Scaling-Up Low-Carbon Energy and Industry

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MIT Global Change Forum
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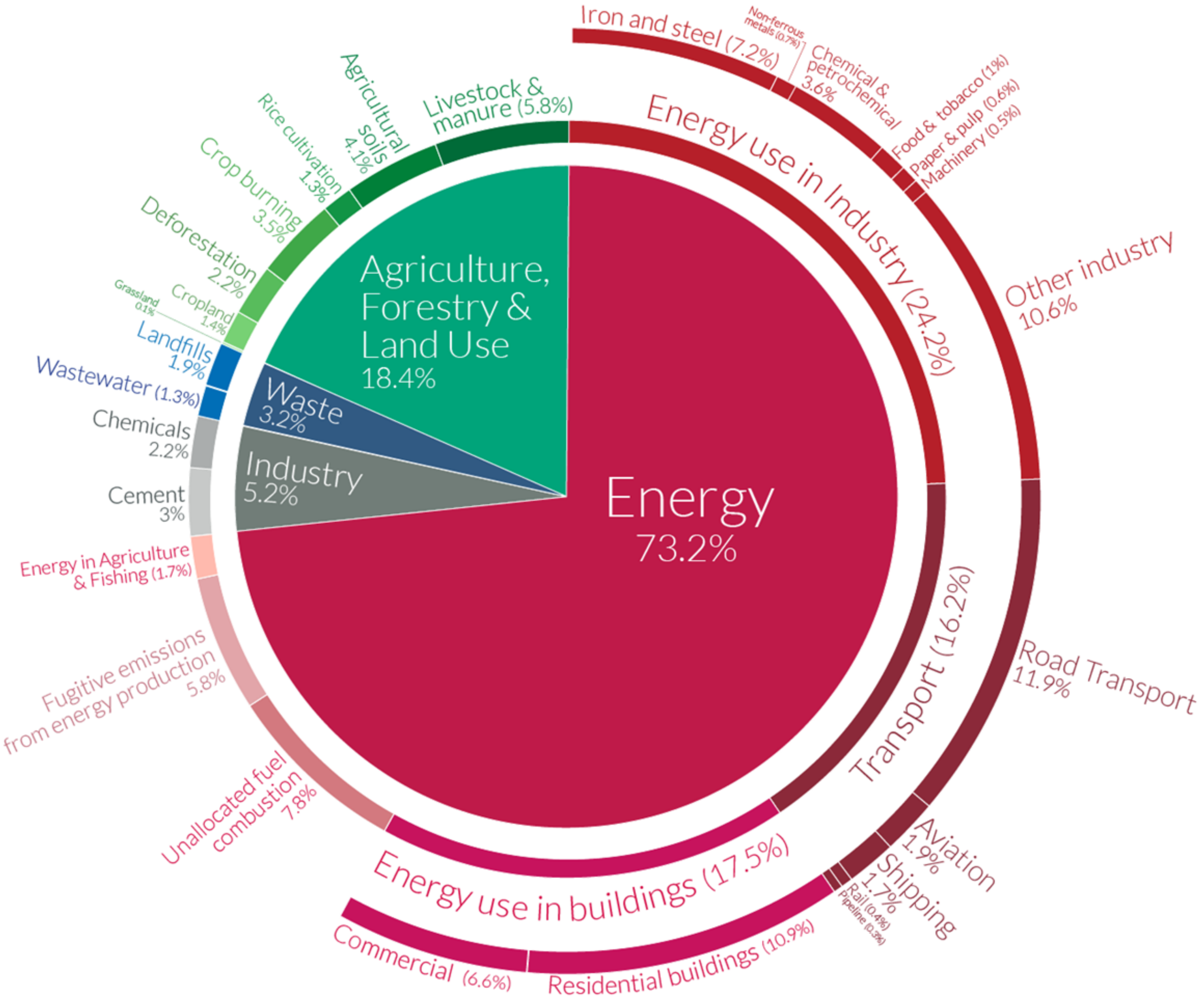
Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

Our World in Data



OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020).

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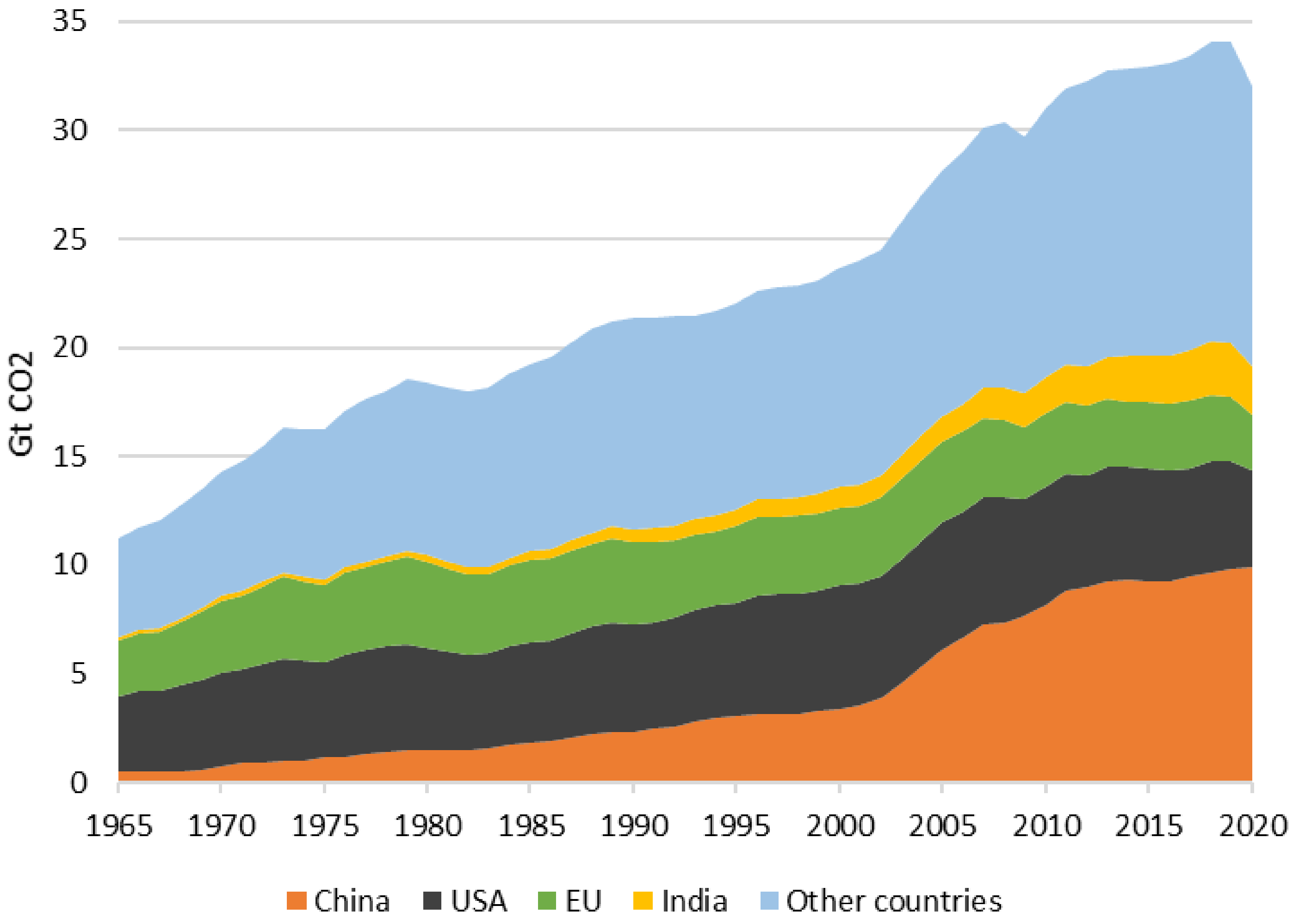
Global Energy-related CO_2 Emissions (1965-2020)



2020

Rest of the world – 40%

India – 7%

EU – 8%

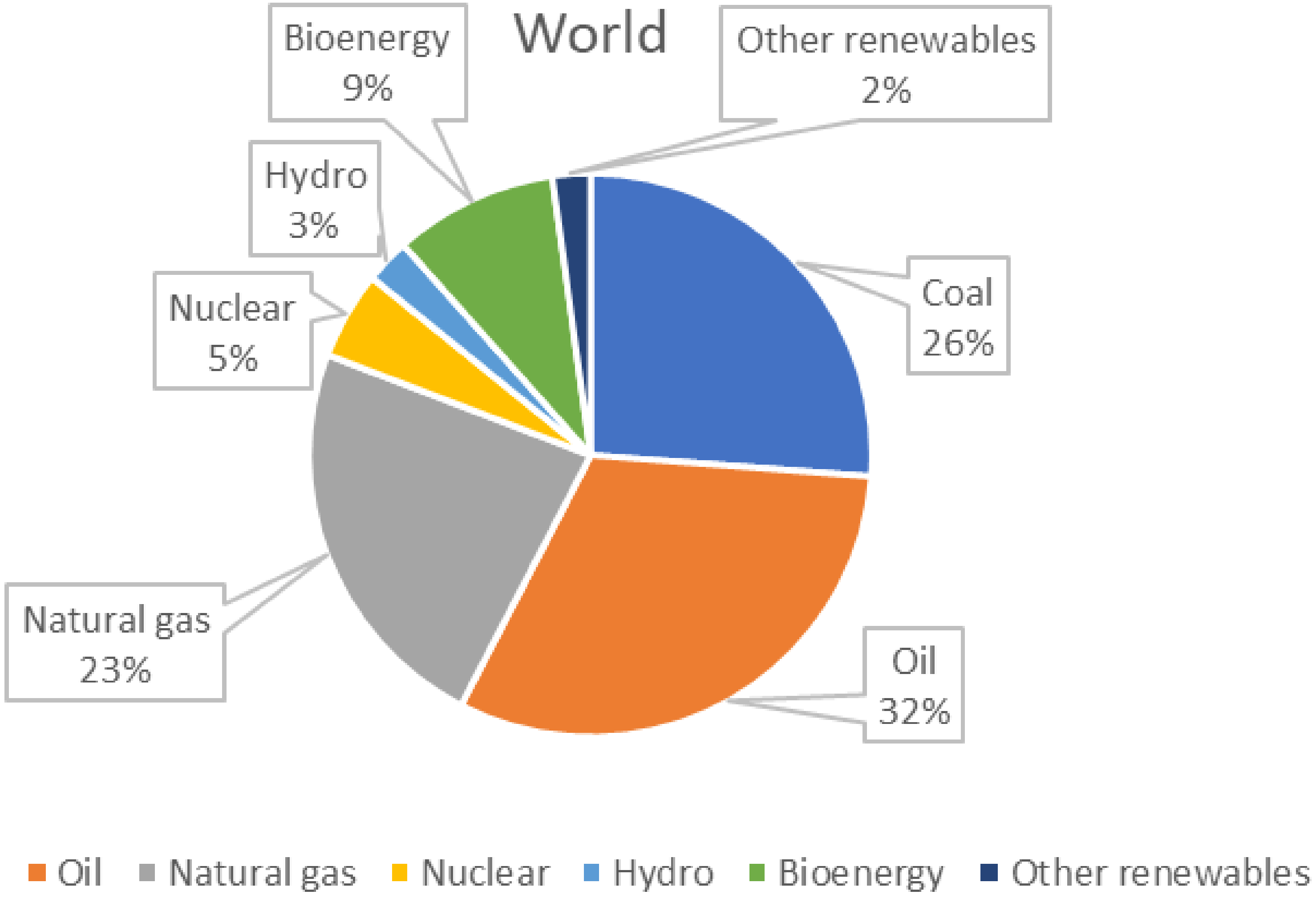
USA – 14%

China – 31%

4 regions = 60% of global emissions

Data source: BP (2021)

Current global primary energy use



Data source: IEA (2021)

