Current and future energy landscape

The role of nuclear in the energy transition

TANDEM & SMR School
24 June 2024

Hal Turton
Planning and Economic Studies Section

IAEA

IAEA – Atoms for Peace and Development

As **an autonomous international organization** within the United Nations system, IAEA is the global centre for cooperation in the nuclear field.

178 Member States
(as of September 2023)

2,500+staff from **over 100 countries**

- HQ in Vienna
- **Laboratories** in Seibersdorf, Monaco and Vienna.
- **Regional offices** in Toronto and Tokyo.
- **Liaison offices** in New York and Geneva

"The Agency is a formidable institution that deals with issues of war and peace, of human health, of energy, food and water – fundamental concerns of all human beings."

Rafael Mariano Grossi, Director General, IAEA

Nuclear Energy

Nuclear Sciences and Applications

Nuclear Safety and Security

Safeguards

Technical Cooperation

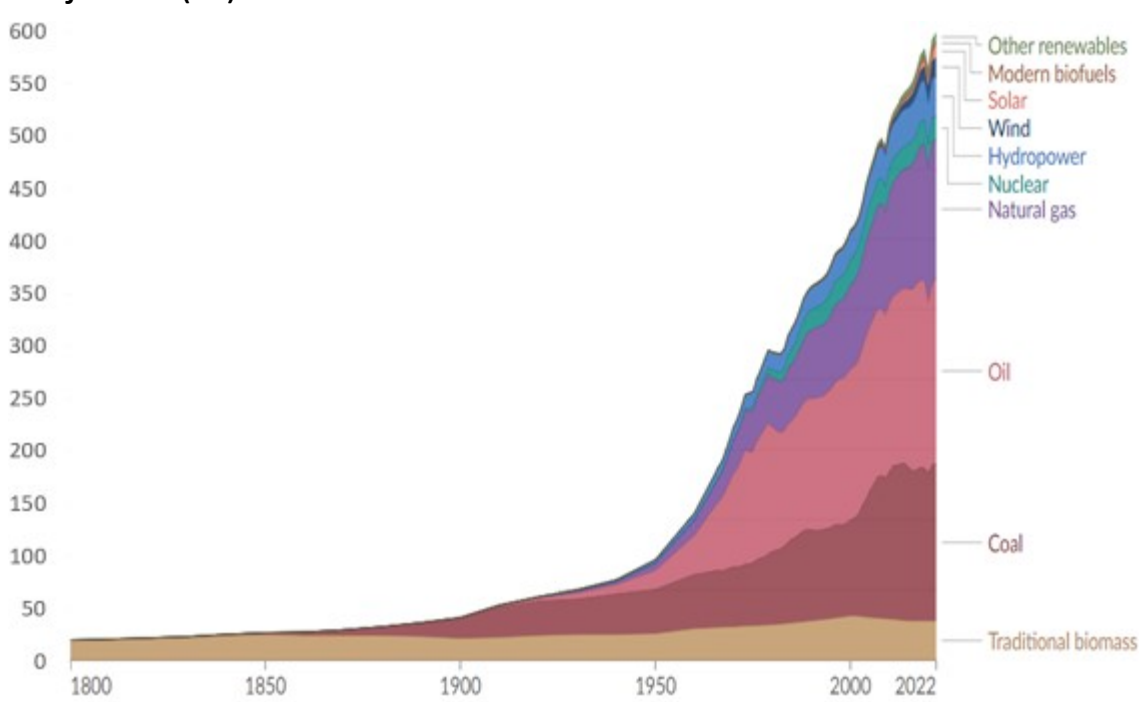
Management

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

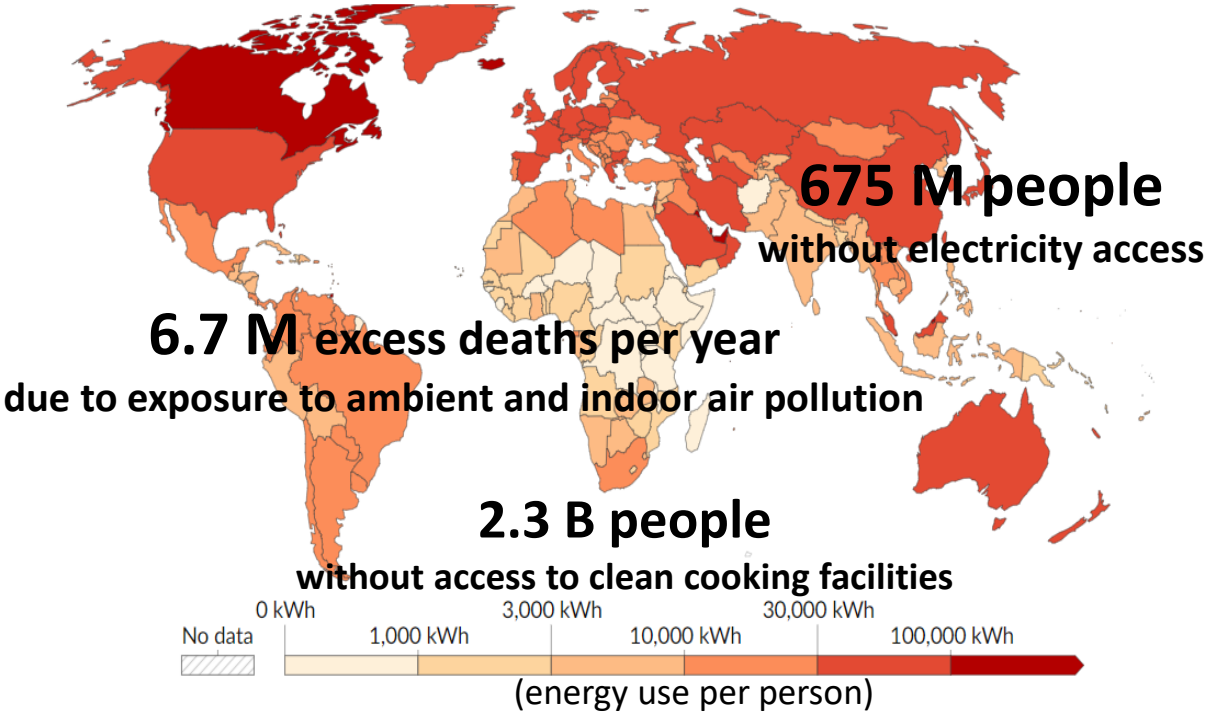
Global energy trends

Energy needs are rising

World Primary Energy Consumption



Global Access to Energy

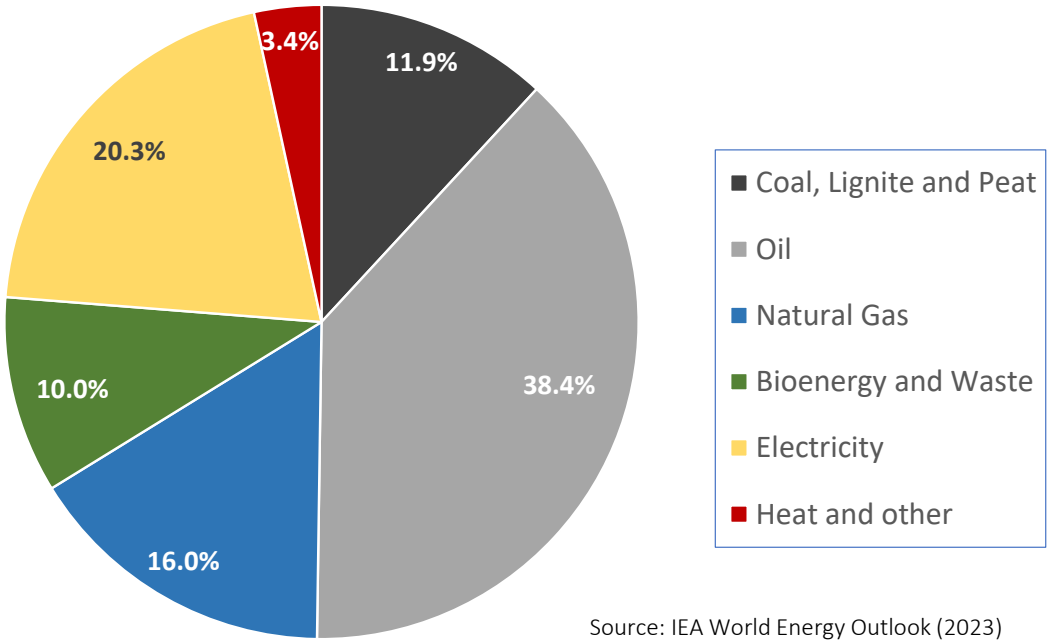


Source: Tracking SDG 7 (2023); Our world in data (2024)

- Energy use is driven by economic development, population growth and technology.
- Energy intensity (energy per unit of GDP) has declined but this has been offset by demand growth.
- New energy sources are supplying increasing demands rather than replacing other sources.

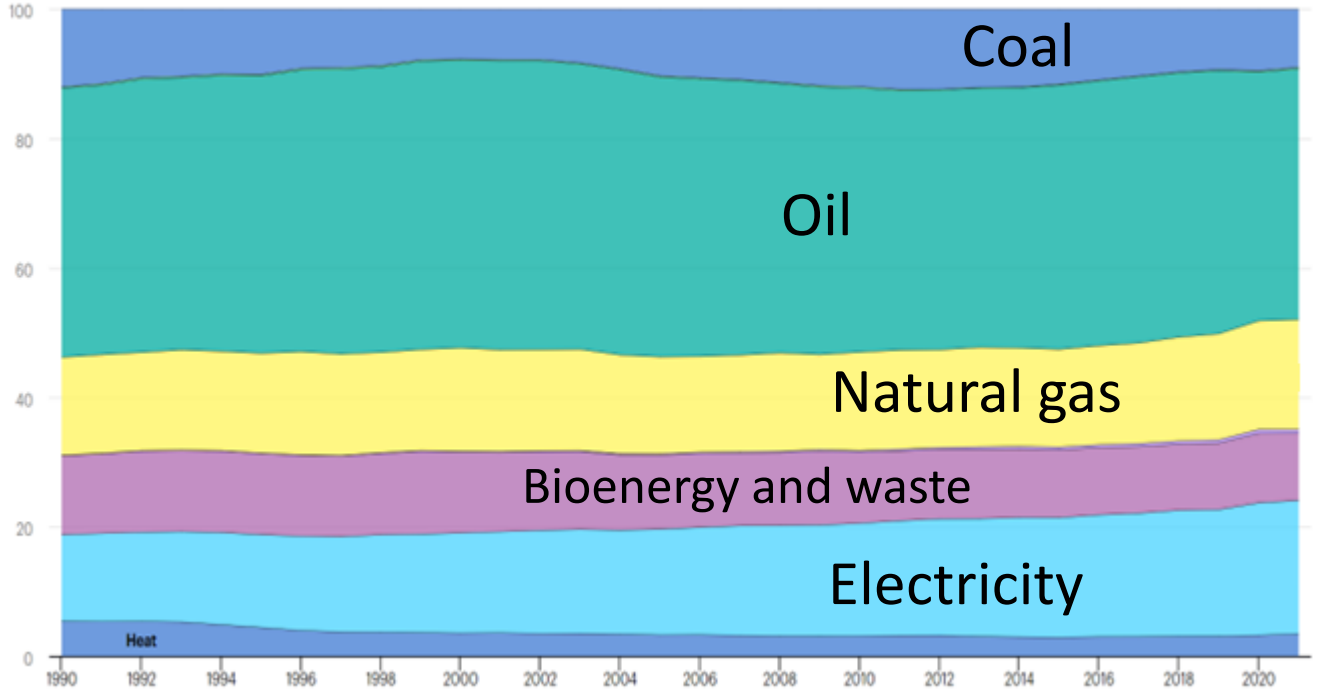
Total energy consumption

Final Energy Consumption by source (2022)



Source: IEA World Energy Outlook (2023)

Final Energy Consumption: 1990-2020

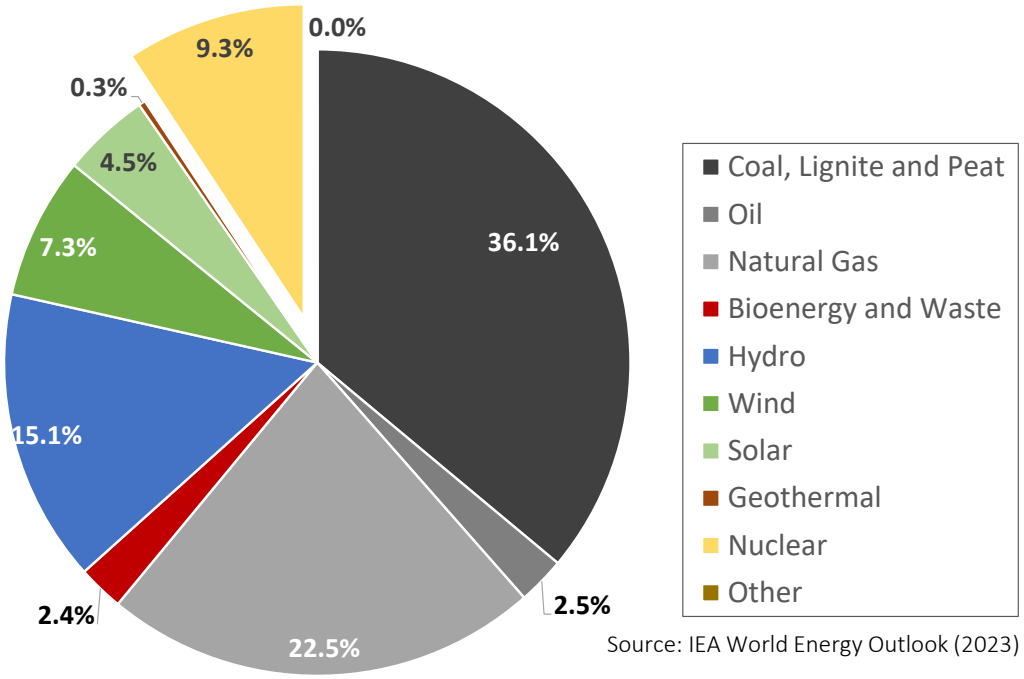


Source: IEA

- Fossil fuels provide 2/3^{rds} of final energy (~80% accounting for their contribution to electricity).
- No significant changes in the last 30 years, but electricity's share is steadily growing.
- There are significant losses in the conversion between primary and final energy.

