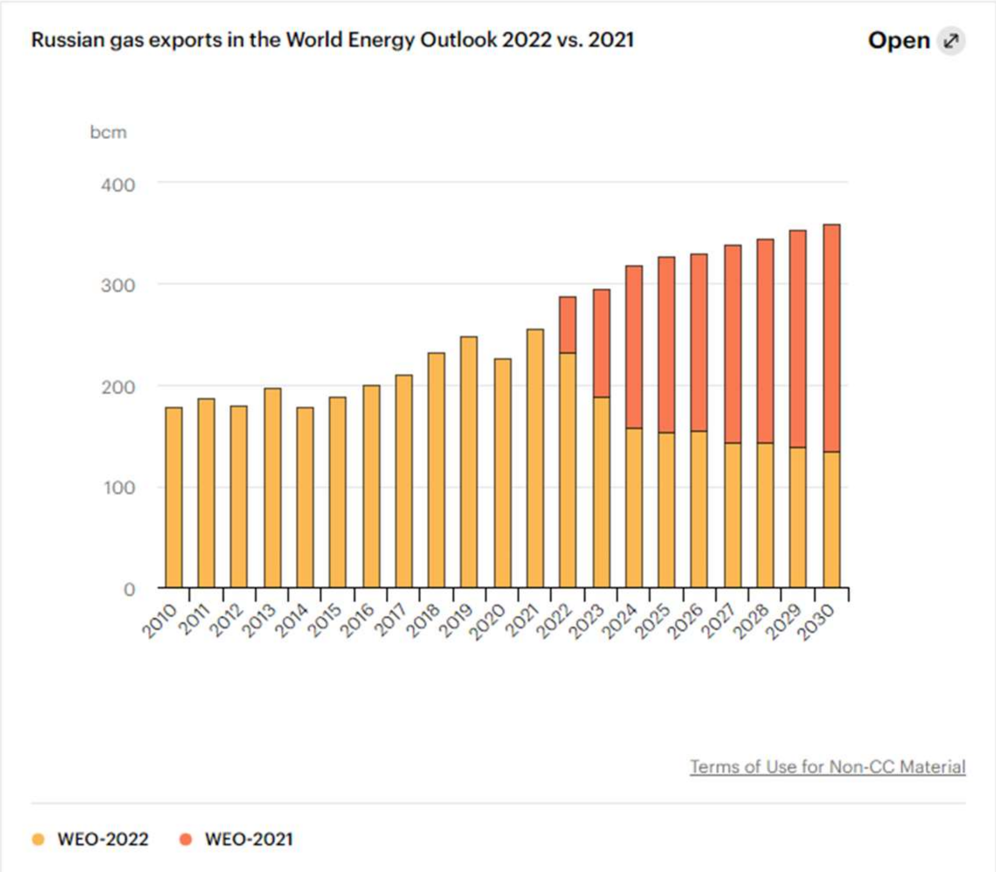
What if transitions don't pick up?

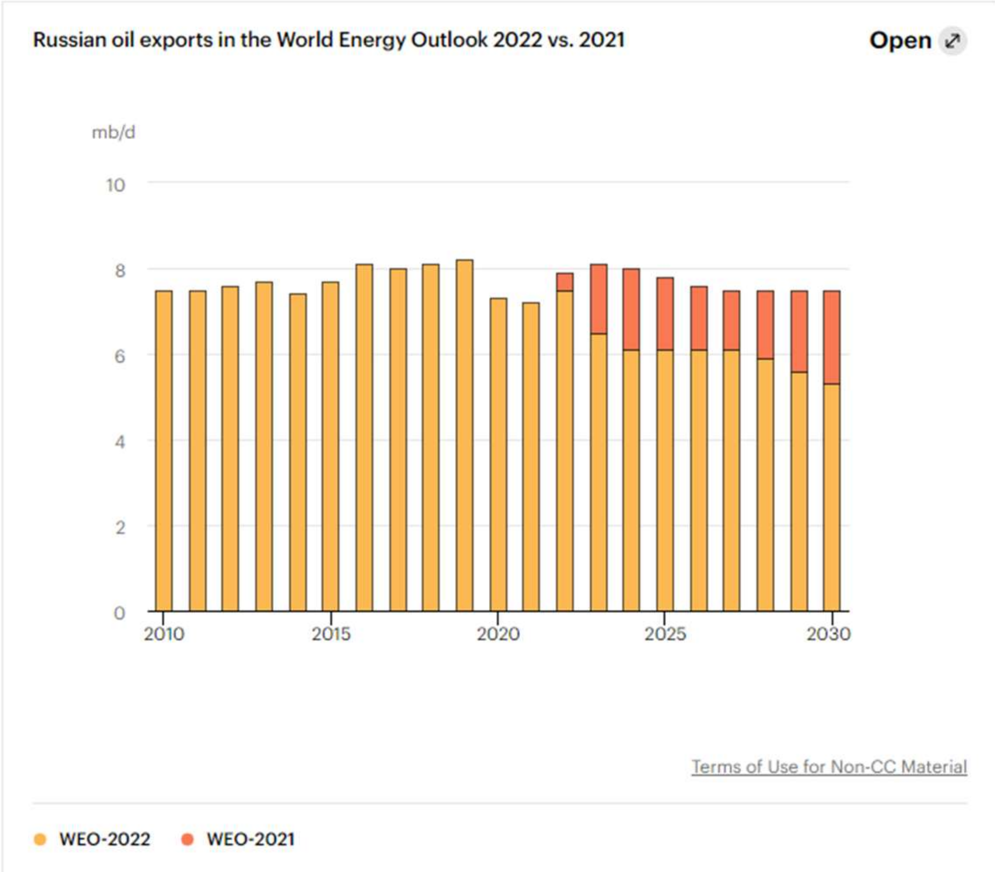
- **If clean energy investment does not accelerate as in the NZE Scenario then higher investment in oil and gas would be needed to avoid further fuel price volatility, but this would also mean putting the 1.5 °C goal in jeopardy.**
  - In the STEPS, an average of almost USD 650 billion per year is spent on upstream oil and natural gas investment to 2030, a rise of more than 50% compared with recent years. This investment comes with risks, both commercial and environmental, and cannot be taken for granted.
  - Despite huge windfalls this year, some Middle East producers are the only part of the upstream industry investing more today than prior to the Covid-19 pandemic.
  - Amid concerns about cost inflation, capital discipline rather than production growth has become the default setting for the US shale industry, meaning that some of the wind has gone from the sails of the main source of recent global oil and gas growth.
- **Immediate shortfalls in fossil fuel production from Russia will need to be replaced by production elsewhere – even in a world working towards net zero emissions by 2050**.
  - The most suitable near-term substitutes are projects with short lead times that bring oil and gas to market quickly, as well as capturing some of the 260 bcm of gas that is wasted each year through flaring and methane leaks to the atmosphere.
  - But lasting solutions to today's crisis lie in reducing fossil fuel demand.
  - Many financial organisations have set goals and plans to scale down investment in fossil fuels.
  - Much more emphasis is needed on goals and plans for scaling up investment in clean energy transitions, and on what governments can do to incentivise this.

Russia loses out in the reshuffling of international trade

- **Russia's invasion of Ukraine is prompting a wholesale reorientation of global energy trade, leaving Russia with a much-diminished position.**
  - All Russia's trade ties with Europe based on fossil fuels had ultimately been undercut in our previous scenarios by Europe's net zero ambitions, but Russia's ability to deliver at relatively low cost meant that it lost ground only gradually.
  - Now the rupture has come with a speed that few imagined possible. In this *Outlook*, more Russian resources are drawn eastwards to Asian markets, but Russia is unsuccessful in finding markets for all of the flows that previously went to Europe. In 2025, Russia's oil production is 2 million barrels a day lower than in the *WEO-2021* and gas production is down by 200 bcm.
  - Longer-term prospects are weakened by uncertainties over demand, as well as restricted access to international capital and technologies to develop more challenging fields and LNG projects.
  - Russian fossil fuel exports never return – in any of our scenarios – to the levels seen in 2021, and its share of internationally traded oil and gas falls by half by 2030 in the STEPS.
- **Russia's reorientation to Asian markets is particularly challenging in the case of natural gas, as the market opportunity for large-scale additional deliveries to China is limited.**
  - Russia is targeting new pipeline links to China, notably the large-capacity Power of Siberia-2 pipeline through Mongolia.
  - However, our demand projections for China raise considerable doubts about the viability of another large-scale gas link with Russia, once the existing Power of Siberia line ramps up to full capacity.
  - In the STEPS, China's gas demand growth slows to 2% per year between 2021 and 2030, compared with an average growth rate of 12% per year since 2010, reflecting a policy preference for renewables and electrification over gas use for power and heat.
  - Chinese importers have been actively contracting for new long-term LNG supplies, and China already has adequate contracted supply to meet projected demand in the STEPS until well into the 2030s.

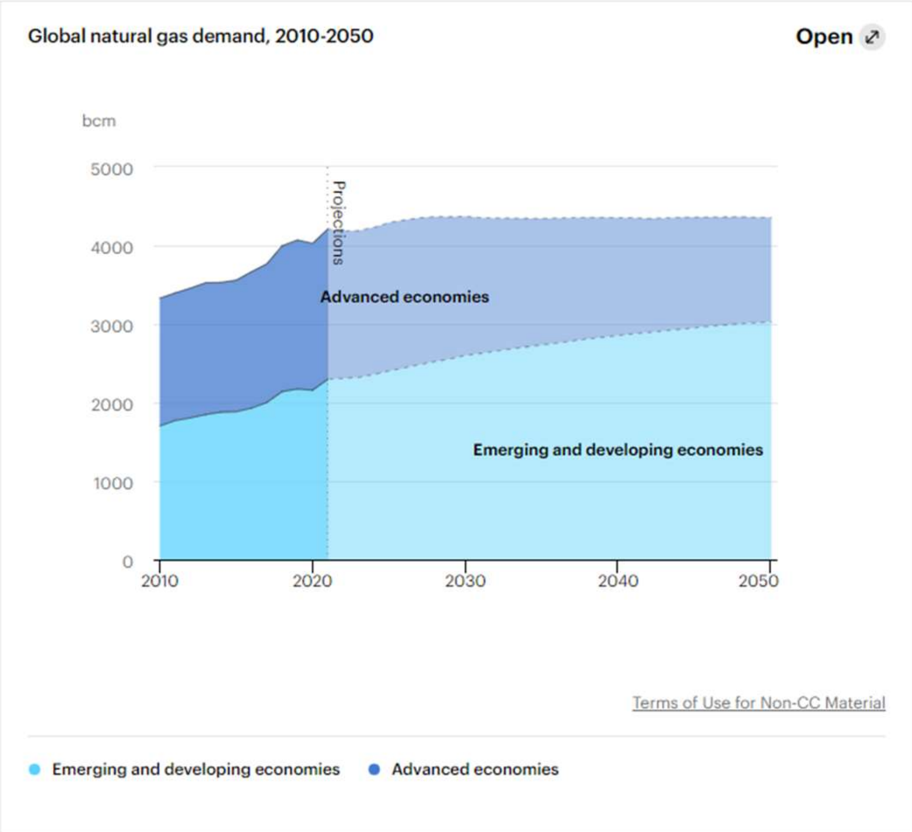
Russia loses out in the reshuffling of international trade

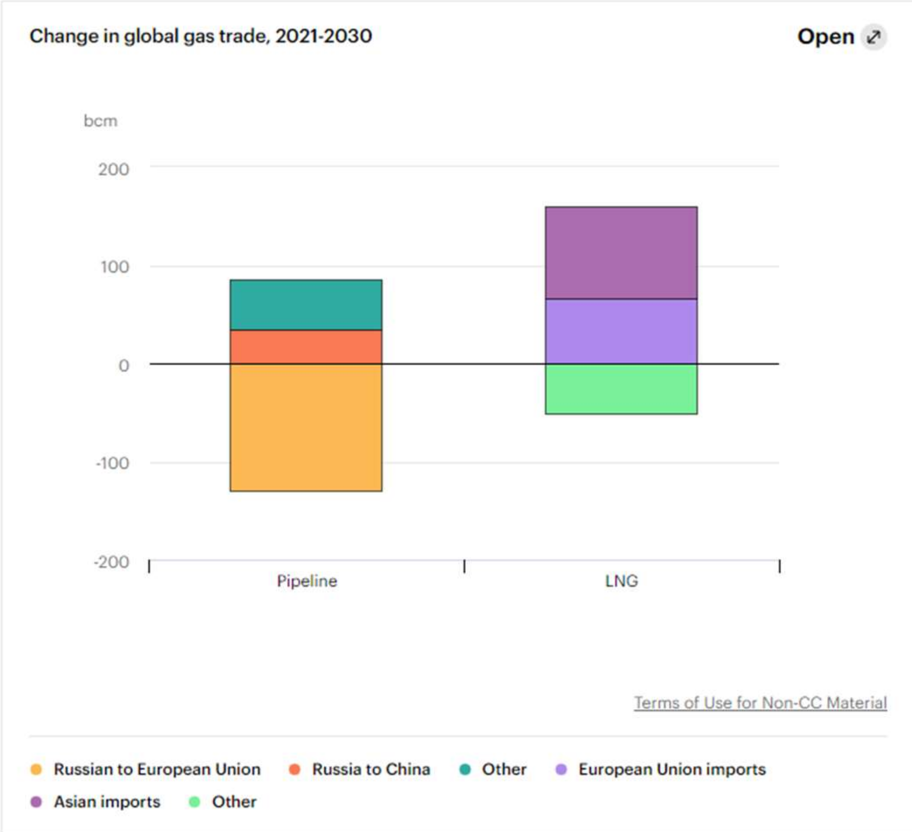




Were the 2010s the "golden age of gas"?

- **One of the effects of Russia's actions is that the era of rapid growth in natural gas demand draws to a close.**
  - In the STEPS, the scenario that sees the highest gas consumption, global demand rises by less than 5% between 2021 and 2030 and then remains flat at around 4 400 bcm through to 2050.
  - The outlook for gas is dampened by higher near-term prices; more rapid deployment of heat pumps and other efficiency measures; higher renewables deployment and a faster uptake of other flexibility options in the power sector; and, in some cases, reliance on coal for slightly longer.
  - The Inflation Reduction Act cuts projected US natural gas demand in 2030 in the STEPS by more than 40 bcm compared with last year's projections, freeing up gas for export. Stronger climate policies accelerate Europe's structural shift away from gas.
  - New supply brings prices down by the mid-2020s, and LNG becomes even more important to overall gas security.
  - But momentum behind natural gas growth in developing economies has slowed, notably in South and Southeast Asia, putting a dent in the credentials of gas as a transition fuel. Most of the downward revision to gas demand to 2030 in this year's STEPS is due to a faster switch to clean energy, although around one-quarter is because gas loses out to coal and oil.

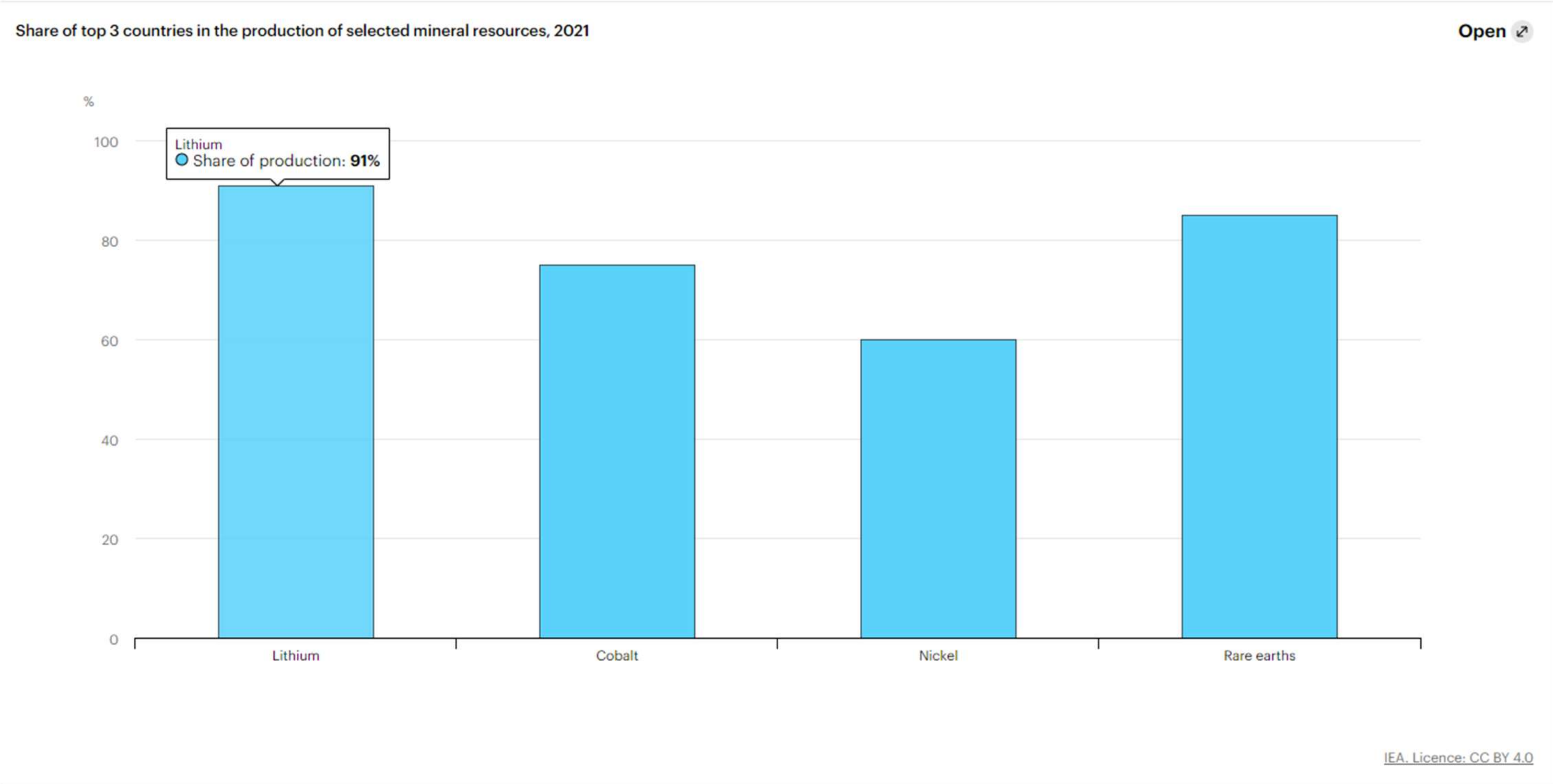




A focus on affordable, secure transitions based on resilient supply chains

- **A new energy security paradigm is needed to maintain reliability and affordability while reducing emissions**.
    - This *Outlook* includes ten principles that can help guide policy makers through the period when declining fossil fuel and expanding clean energy systems co-exist. During energy transitions, both systems are required to function well in order to deliver the energy services needed by consumers, even as their respective contributions change over time.
    - Maintaining electricity security in tomorrow's power systems calls for new tools, more flexible approaches and mechanisms to ensure adequate capacities.
    - Power generators will need to be more responsive, consumers will need to be more connected and adaptable, and grid infrastructure will need to be strengthened and digitalised.
    - Inclusive, people-centred approaches are essential to allow vulnerable communities to manage the upfront costs of cleaner technologies and ensure that the benefits of transitions are felt widely across societies.
    - Even as transitions reduce fossil fuel use, there are parts of the fossil fuel system that remain critical to energy security, such as gas-fired power for peak electricity needs, or refineries to supply residual users of transport fuels. Unplanned or premature retirement of this infrastructure could have negative consequences for energy security.
- **As the world moves on from today's energy crisis, it needs to avoid new vulnerabilities arising from high and volatile critical mineral prices or highly concentrated clean energy supply chains**.
    - If not adequately addressed, these issues could delay energy transitions or make them more costly.
    - Demand for critical minerals for clean energy technologies is set to rise sharply, more than doubling from today's level by 2030 in the APS.
    - Copper sees the largest increase in terms of absolute volumes, but other critical minerals experience much faster rates of demand growth, notably silicon and silver for solar PV, rare earth elements for wind turbine motors and lithium for batteries.
    - Continued technology innovation and recycling are vital options to ease strains on critical minerals markets.
    - High reliance on individual countries such as China for critical mineral supplies and for many clean technology supply chains is a risk for transitions, but so too are diversification options that close off the benefits of trade.