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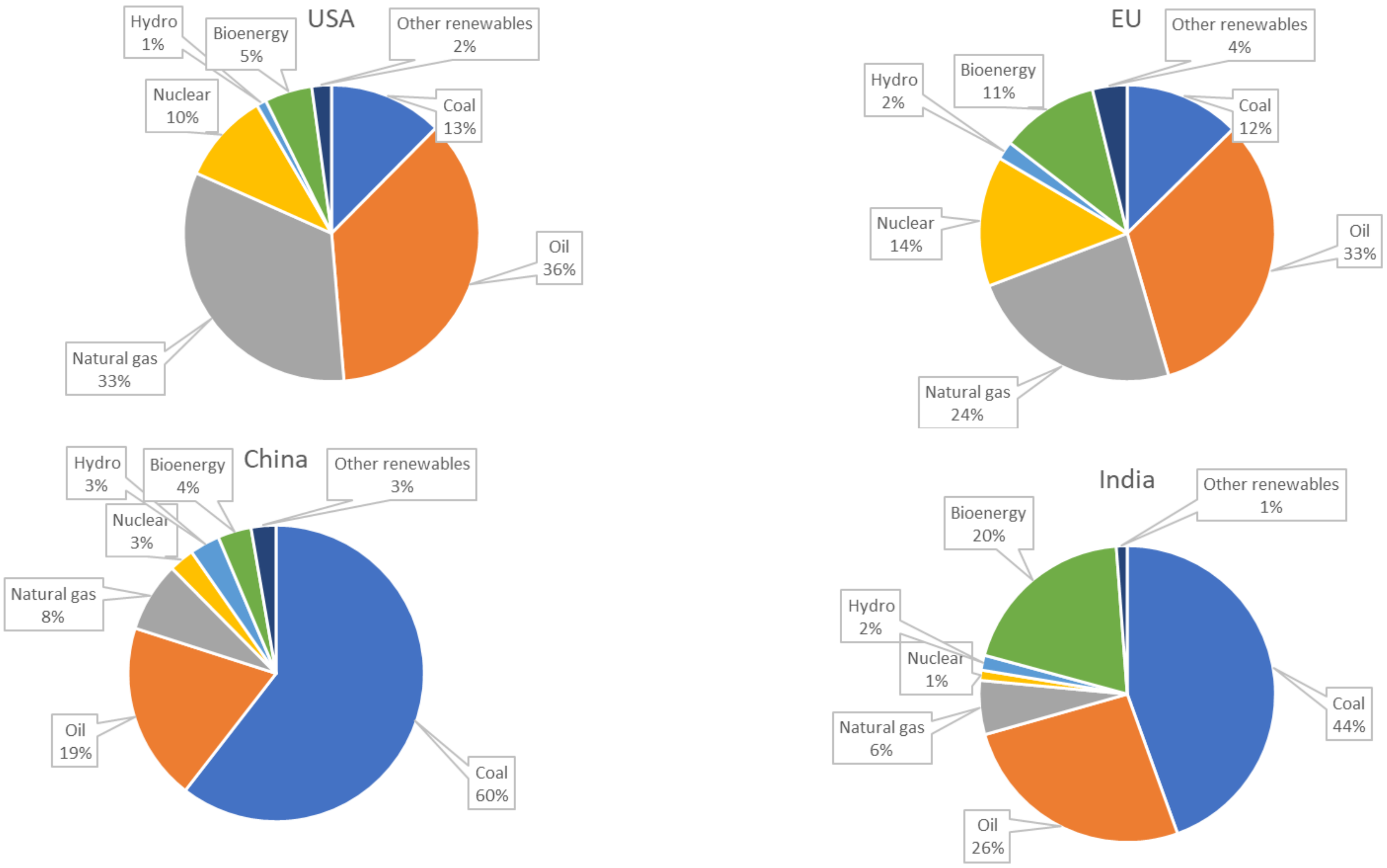
Current primary energy use in major regions

Pathways for decarbonization might differ by country



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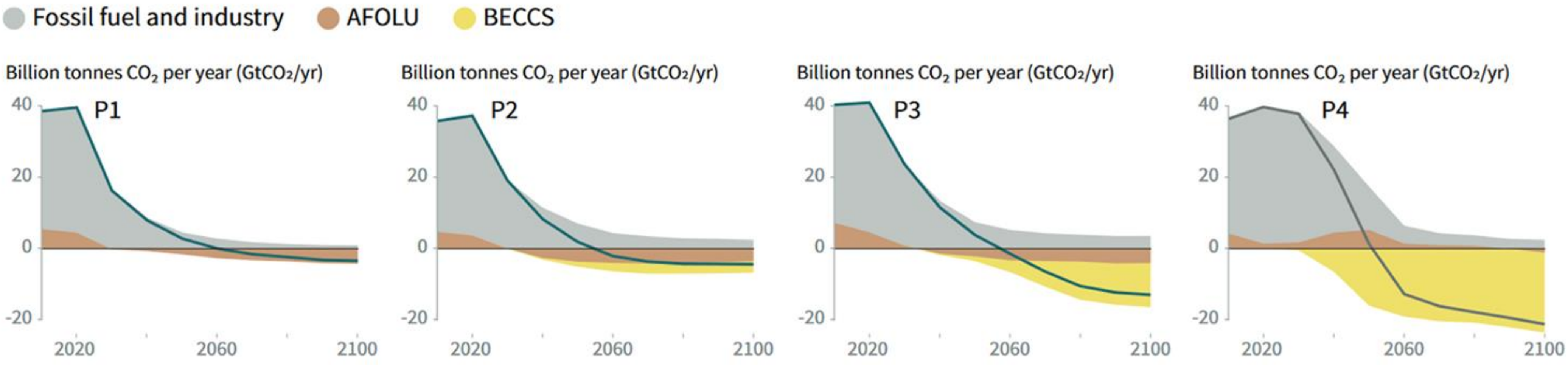
The world has to decarbonize…

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

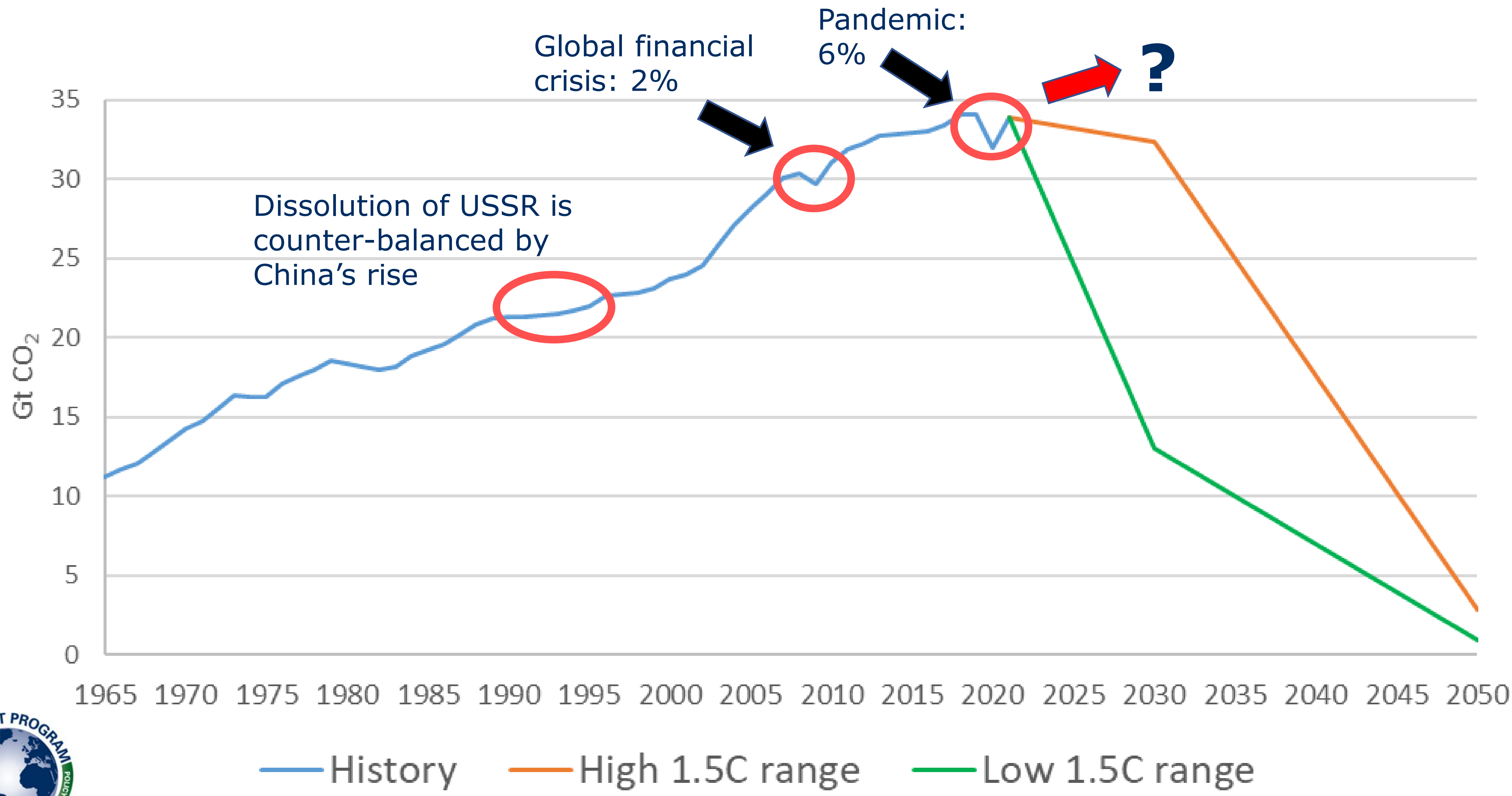
P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Source: IPCC 1.5C Report (2018)

…at an unprecedented pace



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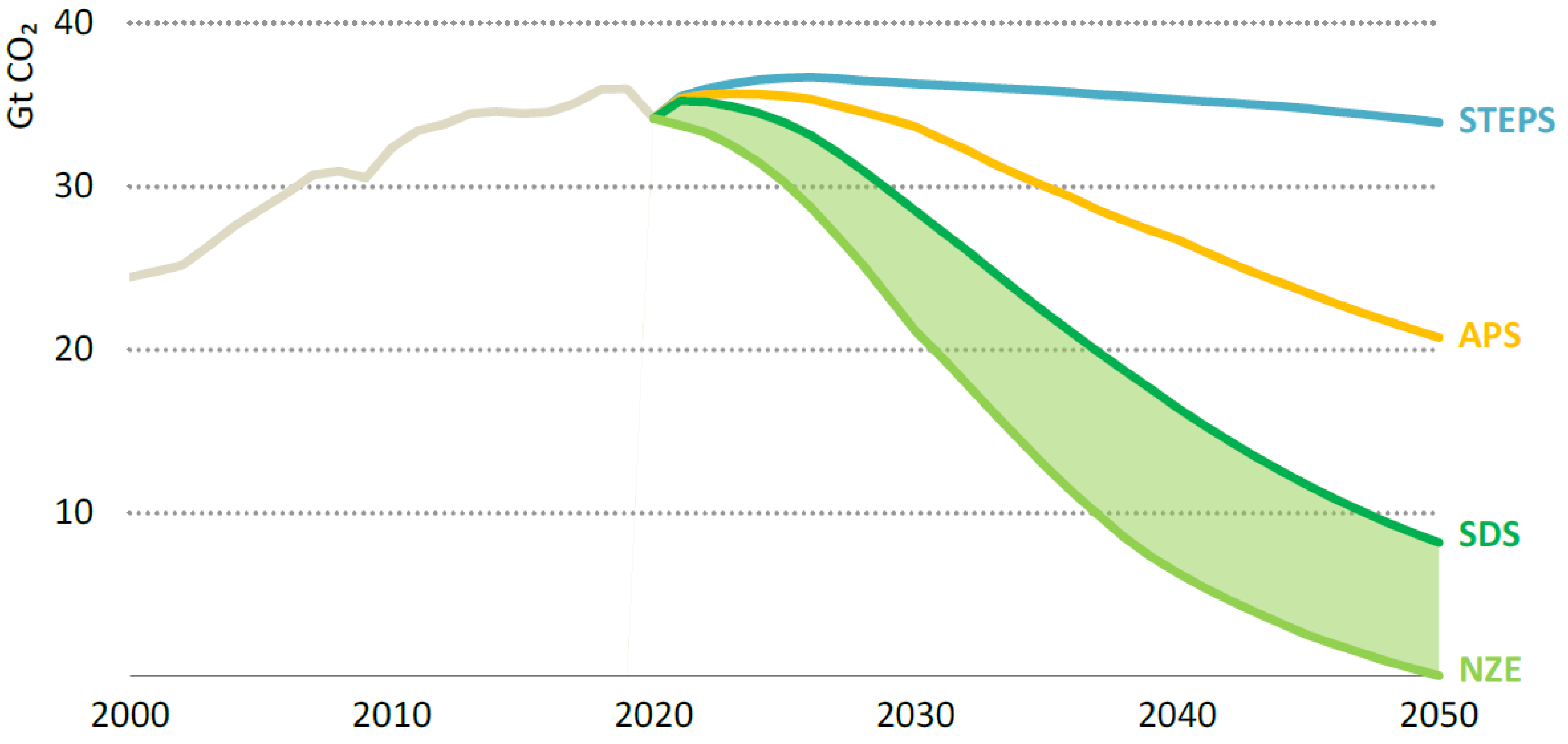
IEA 2021 World Energy Outlook: Goals vs Reality