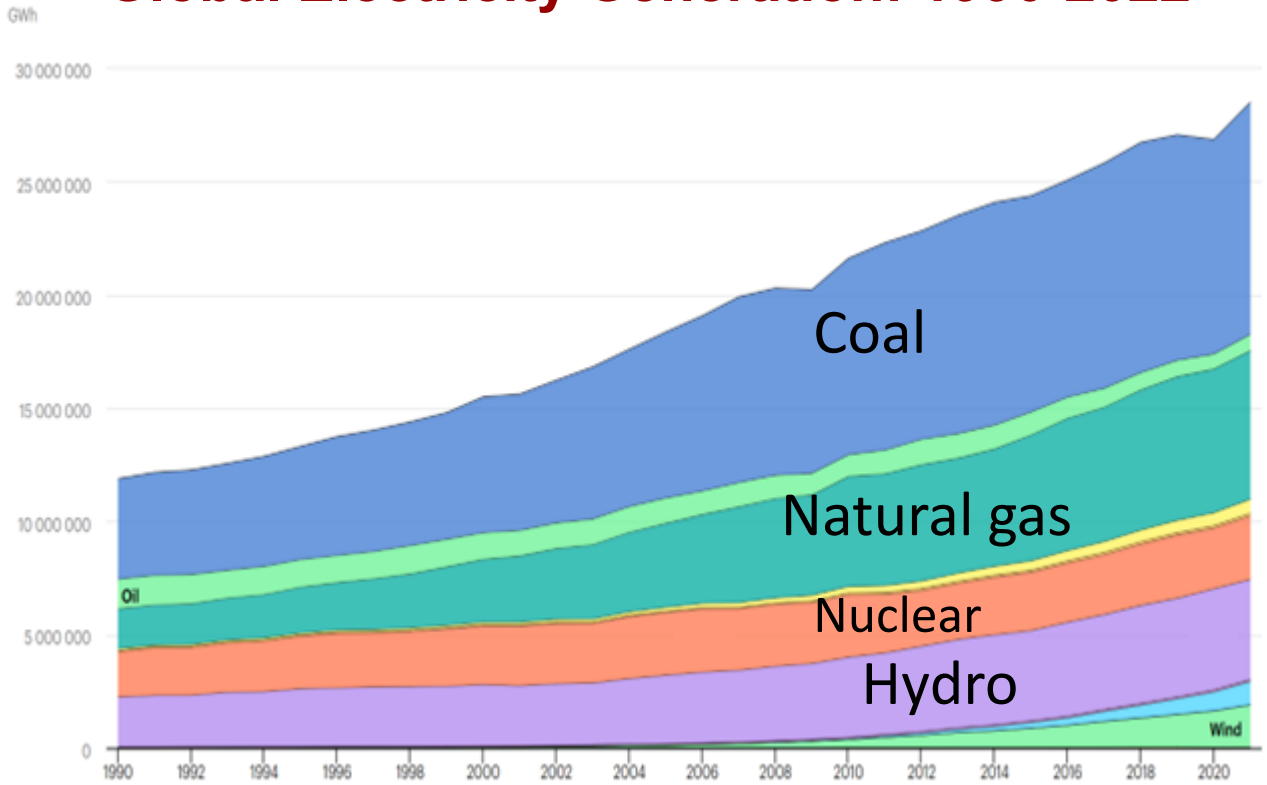
Global electricity generation

Electricity generation in 2022



Source: IEA World Energy Outlook (2023)

Global Electricity Generation: 1990-2022



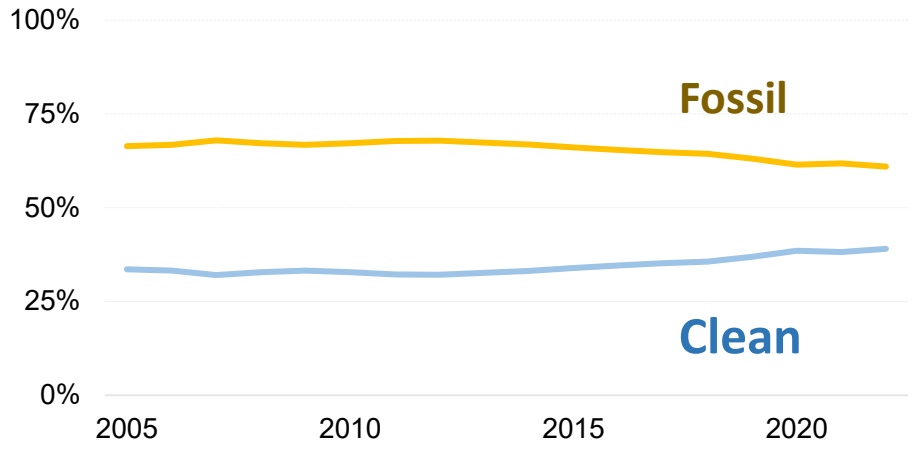
Source: IEA

- Over 60% of global electricity is generated by fossil fuels. Nuclear energy makes up 9.3% of global electricity supply – compared to 15.1% for hydropower, and 11.8% for wind + solar.
- Nuclear generation has not changed significantly over the last 20 years. In 2022 it made up about a quarter of low carbon electricity, according to the IEA.

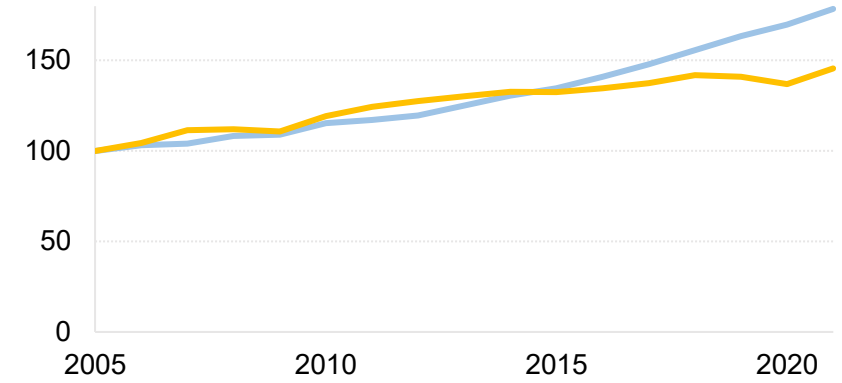
Low carbon electricity generation

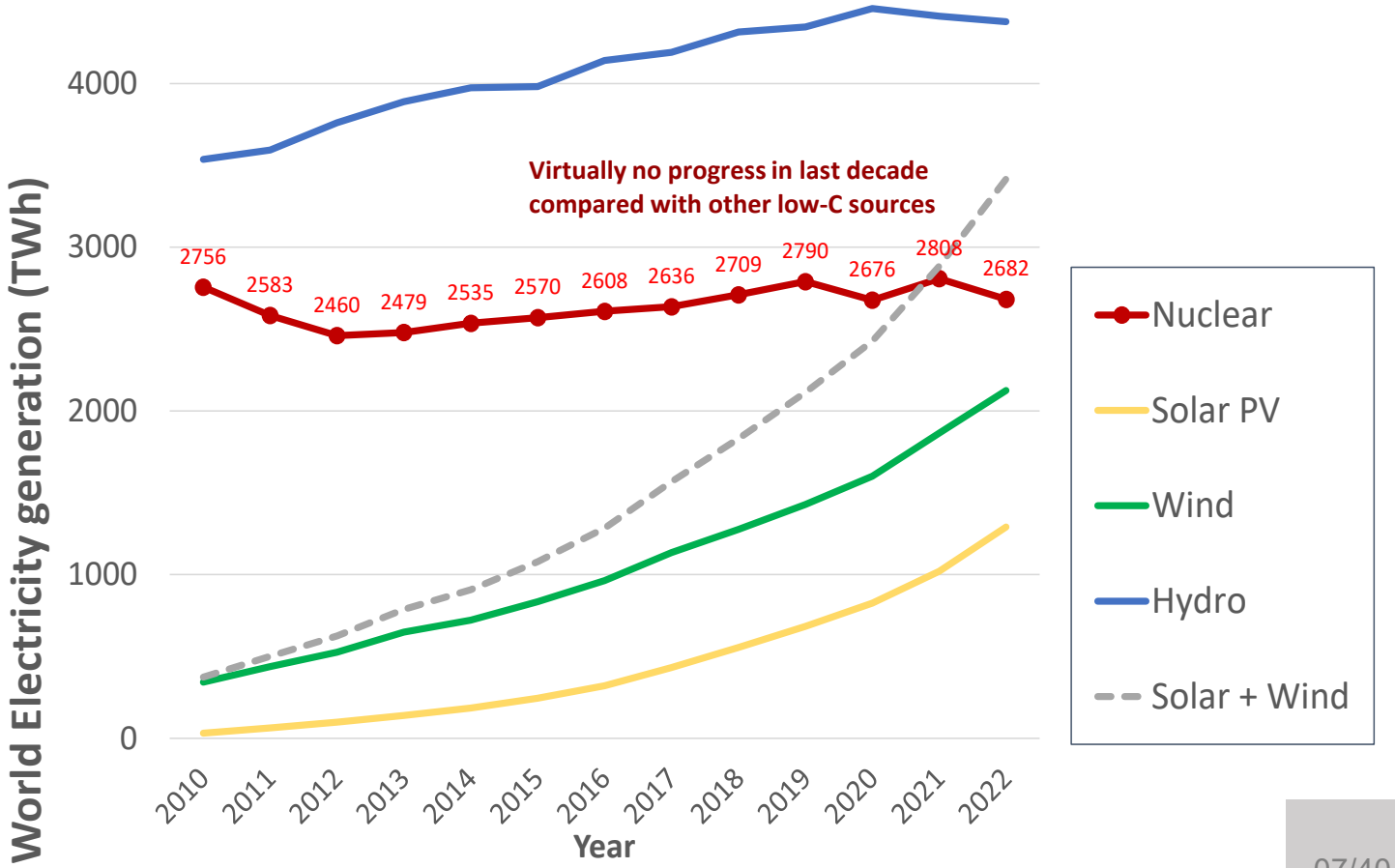
Global electricity generation

Global electricity mix



Index 2005 = 100





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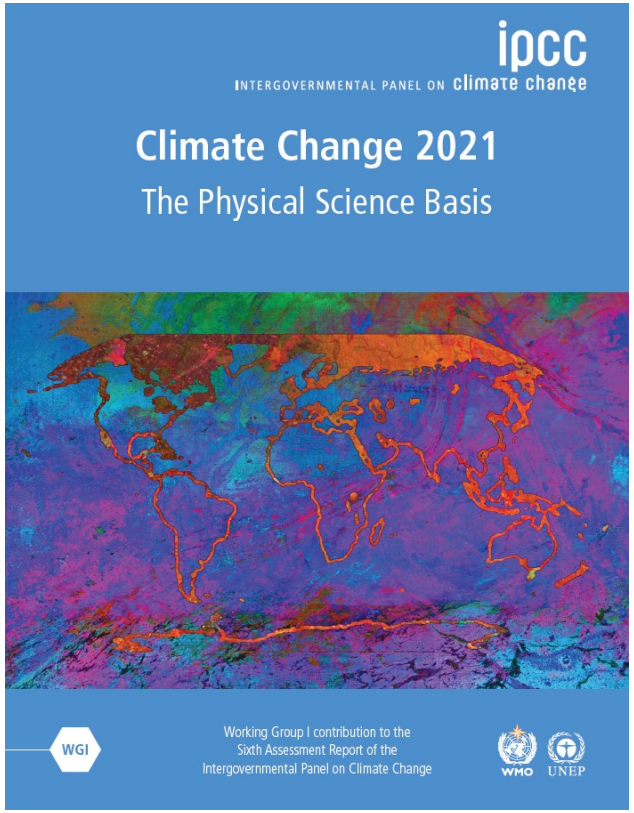
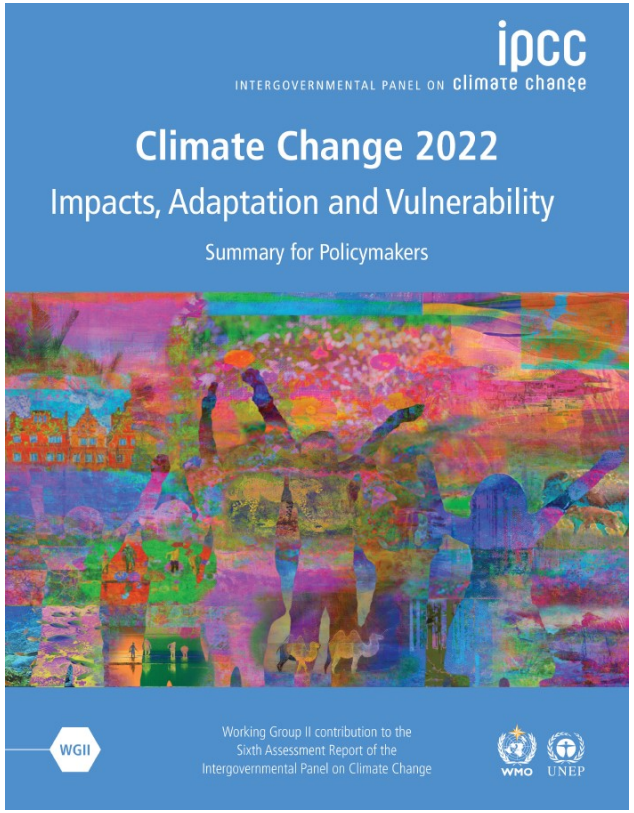
Future trends and pathways