A focus on affordable, secure transitions based on resilient supply chains

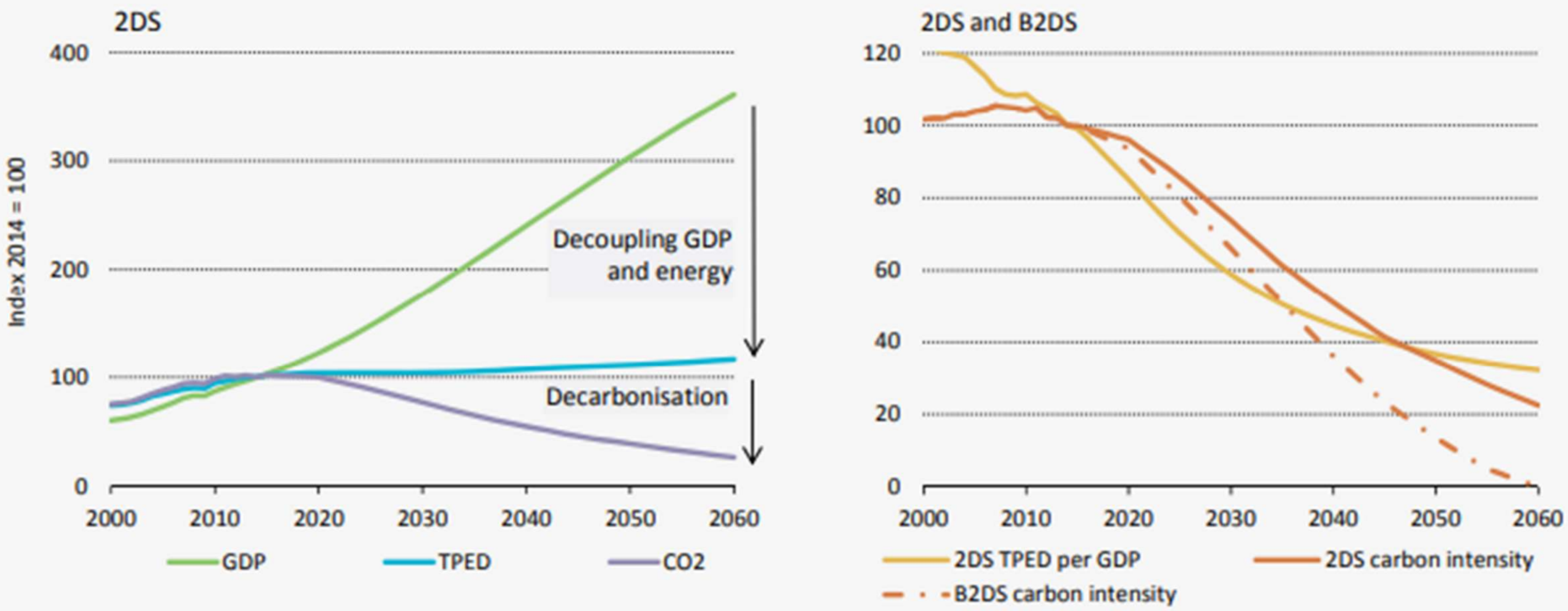


The energy crisis promises to be a historic turning point towards a cleaner and more secure energy system

- **Energy markets and policies have changed as a result of Russia's invasion of Ukraine, not just for the time being, but for decades to come**.
    - The environmental case for clean energy needed no reinforcement, but the economic arguments in favour of cost-competitive and affordable clean technologies are now stronger – and so too is the energy security case.
    - This alignment of economic, climate and security priorities has already started to move the dial towards a better outcome for the world's people and for the planet.
    - Much more remains to be done, and as these efforts gather momentum, it is essential to bring everyone on board, especially at a time when geopolitical fractures on energy and climate are all the more visible.
    - This means redoubling efforts to ensure that a broad coalition of countries has a stake in the new energy economy.
    - The journey to a more secure and sustainable energy system may not be a smooth one. But today's crisis makes it crystal clear why we need to press ahead.

LE SOLUZIONI POSSIBILI

Figure 1.3. Global GDP, primary energy demand and CO_2 emissions

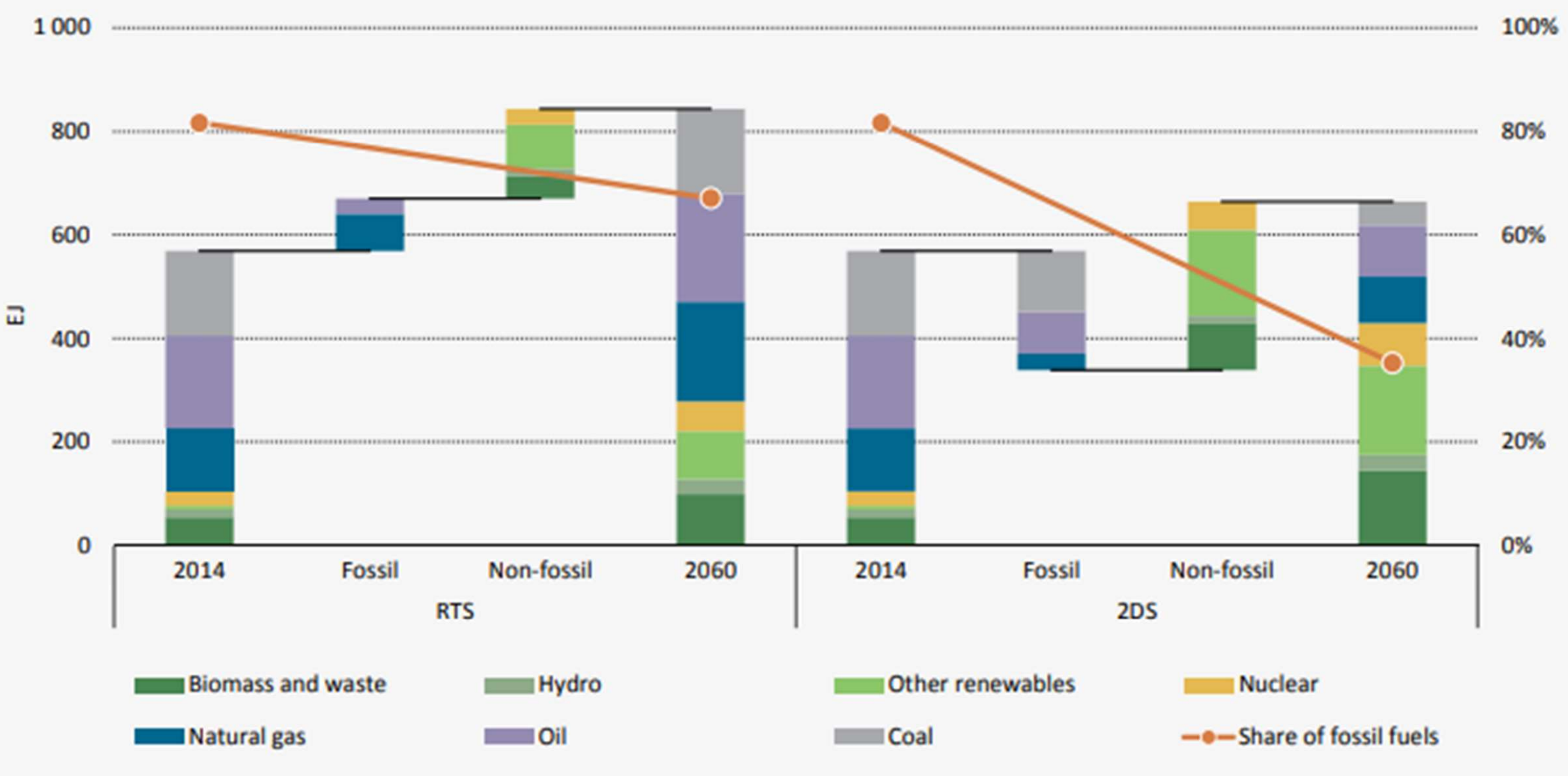


Note: Carbon intensities expressed as CO_2 emissions per unit of GDP.

Source: IEA (2016h), *World Energy Statistics and Balances*; IEA (2016i), *CO_2 Emissions from Fuel Combustion*; IEA (2016c), *World Energy Outlook*; IMF (2016), *World Economic Outlook*.

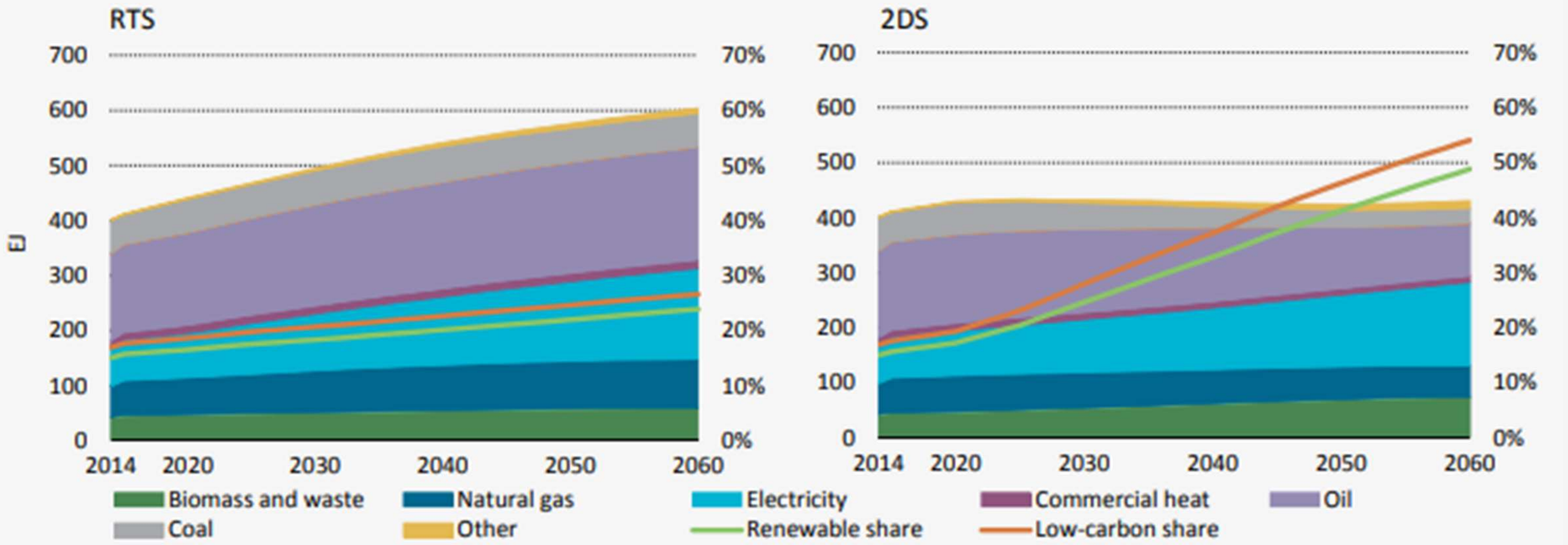
Key point *Achieving the 2DS will require a significant decoupling between energy use and economic growth, with decarbonisation of the energy mix occurring in parallel.*

Figure 1.4. Global primary energy demand in the RTS and 2DS, 2014–60



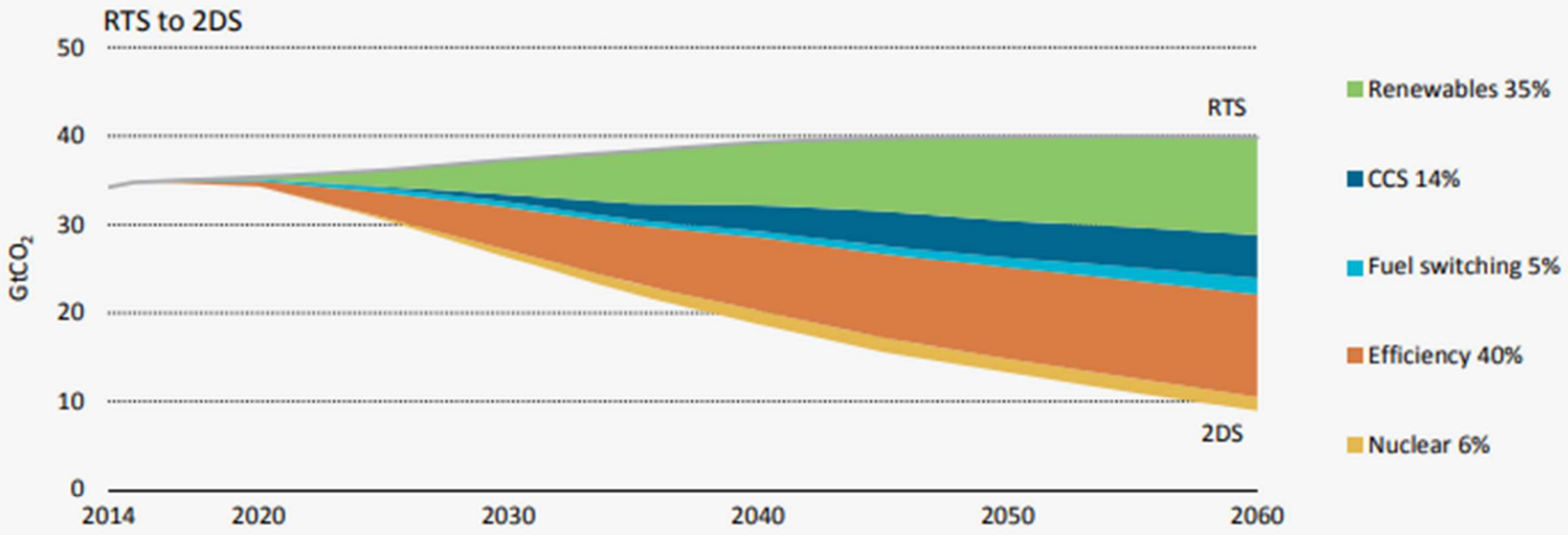
Key point *More than half of primary energy demand is from renewables in the 2DS.*

Figure 1.5. Final energy demand in the RTS and 2DS, 2014-60



Key point *Growth in final energy demand in the 2DS is substantially lower than the RTS, and more than half of it is met by low-carbon sources by 2060 in the 2DS.*

Figure 1.6. Global CO_2 emissions reductions by technology area: RTS to 2DS



Note: CO_2 emissions include both energy-related CO_2 emissions and emissions from industrial processes.

Key point *Achieving the 2DS requires contributions from a diversified technology mix across all sectors.*

Lo scenario 2DS prevede (rispetto a RTS):

- Maggiore utilizzo delle fonti rinnovabili e nucleare
- Aumento dell’efficienza energetica
- Sostituzione dei combustibili (biocarburanti, idrogeno, elettricità)
- Contributo importante anche da Carbon Capture & Sequestration

Achieving our energy and climate goals demands a dramatic scaling up of clean energy technologies

- To avoid the worst consequences of climate change, the global energy system must rapidly reduce its emissions
    - Calls to reduce global greenhouse gas emissions are growing louder every year, but emissions remain at unsustainably high levels.
    - International climate goals call for emissions to peak as soon as possible and then decline rapidly to reach net-zero in the second half of this century.
    - The vast majority of global CO2 emissions come from the energy sector, making clear the need for a cleaner energy system. Global CO2 emissions are set to fall in 2020 because of the Covid-19 crisis, but without structural changes to the energy system, this decline will be only temporary
- Achieving net-zero emissions requires a radical transformation in the way we supply, transform and use energy.
    - The rapid growth of wind, solar and electric cars has shown the potential of new clean energy technologies to bring down emissions.
    - Net-zero emissions will require these technologies to be deployed on a far greater scale, in tandem with the development and massive rollout of many other clean energy solutions that are currently at an earlier stage of development, such as numerous applications of hydrogen and carbon capture.
    - The IEA's Sustainable Development Scenario – a roadmap for meeting international climate and energy goals – brings the global energy system to net-zero emissions by 2070, incorporating aspects of behavioural change alongside a profound transformation in energy system technology and infrastructure
- This report analyses over 800 technology options to examine what would need to happen for the world to reach net-zero emissions by 2050
    - The report focuses primarily on the Sustainable Development Scenario, but it also includes a complementary Faster Innovation Case that explores the technology implications of reaching net-zero emissions globally by 2050.
    - The analysis seeks to assess the challenges and opportunities associated with a rapid, clean energy transition. The report covers all areas of the energy system, from fuel transformation and power generation to aviation and steel production.

