Geopolitics of Nuclear Energy

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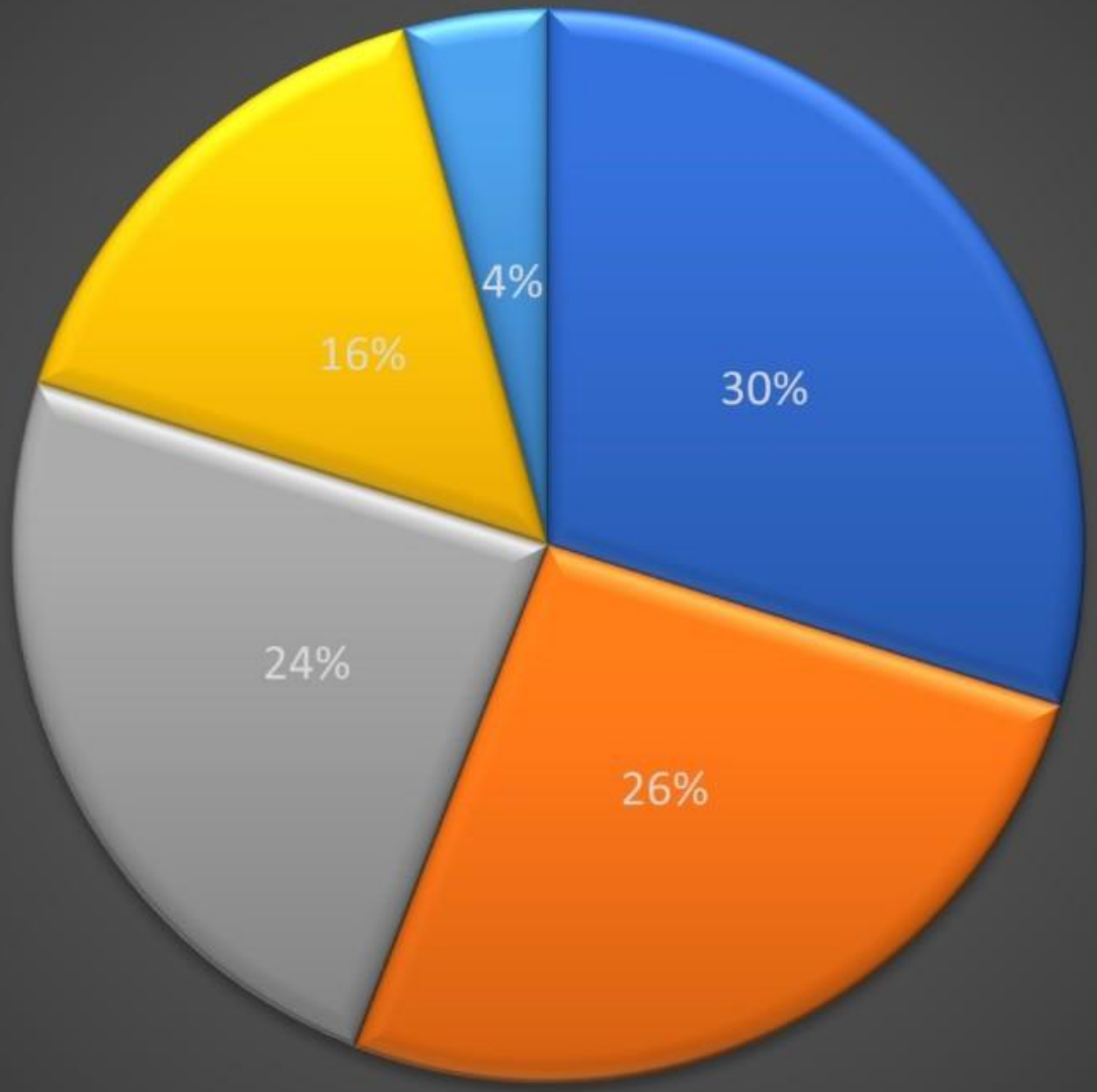
ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ
UNIVERSITY OF PIRAEUS

THE COUNCIL
GREECE IN GLOBAL AFFAIRS
Founded in 2018

Why has nuclear energy failed to meet initial expectations?

Global Energy Consumption (2022)