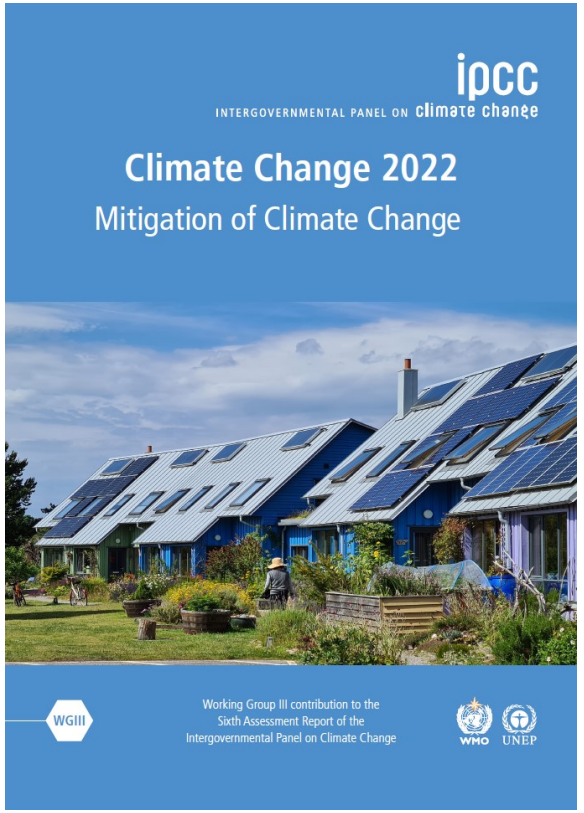
Sixth Assessment Report of the IPCC

- Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change

- Sixth Assessment Report (AR6) addresses the state of scientific, technical and socio-economic knowledge on climate change, its impacts and future risks, and options for reducing the rate of climate change

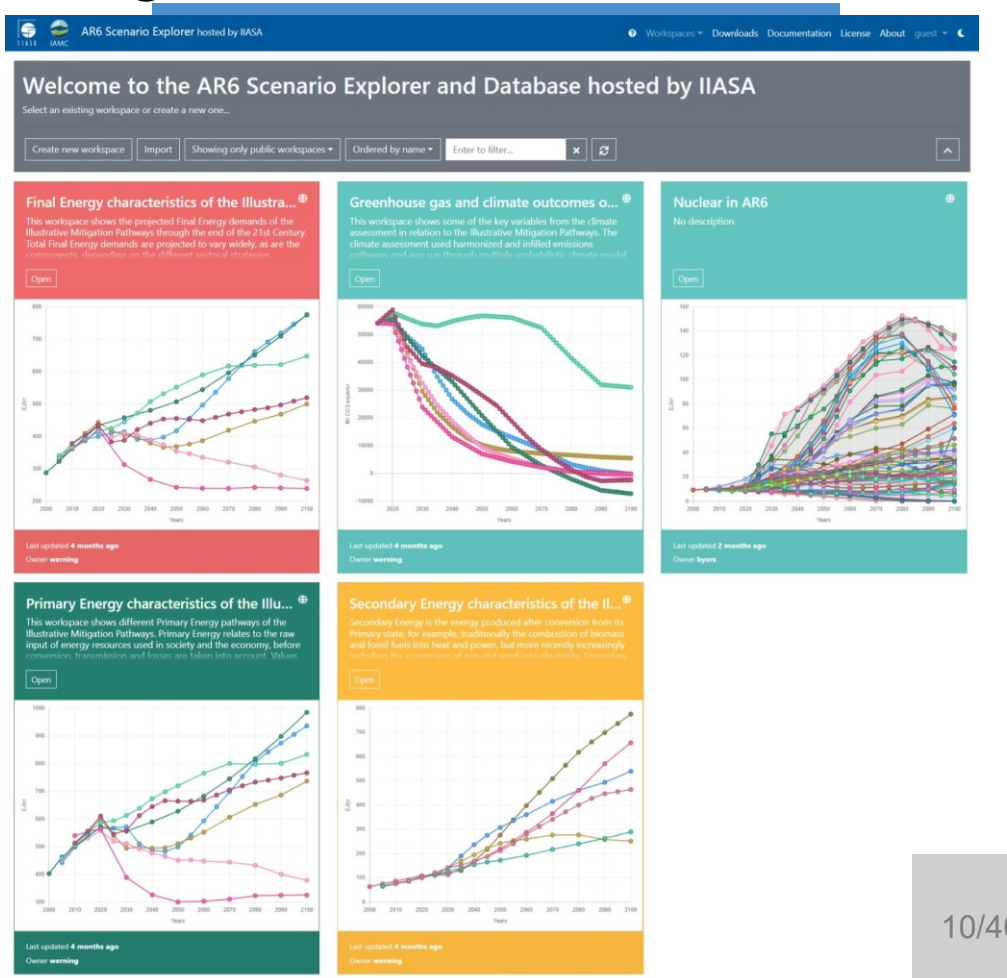




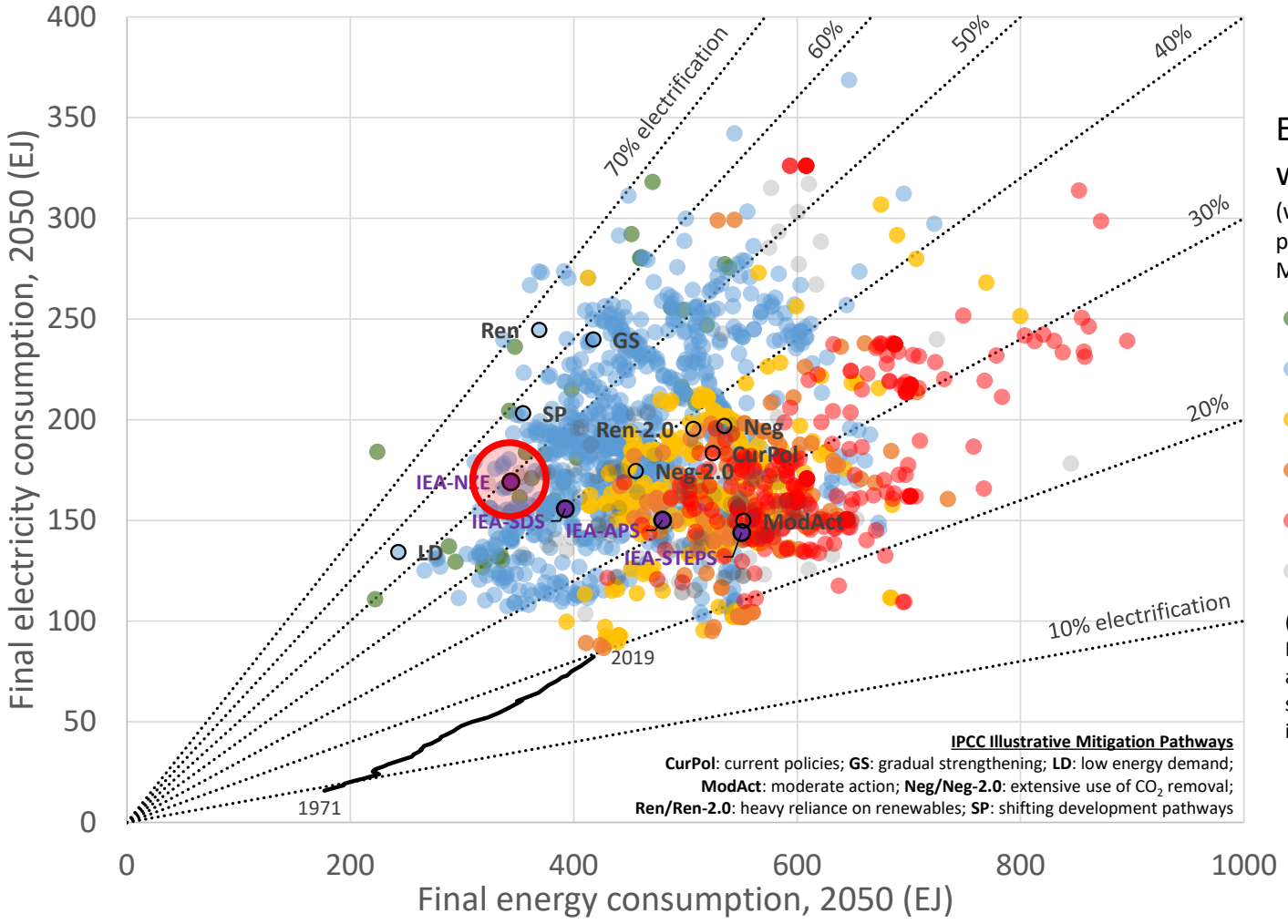


Climate change mitigation scenarios

- IPCC Working Group III contribution to AR6 assesses scenarios of energy system development and climate change
  - from scientific literature
  - generally, developed with **integrated assessment models**
    - *IAMs range from economic models to detailed global energy system models, potentially including different regions, sectors, pollutants, interactions with land and water, and representations of the climate system*
    - *partial-, general, or non-equilibrium, myopic or perfect foresight, optimization or simulation, exogenous or endogenous technological change, etc.*



Key trends: Energy and electricity demand, 2050



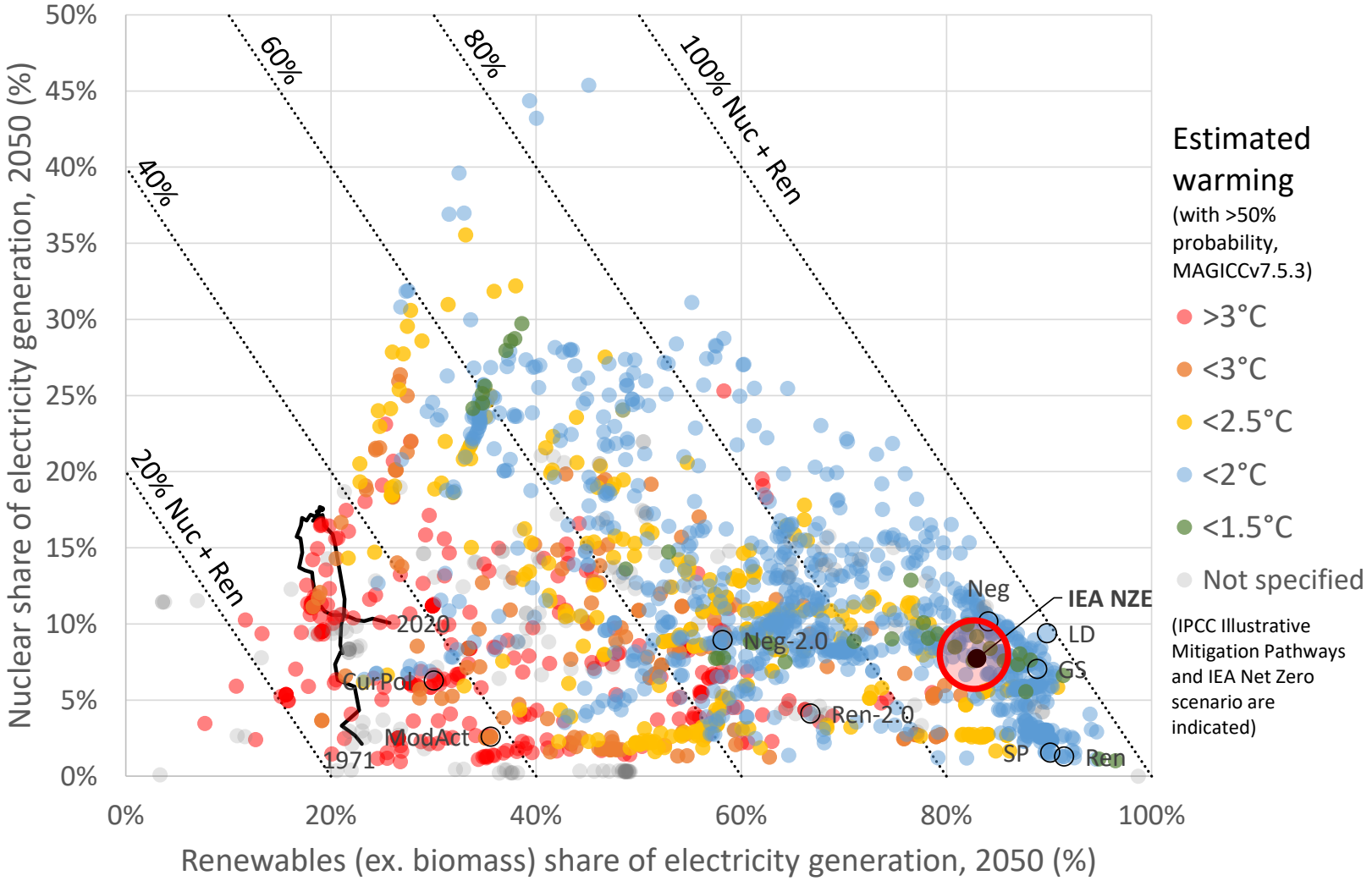
Estimated warming (with >50% probability, MAGICCv7.5.3)