Transforming the power sector alone would only get the world one-third of the way to net-zero emissions

- Many governments have ambitious plans for reducing emissions from the energy sector.
  - Some governments have even put net-zero ambitions into law or proposed legislation, while others are discussing their own net-zero strategies. Many companies have also announced carbon-neutral targets. The success of renewable power technologies gives governments and businesses some cause for optimism. But reaching these targets will require devoting far more attention to the transport, industry and buildings sectors, which today account for more than 55% of CO_2 emissions from the energy system.
- Spreading the use of electricity into more parts of the economy is the single largest contributor to reaching net-zero emissions.
  - In the Sustainable Development Scenario, final electricity demand more than doubles.
  - This growth is driven by using electricity to power cars, buses and trucks; to produce recycled metals and provide heat for industry; and to supply the energy needed for heating, cooking and other appliances in buildings.
- Reaching net-zero emissions in 2050 would require a much more rapid deployment of low-carbon power generation.
  - In the Faster Innovation Case, electricity generation would be about 2.5 times higher in 2050 than it is today, requiring a rate of growth equivalent to adding the entire US power sector every three years.
  - Annual additions of renewable electricity capacity, meanwhile, would need to average around four times the current record, which was reached in 2019.

Electricity cannot decarbonise entire economies alone

- Hydrogen extends electricity's reach.
  - On top of the surging demand for electricity from across different parts of the economy, a large amount of additional generation is needed for low-carbon hydrogen.
  - The global capacity of electrolysers, which produce hydrogen from water and electricity, expands to 3 300 GW in the Sustainable Development Scenario, from 0.2 GW today.
  - In order to produce the lowcarbon hydrogen required to reach net-zero emissions, these electrolysers would consume twice the amount of electricity the People's Republic of China generates today.
  - This hydrogen forms a bridge between the power sector and industries where the direct use of electricity would be challenging, such as in the production of steel from iron ore or fuelling large ships.
- Carbon capture and bioenergy play multifaceted roles.
  - Capturing CO2 emissions in order to use them sustainably or store them (known as CCUS)1 is a crucial technology for reaching net-zero emissions.
  - In the Sustainable Development Scenario, CCUS is employed in the production of synthetic low-carbon fuels and to remove CO2 from the atmosphere.
  - It is also vital for producing some of the low-carbon hydrogen that is needed to reach net-zero emissions, mostly in regions with low-cost natural gas resources and available CO2 storage.
  - At the same time, the use of modern bioenergy triples from today's levels. It is used to directly replace fossil fuels (e.g. biofuels for transport) or to offset emissions indirectly through its combined use with CCUS.
- A secure and sustainable energy system with net-zero emissions results in a new generation of major fuels.
  - The security of today's global energy system is underpinned in large part by mature global markets in three key fuels – coal, oil and natural gas – which together account for about 70% of global final energy demand.
  - Electricity, hydrogen, synthetic fuels and bioenergy end up accounting for a similar share of demand in the Sustainable Development Scenario as fossil fuels do today.

L'importanza dell'innovazione

- Il raggiungimento della neutralità climatica dipende dalla capacità di innovare significativamente in una serie di ambiti, tra cui: generazione elettrica, idrogeno, bioenergy, CCS
  - Oltre un terzo della riduzione cumulate delle emissioni necessaria nello scenario SDS risulta da tecnologie che non hanno ancora provato la loro fattibilità economica
  - Per lo scenario FIC, la quota sale alla metà
- Long-distance transport and heavy industry are home to the hardest emissions to reduce.
  - Energy efficiency, material efficiency and avoided transportation demand (e.g. substituting personal car travel with walking or cycling) all play an important role in reducing emissions in long-distance transport and heavy industries.
  - But nearly 60% of cumulative emissions reductions for these sectors in the Sustainable Development Scenario come from technologies that are only at demonstration and prototype stages today.
  - Hydrogen and CCUS account for around half of cumulative emissions reductions in the steel, cement and chemicals sectors.
  - In the trucking, shipping and aviation sectors, the use of alternative fuels – hydrogen, synthetic fuels and biofuels – ranges between 55% and 80%.
  - Highly competitive global markets, the long lifetime of existing assets, and rapidly increasing demand in certain areas further complicate efforts to reduce emissions in these challenging sectors.
  - Fortunately, the engineering skills and knowledge these sectors possess today are an excellent starting point for commercialising the technologies required for tackling these challenges.

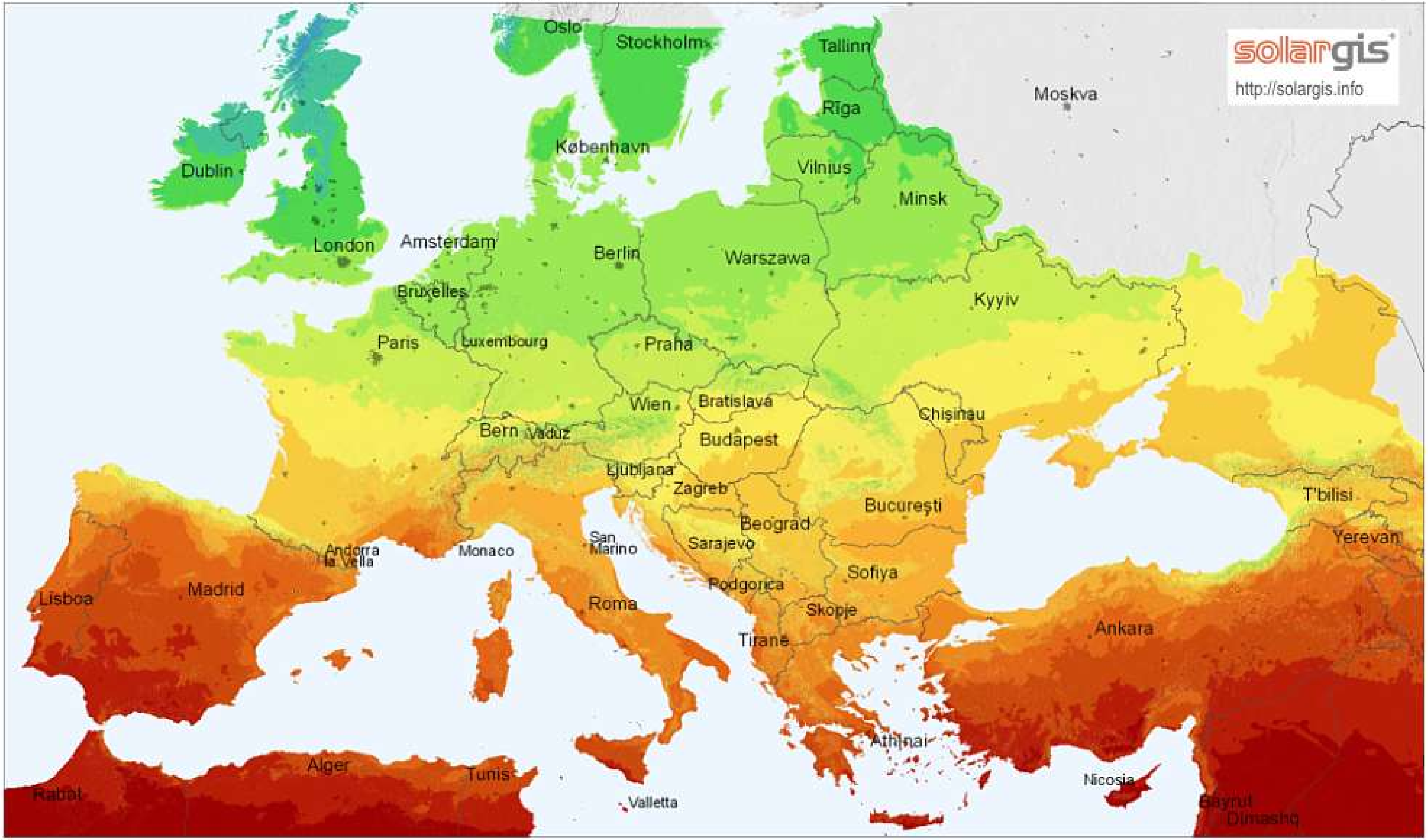
Inerzie del passato

- Emissions from existing assets are a pivotal challenge
  - Power and heavy industry together account for about 60% of emissions today from existing energy infrastructure, climbing to nearly 100% in 2050 if no action is taken.
  - Reaching net-zero will depend on how we manage the emissions challenge presented by these sectors' long-lasting assets, many of which were recently built in Asian economies and could operate for decades to come.
  - The situation underscores the need for hydrogen and CCUS technologies. Ensuring that new clean energy technologies are available in time for key investment decisions will be critical.
  - In heavy industries, for example, strategically timed investments could help avoid around 40% of cumulative emissions from existing infrastructure in these sectors.

Il ruolo delle politiche pubbliche

- Governments will need to play the decisive role
  - While markets are vital for mobilising capital and catalysing innovation, they will not deliver net-zero emissions on their own.
  - Governments have an outsized role to play in supporting transitions towards net-zero emissions.
  - Long-term visions need to be backed up by detailed clean energy strategies involving measures that are tailored to local infrastructure and technology needs.
- Effective policy toolkits must address five core areas
  - Tackle emissions from existing assets
  - Strengthen markets for technologies at an early stage of adoption
  - Develop and upgrade infrastructure that enables technology deployment
  - Boost support for research, development and demonstration
  - Expand international technology collaboration.
  - Economic stimulus measures in response to the Covid-19 crisis offer a key opportunity to take urgent action that could boost the economy while supporting clean energy and climate goals, including in the five areas above.

Gradiazione solare globale sul piano orizzontale — Europa



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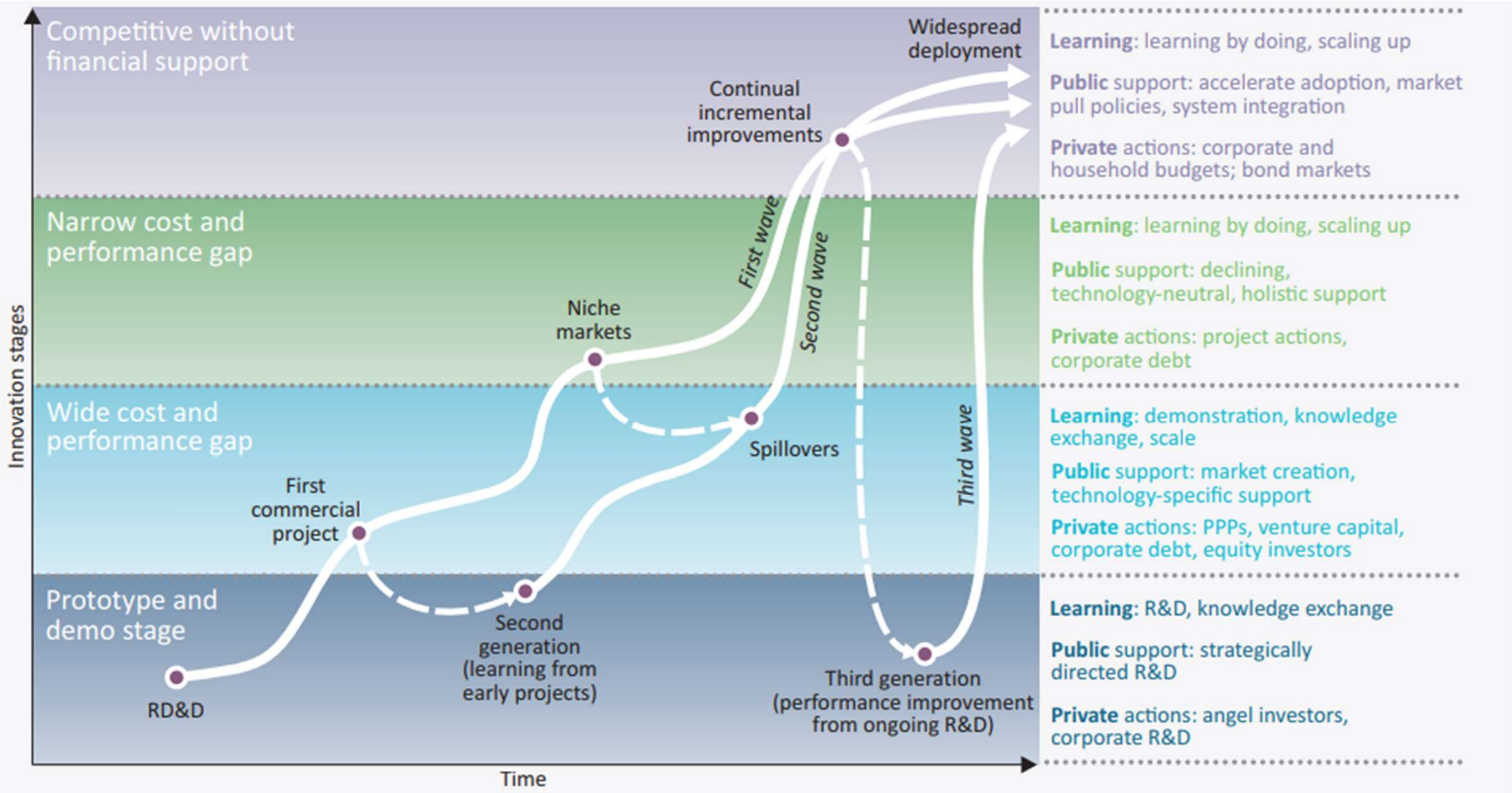
0 250 500 km

Figure I.1. Energy technology innovation process



Notes: PPP = public-private partnerships. RD&D = research, development and demonstration. R&D = research and development.

Key point *Energy technologies require support across all innovation stages.*

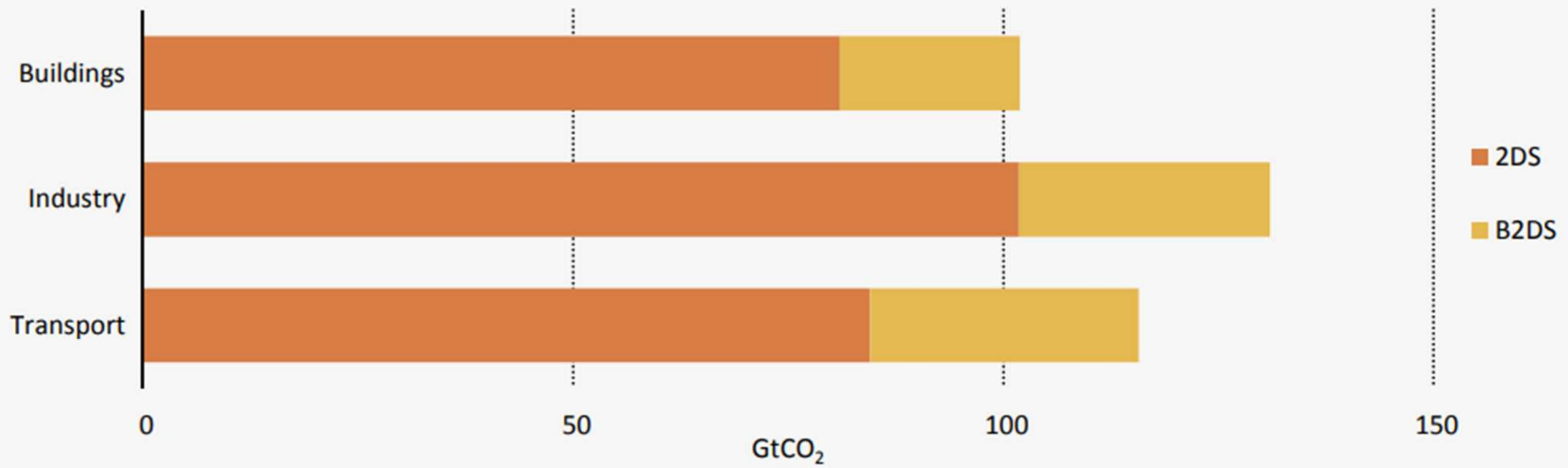
Source: International Energy Agency, Energy Technology Perspectives, 2017

Una strategia in cinque mosse

- Aumento dell'efficienza energetica
- Elettrificazione
- Decarbonizzazione della generazione di elettricità
- Biocombustibili
- Cattura e sequestro del CO_2 (CCS)

Il possibile contributo dell'efficientamento energetico

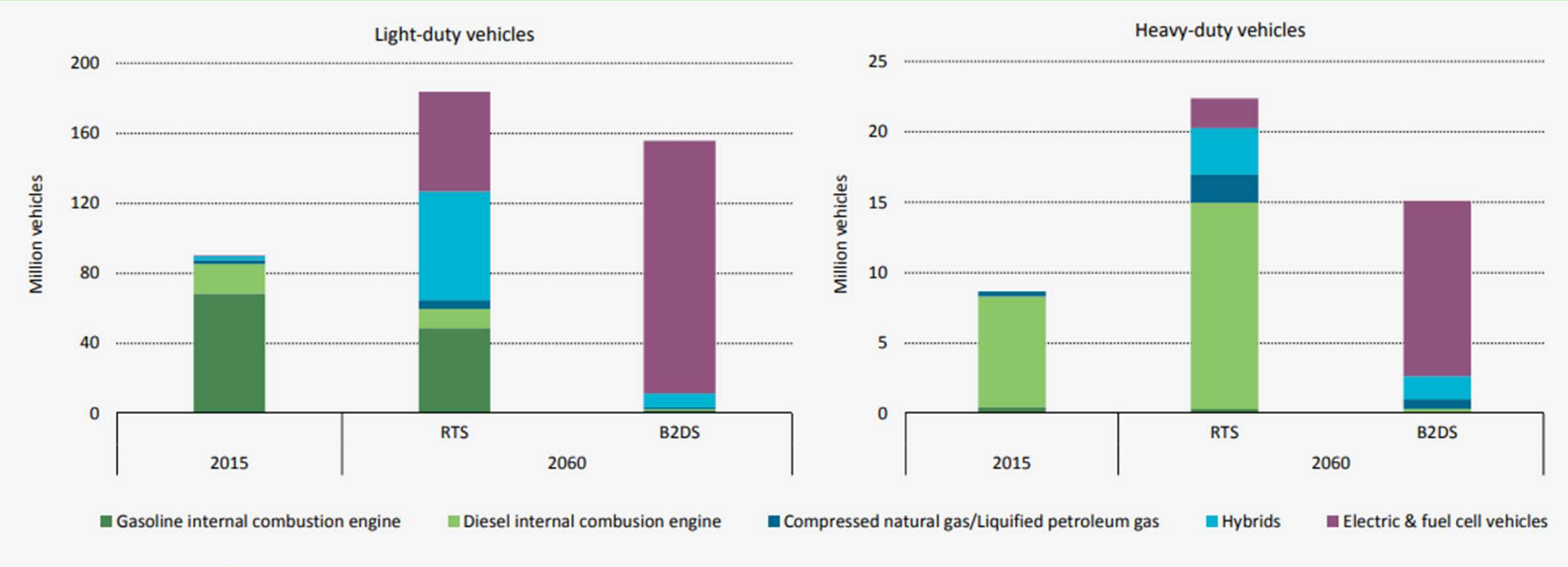
Figure 1.10. Contribution of energy efficiency to cumulative CO_2 reductions in the 2DS and B2DS