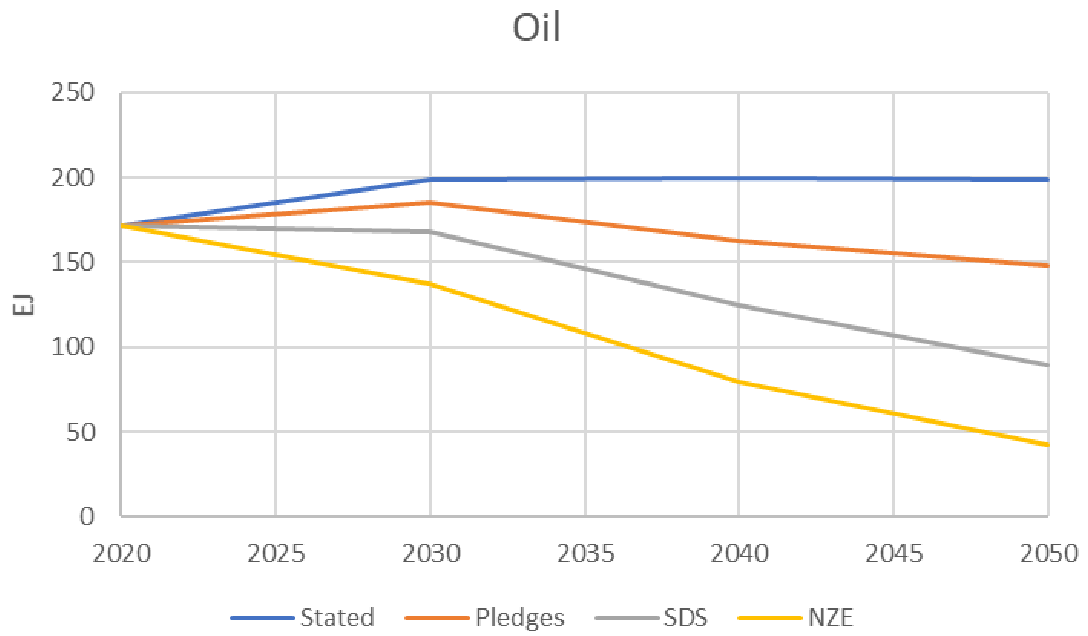
STEPS (Stated Policies Scenario) reflects current policy settings

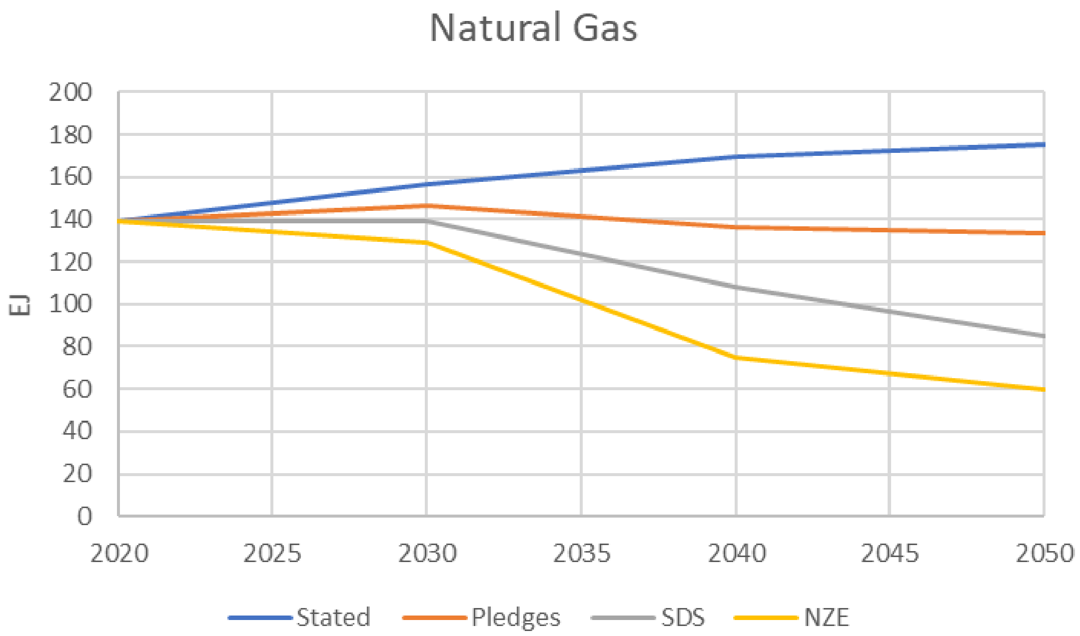
APS (Announced Pledges Scenario) assumes that all NDCs and longer term targets are met

SDS (Sustainable Development Scenario) meets UN SDGs

NZE (Net zero Emissions by 2050) for global energy sector

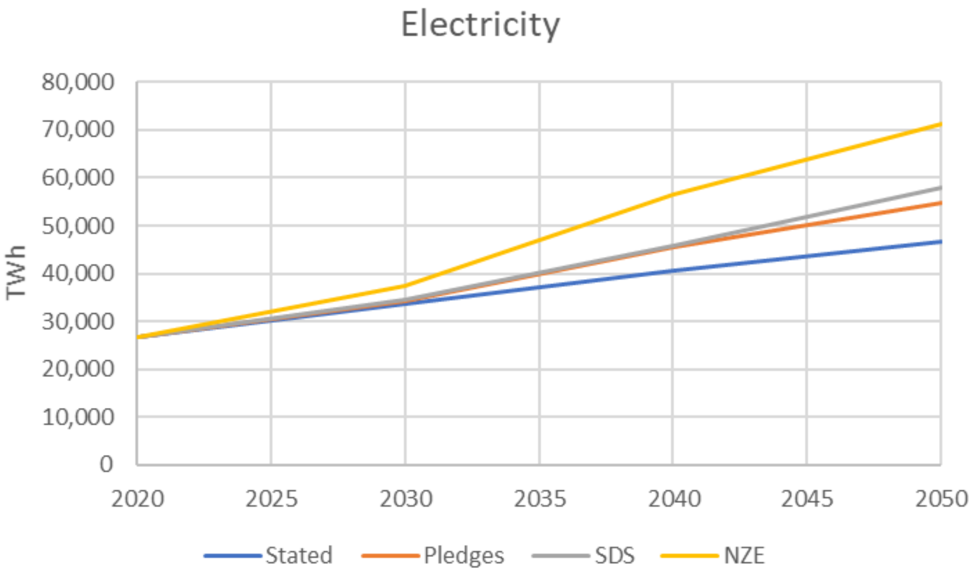
Big picture for global fuel use (oil, gas, electricity)





Oil production
reduction relative to 2020

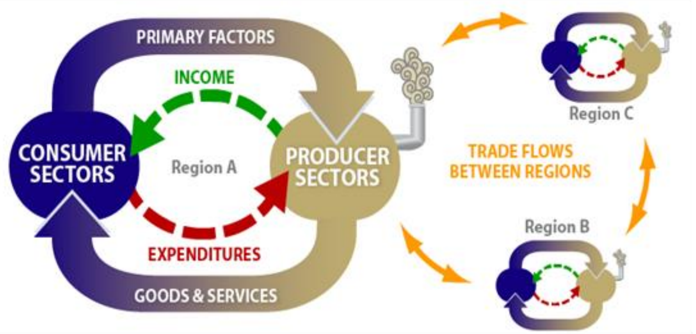
IEA 2030		IEA 2050	
Stated	-15%	Stated	-15%
Pledges	-8%	Pledges	14%
SDS	2%	SDS	48%
NZE	20%	NZE	75%



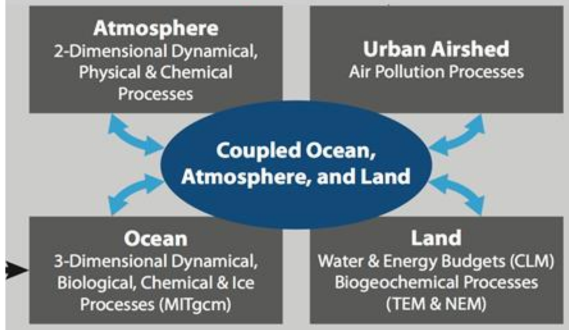
Projections from IEA NZE2050 and WEO2021

MIT: Integrated Modeling across Systems, Sectors and Scales

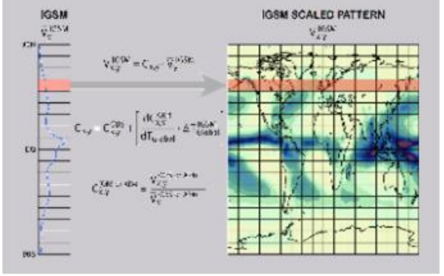
Economic Markets: *Trade, Energy, Agriculture, Transport, Industry, Land-Use Change, Population Dynamics, Infrastructure, Natural Resources* (Global to Regional Scale)