- <1.5°C
- <2°C
- <2.5°C
- <3°C
- >3°C
- Not specified

(IPCC Illustrative Mitigation Pathways and IEA WEO 2021 scenarios are indicated)

- 1971–2019
  - →>2x final energy, >5x electricity
- 2019–2050
  - **>3°** → trends continue
  - **2–3°** → up to +50% FE, ~+100% elec
  - **<2°** → +/-50% FE, up to ~4x electricity
  - **IEA-NZE**: -20% FE, x2 elec
- Strong electrification

Clean electricity mix, 2050

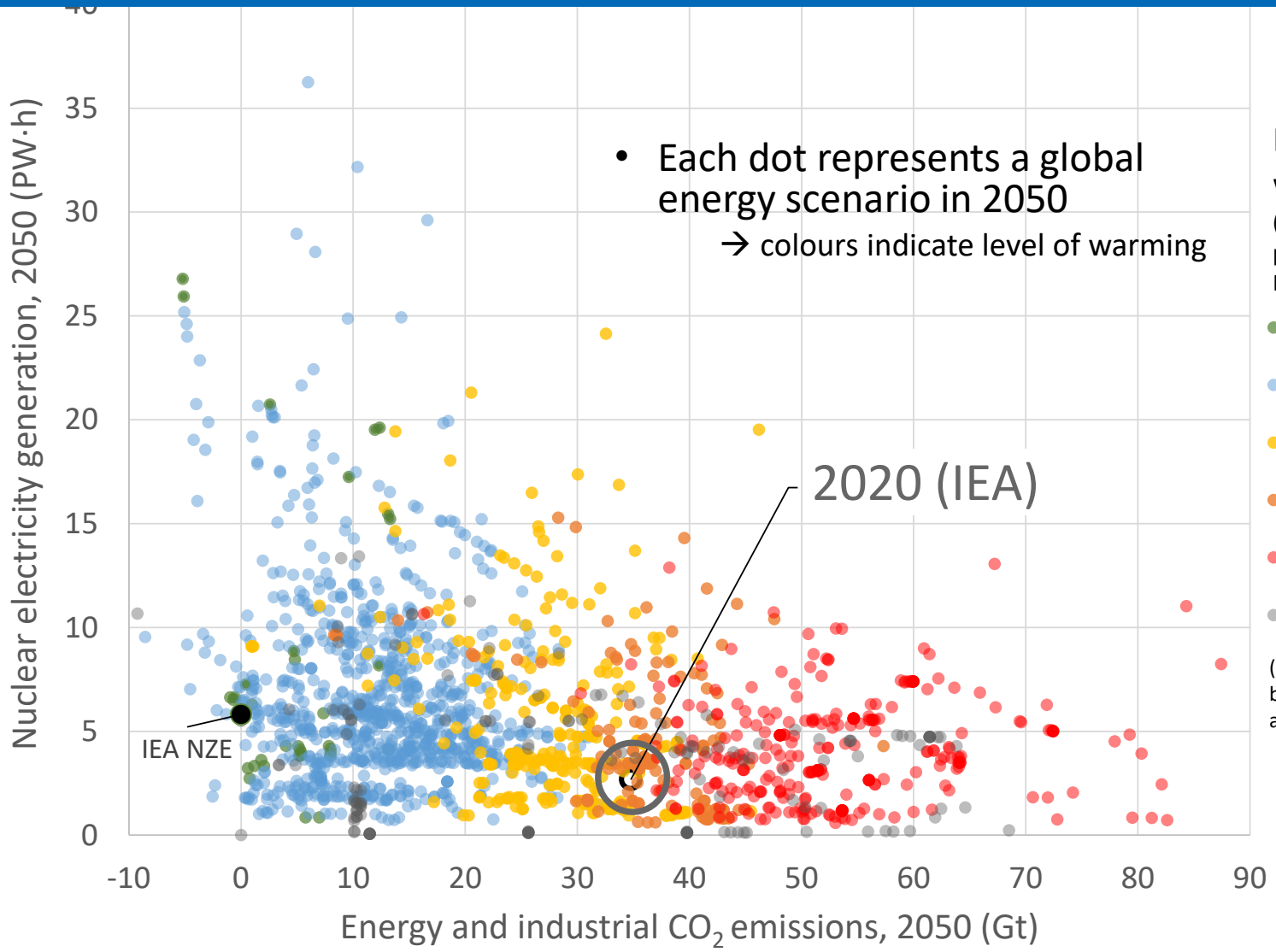


- 1971–2020
  → 20–40% clean elec (nuclear up to ~18%)
- 2020–2050
  >3° → 20–60+% (nuclear up to 25%)
  2–3° → >40% (nuclear up to 35%)
  <2° → >60% (nuclear up to 45%)

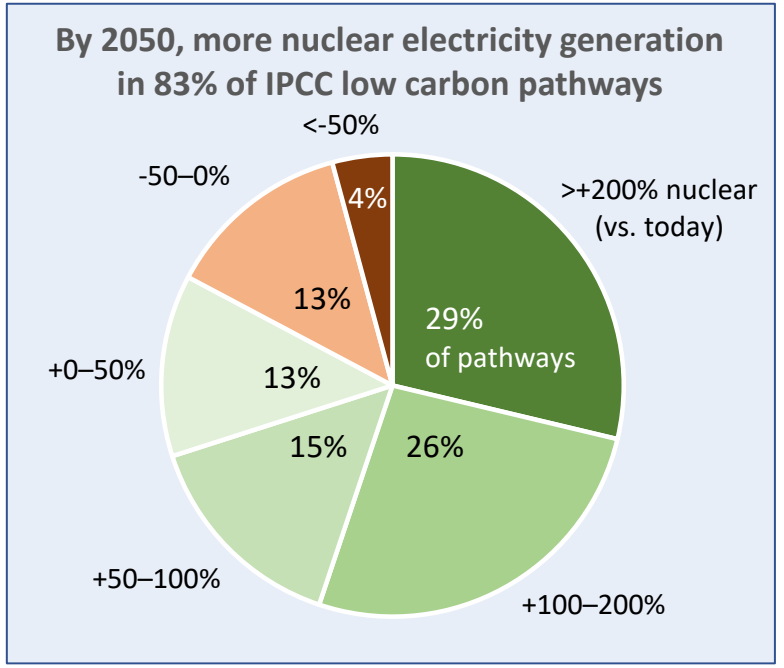
  IEA-NZE: 90% clean elec (nuclear ~7.5%)

- Nuclear **and** renewables

Key trends in low carbon transitions:
Nuclear electricity generation and CO_2 emissions, 2050



- Most scenario pathways envisage an increase in nuclear generation



The role of nuclear: an overview

Nuclear energy and climate change mitigation

- Nuclear energy has one of the **smallest greenhouse gas footprints** of all electricity generation technologies
- Nuclear energy enables decarbonized, secure **electricity systems**
- Nuclear power plants can also produce of **heat**, potable **water** and **hydrogen** to decarbonize other energy uses
- Nuclear energy supports climate **resilient** energy systems
- Nuclear energy delivers **sustainable development** across environmental, economic and social dimensions
- Nuclear energy's potential can be realized with **policies** that guide markets, share risks and empower partnerships **to enable investment**

https://www.iaea.org/topics/nuclear-power-and-climate-change/climate-change-and-nuclear-power-2022

Selected key indicators

26%

global gross low carbon electricity provided by nuclear energy in 2021.

25%

electricity needs in the United Arab Emirates met by the Barakah nuclear power plant, nearly halving power sector carbon emissions in the Emirate of Abu Dhabi by 2025.

32%

global nuclear generation from emerging markets and developing economies in 2021.

>2x

increase in annual electricity sector investment needed between 2023 and 2030 to achieve net zero emissions by 2050, including a projected US $100 billion for nuclear investment annually.

55

nuclear reactors in nine countries provided **district heat** in 2021.

33+

countries that include nuclear energy in their sustainable finance taxonomies or roadmaps, accounting for close to half of global energy emissions.

<0.5%

nuclear electricity production lost between 1990 and 2020 due to weather events.

23%

projected decrease in power costs in France by 2050 with nuclear new build compared to a case without new nuclear power plants.

Key messages

A cost-effective energy transition can be achieved with a combination of nuclear and renewable energy.

Nuclear, as a scalable, dispatchable and low carbon source of electricity, contributes significantly to the security of energy supply, and can do even more in a decarbonized system.

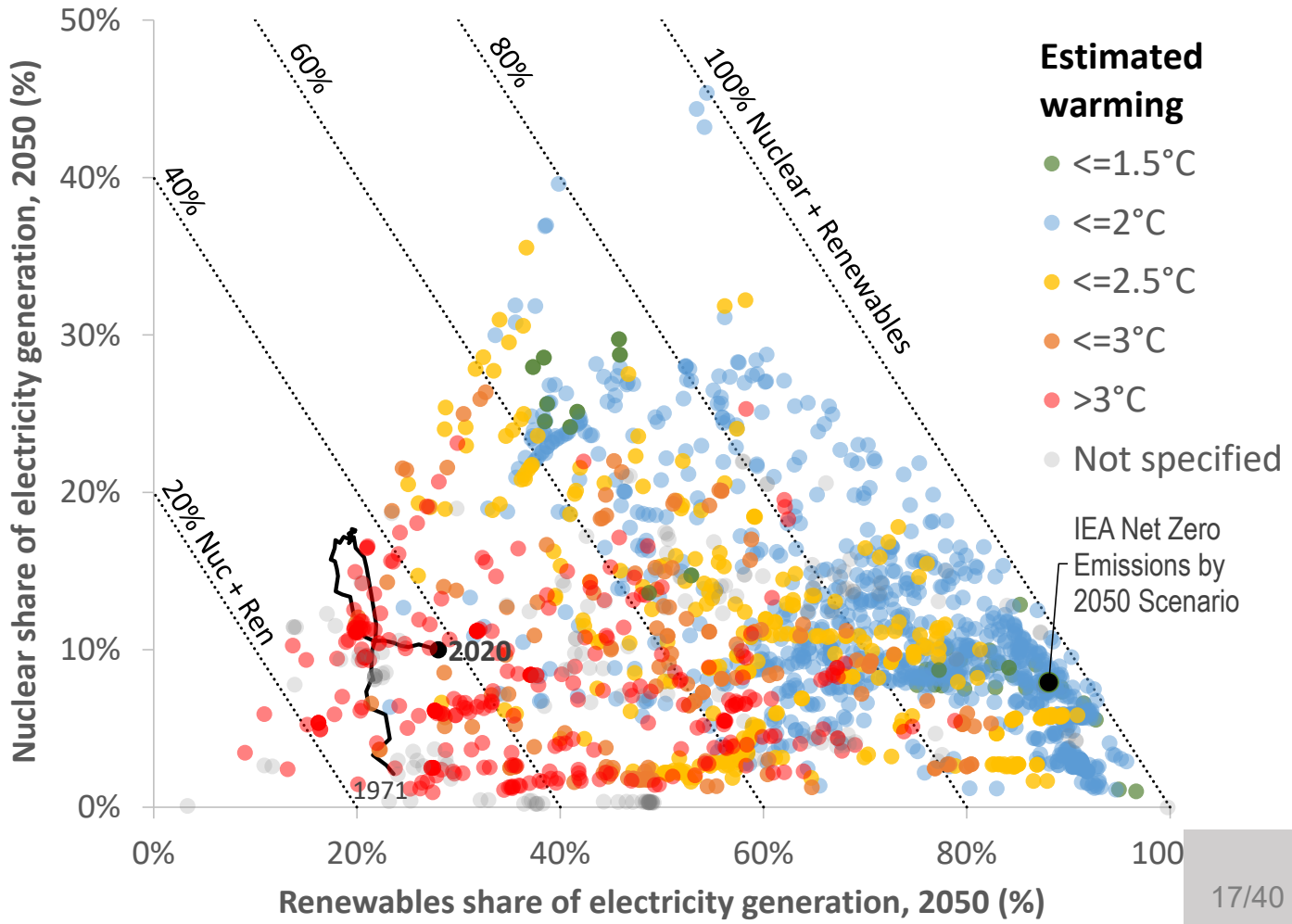
Sizeable deployment of nuclear power increases the chances of achieving a net zero future.