Key point *Energy efficiency measures play a critical role in delivering emissions reductions across end use sectors*

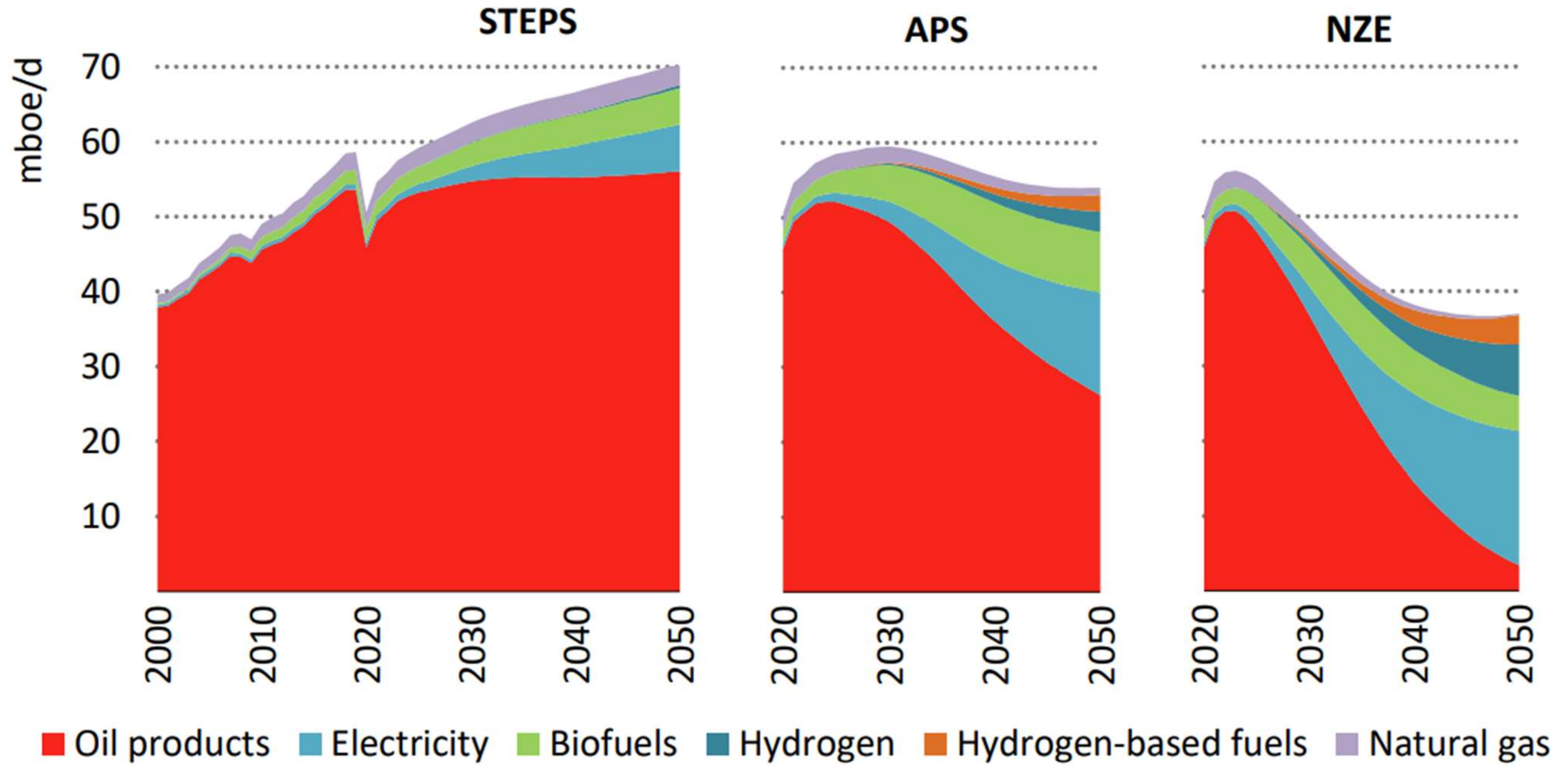
Il possibile contributo dell'elettrificazione del trasporto

Figure 1.11. Vehicle sales and technology shares in 2015 and in 2060 in the RTS and B2DS



Key point *Electricity can become the primary fuel for land-based transport, but not without assertive policies and directed investment.*

Figure 1.13 ▷ Energy use in transport by scenario, 2000-2050

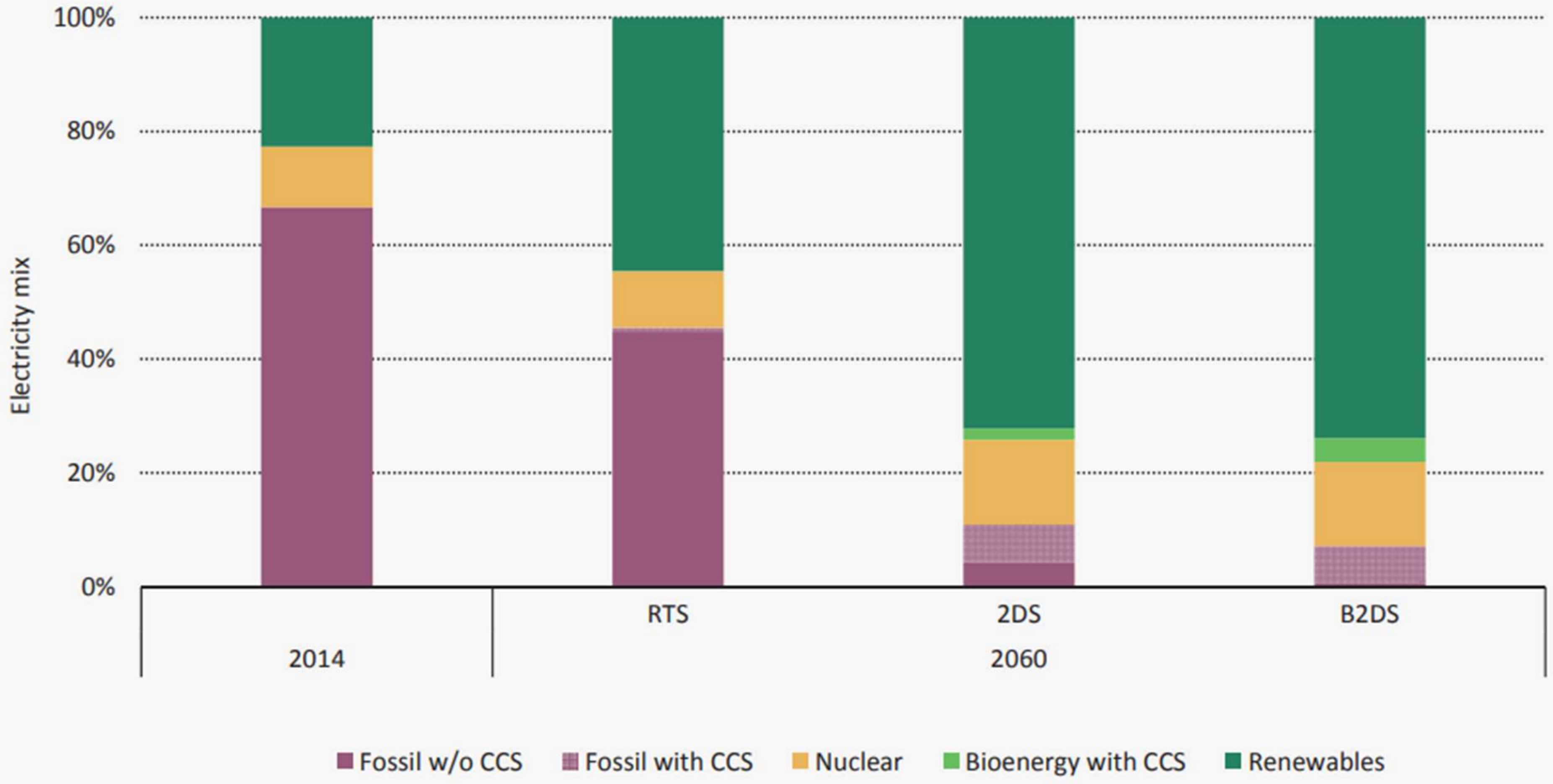


Transport has long been the bedrock of oil demand, but its role weakens in the APS and NZE Scenario as electricity displaces very large volumes of oil

Note: mboe/d = million barrels of oil equivalent per day.

Come deve cambiare il «parco della generazione elettrica»

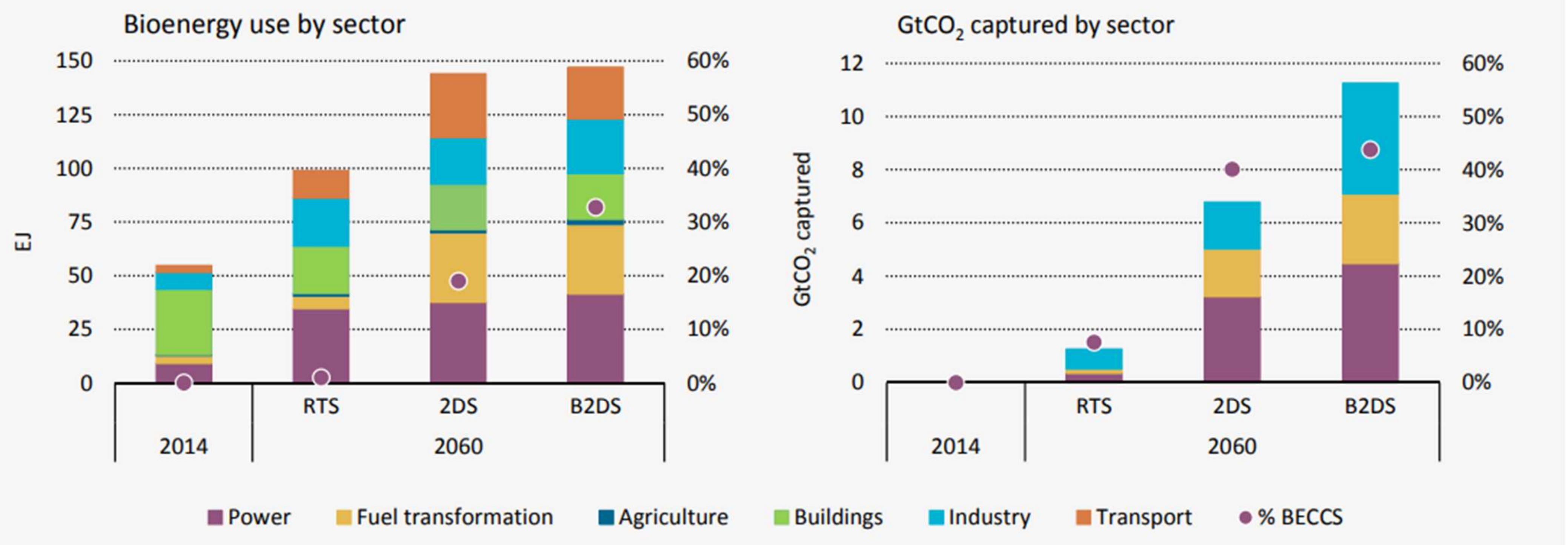
Figure 1.12. Power generation fuel mix by scenario, 2014 and 2060



Key point *The fuel mix to generate electricity in the 2DS and B2DS would be vastly different from today's mix.*

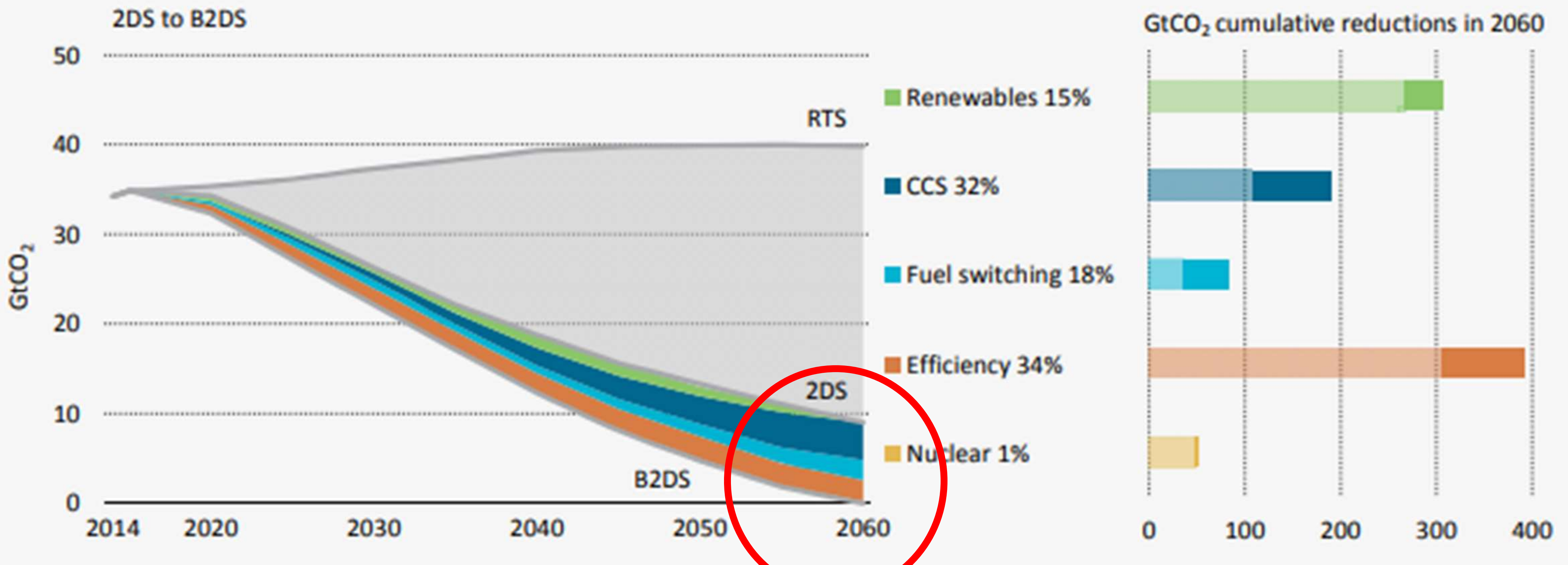
Biocarburanti e CCS

Figure 1.13. Bioenergy use and CO_2 capture in the RTS, 2DS and B2DS



Key point *A growing percentage of bioenergy use will need to have CO_2 capture in the 2DS and B2DS.*

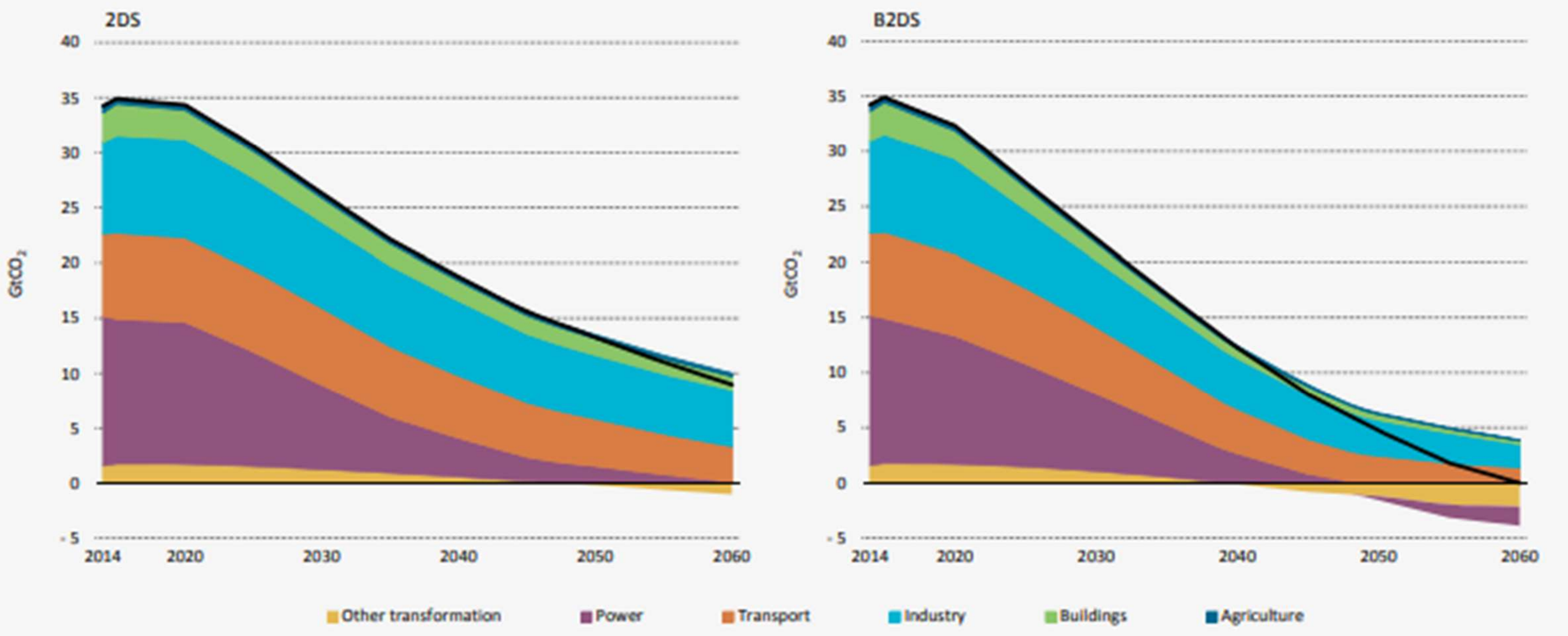
Figure 1.9. Global CO_2 emissions reductions by technology area and scenario



Note: Light areas in the right graph represent cumulative emissions reductions in the 2DS, while dark areas represent additional cumulative emissions reductions needed to achieve the B2DS.

Key point *Pushing energy technology beyond the 2DS could deliver net-zero CO_2 emissions by 2060.*

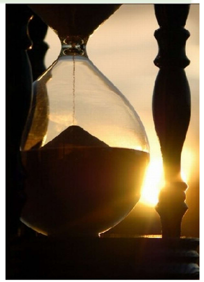
Figure 1.8. Remaining CO_2 emissions in the 2DS and B2DS



Note: Solid lines represent net energy sector CO_2 emissions for each scenario.

Key point *The remaining CO_2 emissions from industry and transport in the 2DS must be targeted in the B2DS, with negative emissions necessary to achieve net-zero energy sector emissions by 2060.*

IL TEMPO SCORRE!!