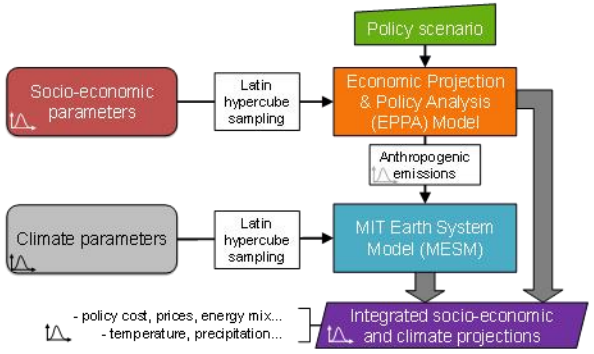
Physical Systems
MIT Earth System Model



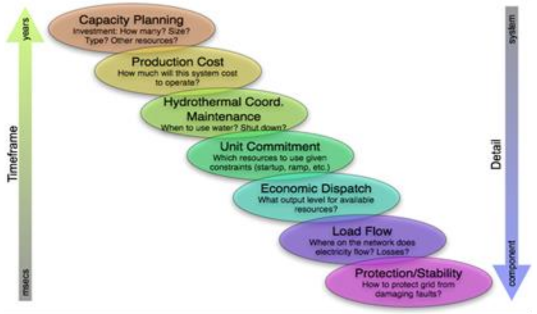
Pattern Scaling & Extreme Events



Probabilistic Ensembles & Integrated Projections



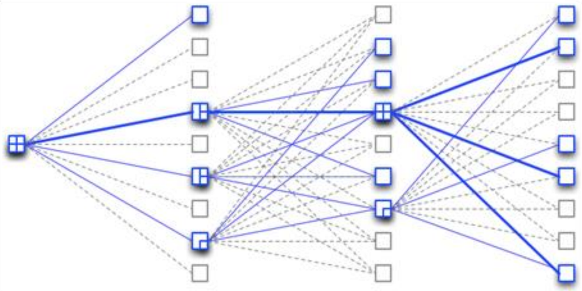
Detailed Electricity Models



Water Resource System Model

CAM3 & WRF

Decision-Making Frameworks



Integrated complex systems and their potential evolution

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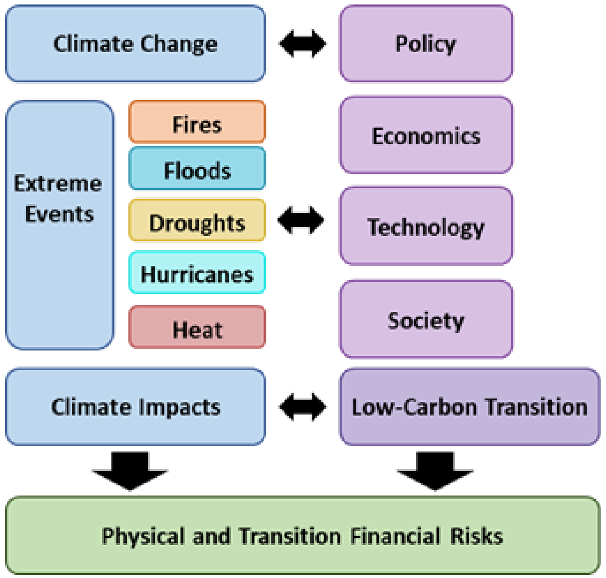
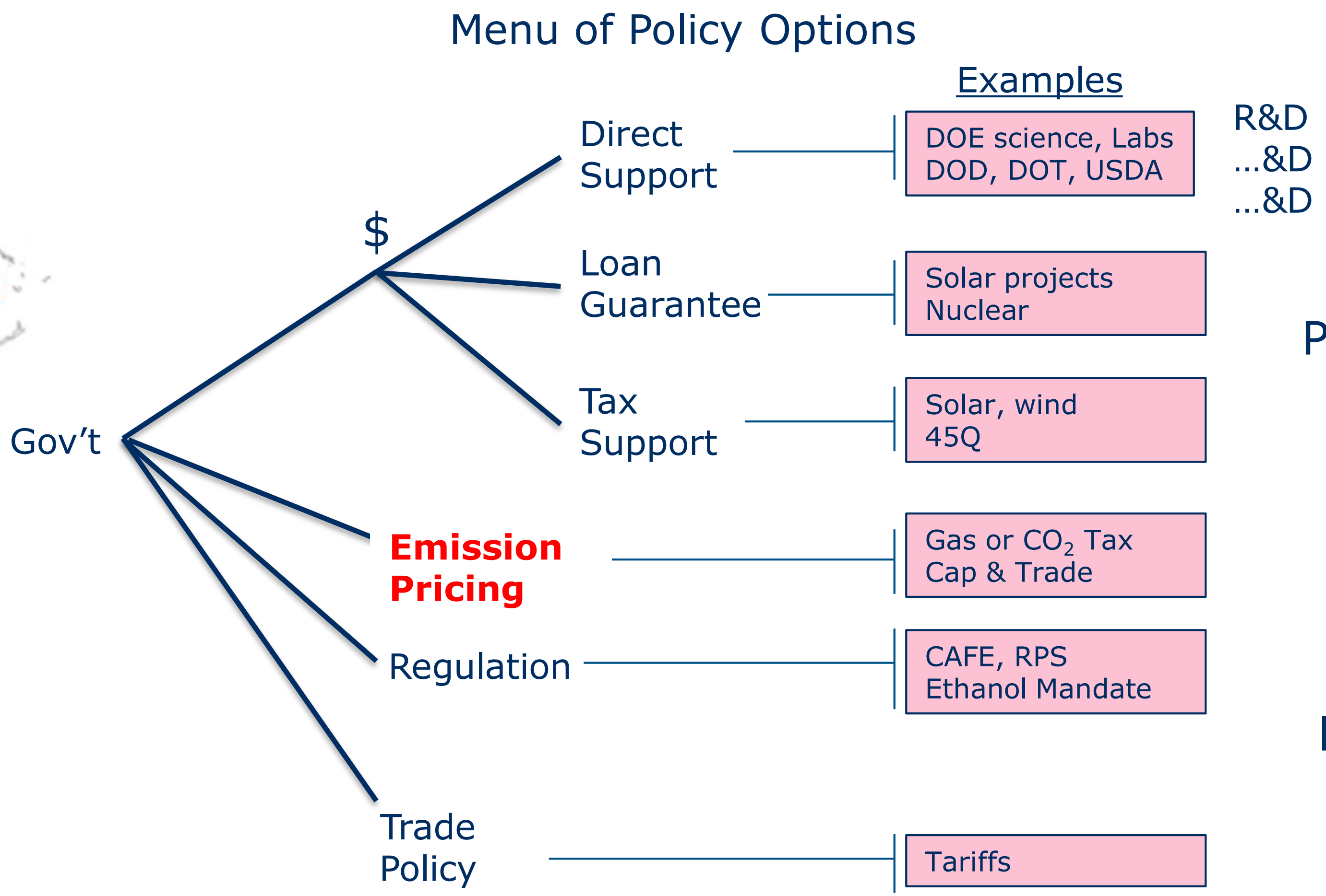
Assessment at Different Scales





Pathway for a particular sector or technology might be different when a **portfolio** of options is considered

Assess: industry level transitional risks
at different geographic ***scales:*** local, continental, global

Recent applications of the MIT Joint Program tools show wide variety of research efforts

Projecting Energy and Climate
Paltsev (2020) Economics of Energy and Env Policy, 9(1), 43-62.

Geopolitics of Renewables
Paltsev (2016) Bulletin of the Atomic Scientists, 72(6), 390-395.

Health Co-Benefits of Renewables
Dimanchev et al (2019) Environmental Research Letters, 14(8).

Climate Change Effects on Agriculture
Gurgel et al (2021) Climatic Change, 166(29).

Covid-19 Effects on the Paris Agreement
Chen et al (2021) Humanities and Soc Sci Comm, 8(16).

Decarbonizing Hard-to-Abate Sectors
Paltsev et al (2021) Applied Energy, 300, 117322.

Global Electrification of Light-Duty Vehicles
Ghandi and Paltsev et al (2020) Transportation Research D, 87, 102524.

Economics of Bioenergy with CCS (BECCS)
Fajardy et al (2021) Global Environ Change, 68, 102262.

Global CCS Scenarios
Morris et al (2021) Climate Change Economics, 12, 215001.

Cost of Low-Carbon Power Generation
Morris et al (2019) Int J GHG Control, 87, 170-187.

MIT 2021 Global Change Outlook
Charting the Earth's Future Energy, Managed Resources, Climate, and Policy Prospects
https://globalchange.mit.edu

The current path is not consistent with stabilizing at 1.5°C or 2°C

MIT Joint Program Outlook Dashboard

Select Scenario to Plot

Paris Forever

Current (as of March 2021) Paris Nationally Determined Contribution (NDC) targets are met by all countries by 2030 and retained thereafter