Nuclear energy and the transition to low carbon electricity systems

Key messages

A cost-effective energy transition can be achieved with a combination of nuclear and renewable energy.

→ Increasing shares of nuclear and renewable energy in the electricity generation mix across IPCC AR6 mitigation scenarios
(each dot represents an individual scenario coloured according to the estimated temperature increase)



Nuclear production of heat, potable water and hydrogen

Key messages

In addition to low carbon electricity, nuclear capacity is able to supply heat and hydrogen as alternative energy products.

An expanded use of non-electric applications of nuclear power including desalination, district heating and hydrogen production can be used to reduce emissions and increase the security of supply of the global energy system.

Nuclear production of heat, potable water and hydrogen

Key messages

In addition to low carbon electricity, nuclear capacity is able to supply heat and hydrogen as alternative energy products.

→ District heating output (electric equivalent) of nuclear power plants

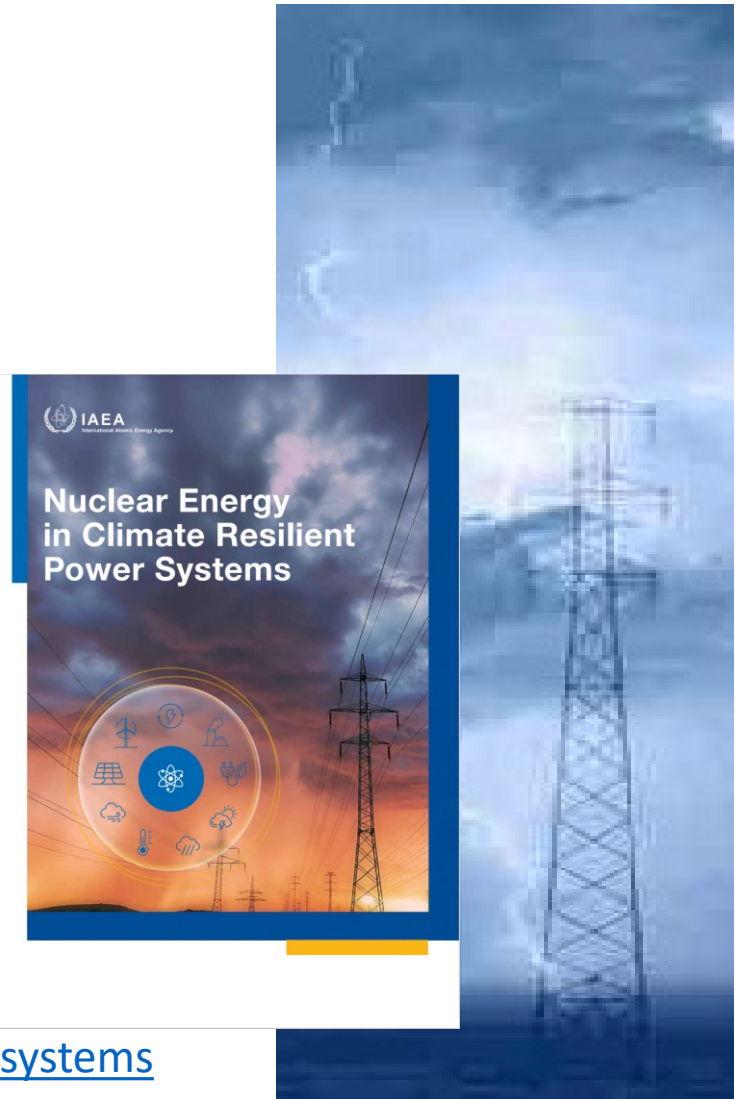
Climate resilient nuclear infrastructure

Key messages

Global energy infrastructures will be increasingly exposed to frequent and severe climate hazards.

The nuclear sector is well prepared to face changing environmental conditions in the foreseeable future.

Integrating the latest advances in climate science, including the better representation of future climate risks and new climate hazards at the local scale, can greatly contribute to strengthening the climate resilience of nuclear infrastructures.



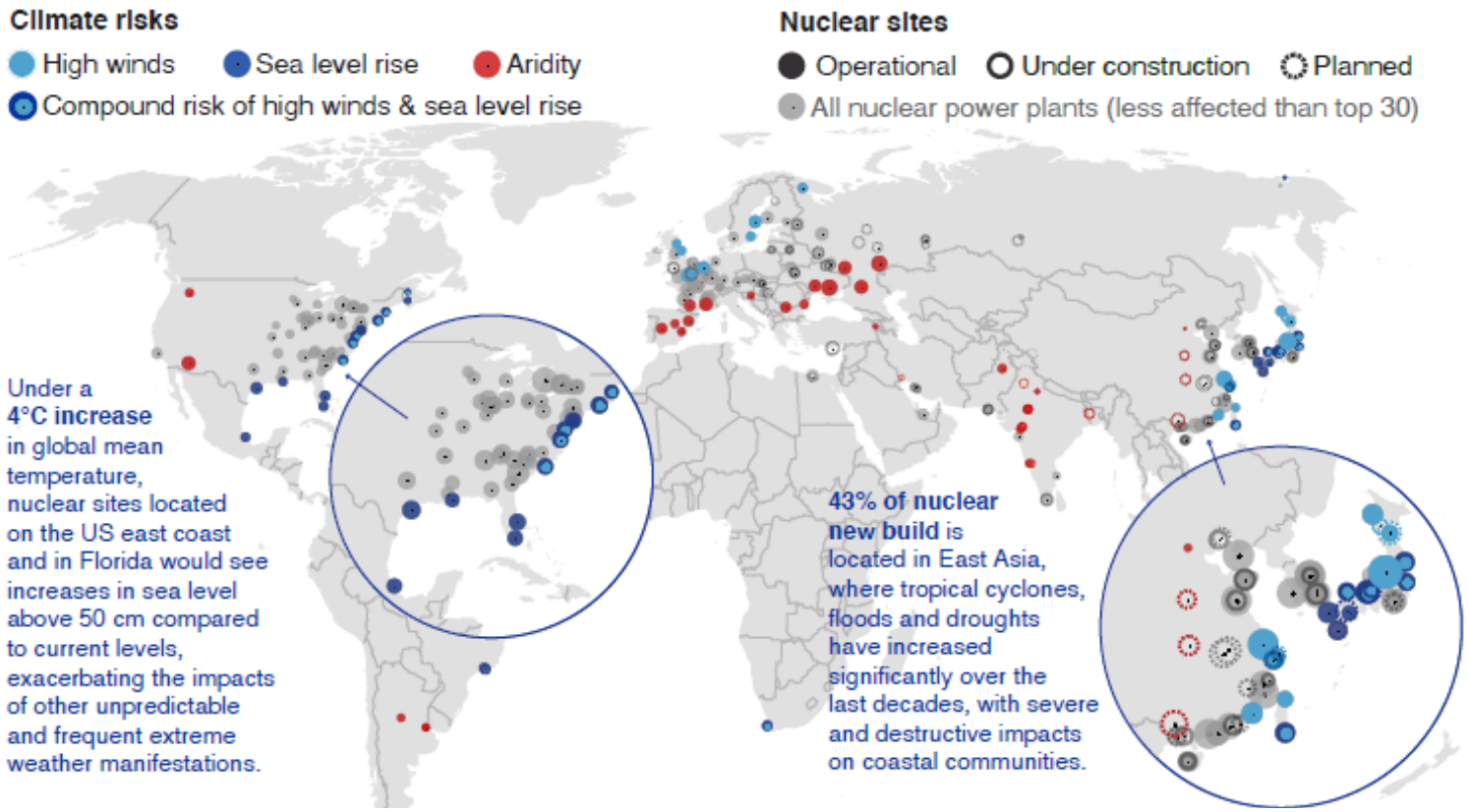
https://www.iaea.org/publications/15557/nuclear-energy-in-climate-resilient-power-systems

Climate resilient nuclear infrastructure

Key messages

Global energy infrastructures will be increasingly exposed to frequent and severe climate hazards.

→ Global overview of the most significant environmental changes around selected nuclear power plant site locations

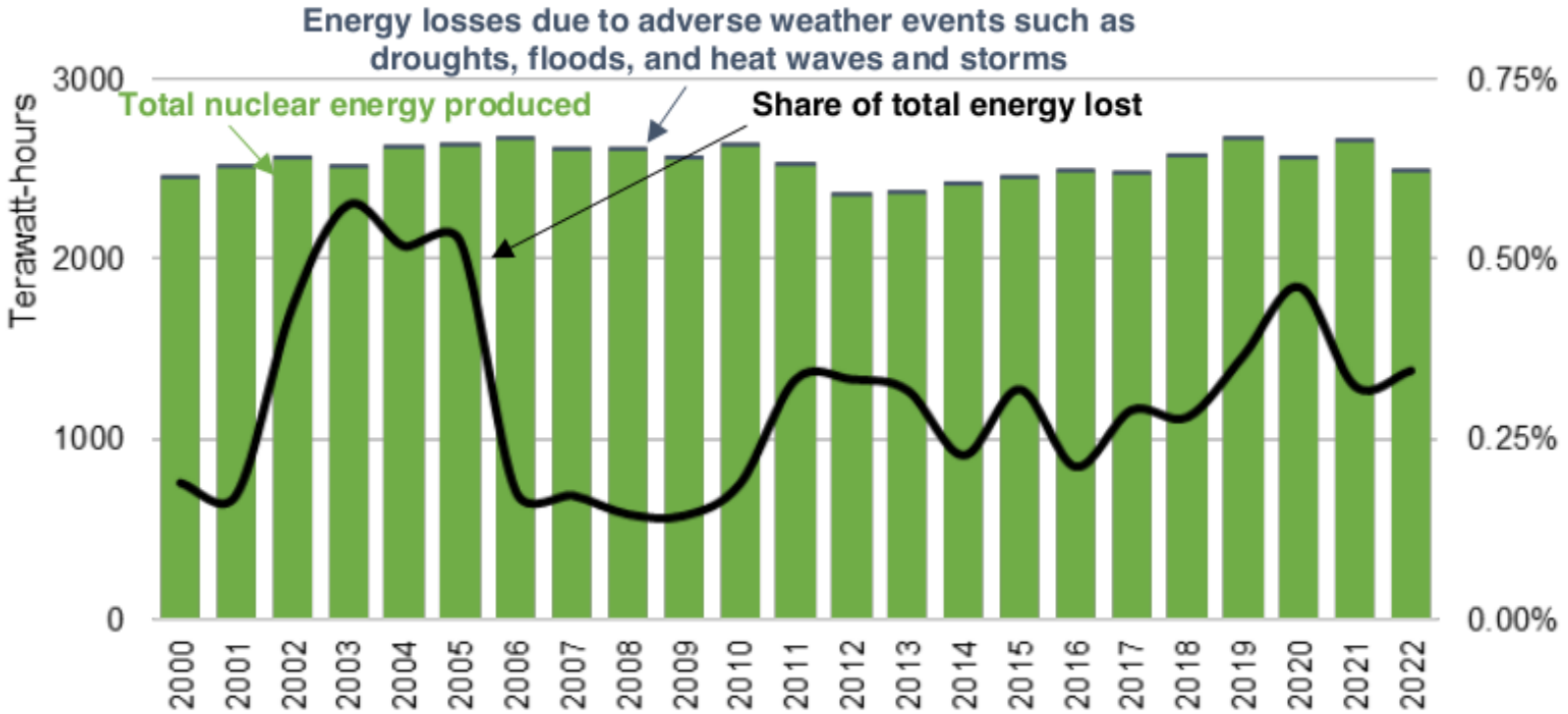


Climate **resilient** nuclear infrastructure

Key messages

The nuclear sector is well prepared to face changing environmental conditions in the foreseeable future.

→ Annual nuclear energy production and weather-related losses, 2020–2022



Source: IAEA Power Reactor Information System (PRIS)

Policies enabling investment for a secure, low carbon energy transition

Key messages

A coherent set of policy, regulatory, infrastructure and other measures is vital to guide markets and investors, foster cooperation and manage risks.

Significant mobilization of energy investment for climate action, balanced with support for broader development and energy security needs, can drive nuclear investment.