Minerals used in selected clean energy technologies

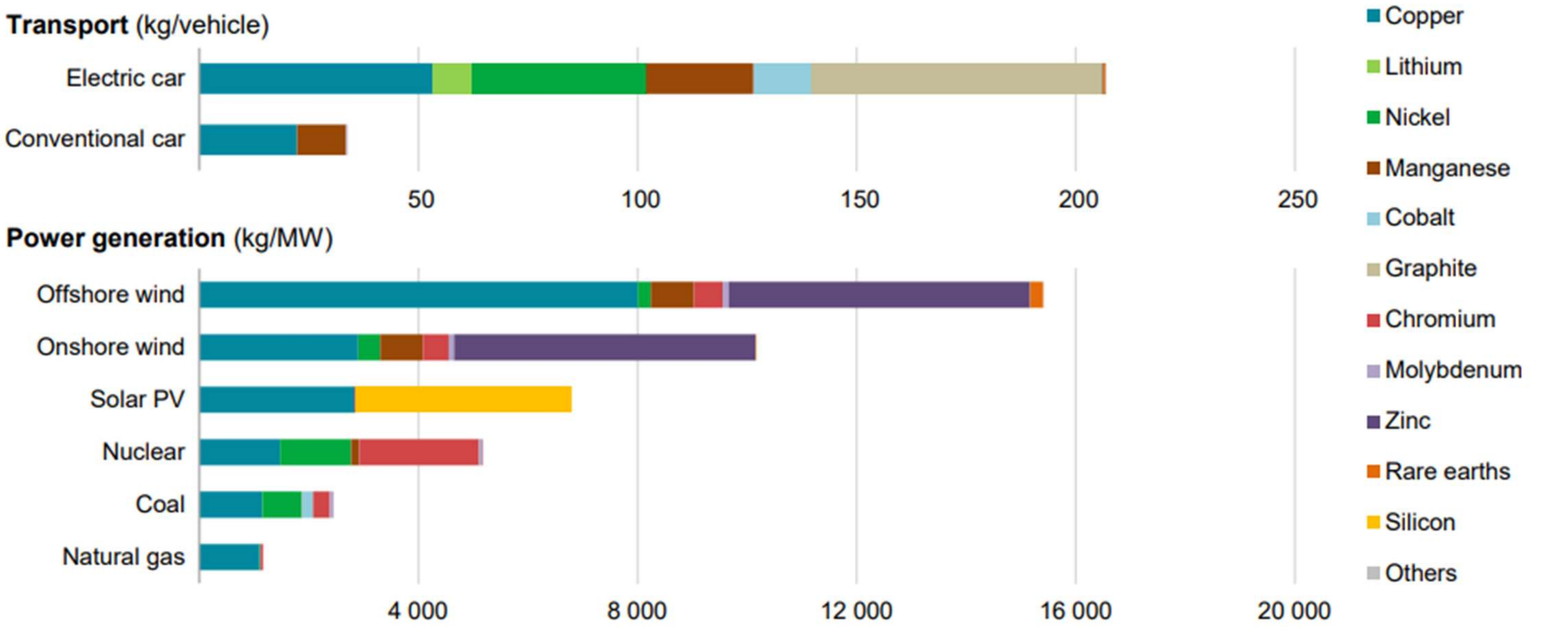
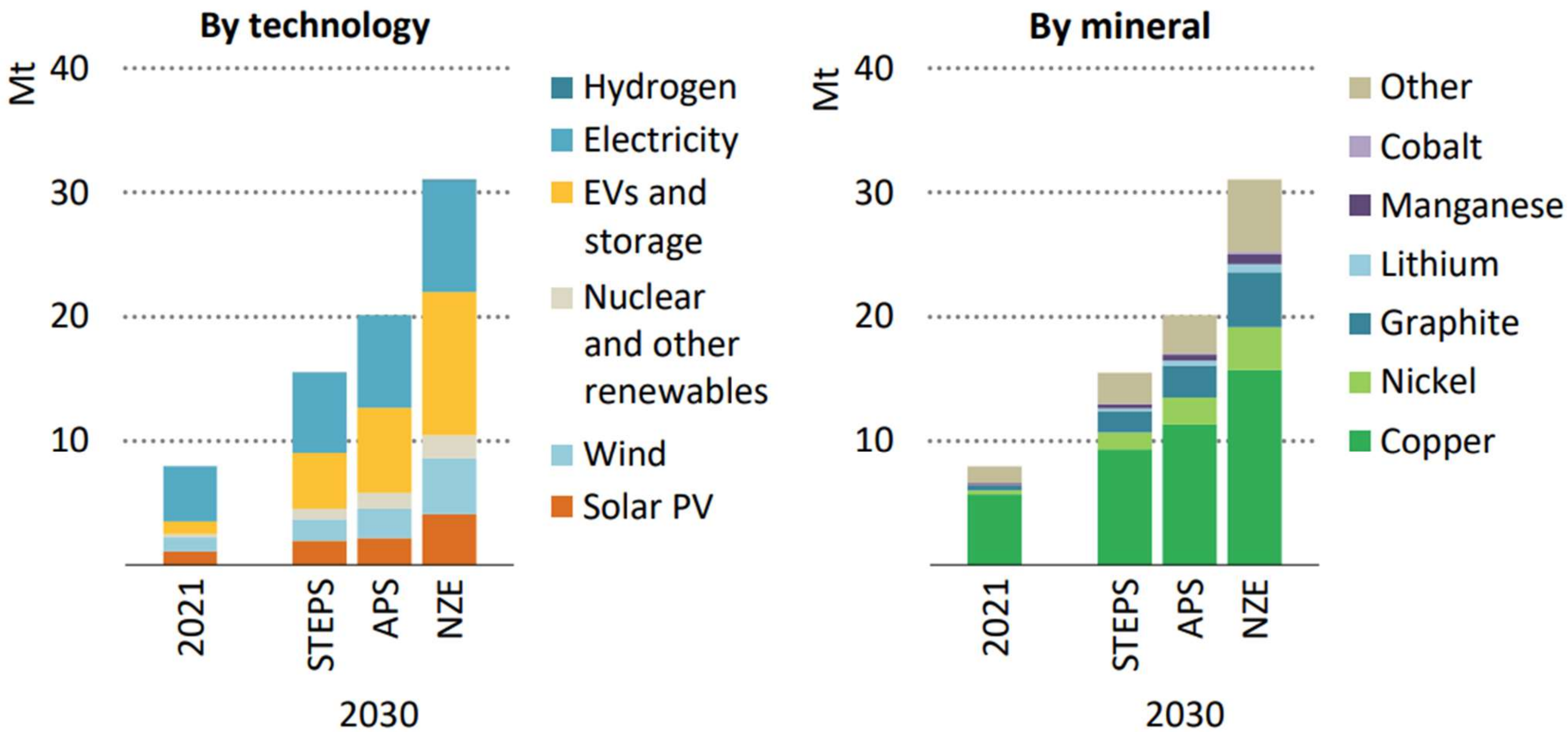
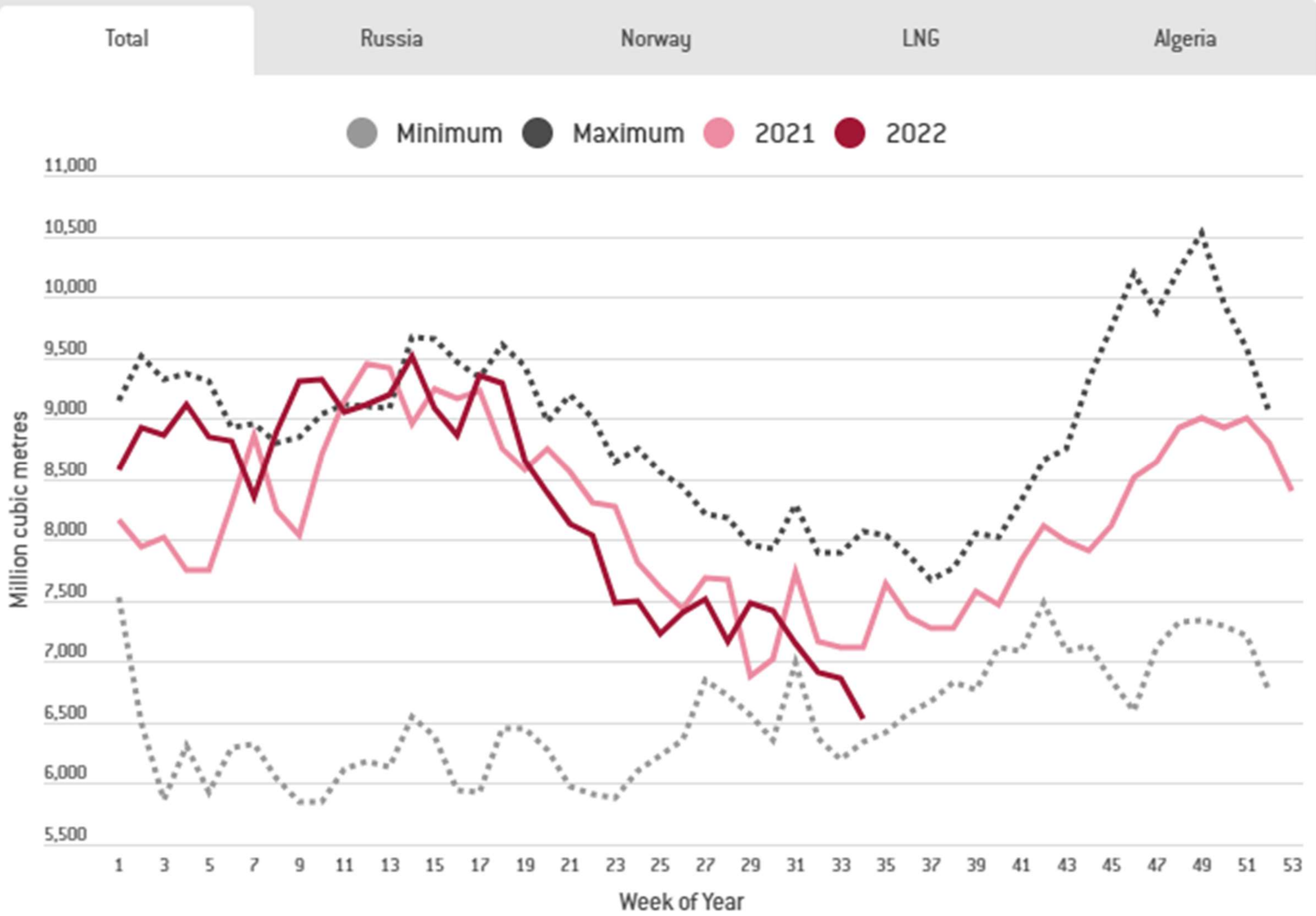


Figure 1.11 ▷ Mineral requirements for clean energy technologies by scenario, 2021 and 2030

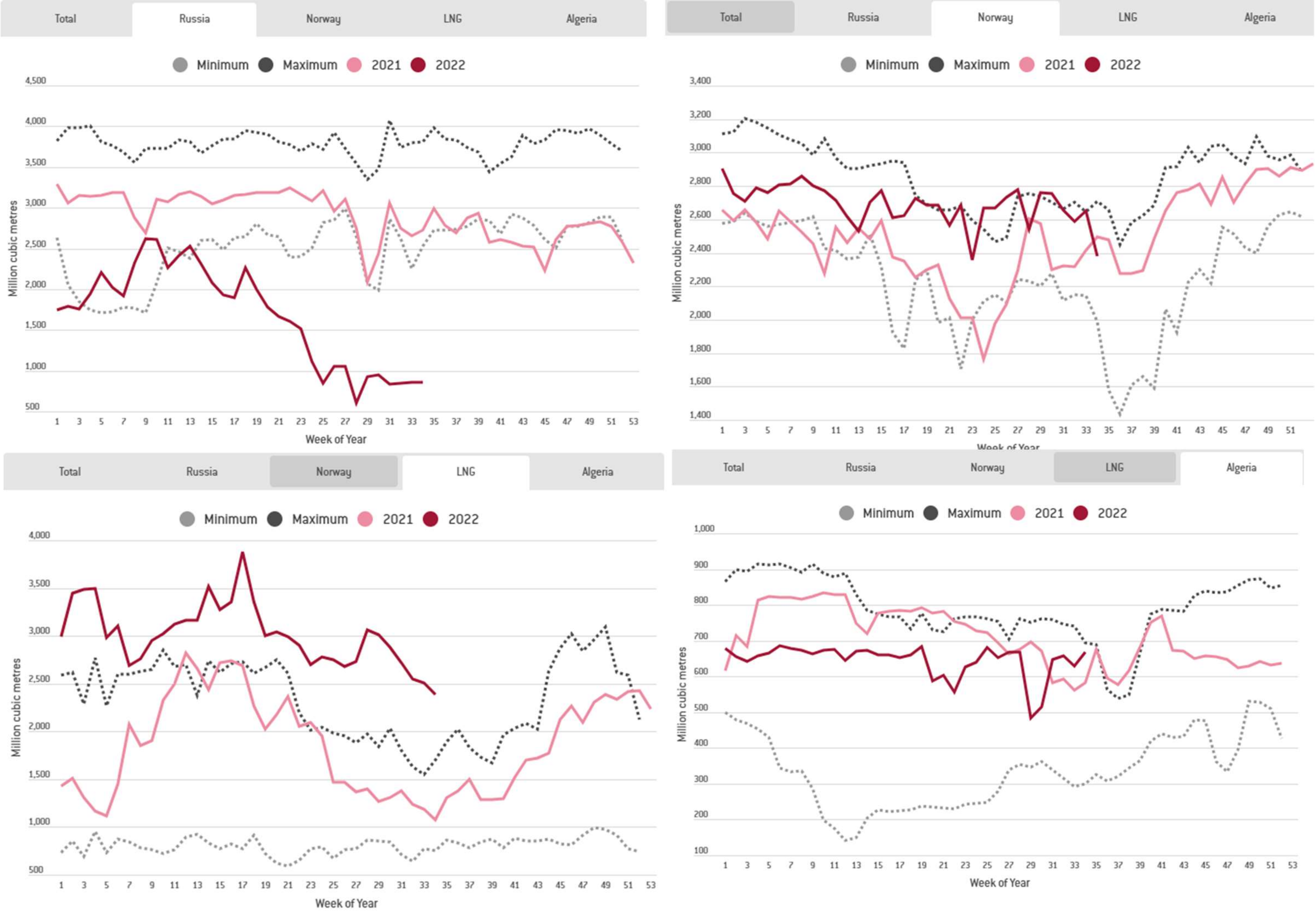


Mineral requirements for clean energy technologies quadruple to 2030 in the NZE Scenario, with particularly high growth for materials for electric vehicles

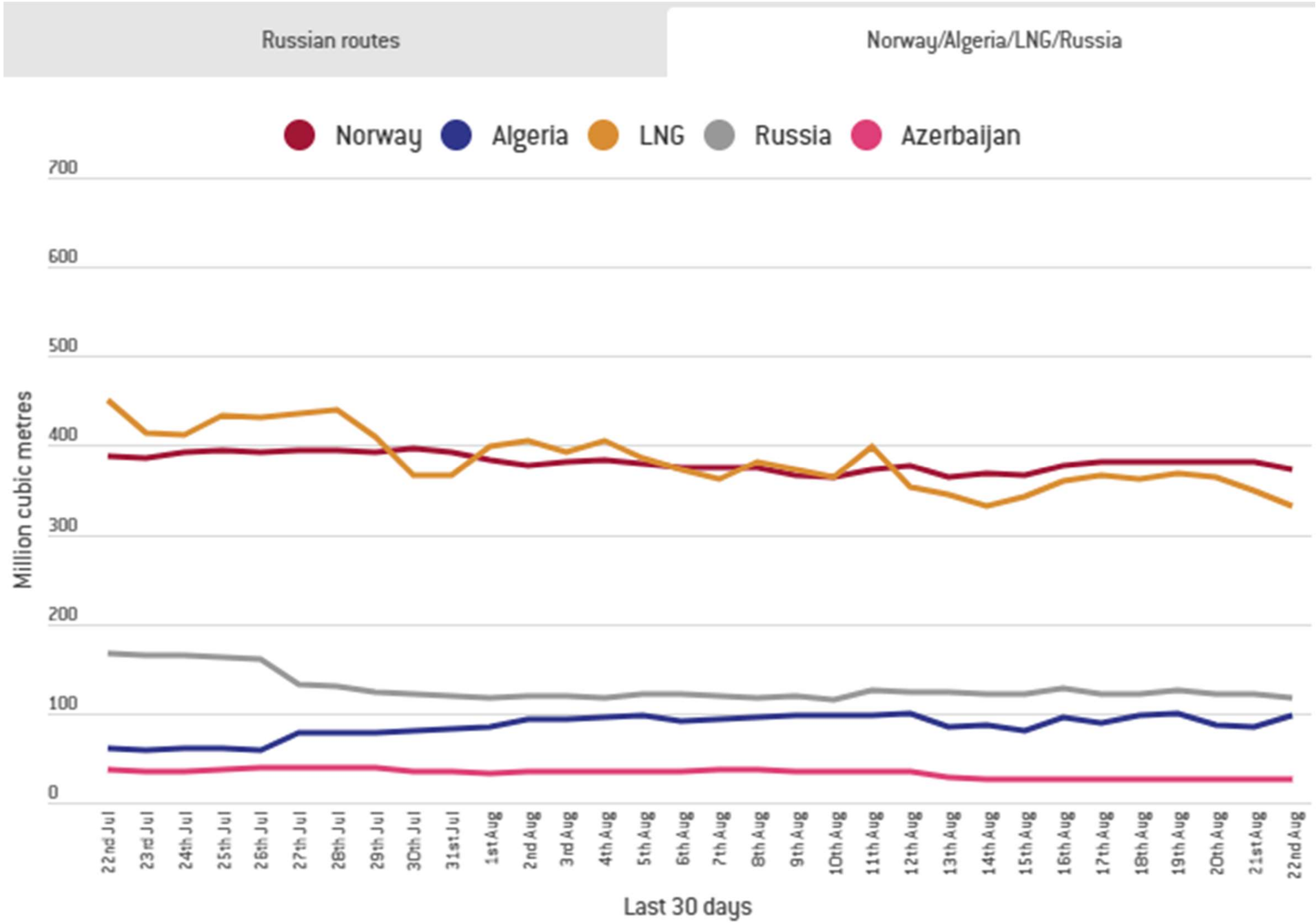
Notes: Mt = million tonnes; EVs = electric vehicles. Includes most of the minerals used in various clean energy technologies, but does not include steel and aluminium. See IEA (2021b) for a full list of minerals assessed.