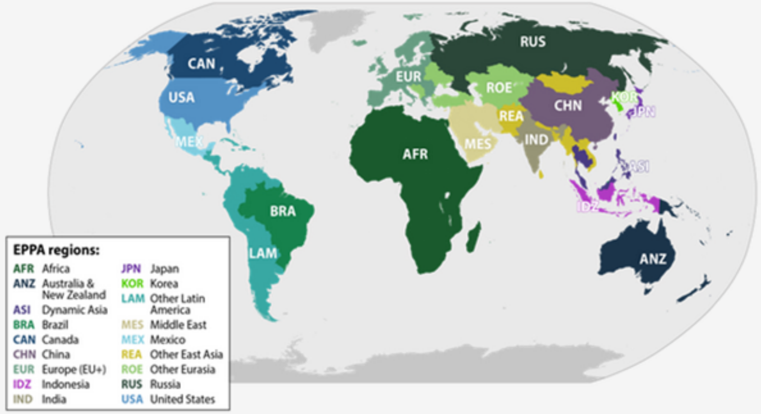
Data Type

- (•) Emissions and Climate
- ( ) Energy and Economics

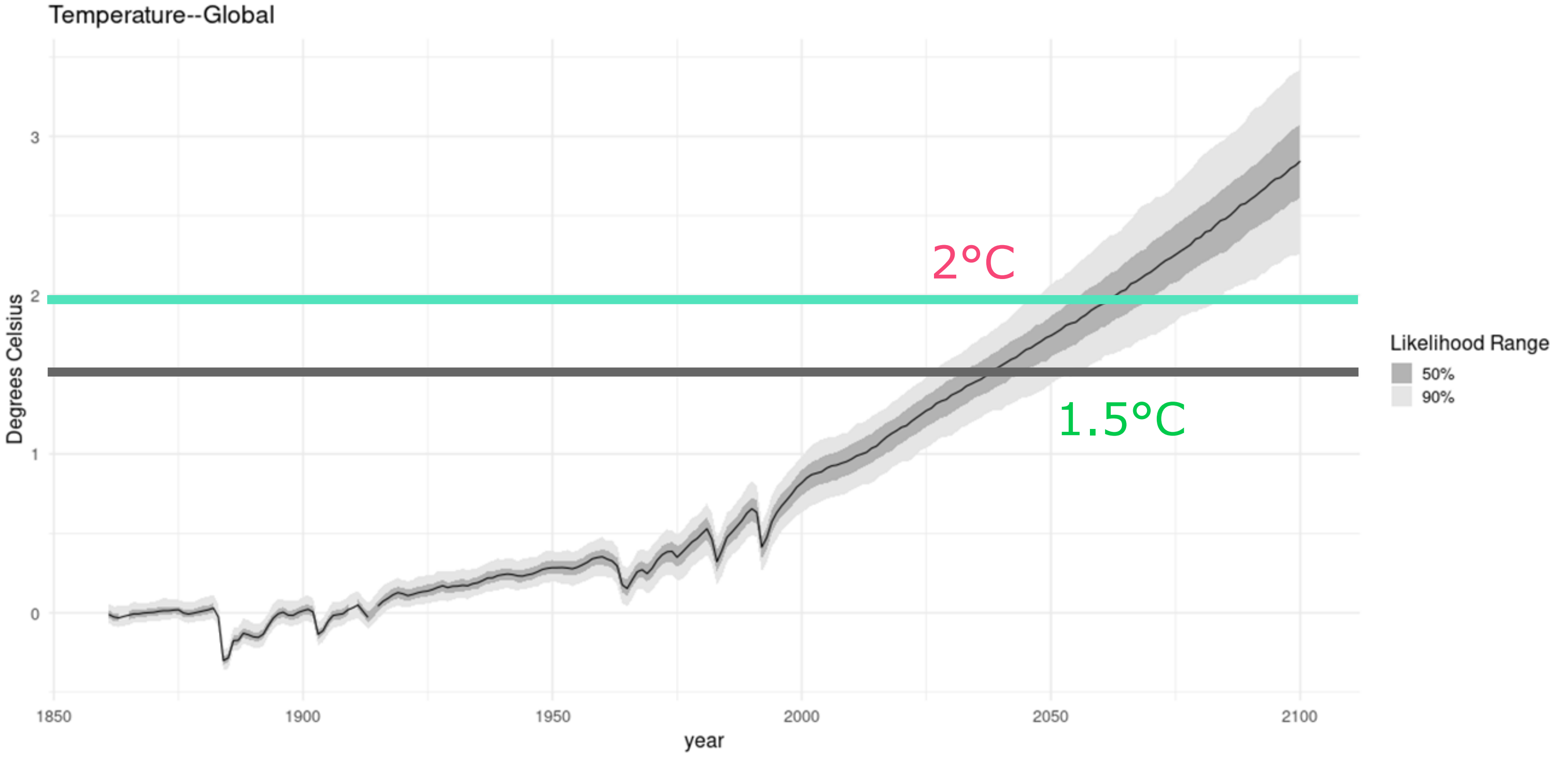
Select Data to Plot

Temperature--Global

- [ ] Plot Difference vs Another Scenario



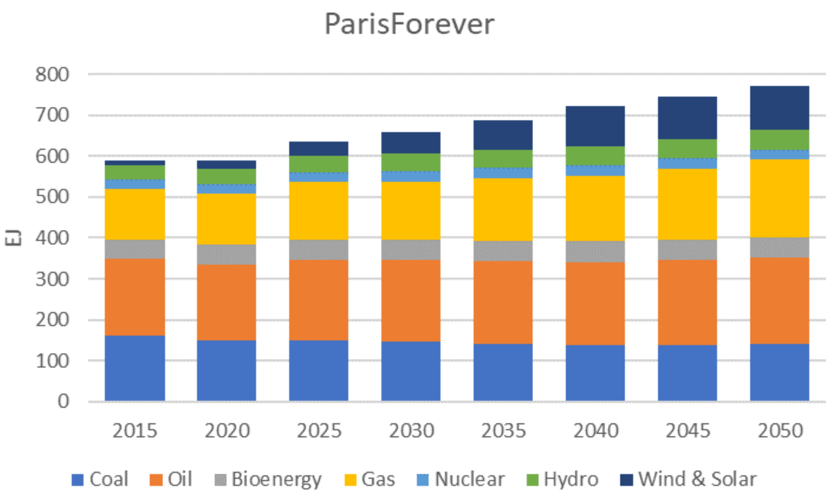
Download the full Outlook report

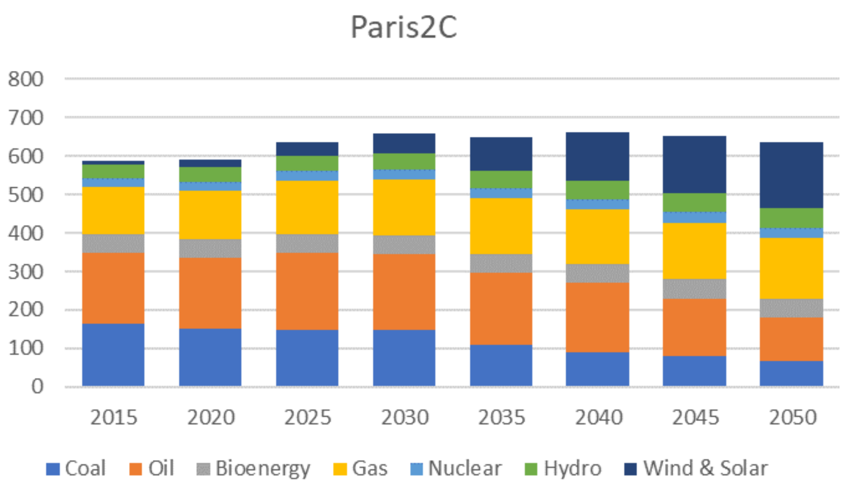


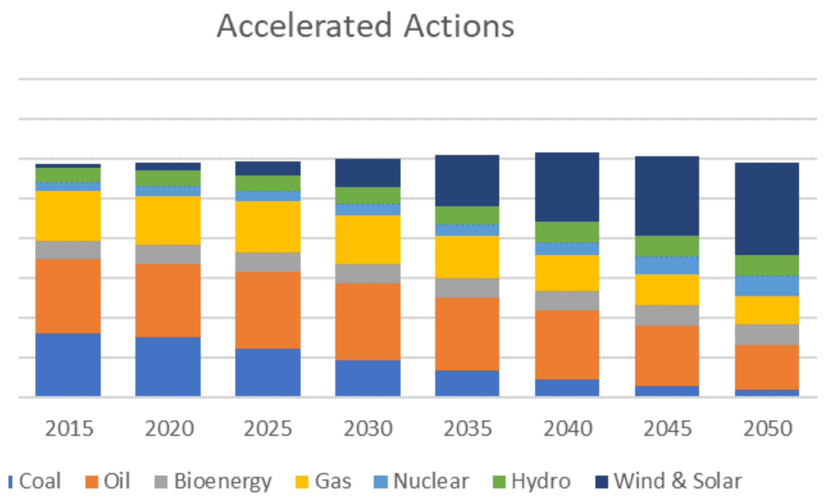
Change in global average surface air temperature relative to pre-industrial (1861-1880) levels. The thick black line is the median, the 50% likelihood range reflects the 25th to 75th percentiles, and the 90% likelihood range reflects the 5th to 95th percentiles. Likelihood ranges in historical years reflect measurements errors.

https://globalchange.mit.edu/news-media/jp-news-outreach/why-earth-needs-course-correction-now

Global Primary Energy







Global from the current 80% to **70%** in 2050. Wind primary energy use in the *Paris Forever scenario* grows to about 770 exajoules (EJ) by 2050, up by 31% from about 590 EJ in 2020. The share of fossil fuels drops and solar – **6**-fold increase.

In the *Paris 2°C* scenario, the fossil fuel share drops to about **50%** in 2050, wind and solar energy grow almost **9** times from 2020 to 2050.

In the *Accelerated Actions* scenario, the fossil fuel share drops to about **34%**, wind and solar energy grow almost **13** times from 2020 to 2050.

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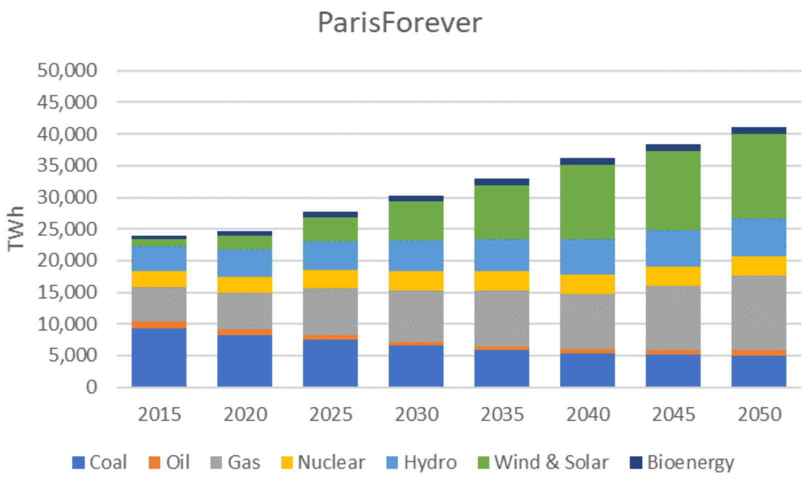
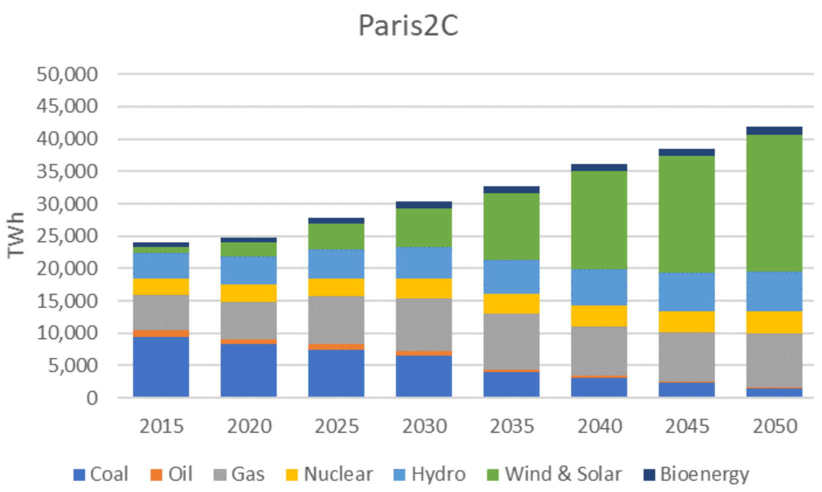
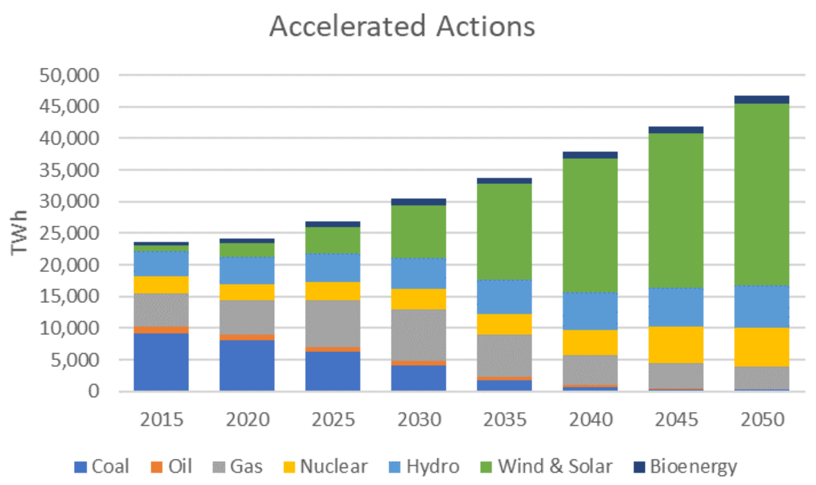
Global Electricity Production



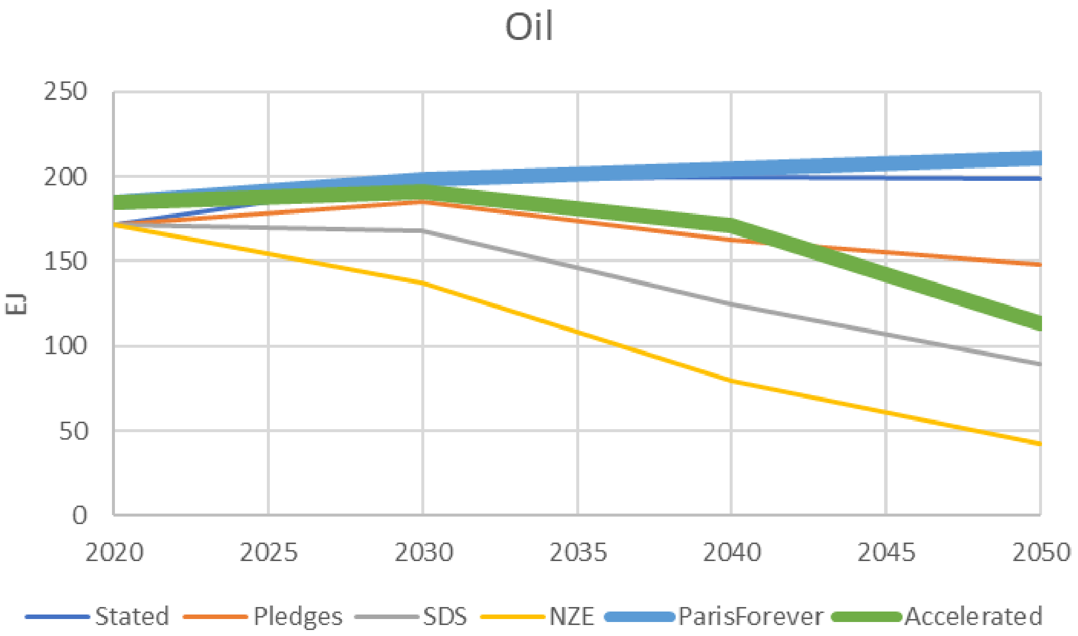


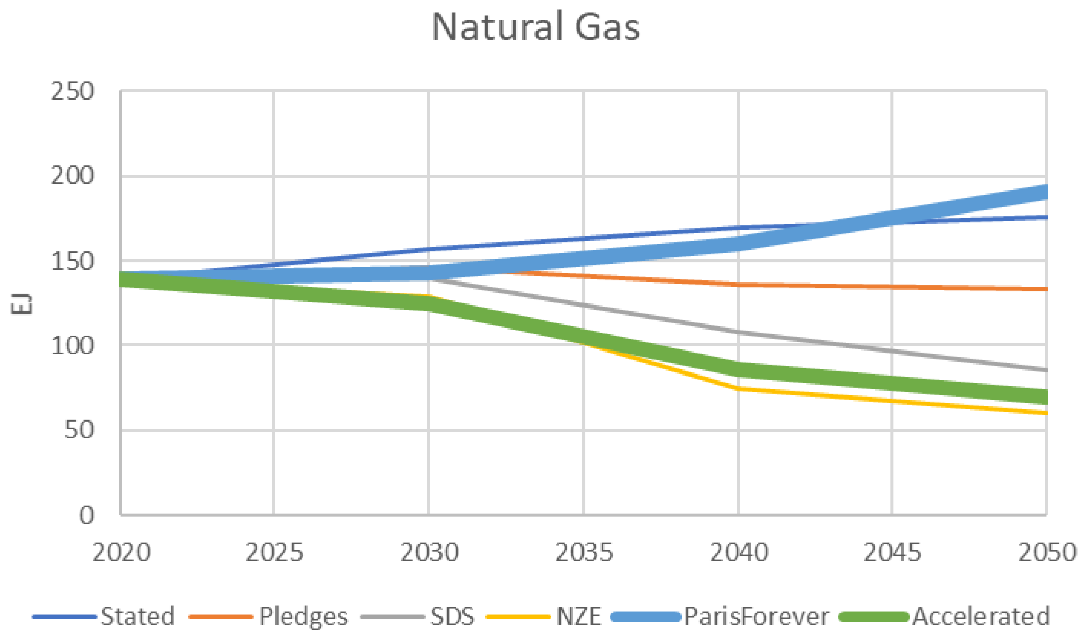


In the *Paris Forever* scenario, global electricity production (and use) grows by **67%** from 2020 to 2050. In comparison to primary energy growth of 31% over the same period, electricity grows about twice as fast, resulting in a continuing electrification of the global economy.