Policies enabling investment for a secure, low carbon energy transition

Key messages

→ Nuclear energy in NDCs (nationally determined contributions) and LTSs (long term strategies) under the Paris Agreement

	Using nuclear power today	Constructing first nuclear power plant	Other countries
Nuclear energy in NDC and LTS	Canada, China, Ukraine, UK, USA		
Nuclear energy in NDC only	Argentina, Armenia, India, Iran (Islamic Rep.), Russian Fed., United Arab Emirates	Türkiye	Korea (DPR) Ghana
Nuclear energy in LTS only	Czech Rep., Finland, France, Hungary, Japan, Mexico, Netherlands, Slovakia, Slovenia, Sweden		Australia, Colombia, Morocco, Singapore
Nuclear energy not included in NDC or LTS (or mentioned in the context of moratoria or phase-outs)	Belarus, Belgium, Brazil, Bulgaria, Germany, Korea, Rep., Pakistan, Romania, Switzerland, South Africa, Spain	Bangladesh, Egypt	Rest of the world

~70% of global energy related GHG emissions

Policies enabling investment for a secure, low carbon energy transition

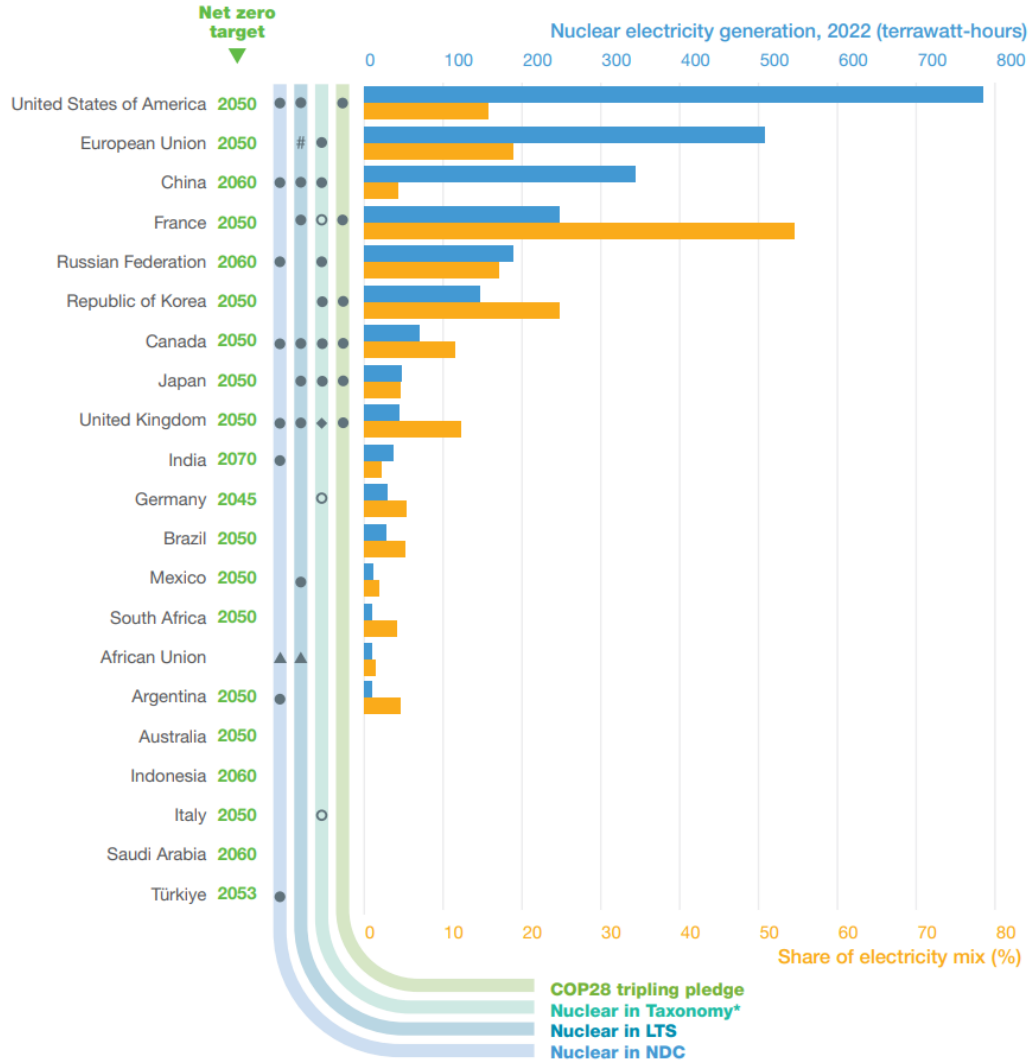
Key messages

A coherent set of policy, regulatory, infrastructure and other measures are vital to guide markets and investors, foster cooperation and manage risks.

Significant mobilization of energy investment for climate action, balanced with support for broader development and energy security needs, can drive nuclear investment.

→ **Nuclear energy in sustainable investment taxonomies (mid-2022)**

→ Now also included by: Canada, Kazakhstan, UK



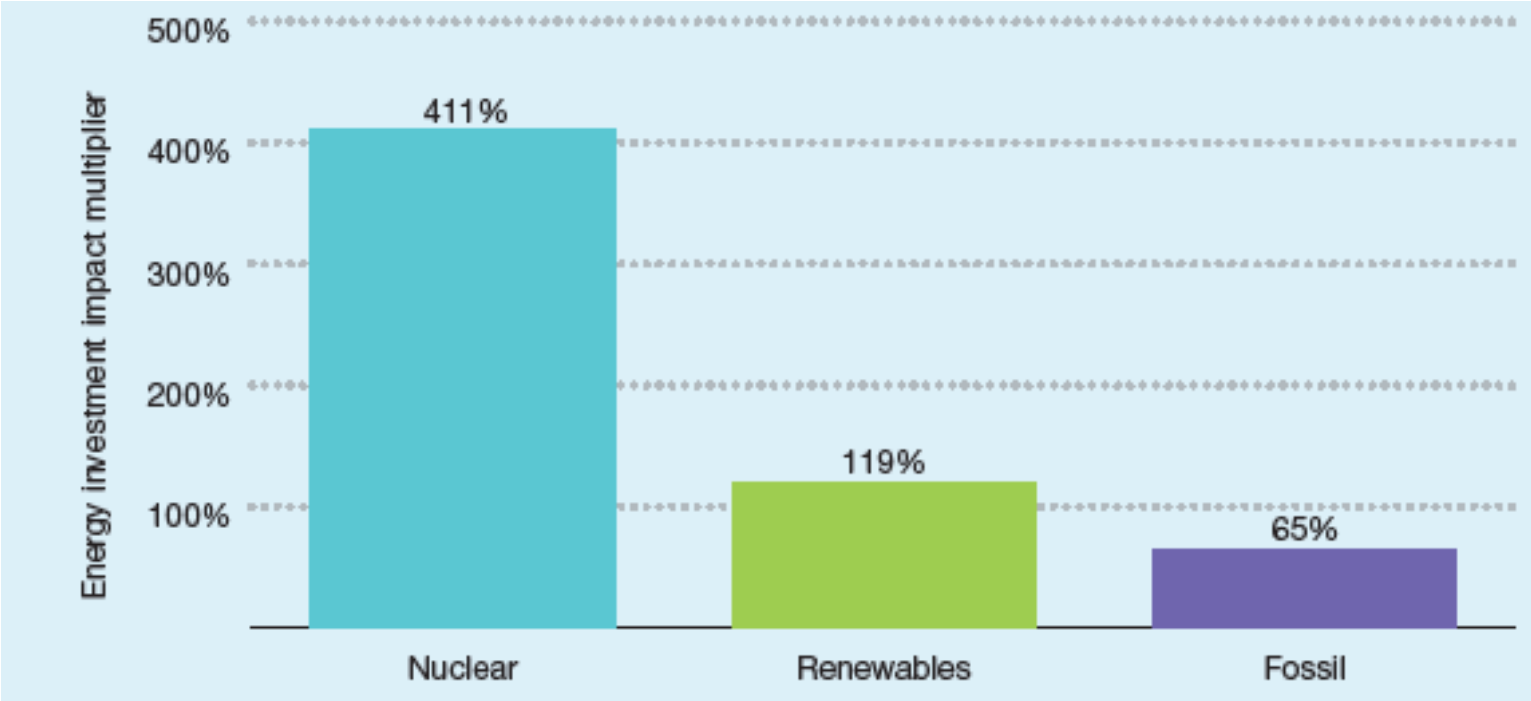
Policies enabling investment for a secure, low carbon energy transition

Key messages

→ Green multipliers for investment in nuclear and other energy sources

The multiplier — i.e. the change in GDP divided by the change in investment spending — for nuclear energy is estimated to be ~6x that of fossil energy and ~3x renewable energy.

Nuclear investment also stimulates more investment in other parts of the economy and produces a larger boost in employment.



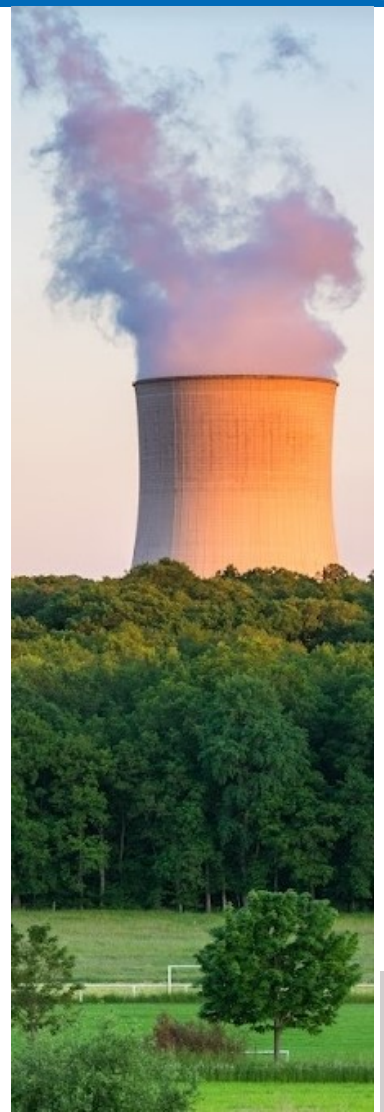
Source: IMF (Batini et al. 2021)

Nuclear energy and sustainability

Key messages

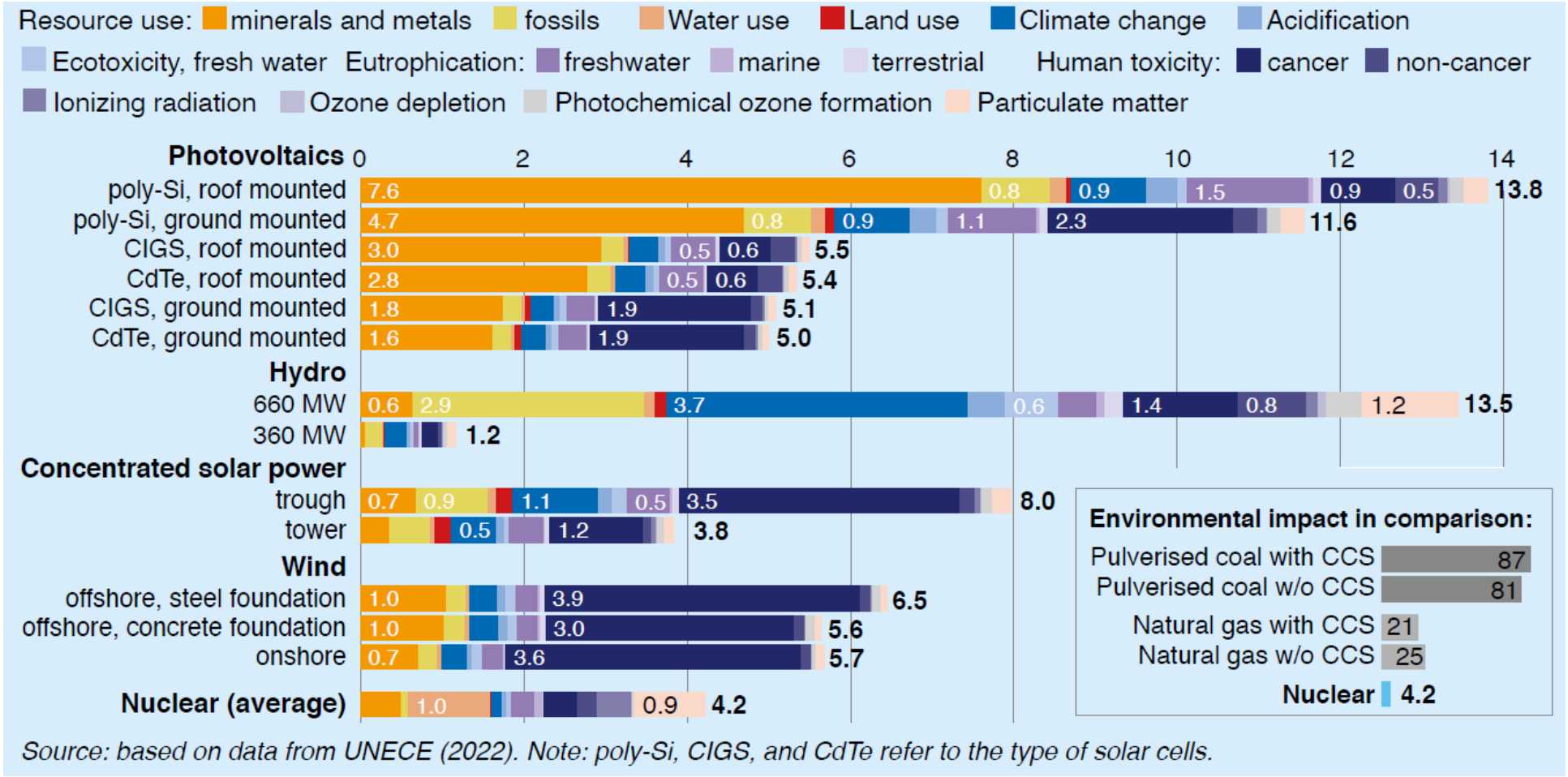
When assessed on a life cycle basis, the environmental impact of nuclear energy is on par with renewable energy alternatives.