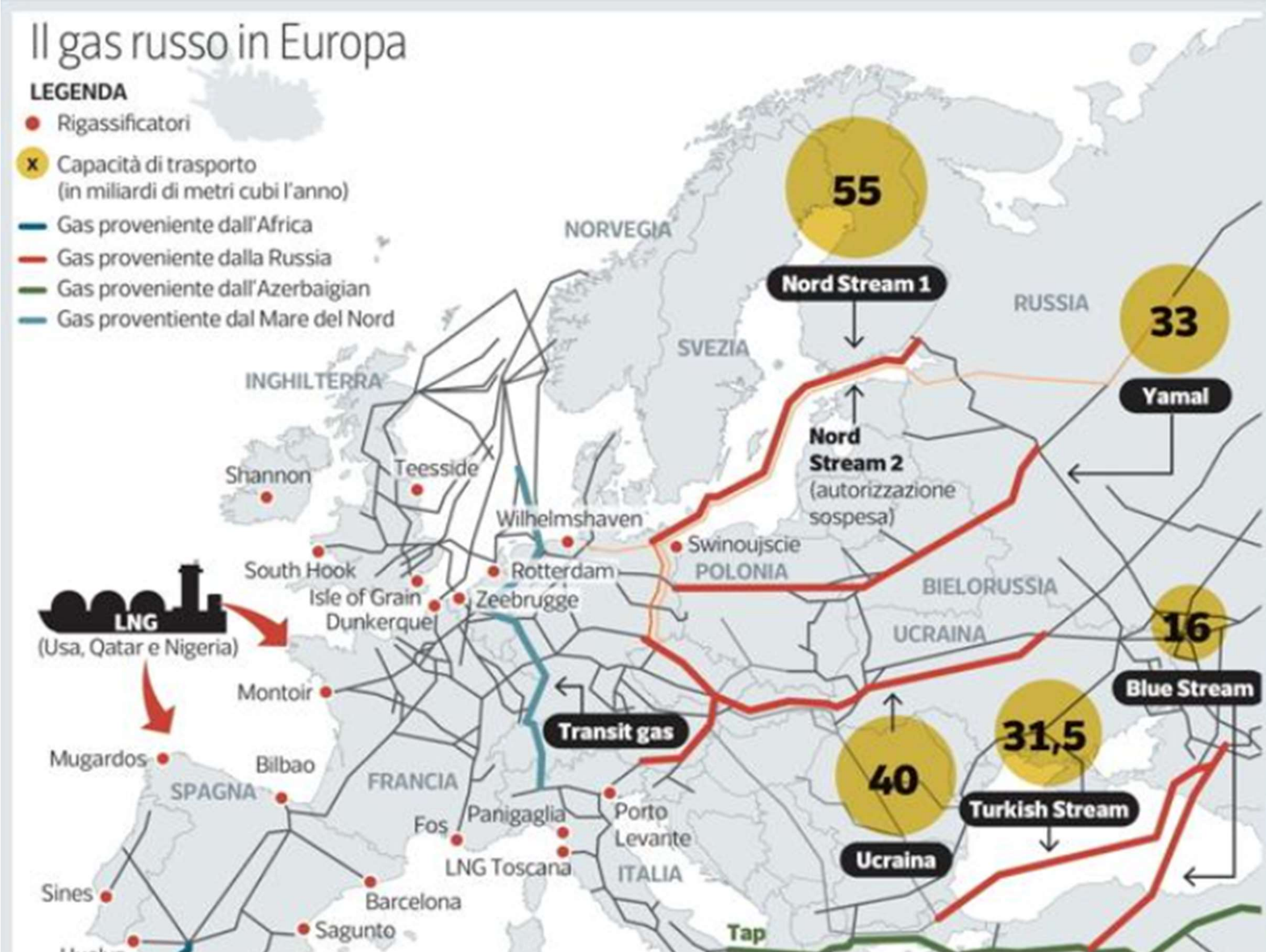
Fonte: Bruegel Gas Database (https://www.bruegel.org/dataset/european-natural-gas-imports)



Fonte: Bruegel Gas Database (https://www.bruegel.org/dataset/european-natural-gas-imports)


Russian routes
Norway/Algeria/LNG/Russia
Norway
Algeria
LNG
Russia
Azerbaijan
Million cubic metres
700
600
500
400
300
200
100
0
22nd Jul
23rd Jul
24th Jul
25th Jul
26th Jul
27th Jul
28th Jul
29th Jul
30th Jul
31st Jul
1st Aug
2nd Aug
3rd Aug
4th Aug
5th Aug
6th Aug
7th Aug
8th Aug
9th Aug
10th Aug
11th Aug
12th Aug
13th Aug
14th Aug
15th Aug
16th Aug
17th Aug
18th Aug
19th Aug
20th Aug
21st Aug
22nd Aug
Last 30 days


I gasdotti verso l'Europa
Rete principale da Russia, Norvegia, Turchia e Africa
gasdotti in attività
gasdotti in progetto
portata in Gm³
109,1
170,6
21,4
Norvegia
Mare del Nord
Danimatca
NORTH STREAM 2
NORTH STREAM 1
NORTHERN LIGHT
Russia
BROTHERHOOD
YAMAL
Polonia
Regno Unito
Olanda
Germania
Slovacchia
Ucraina
PROGRESS
Francia
Austria
Ungheria
SOYUZ
Moldavia
Kazakstan
Romania
Mar Nero
Serbia
Bulgaria
TURKISH STREAM
WHITE STREAM
ITALIA
Albania
BLUE STREAM
Spagna
Grecia
TANAP
Azerbaigian
Mar Caspio
Turkmenista
Turchia
Tunisia
TRANSMED
Algeria
Mar Mediterraneo
EASTMED
Cipro
Iran
GREENSTREAM
Libia


Il gas russo in Europa
LEGENDA
Rigassificatori
x
Capacità di trasporto
(in miliardi di metri cubi l'anno)
Gas proveniente dall'Africa
Gas proveniente dalla Russia
Gas proveniente dall'Azerbaigian
Gas proventiente dal Mare del Nord
NORVEGIA
SVEZIA
RUSSIA
INGHILTERRA
POLONIA
BIELORUSSIA
UCRAINA
FRANCIA
SPAGNA
ITALIA
55
Nord Stream 1
33
Yamal
Nord
Stream 2
(autorizzazione
sospesa)
16
Blue Stream
31,5
Turkish Stream
40
Ucraina
Transit gas
Tap
LNG
(Usa, Qatar e Nigeria)
Shannon
Teesside
Wilhelmshaven
Swinoujscie
South Hook
Rotterdam
Isle of Grain
Zeebrugge
Dunkerque
Montoir
Mugardos
Bilbao
Panigaglia
Porto
Levante
Fos
LNG Toscana
Sines
Barcelona
Sagunto

Gli scenari considerati nel World Energy Outlook

- STATED POLICY SCENARIO (STEPS):
  - si basa sullo stato dell'arte e sugli impegni già sottoscritti
  - Rappresenta già un passo avanti significativo rispetto a «business as usual»
  - Implica una sostanziale trasformazione del mix energetico da realizzare entro il 2060, e una drastica riduzione delle emissioni
  - Implica un riscaldamento di 2,7°C per il 2100, ma ancora in crescita nel periodo successivo
- SUSTAINABLE DEVELOPMENT SCENARIO (SDS):
  - si basa su mix di tecnologie coerenti con obiettivo di contenere il riscaldamento a max 2°C, stabilizzandolo in seguito
  - Implica una riduzione delle emissioni a partire dal 2019, con il raggiungimento della neutralità climatica nel 2070
- FASTER INNOVATION CASE (FIC):
  - si basa sull'applicazione più spinta possibile di tutte le tecnologie attualmente disponibili e sullo sviluppo più rapido possibile dell'innovazione tecnologica
  - Consentirebbe di raggiungere la neutralità climatica nel 2050

Adattamento degli scenari nel WEO22

- In 2021, the IEA published its report Net Zero by 2050: A Roadmap for the Global Energy Sector.
  - However, in the short time since then much has changed.
  - The global economy has rebounded from the Covid-19 pandemic, and the first global energy crisis has seen world energy prices touching record levels in many markets, bringing energy security concerns to the fore.
- In 2021, emissions rose by a record 1.9 Gt to reach 36.6 Gt,
  - driven by extraordinarily rapid post-pandemic economic growth,
  - slow progress in improving energy intensity,
  - and a surge in coal demand even as renewables capacity additions scaled record heights.
  - Recent investment in fossil fuel infrastructure not included in our 2021 NZE Scenario would result in 25 Gt of emissions if run to the end of its lifetime (around 5% of the remaining carbon budget for 1.5 °C).
- Despite these mostly discouraging developments, the pathway detailed in the Net Zero Emissions by 2050 (NZE) Scenario remains narrow but still achievable.
  - This update to the NZE Scenario offers a comprehensive account of how policymakers and others could respond coherently to the challenges of climate change, energy affordability and energy security.
- Between 2021 and 2030, low emissions sources of supply grow by around 125 EJ in the NZE Scenario.
  - This is equivalent to the growth of world energy supply from all sources over the last fifteen years.
  - Among low emissions sources, modern bioenergy and solar increase the most, rising by around 35 EJ and 28 EJ respectively to 2030.
  - Over the period to 2050, however, the largest growth in low-emissions energy supply comes from solar and wind.
  - By 2050, unabated fossil fuels for energy uses account for just 5% of total energy supply: adding fossil fuels used with CCUS and for non-energy uses raises this to slightly less than 20%.
- In the NZE Scenario, electricity becomes the new linchpin of the global energy system, providing more than half of total final consumption and two-thirds of useful energy by 2050.
  - Total electricity generation grows by 3.3% per year to 2050, which is faster than the global rate of economic growth across the period.
  - Annual capacity additions of all renewables quadruple from 290 GW in 2021 to around 1 200 GW in 2030.
  - With renewables reaching over 60% of total generation in 2030, no new unabated coal- fired plants are needed. Annual nuclear capacity additions to 2050 are nearly four- times their recent historical average.
- Increased supplies of clean energy are complemented in the NZE Scenario by measures to save energy, bringing benefits in terms of emissions reductions, affordability and energy security.
  - In the NZE Scenario, energy intensity improvements to 2030 are nearly three times faster than over the past decade.
  - In 2030, energy savings from energy efficiency, material efficiency, and behavioural change amount to around 110 EJ, equivalent to the total final consumption of China today.

Adattamento degli scenari nel WEO22

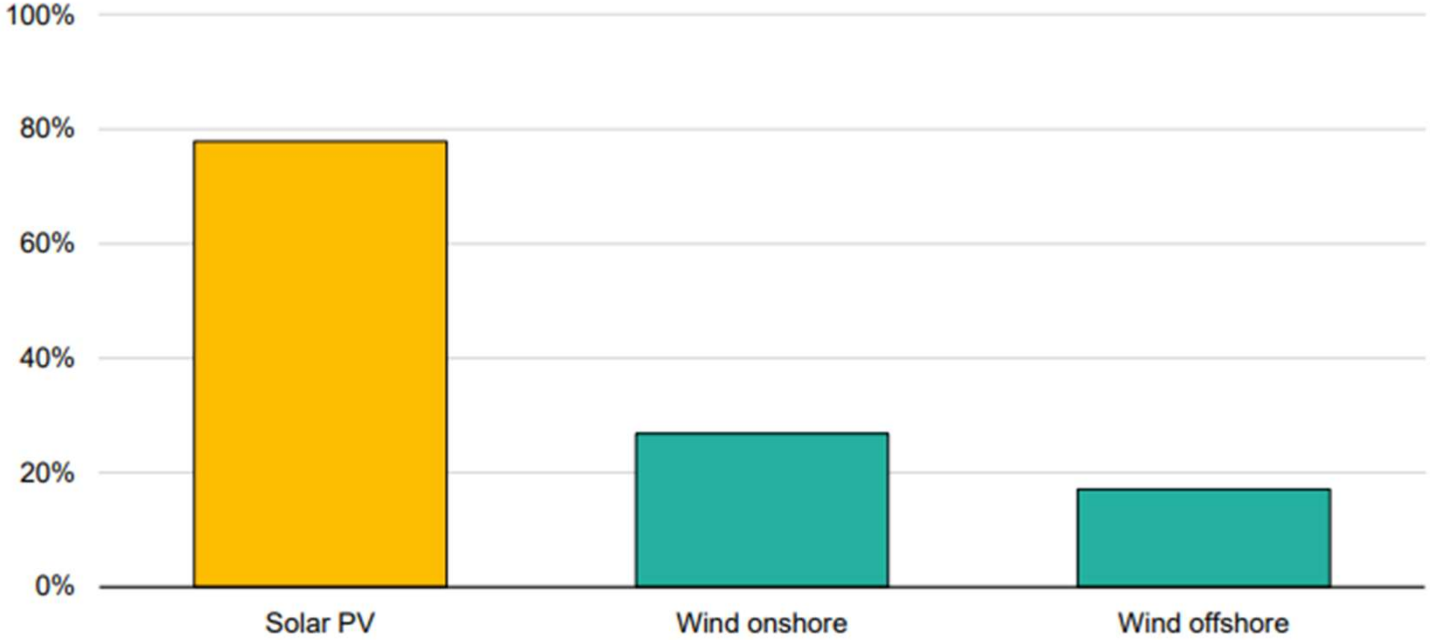
- End-use sectors all achieve emissions reductions of over 90% by 2050.
    - Hydrogen and hydrogen-based fuels are deployed in heavy industry and long-distance transport, and their share in total final consumption reaches around 10% in 2050.
    - Bioenergy use is kept to around 100 EJ in the interests of sustainability and reaches around 15% of total final consumption in 2050.
    - CO2 capture totals 1.2 Gt in 2030, rising to 6.2 Gt in 2050, and more than 60% of this occurs in industry and other fuel transformation sectors.
- The NZE Scenario requires a large increase in investment in clean energy.
    - Energy investment accounted for just over 2% of global GDP annually between 2017 and 2021, and this rises to nearly 4% by 2030 in the NZE Scenario.
    - Electricity generation from renewables sees one of the largest increases, rising from USD 390 billion in recent years to USD 1 300 billion by 2030.
    - This level of spending in 2030 is equal to the highest level ever spent on fossil fuel supply (USD 1.3 trillion spent on fossil fuels in 2014).
- There are some positive indications that clean energy technology is now rapidly scaling up.
    - Announced EV battery production capacity for 2030 is only 15% lower than the level of battery demand underpinning the NZE Scenario in the same year,
    - announced expansions of solar PV production capacity would be essentially sufficient to achieve the level of deployment envisaged in the NZE Scenario, if they are successfully delivered on time.
    - Assuming full implementation of all announced manufacturing capacity expansions including speculative projects, the cumulative output of electrolyser manufacturing capacity could reach 380 GW by 2030, which is still little more than half of 2030 needs in the NZE Scenario.
- There are however many areas where progress is well short of what is envisaged in the NZE Scenario.
    - The path to success requires policy makers to do much more to provide signals on the demand side, to develop the clean technology supply chain as a whole, to ensure that supply chains are diverse and resilient, and to promote the coordinated growth of different parts of particular supply chains.
- Total energy sector employment increases from just over 65 million today to 90 million in 2030 in the NZE Scenario.
    - New jobs in clean energy industries reach 40 million by 2030, outweighing job losses in the fossil fuel-related industries.
    - Fossil fuel supply jobs decrease by 7 million by 2030 in the NZE Scenario, with coal supply seeing the sharpest decline as mechanisation and decarbonisation efforts lead to further downsizing of the industry.
    - Shortages of skilled labour in clean energy construction projects are already starting to be seen, underlining the importance of strategic and proactive labour policies to build up the workforce needed for the rapid expansion of clean energy technologies.

GLI OSTACOLI

Le energie rinnovabili sono la soluzione?

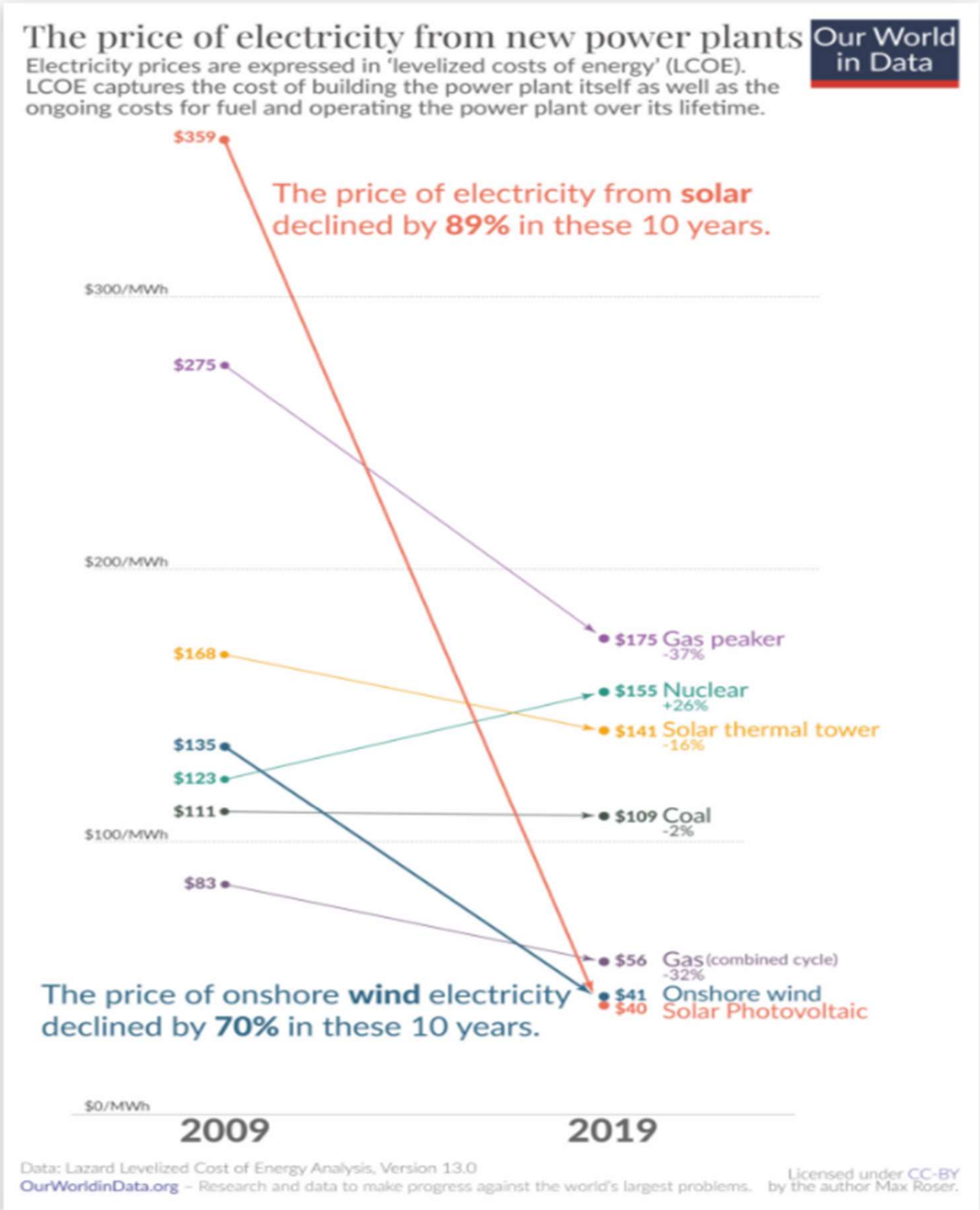
- Progressi superiori alle attese
    - I costi di investimento e unitari sono diminuiti in modo spettacolare, raggiungendo la competitività con le fonti fossili
    - Potenziale di sviluppo molto grande (es. superficie tetti e facciate in Italia è pari a oltre 1000 kmq, quelli attualmente utilizzati per impianti solari sono solo una piccola frazione
- Alcune caratteristiche da non dimenticare
    - Le rinnovabili non sono programmabili; serve capacità alternativa in grado di attivarsi all'occorrenza (gas)
    - In ogni caso non si produce dal solare di notte!
    - Le rinnovabili sono «estensive»: consumo di suolo, impatto sul paesaggio, water-energy-food nexus
    - Nei costi della «generazione distribuita» va contabilizzato anche quello per rifare le reti di distribuzione e trasporto
    - Anche le rinnovabili comportano emissioni (estrazione e/o riciclo dei materiali, produzione di impianti e attrezzature, etc)
    - Per le FER e per le batterie servono materiali scarsi o «geopoliticamente problematici»
- Alcuni rimedi possibili
    - Considerare anche altre fonti «carbon free», es. nucleare
    - Investire nello stoccaggio (batterie)
    - Usare eccedenza capacità per generare idrogeno e altri carburanti «puliti»