Electricity generation from **renewable sources** becomes a dominant source of power by 2050 in all scenarios, providing **70-80%** of global power generation by midcentury in the climate stabilization scenarios

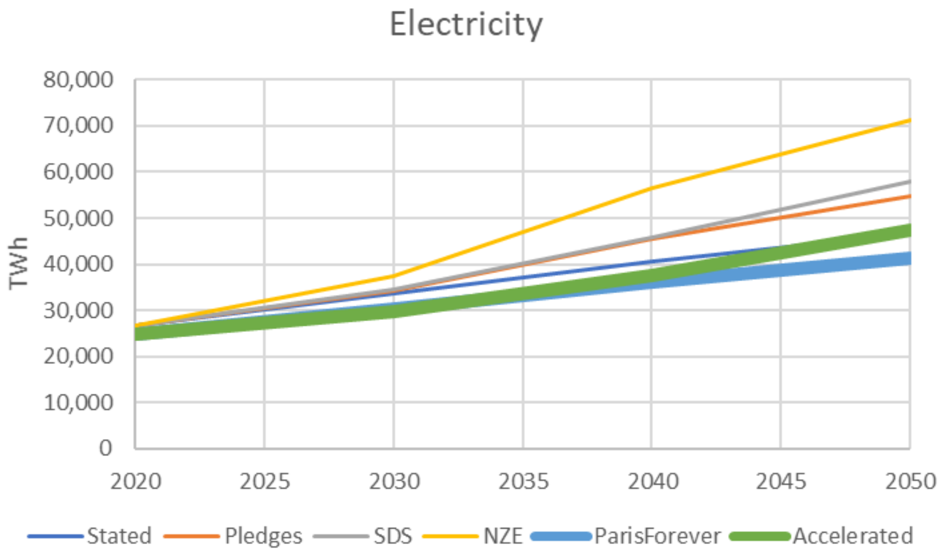
Compare IEA and MIT Joint Program Outlook





Liquid bioenergy is not reported in oil by IEA

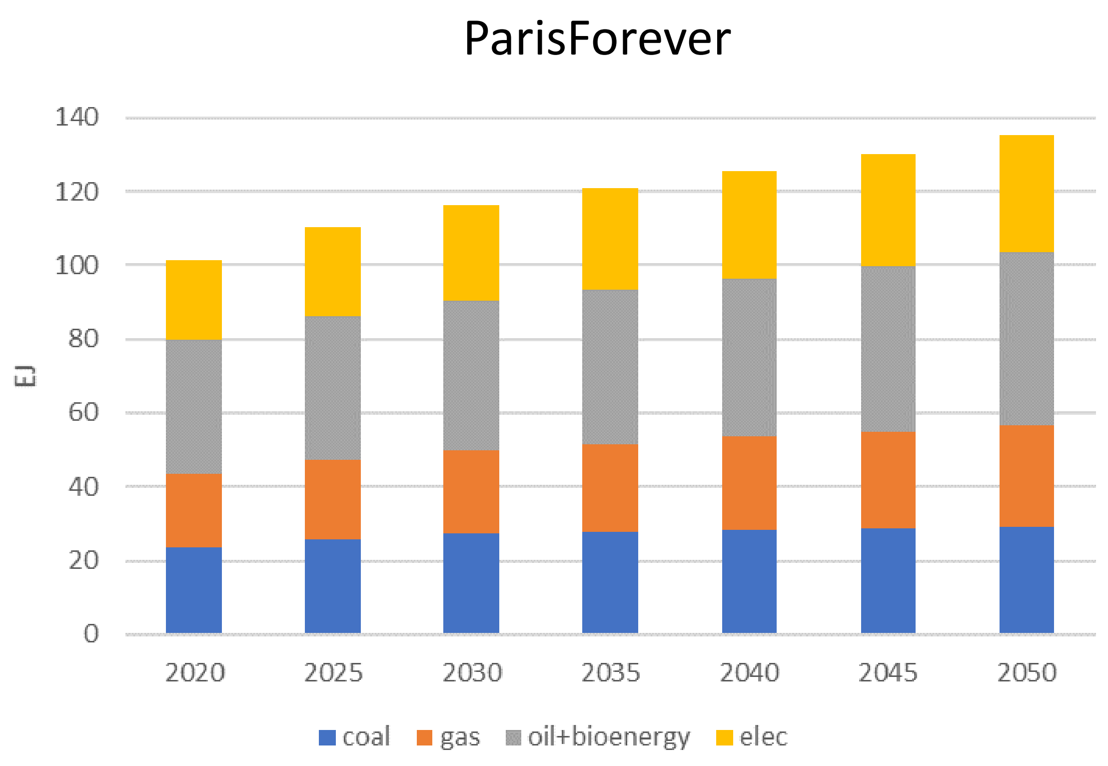
2050 range: 12-19 EJ

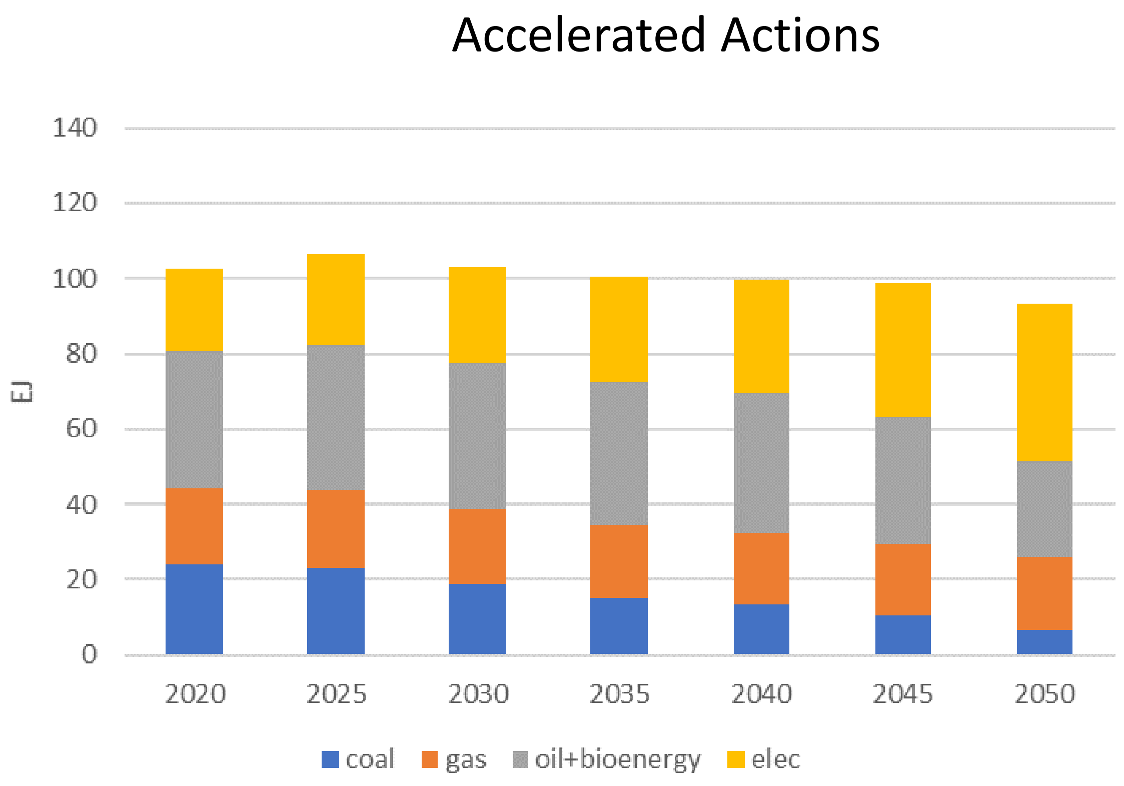


Projections from IEA NZE2050 and WEO2021

Bold lines represent scenarios from MIT Joint Program Outlook

Projections of Global Industry Energy Use





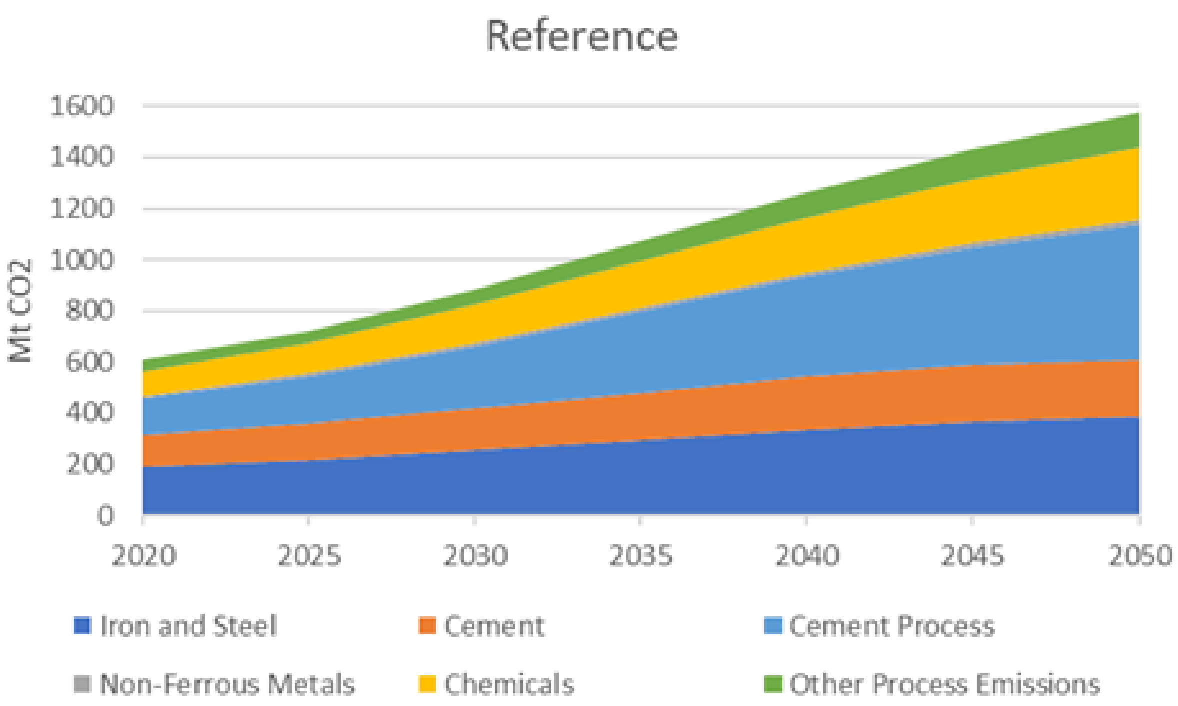
For scenario descriptions see:
MIT Joint Program Outlook

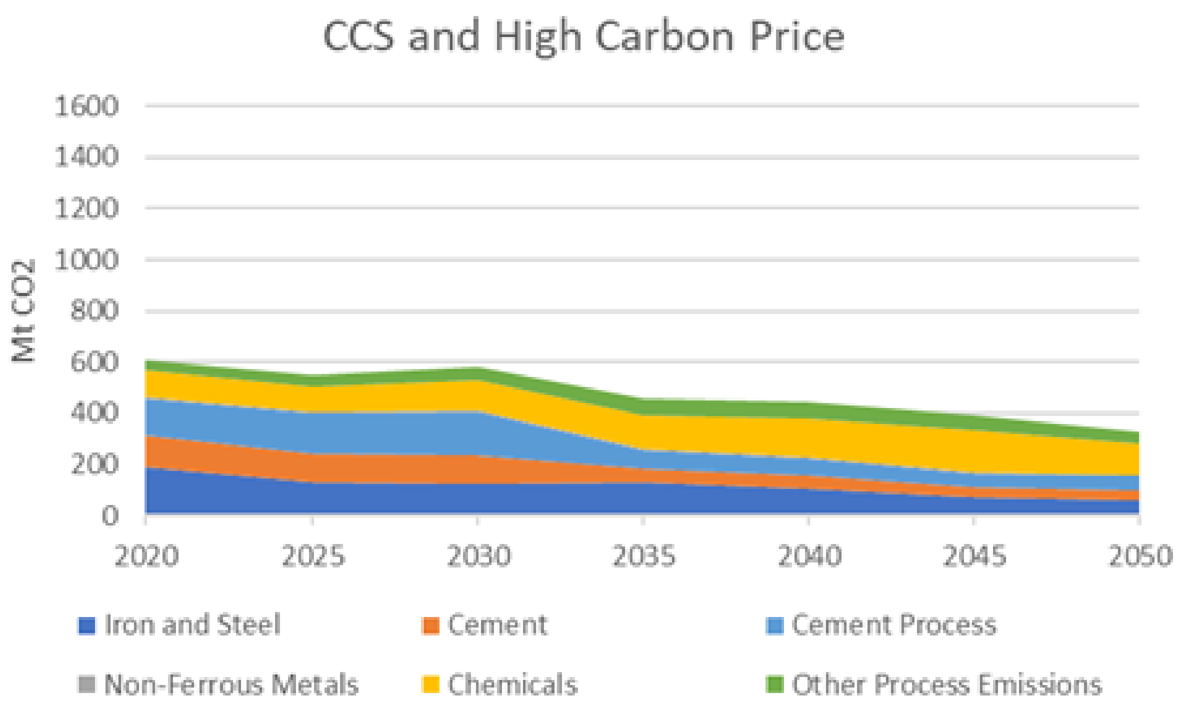
Note about the scale in 2020:

Total energy use	600 EJ
Final energy use	400 EJ
Transport	100 EJ

https://globalchange.mit.edu/news-media/jp-news-outreach/why-earth-needs-course-correction-now