Energy players are increasingly deploying integrated policy and corporate strategies that work towards carbon neutrality and other sustainable development objectives, particularly biodiversity preservation and restoration.



Nuclear energy and sustainability

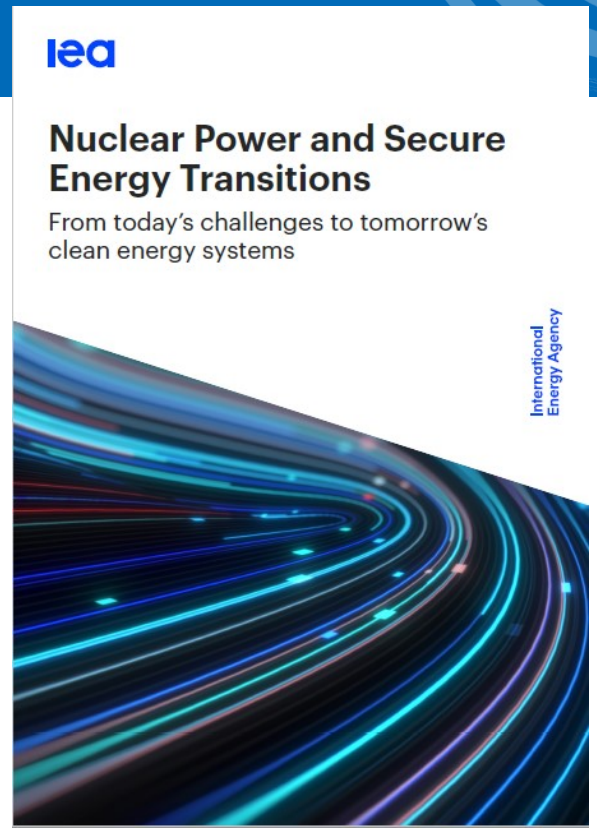
Life cycle impacts of renewable and nuclear technologies (per kWh)



Source: based on data from UNECE (2022). Note: poly-Si, CIGS, and CdTe refer to the type of solar cells.

Recap: Nuclear power, backbone of low C energy systems

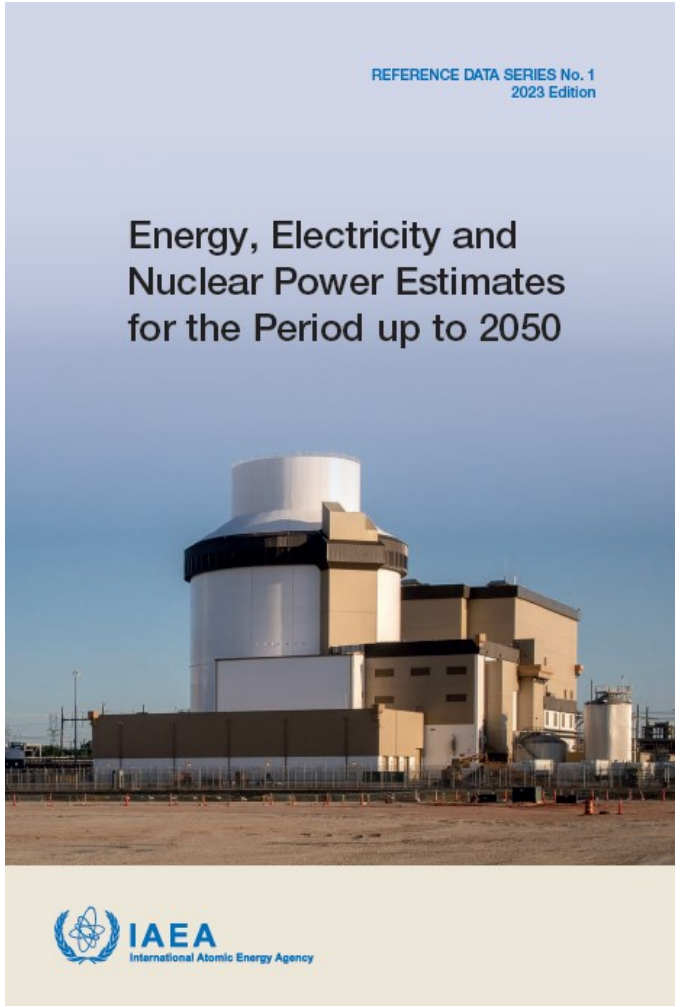
- **Sustainable**:
  - Low carbon:
    - Among the smallest C footprints of all technologies
    - 70 Gt CO_2 avoided in past five decades, more 1 Gt avoided each year
  - Integration into numerous sustainable investment taxonomies
- **Flexible, dispatchable**:
  - Supports cost-effective integration of large %shares of renewables
- **Security of supply**:
  - Low dependency on cost fuel, widespread U resources, storage fuel on site
  - Among the low C technologies least intensive in critical minerals
- Can help contribute to a **less costly transition** (system costs)
- Can contribute to **climate-resilient energy systems**
- Can help **decarbonize beyond the power sector**

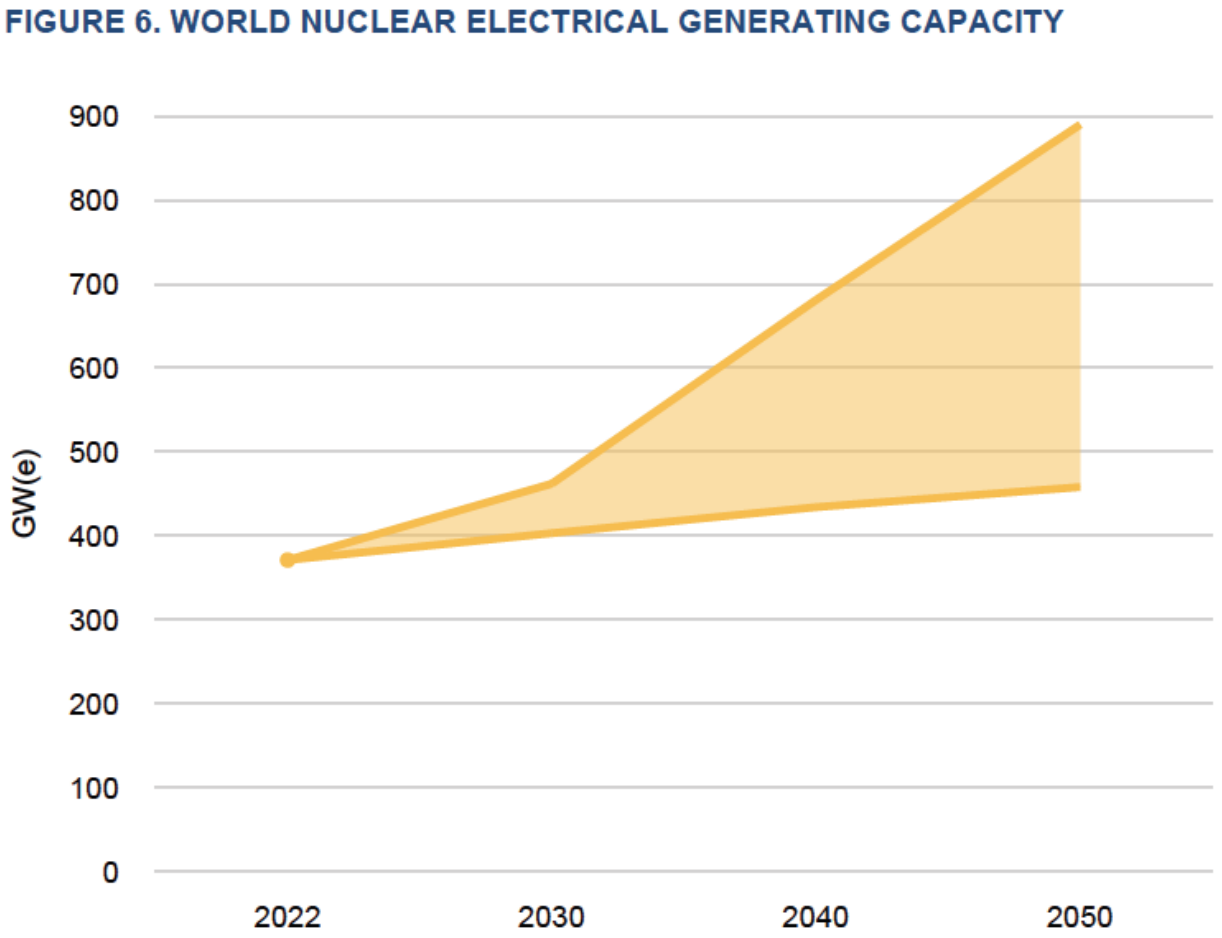


"without the support of nuclear power **we have no chance** to reach our climate targets on time"

Dr Fatih Birol, IEA

IAEA's nuclear projections to 2050

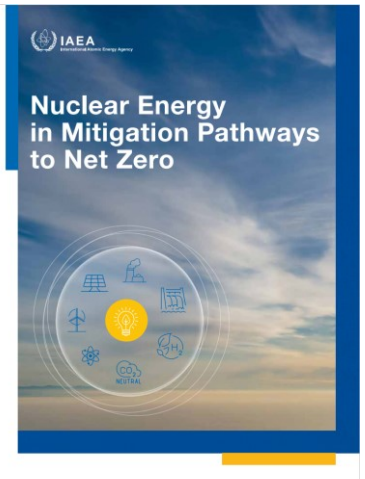


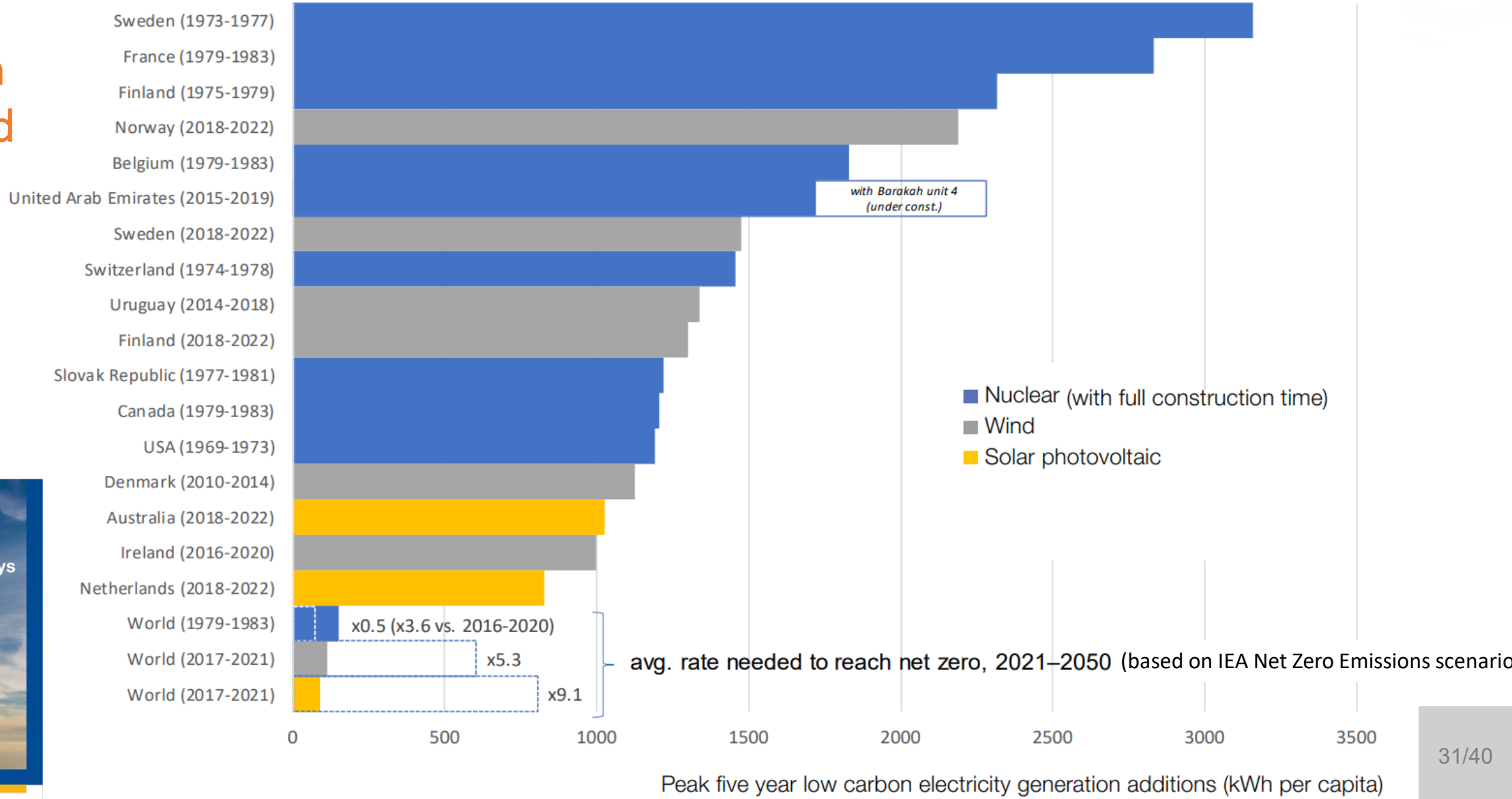


https://www.iaea.org/publications/15487/energy-electricity-and-nuclear-power-estimates-for-the-period-up-to-2050