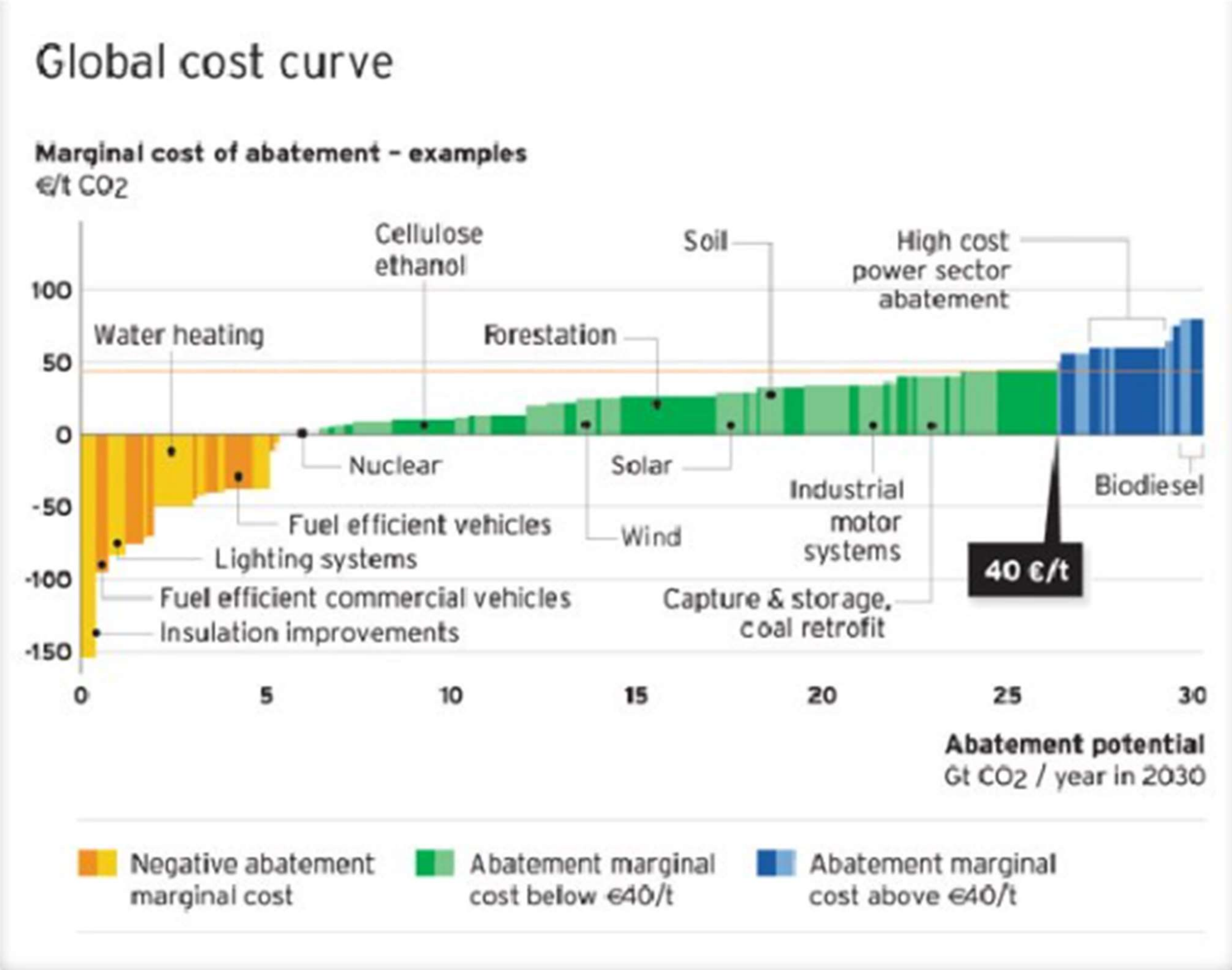
Figure 1.5 Reduction in capital cost since 2010 for PV and wind power generation technologies



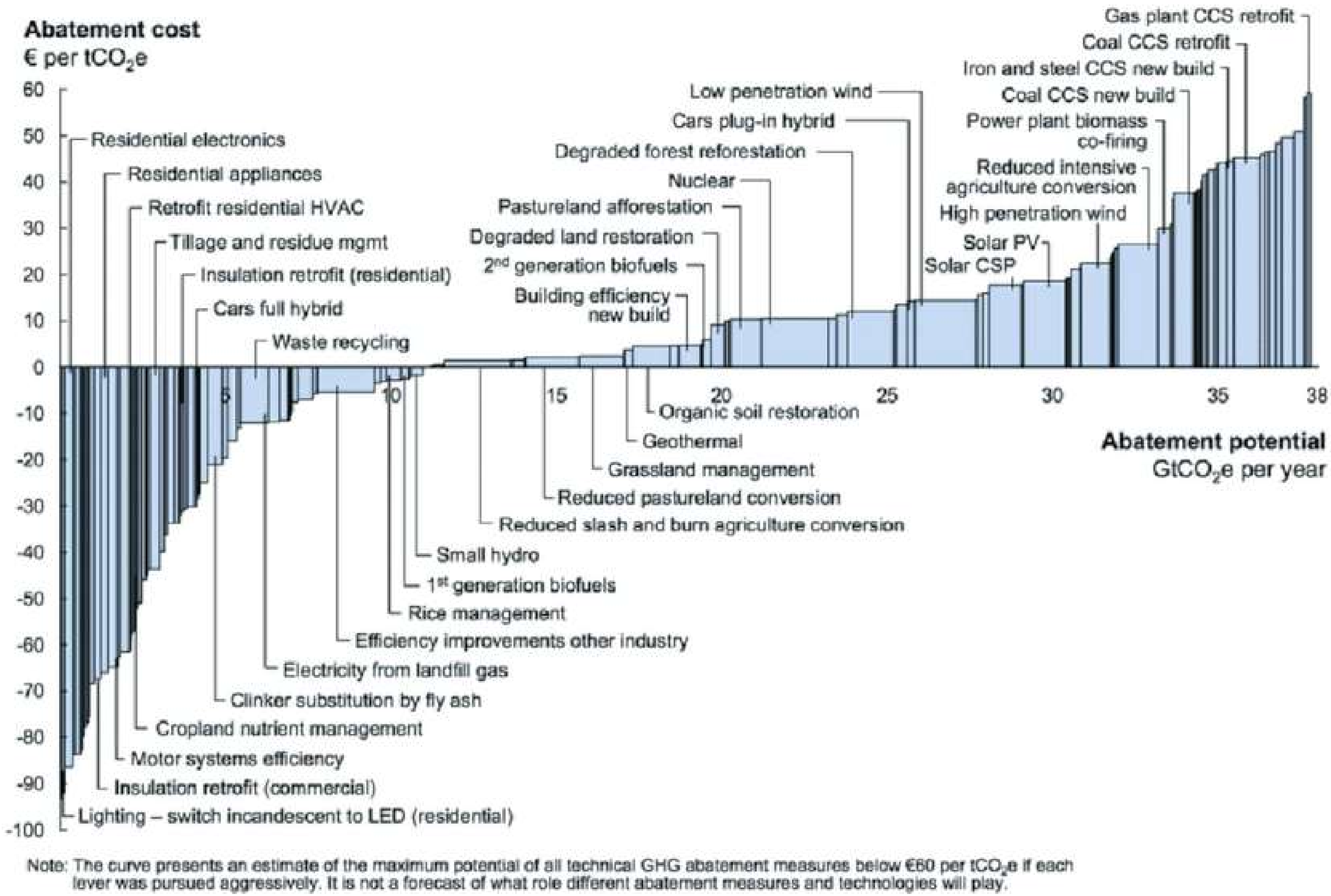
Source: Based on IEA (2019b).

Significant cost reductions in solar PV and wind technologies have led to a major shift in investment and a rapid transformation of the generating mix.


The price of electricity from new power plants
Our World in Data
Electricity prices are expressed in 'levelized costs of energy' (LCOE).
LCOE captures the cost of building the power plant itself as well as the ongoing costs for fuel and operating the power plant over its lifetime.
$359
The price of electricity from solar declined by 89% in these 10 years.
$300/MWh
$275
$200/MWh
$175 Gas peaker
-37%
$168
$155 Nuclear
+26%
$141 Solar thermal tower
-16%
$135
$123
$111
$109 Coal
-2%
$100/MWh
$83
$56 Gas (combined cycle)
-32%
The price of onshore wind electricity declined by 70% in these 10 years.
$41 Onshore wind
$40 Solar Photovoltaic
$0/MWh
2009
2019
Data: Lazard Levelized Cost of Energy Analysis, Version 13.0
OurWorldinData.org – Research and data to make progress against the world's largest problems.
Licensed under CC-BY by the author Max Roser.



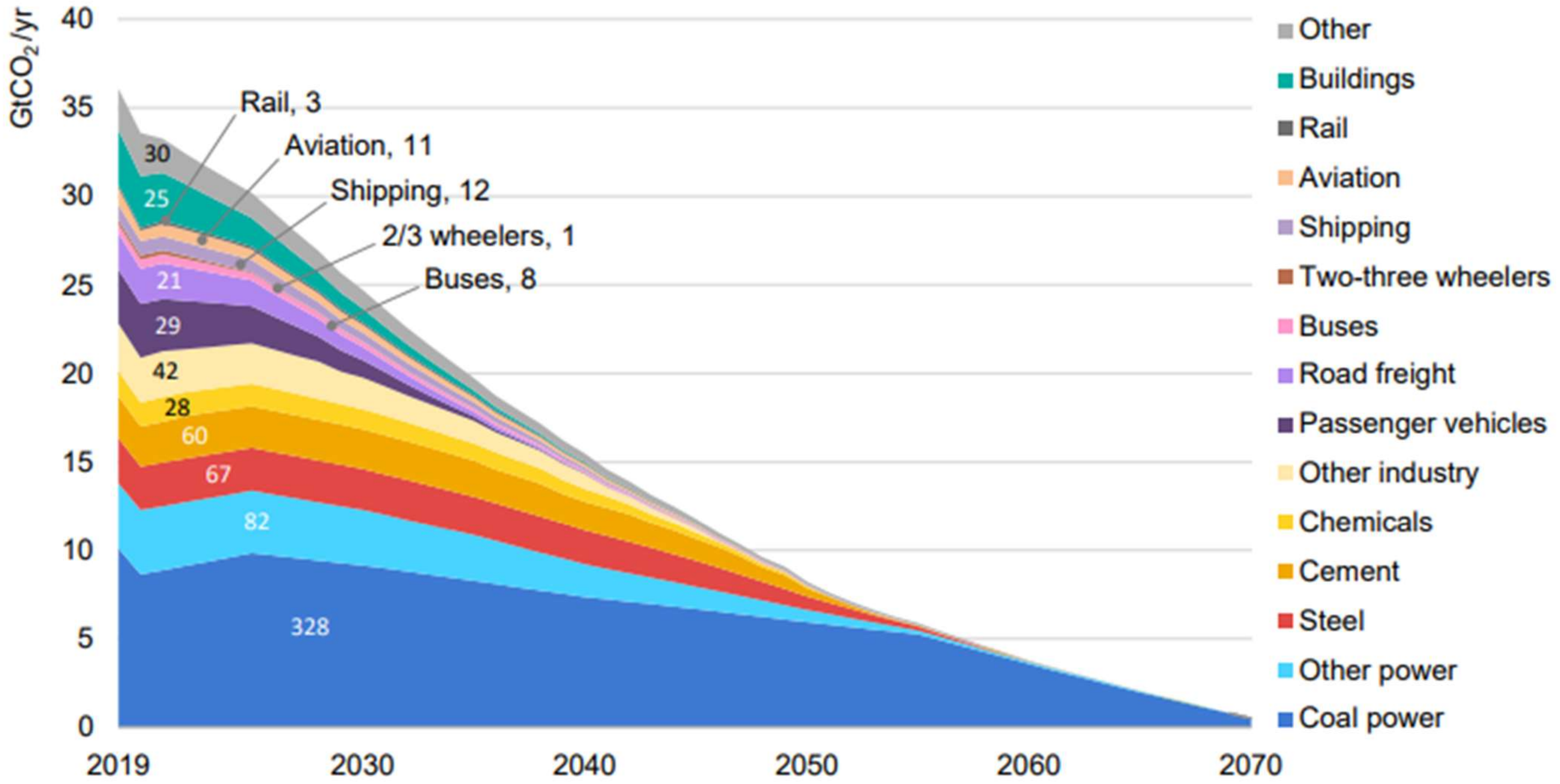
Source: McKinsey



Source: McKinsey

IMPATTI SUL PAESAGGIO…

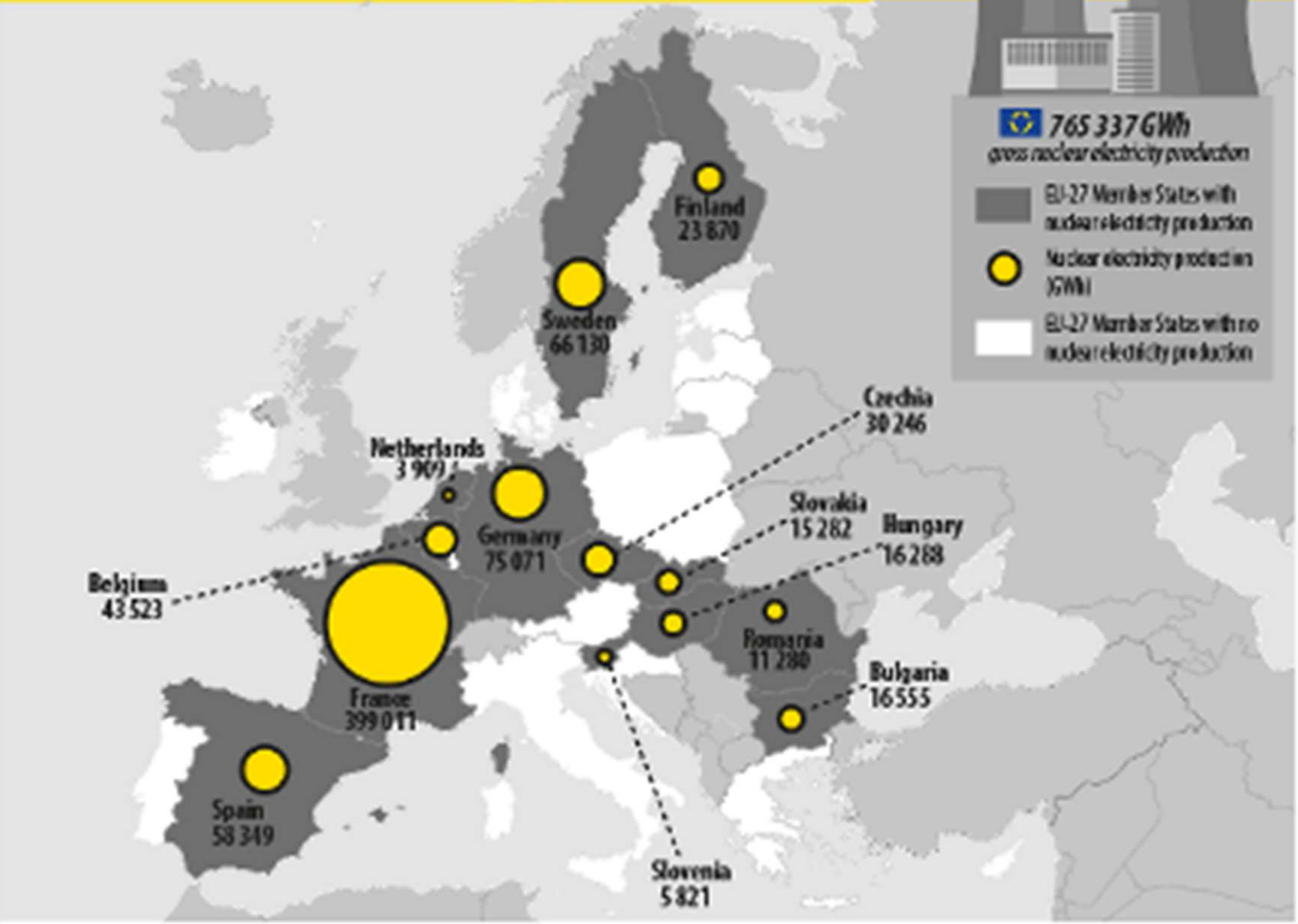
Figure 1.11 Global CO_2 emissions from existing energy infrastructure by sub-sector, 2019-70



Notes: Includes assets under construction in 2019, the base year of this analysis. Numeric area labels on the graph denote cumulative emissions quantities by sub-sector in $GtCO_2$. Analysis includes industrial process emissions, and emissions are accounted for on a direct basis. Annual operating hours over the remaining lifetime are based on the level in 2019.