Example: India's Hard-to-Abate Sectors

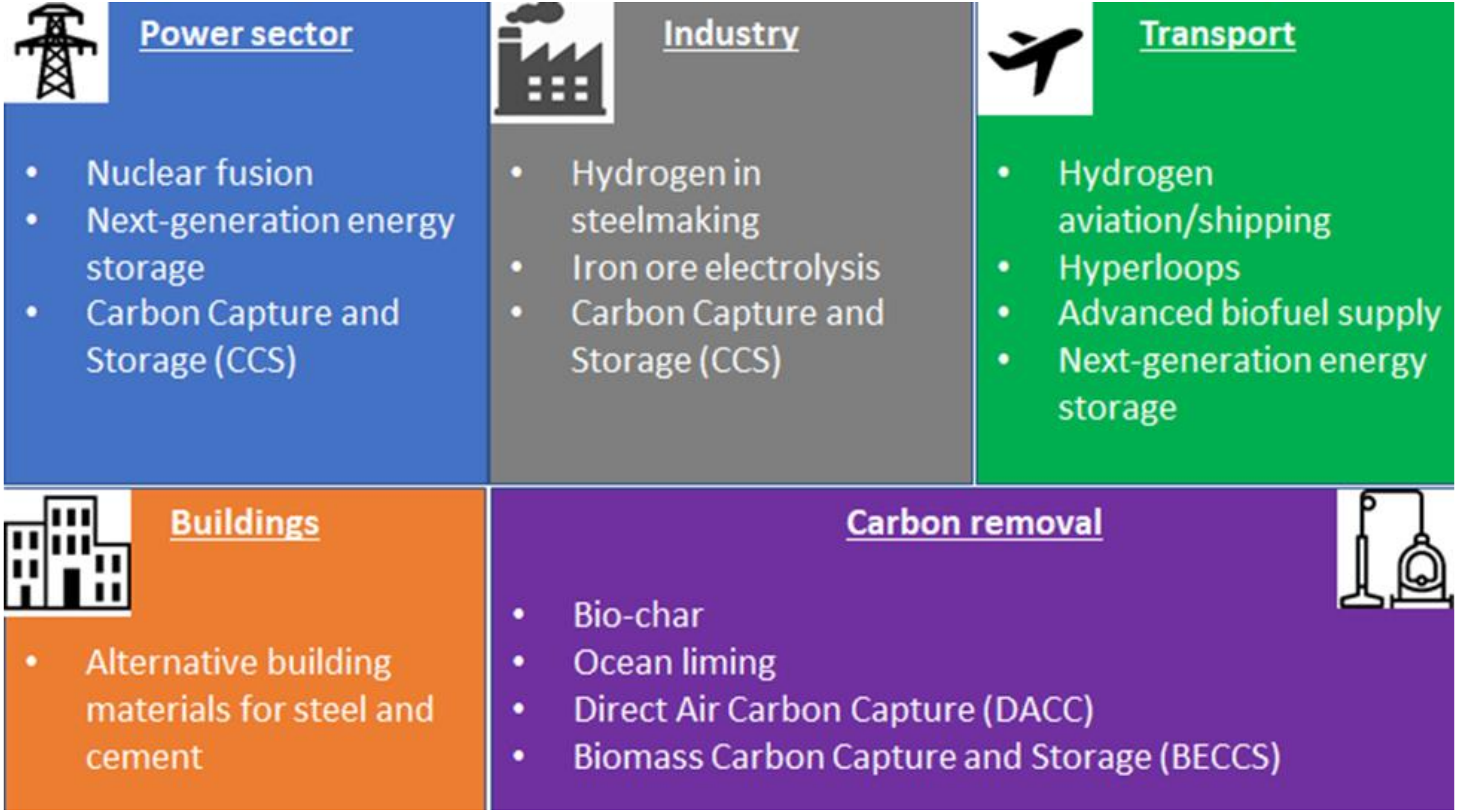




CO_2 Emissions in Hard-to-Abate Sectors in India in Different Scenarios

For scenario descriptions see:
MIT Joint Program Report 355

https://globalchange.mit.edu/publication/17673



Graphics: EPFL

Also important: Demand Side Management

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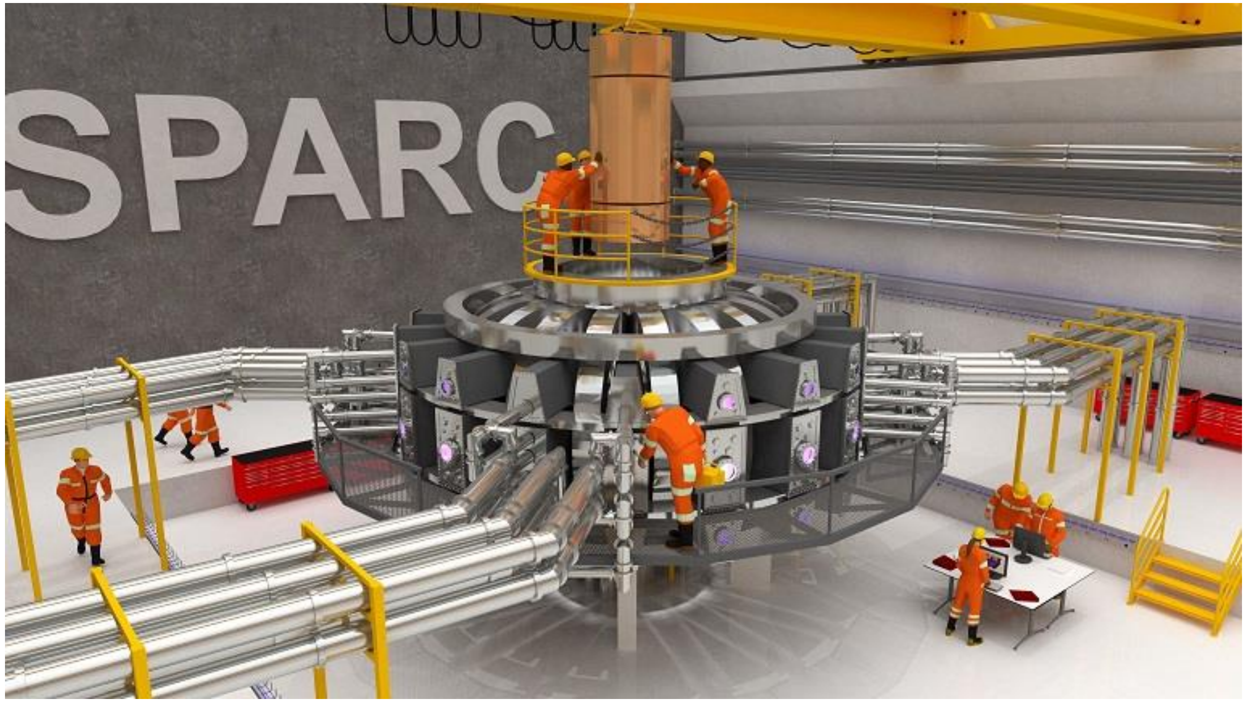
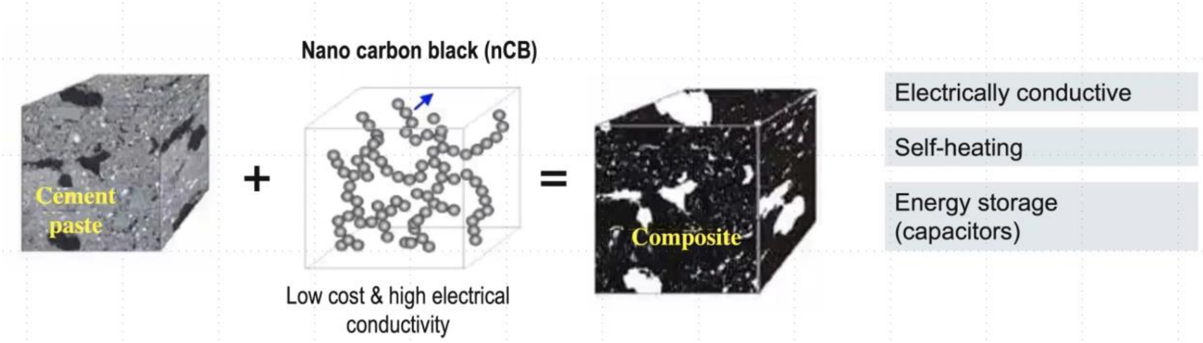
Wide range of future technologies are needed





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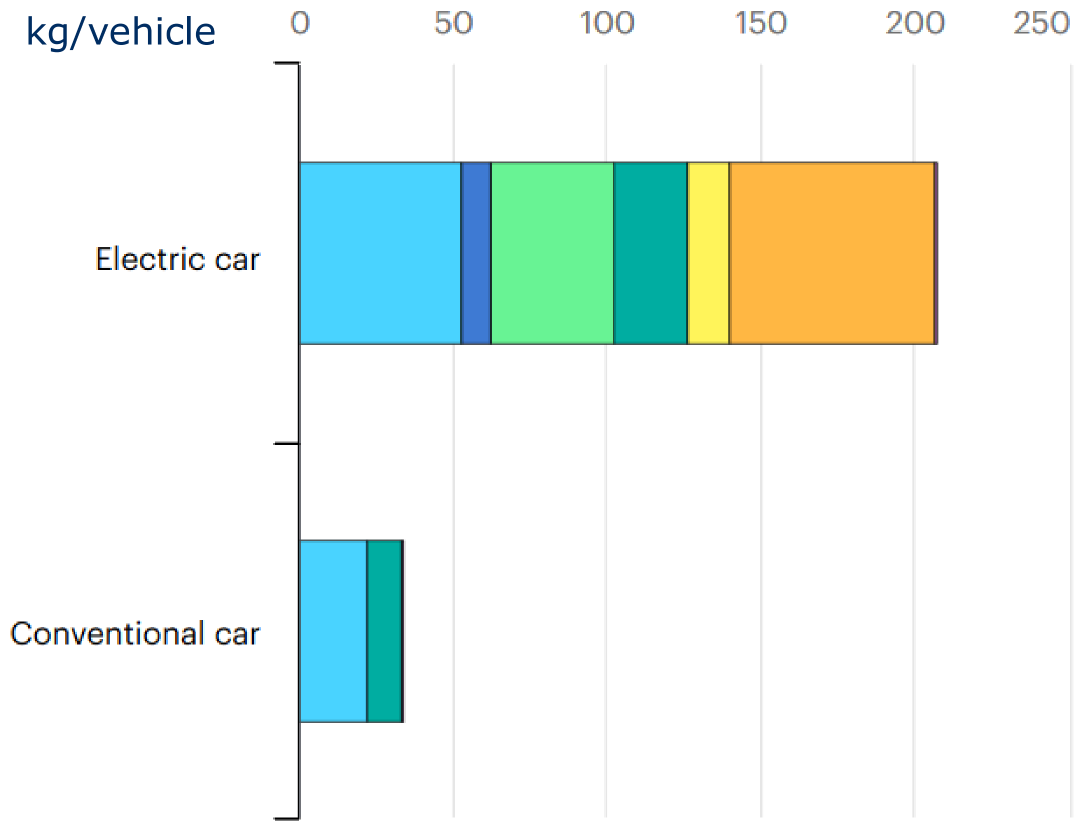
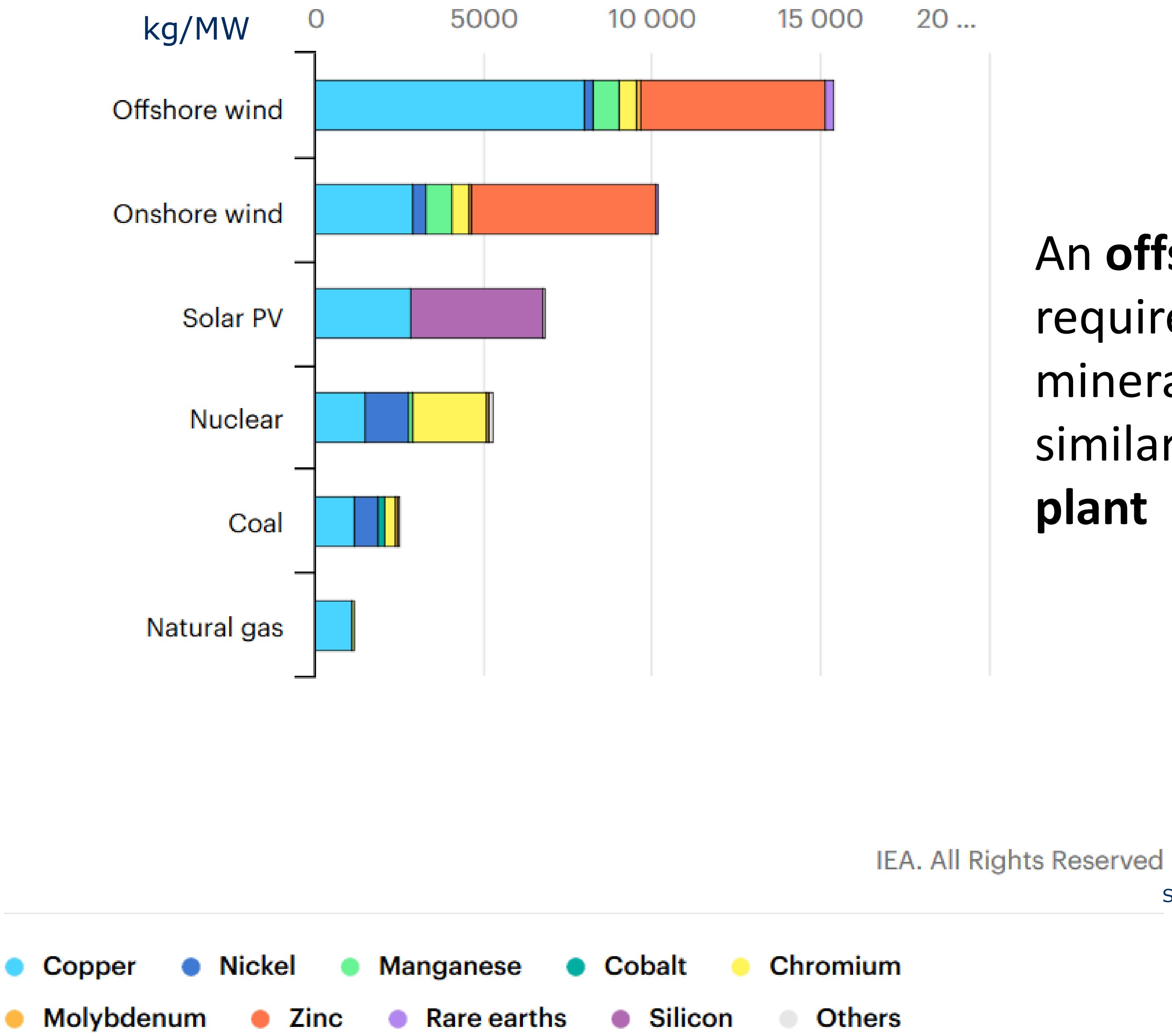
Materials used in EV compared to conventional cars