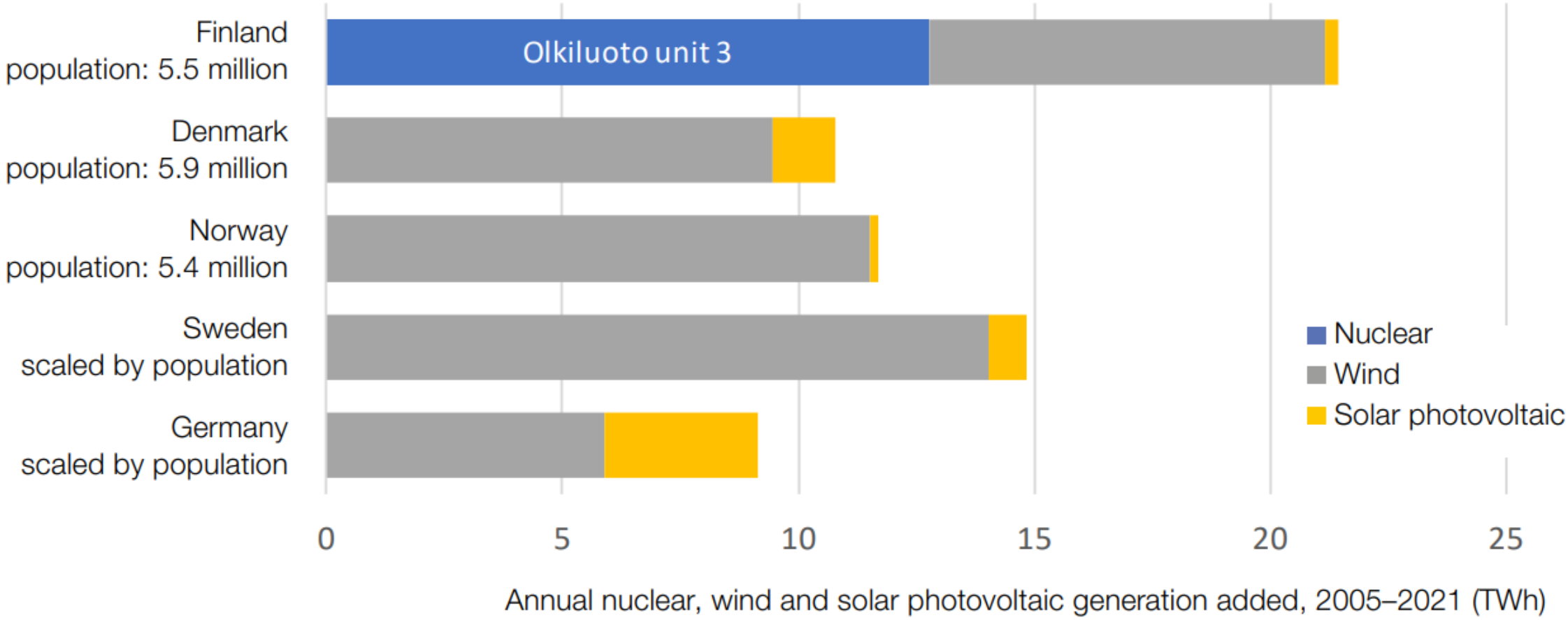
Nuclear deployment: is a doubling or more realistic?

Nuclear can be deployed rapidly to track low carbon pathways





Even with delays, nuclear energy delivers rapid decarbonization
– e.g. Finland's Olkiluoto-3 (~12 years delayed)



https://www.iaea.org/publications/15558/nuclear-energy-in-mitigation-pathways-to-net-zero

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Nuclear energy at COP28 and beyond

COP28 outcomes

- Plenary adopted the Outcome of the first global stocktake by consensus on December 13
- Text calls to **accelerate nuclear**
  - https://unfccc.int/documents/636608

28. *Further recognizes* the need for deep, rapid and sustained reductions in greenhouse gas emissions in line with 1.5 °C pathways and *calls on* Parties to contribute to the following global efforts, in a nationally determined manner, taking into account the Paris Agreement and their different national circumstances, pathways and approaches:

(a) Tripling renewable energy capacity globally and doubling the global average annual rate of energy efficiency improvements by 2030;

(b) Accelerating efforts towards the phase-down of unabated coal power;

(c) Accelerating efforts globally towards net zero emission energy systems, utilizing zero- and low-carbon fuels well before or by around mid-century;

(d) Transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science;

(e) Accelerating zero- and low-emission technologies, including, inter alia, renewables, nuclear, abatement and removal technologies such as carbon capture and utilization and storage, particularly in hard-to-abate sectors, and low-carbon hydrogen production;

(f) Accelerating and substantially reducing non-carbon-dioxide emissions globally, including in particular methane emissions by 2030;

(g) Accelerating the reduction of emissions from road transport on a range of pathways, including through development of infrastructure and rapid deployment of zero- and low-emission vehicles;

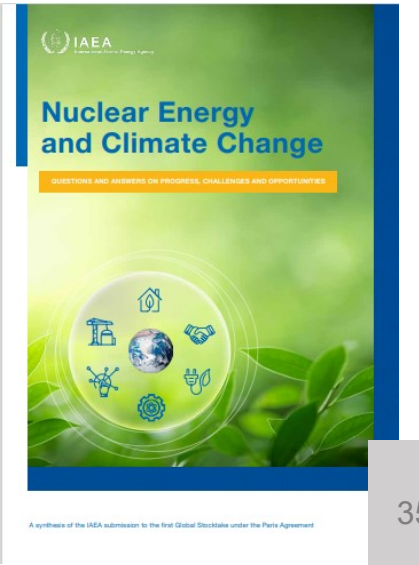
(h) Phasing out inefficient fossil fuel subsidies that do not address energy poverty or just transitions, as soon as possible;

29. *Recognizes* that transitional fuels can play a role in facilitating the energy transition while ensuring energy security;

30. *Welcomes* that over the past decade mitigation technologies have become increasingly available, and that the unit costs of several low-emission technologies have fallen continuously, notably wind power and solar power and storage, thanks to technological advancements, economies of scale, increased efficiency and streamlined manufacturing processes, while recognizing the need to increase the affordability and accessibility of such technologies;

Nuclear and IAEA at COP28

- Declaration by 25 countries pledging to **triple** nuclear capacity by 2050
- Release of IAEA statement* highlighting the role of nuclear energy in achieving net zero
- Numerous (~30) events at the IAEA's **Atoms4Climate** pavilion, on topics ranging from ocean health to sustainable energy investment
- Collaboration with Member States and international orgs. (China, Canada, France, FAO, SEforALL, WMO and others)
- Earlier in 2023, IAEA contributed to first Global Stocktake under the Paris Agreement →



* https://www.iaea.org/newscenter/statements/iaea-statement-on-nuclear-power-at-cop28
https://www.iaea.org/publications/15503/nuclear-energy-and-climate-change-questions-and-answers-on-progress-challenges-and-opportunities


IAEA Statement on Nuclear Power
COP28


United Nations
Climate Change
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DUBAI 2023


IAEA


OCEAN
UNDERSTANDING AND MITIGATING OCEAN ACIDIFICATION
WATER
SUPPORTING SUSTAINABLE WATER RESOURCE MANAGEMENT
ATOMS4CLIMATE
ATOMS4 CLIMATE
IAEA

Nuclear Energy Summit 2024
Building on momentum from COP28

- In March 2024, IAEA convened the first Nuclear Energy Summit at Heads of State level.
- Countries emphasized the importance of using nuclear power to achieve energy security, climate goals and drive sustainable development.
- Increased financing, workforce development (including attracting diverse talent) and more proactive support to nuclear newcomer countries were identified as key to long term success.

"The Nuclear Energy Summit must be a turning point for nuclear energy, calling for global investment across all economies."

IAEA Director General,
Rafael Mariano Grossi

IAEA Support for Member States' Sustainable Energy Strategies

- … ***assist*** Member States in reinforcing national capabilities to conduct energy system analysis, so that countries can assess options and develop ***their own sustainable energy strategies,*** *i.e. support decision and policy making*

- …***strengthen*** the provision of support to Member States in ***integrating the SDGs***…through national and regional ***energy studies***

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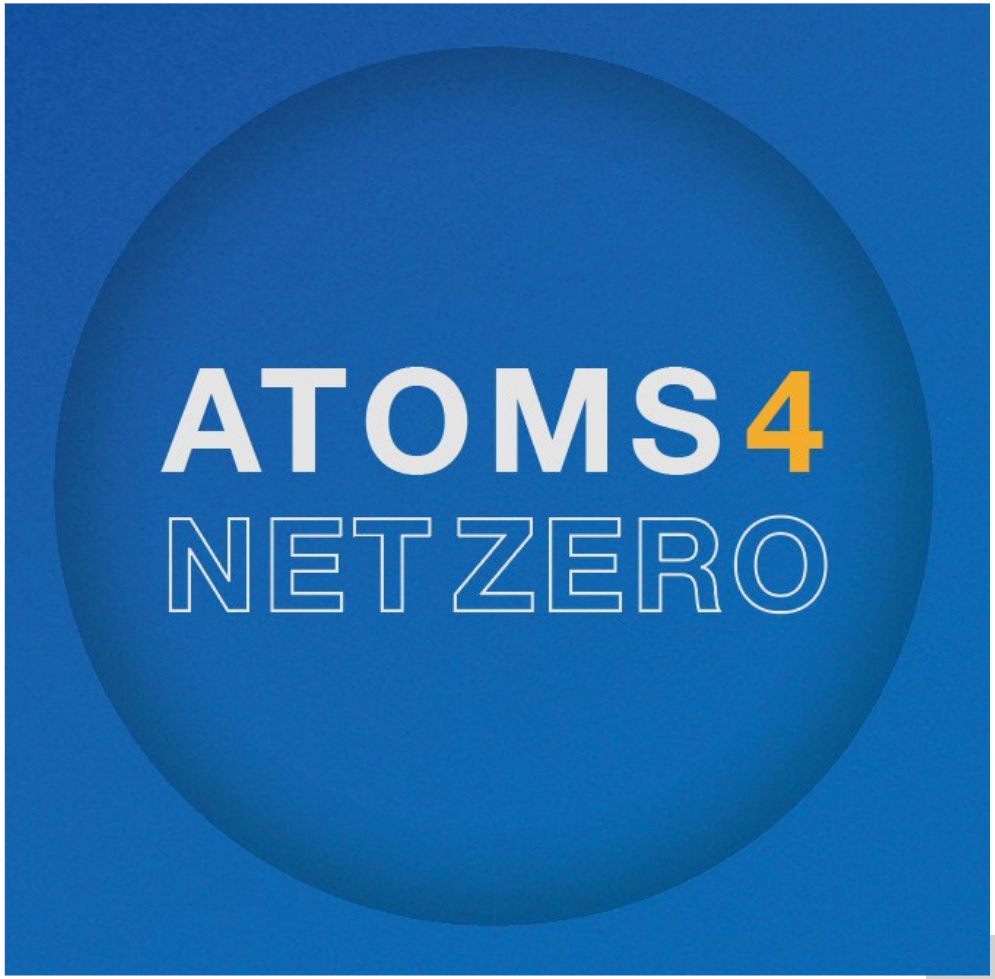
IAEA Atoms4NetZero Initiative

- Launched at COP27 by IAEA **Director General Rafael Mariano Grossi**
- Builds on decades supporting Member States to develop capacity in sustainable energy planning.
- Through Atoms4NetZero, the IAEA is providing **analytical tools** and **expertise** to help countries model how nuclear power can contribute to reducing greenhouse gas emissions to as close to zero as possible by 2050.
- Atoms4NetZero is helping countries assess the potential of **innovative nuclear technologies**, including **small modular reactors**, to support their long term strategies to decarbonize electricity generation and other carbon intensive sectors.



Thank you

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