Assuming typical lifetimes and operating regimes, cumulative emissions from existing energy infrastructure could reach nearly 750 $GtCO_2$ by 2070.

Nuclear energy in the EU



14 EU Member States without nuclear electricity production:

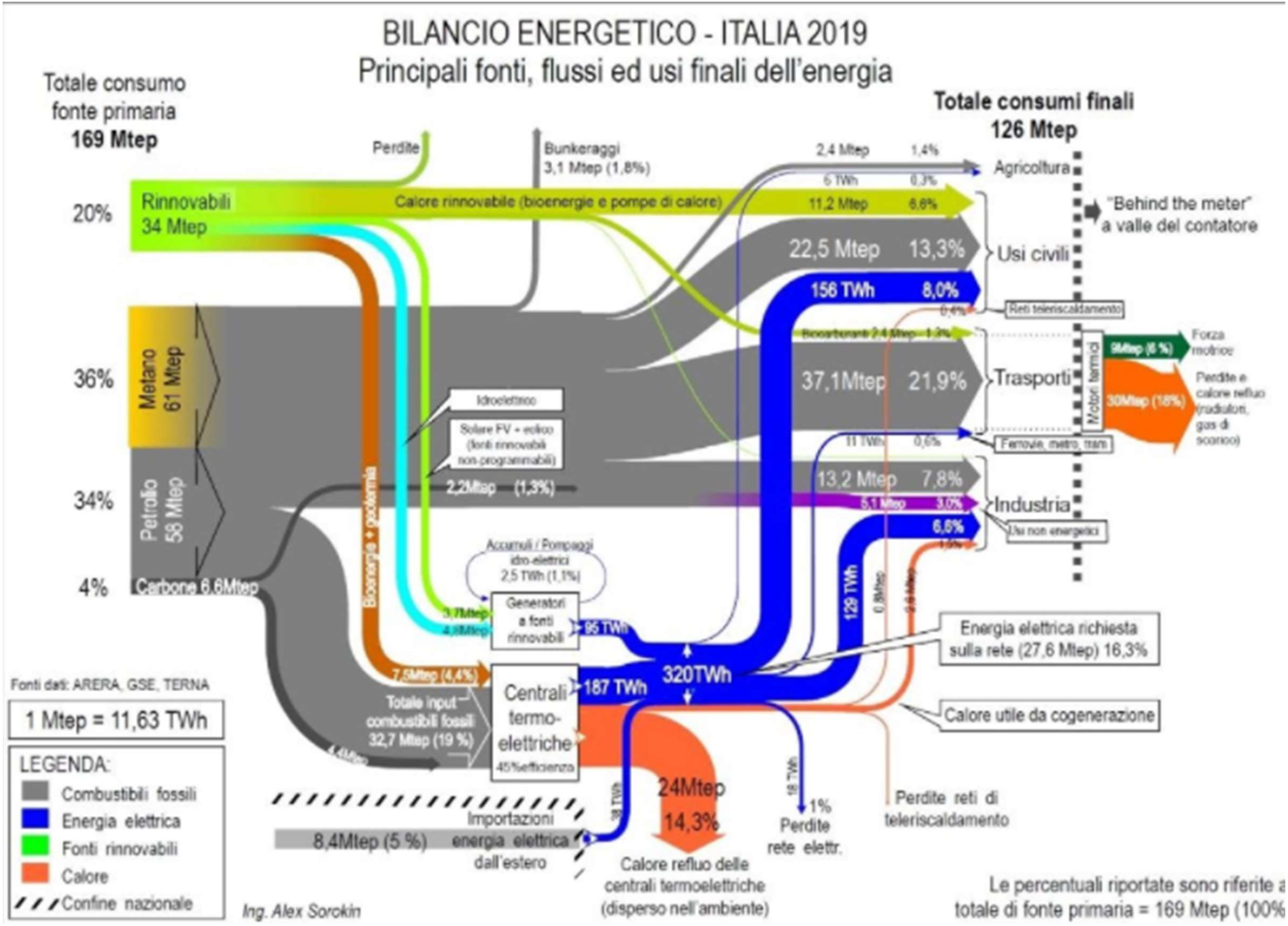
Denmark, Estonia, Ireland, Greece, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Malta, Austria, Poland, Portugal.

Data for 2019.

Source: Eurostat (nrg_ind_nuc)

ec.europa.eu/eurostat

UNO SGUARDO ALL'ITALIA


BILANCIO ENERGETICO - ITALIA 2019
Principali fonti, flussi ed usi finali dell'energia
Totale consumo fonte primaria
169 Mtep
Totale consumi finali
126 Mtep
Perdite
Bunkeraggi
3,1 Mtep (1,8%)
20%
Rinnovabili
34 Mtep
Calore rinnovabile (bioenergie e pompe di calore)
2,4 Mtep 1,4%
6 TWh 0,3%
11,2 Mtep 6,6%
Agricoltura
"Behind the meter"
a valle del contatore
22,5 Mtep 13,3%
Usi civili
156 TWh 8,0%
0,4%
Reti teleriscaldamento
36%
Metano
61 Mtep
Biocarburanti 2,4 Mtep 1,3%
Forza motrice
9Mtep (6 %)
37,1Mtep 21,9%
Trasporti
Motori termici
30Mtep (18%)
Perdite e calore refluo (radiatori, gas di scarico)
Idroelettrico
Solare FV + eolico
(fonti rinnovabili
non-programmabili)
11 TWh 0,6%
Ferrovie, metro, tram
34%
Petrolio
58 Mtep
2,2Mtep (1,3%)
13,2 Mtep 7,8%
5,1 Mtep 3,0%
Industria
6,6%
Usi non energetici
1,5%
4%
Carbone 6,6Mtep
Bioenergie + geotermia
Accumuli / Pompaggi
idro-elettrici
2,5 TWh (1,1%)
3,7Mtep
4,8Mtep
Generatori
a fonti
rinnovabili
95 TWh
129 TWh
0,8Mtep
2,6 Mtep
Energia elettrica richiesta
sulla rete (27,6 Mtep) 16,3%
320TWh
7,5Mtep (4,4%)
Centrali
termo-
elettriche
45%efficienza
187 TWh
Totale input
combustibili fossili
32,7 Mtep (19 %)
4,4Mtep
Calore utile da cogenerazione
Fonti dati: ARERA, GSE, TERNA
1 Mtep = 11,63 TWh
LEGENDA:
Combustibili fossili
Energia elettrica
Fonti rinnovabili
Calore
Confine nazionale
38 TWh
8,4Mtep (5 %)
Importazioni
energia elettrica
dall'estero
24Mtep
14,3%
Calore refluo delle
centrali termoelettriche
(disperso nell'ambiente)
18 TWh
1%
Perdite
rete elettr.
Perdite reti di
teleriscaldamento
Ing. Alex Sorokin
Le percentuali riportate sono riferite a
totale di fonte primaria = 169 Mtep (100%

La sfida della transizione energetica in Italia

- La situazione attuale
  - Mix energetico: 20% elettrico, il resto è quasi tutto fossile
  - Energia elettrica prodotta con mix di rinnovabili (28,0%, 42,7% contando anche import) e fossili (57,3%)
- Elettrificazione
  - Obiettivo: passare da 20% a 55% di elettrico su totale
  - Significa raddoppiare l'attuale capacità di generazione! Da 320 a 650 TWh/anno
  - Per ipotizzare di fare tutto ciò con le rinnovabili, tenendo conto anche della necessità di «ridondanza», bisognerebbe installare 20 GW all'anno per i prossimi 30 anni!
  - Il PEN ne prevede per ora «solo» 70 da realizzare entro il 2030
  - Peraltro, attualmente, ne installiamo meno di 1 GW/anno!!
  - I siti «meno problematici» sono stati sfruttati per primi ⇔ crescente conflittualità con paesaggio, consumo di suolo etc

La sfida della transizione energetica in Italia

- La capacità di accumulo
  - Servirebbero solo per l'Italia batterie di accumulo in grado di stoccare almeno 1 TWh; vanno sostituite ogni 10 anni
  - Senza contare la domanda di batterie per auto elettriche etc
  - Attualmente installati: 120 MW
  - La produzione mondiale di batterie è attualmente pari a 1/3 di questa cifra!
- Gli obiettivi sono poco realistici, a meno che:
  - Non si contemplino anche altre strade, attualmente meno considerate (o non considerate per nulla): nucleare, CCS, solare termodinamico, biocarburanti alternativi, eolico offshore
  - Non si contemplino strategie fondate (anche) sull'importazione
  - Non si ricorra a sistemi di incentivazione più massicci (con conseguenze inevitabili su costo energia!)

Farla facile

- Tendenze inerziali: il consumo globale di energia è sempre in aumento (e accelerazione)
  - Domanda mondiale: da 1995 a 2015 passa da 4,5 a 13,1 Btep
  - Nel ventennio precedente, aumento di «soli» +2,8
  - Gran parte dell'aumento è dovuto alla domanda dei PVS, mentre quella dei paesi sviluppati si contrae anche grazie a maggiore efficienza energetica
- Invertire questo trend richiede una rivoluzione economica, tecnologica e sociale
  - Condizioni istituzionali straordinarie
  - Soluzione di trade-off sostanziali, di cui manca la consapevolezza nelle autorità chiamate a governarle

Interrogativi decisivi ma ancora irrisolti

- Lock-in tecnologico e path dependence
  - Sunk cost dei precedenti investimenti
  - Rigidità strutturali vincolano lo stock di capitale articolato in una miriade di unità e organizzazioni socio-economiche che su queste si sono modellate
- Chi decide cosa fare?
  - Il mercato è guidato dalle libere scelte degli individui, orientate dalla ricerca del profitto e del benessere individuale
  - Lasciare che sia il mercato a farlo presuppone che la domanda dei cittadini si orienti «spontaneamente» verso
  - Viceversa, se deve farlo lo stato (anche contro la volontà dei cittadini) presuppone una capacità di governo, una legittimazione a decidere e una continuità bipartisan durevole nel tempo
  - Esempio: il Piano Net Zero 2050 di Parigi

Interrogativi decisivi ma ancora irrisolti

- Chi paga?
  - Se riversato sui consumatori finali, l'impatto potrebbe essere dirompente nel breve-medio termine (con evidenti problemi di tenuta sociale e di consenso politico)
  - Impatto sottovalutato soprattutto nei PVS, ma anche nei PS
  - Stiglitz-Stern (e Roventini in Italia): spesa pubblica in deficit potrebbe ripagarsi grazie al potenziale di generazione di crescita economica
- Geopolitica materie prime
  - Fornitura concentrata nelle mani di pochi paesi (Cina in particolare)
  - «Urban mining» può avere ruolo significativo ma ancora non decolla (solo questione di prezzi?)
- Ruolo del mercato: torniamo ai monopoli pubblici?
  - Politica industriale orientata al «reshoring» delle industrie strategiche per la transizione

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Due parole sulla montagna

- Opportunità
  - Idroelettrico (ma nel 2022 -37%!!) ⇔ ruolo strategico dei bacini per lo stoccaggio
    - Potenziale largamente sfruttato in ITA
    - CH prevede sviluppo di impianti a bacino per ulteriori 2TWh per il 2040
  - Sviluppo di PV e W in aree vocate
  - Biomasse (CCUS + fonte rinnovabile)
  - Fonti non tradizionali (geotermia; pompe di calore ad aria)
  - Efficienza energetica (es. uso del legno nelle costruzioni)
  - L'esperienza delle «cooperative storiche»
- Rischi
  - Cambiamenti climatici incidono su risorse energetiche «montane»
  - Impatto sul paesaggio (CIPRA già sul piede di guerra!)
  - «Generazione distribuita» vs. «generazione immessa nelle reti di distribuzione» ⇔ necessità di ricostruire le reti di distribuzione
  - Nuove reti di trasporto e interconnessione: analogia con vie di comunicazione?
  - Innamorarsi di modelli «romantici» e autarchici può essere pericoloso

The solar plant on Muttsee dam (under construction here) reaches maximum output when snow reflects sunlight onto the cells

Run-of-river power plants like the one in Wildegg-Brugg meet 35 per cent of Switzerland's electricity needs but generate three-quarters of their electricity between May and October.

Fonti

- UN, Sustainable Development Goals, www.sdg.org
- IEA, World Energy Outlook 2021
- IEA, Energy technology Perspectives 2020
- Our World in Data

Energia e sviluppo sostenibil[illegible] alla ricerca di una strada p[illegible]ile

GRAZIE PER L'ATTENZIONE

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Appunti seminario Roventini CIMET

- Studio Sant'Anna: costi causati da CC in aumento
- Impatto dovuto non solo a «t media», ma a variazioni repentine della t
- IPCC: situazione disperata, ma non completamente persa, ma occorre cambiamento strutturale, non possiamo limitarci ad aggiungere nuove fonti di energia ma sostituire quelle esistenti
- Ma allora perché Nordhaus (es) dice che la t ottimale è 3,5-4 °C? errore nei modelli di crescita statici:
    - sottostimano impatti (distribuz eventi futuri ignota; cigni neri in abbondanza, tipping points)
    - Sottostimano benefici (disoccupazione, innovazione, cambiamento tecnologico, rendimenti di scala etc) <=> sono tutti modelli di piena occupazione
    - Tasso di sconto inadeguato
    - Non tengono conto di effetti distributivi intra- ed intergenerazionali
    - Non tiene conto di isteresi ⇔ shock che modificano in modo strutturale il PIL di pieno impiego e la crescita del PIL potenziale
- Opportunità della transizione
    - Uscire dalla stagnazione secolare ⇔ nuovo traino alla crescita
    - Occasione simile a «economia di guerra»
    - Stern e Stiglitz, 2023: Tackling cc can unleash higher growth for the coming 2-3 decades
    - Stern 2023: « … indeed the only sustainable story of growth»
    - «è una guerra, non può essere lasciata al mercato» (Der Spiegel, Hatte Marx doch recht?
    - Politiche «market friendly» sono insufficienti, serve nuovo ruolo per lo stato per fare investimenti, regolamentazioni, politiche di innovazione, R&S, green industrial policy
    - Keynes 1926: lo stato non deve fare quello che la gente già fa e correggere market failures, ma quelle che al presente non vengono fatte da nessuno
    - IEA: investimenti devono salire almeno de. 2% entro il 2030
    - Stern e Stiglitz 2023 Tabella con potenziale moltiplicativo degli investimenti pubblici green
- Green industrial policies
    - Ruolo chiave di PI nello sviluppo dei paesi late-comers, da Germania a Giappone, Corea, Cina
    - Non vuol dire per forza «dirigismo». Non stato-padrone ma guida (es. Ilzetky 2023 su effetti di Apollo etc Kantor e Whalley
    - Argomento che lo stato spreca è sbagliato, perché sappiamo già cosa andrebbe fatto: elettrificare, rinnovabili, bloccare caldaie a gas, phaseout (e non incentivi come 110% a chi cambia la caldaia), mobilità elettrica. Roadmap la mostra già IEA
- Non esiste «neutralità tecnologica»
    - Costi del solare ed eolico sono diminuiti al di sotto, prezzi di altre in aumento, anche batterie hanno prezzi in diminuzione
    - Rinnovabili sono anche più coerenti con indipendenza energetica

Appunti seminario Roventini CIMET

- Costruire filiere verdi: solare, eolico, batterie, pompe di calore, fuel cell hanno ora il principale centro di produzione in Cina. Anche qui siamo paradossalmente late comers
- Eventuali sussidi devono essere condizionati
- Re-shoring (es. giga factory pannelli solari)
- IEA afferma necessità di forte ruolo dei governi
- Anche settori «hard to abate» (cemento, acciaio, plastica, mobilità) richiedono forte mobilitazione risorse pubbliche
- IEA: capacità esistente e pianificata in molti settori chiave si sta già assestando (pannelli solari), ma non in tutti (fuel cell, eolico offshore, batterie, pompe di calore.
- Italia
    - Non messa così male. CREF (Sbardella 2022) mostra imprese italiane ben posizionate nell'export globale
    - Forte ruolo delle imprese pubbliche (ENEL: centrali integrate, Terna: elettrodotti sottomarini, Saipem: parti offshore)
    - ENI è ostacolo alla transizione perché vuole spingere solo su gas (e, al limite, carburanti sintetici) e rema contro
    - Stato mira più ad incassare dividendi che a fare politica industriale (contra, proposta n.3 Forum Disuguaglianza Diversità)
    - Necessità di fare sistema usando impresa pubblica come traino
    - Esempio: progetto svedese HYBRIT per acciaio verde fatto con idrogeno: JV di SAAB, Vattenfall, Sandvik, Università. Mette insieme D e S di acciaio
- IEA: potenziale di creazione di posti di lavoro con decarbonizzazione da 32 a 70 mln posti di lavoro (e con stipendi migliori, specie per occupazioni a basso livello di istruzione
- E' una distruzione creatrice alla Schumpeter! Settore auto dovrà ricollocare gran parte della sua forza lavoro, almeno 60%
- Attenzione però: non possiamo scegliere se farla o no. Chi oggi difende posti nel breve periodo arriverà tardi per l'ennesima volta
- Sfruttare le crisi aziendali (es. caso GKN di Firenze, produceva semiassi, S. Anna l'ha aiutata a ricollocarsi nel settore rinnovabili, piano è rimasto lettera morta).
- Flessibilizzazione del lavoro non è servita a niente!! Lo dice anche Bankitalia, FMI (Hoffmann), ha aumentato disuguaglianze ma non ha creato lavoro né ricchezza. Serve ad es. salario minimo, no ai contratti pirata e contratti a termine. Transizione verde va in questa direzione.

Appunti seminario Roventini CIMET

- Chi paga?
- Se è vero che investimenti verdi possono cambiare sentiero di crescita di LP, si ripaga da solo nel lungo periodo
- Nel breve:
    - Tassazione extra profitti
    - Green tax reform progressiva
    - Chancel (2021): emissioni del 50% più povero sono già basse e in linea con obiettivi 2030, sono le emissioni del 10% più ricco a doversi ridurre. Tassare i redditi, i patrimoni? O tassare progressivamente i consumi energetici?
    - «NGEU permanente»
    - CDP brasiliana: creare fondi di investimento pubblici vincolati ad investire in green economy
- «Ultima chiamata» per l’Italia?

https://www.youtube.com/watch?v=Sm5kFXpJc9k&ab_channel=CARTONIMORTI