A typical **electric car** requires **six times** the mineral inputs of a **conventional car**

Source: IEA (2021)

Materials used in clean power generation technologies compared to others



An **offshore wind plant** requires **13 times** more mineral resources than a similarly sized **gas-fired power plant**

Source: IEA (2021)

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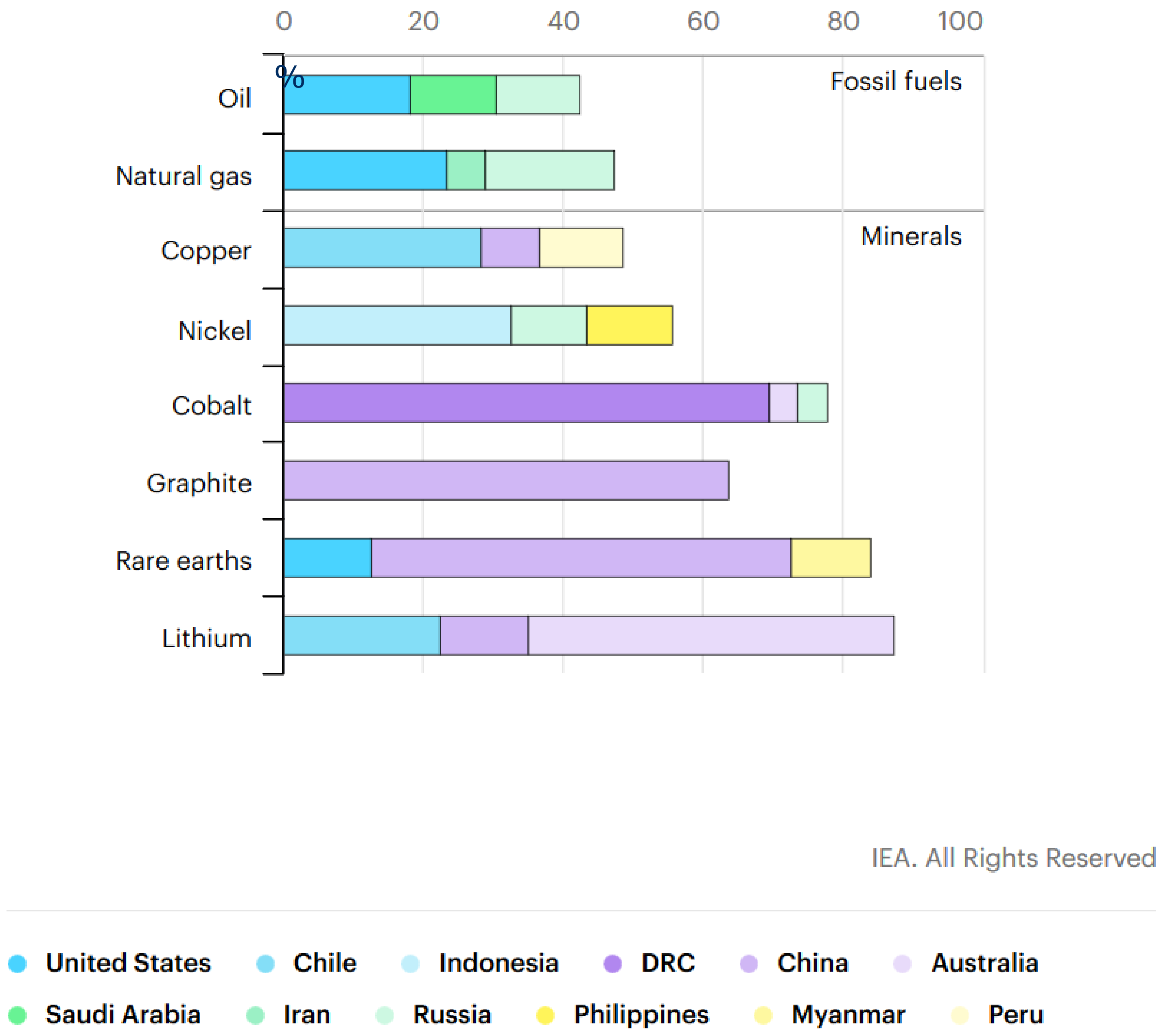
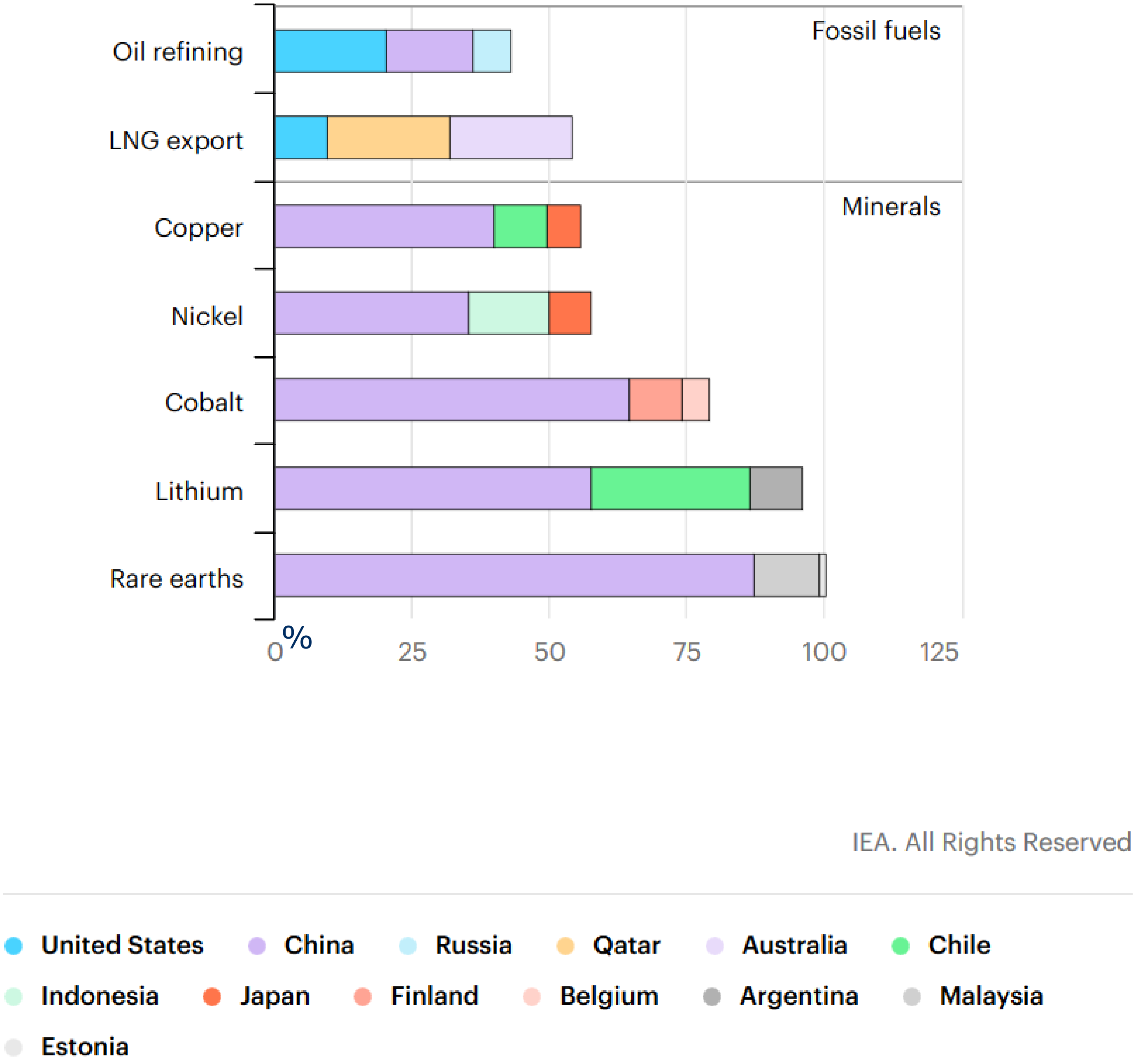
Share of top three producing countries in *extraction* (2019)



Source: IEA (2021)

Share of top three producing countries in *processing* (2019)



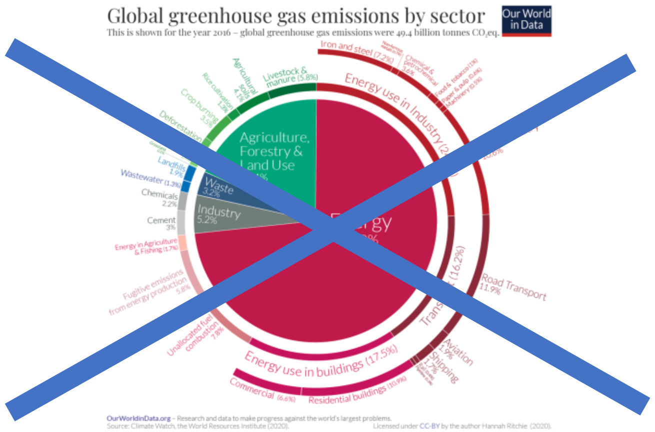
Source: IEA (2021)

Minerals for Clean Energy Transition

- Clean-energy technologies are **more minerals-intensive** than their fossil-fuel counterparts.
- The growth of clean energy will **rapidly raise demand** for key minerals.
- **Mining and processing** of those minerals are **geographically concentrated**, often in countries with weak labor and environmental protections.
- Mineral **mines and processing** facilities often **pollute** water and impact landscapes.
- Production may not be able to expand fast enough to keep up with demand, which could cause **supply issues** and **price fluctuations**.

How do we get to net-zero emissions? How quickly?

Pledges by numerous governments and companies to reach **net-zero** greenhouse gas (**GHG**) emissions, **but Action Plans are needed**



Opportunities and challenges for **scalable** low-carbon energy options

Economic: Do we have technologies? Are they economically competitive? Do we have policies to support them? Lifestyle changes?

Geopolitical: Impacts of de-carbonization on other goals? COVID implications for a rise of protectionism? Stability of energy exporters?

Environmental: Physical risks from climate change will be there regardless of emission reduction. Impacts from low-carbon options (e.g., car battery recycling). Minerals for clean energy transition.

zero Emission

Thank you

Questions or comments?
Please contact Sergey Paltsev at paltsev@mit.edu