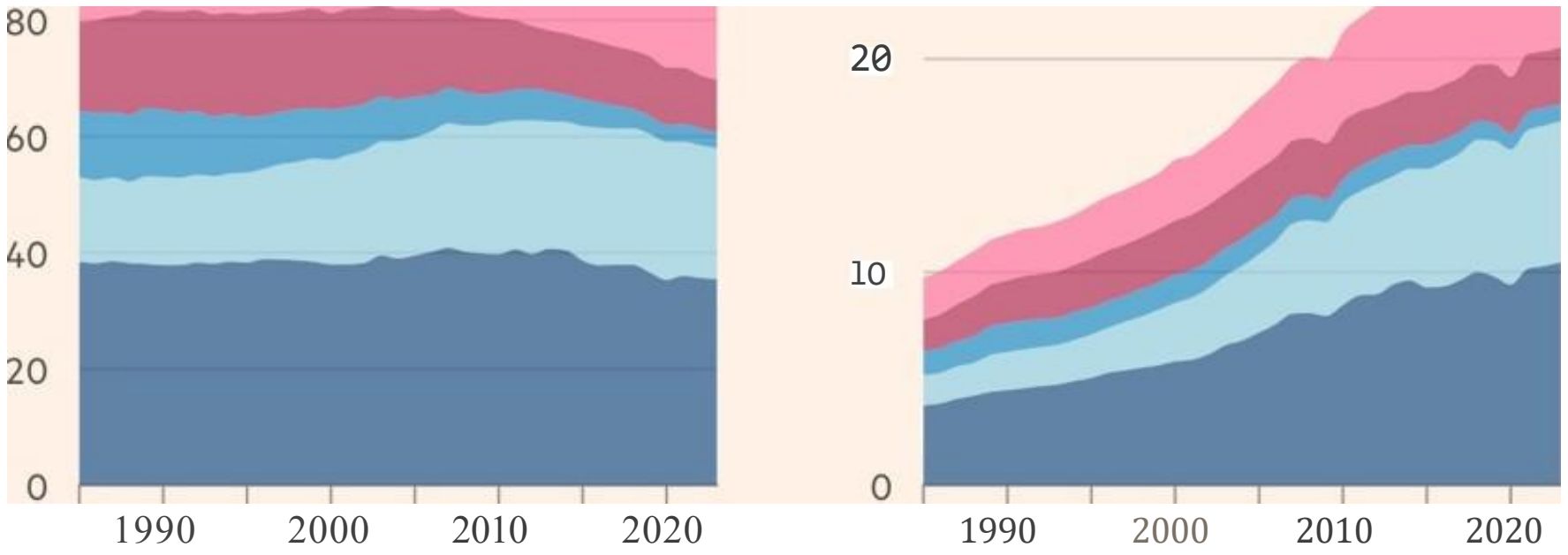


World electricity generation, by source, 198 5 to 2023

Coal Gas Oi1 Nuclear Renewables

Share of total (â}

'000 of TWh



I INANCIAL TIMES

Source: Ember, Energy institute; Our World in Data

THE SHARE OF NUCLEAR POWER PLANTS
IN GLOBAL ELECTRICITY PRODUCTION

THE INSIDER

Source: IEA (2023), World Nuclear Report (2024)

Nuclear generation and emissions intensity of power sector (rebased, Dec 2020 = 100)

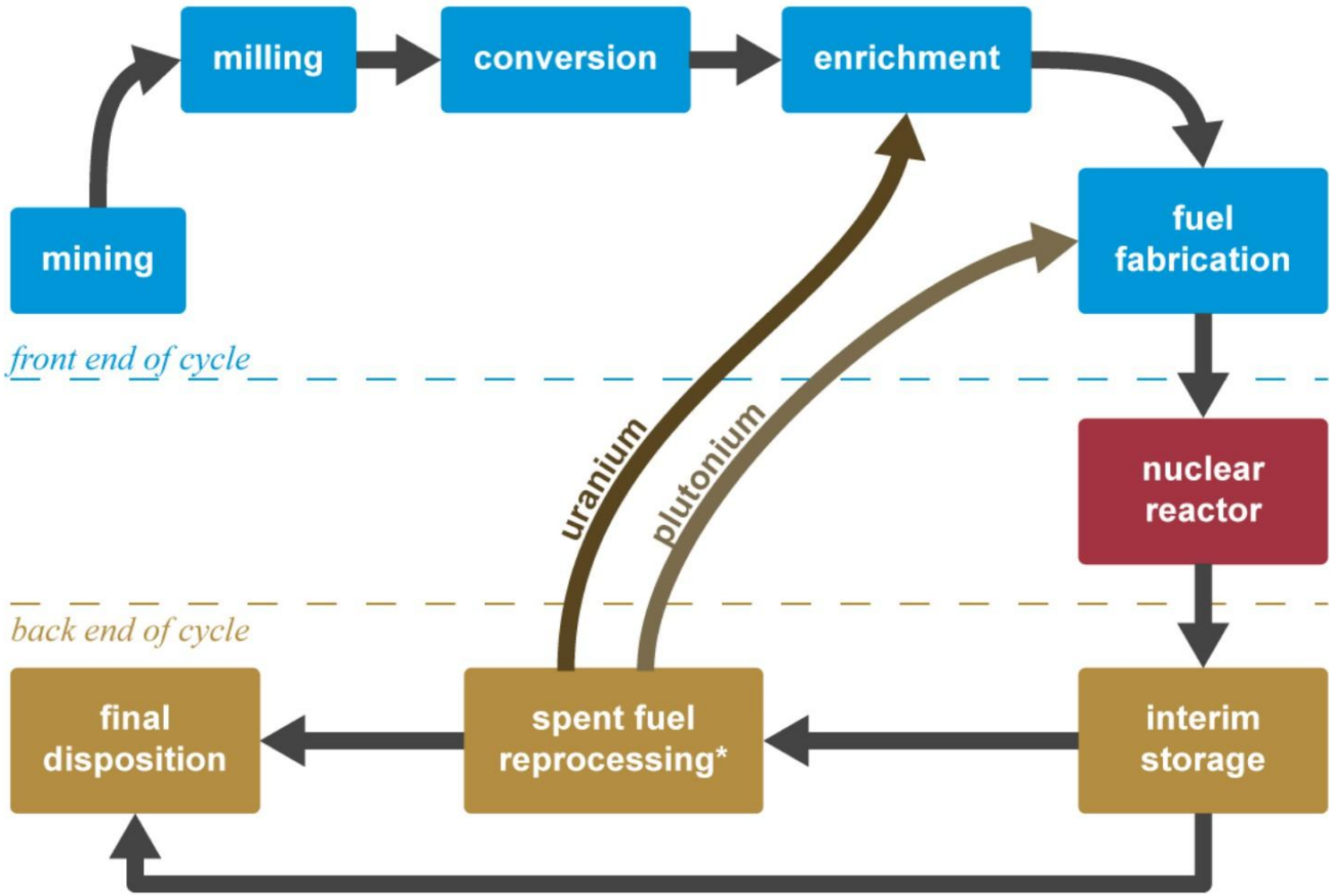
Source: Ember
FT graphic: John Burn-Murdoch / @jburnmurdoch

For what reasons has nuclear power failed to meet initial expectations?

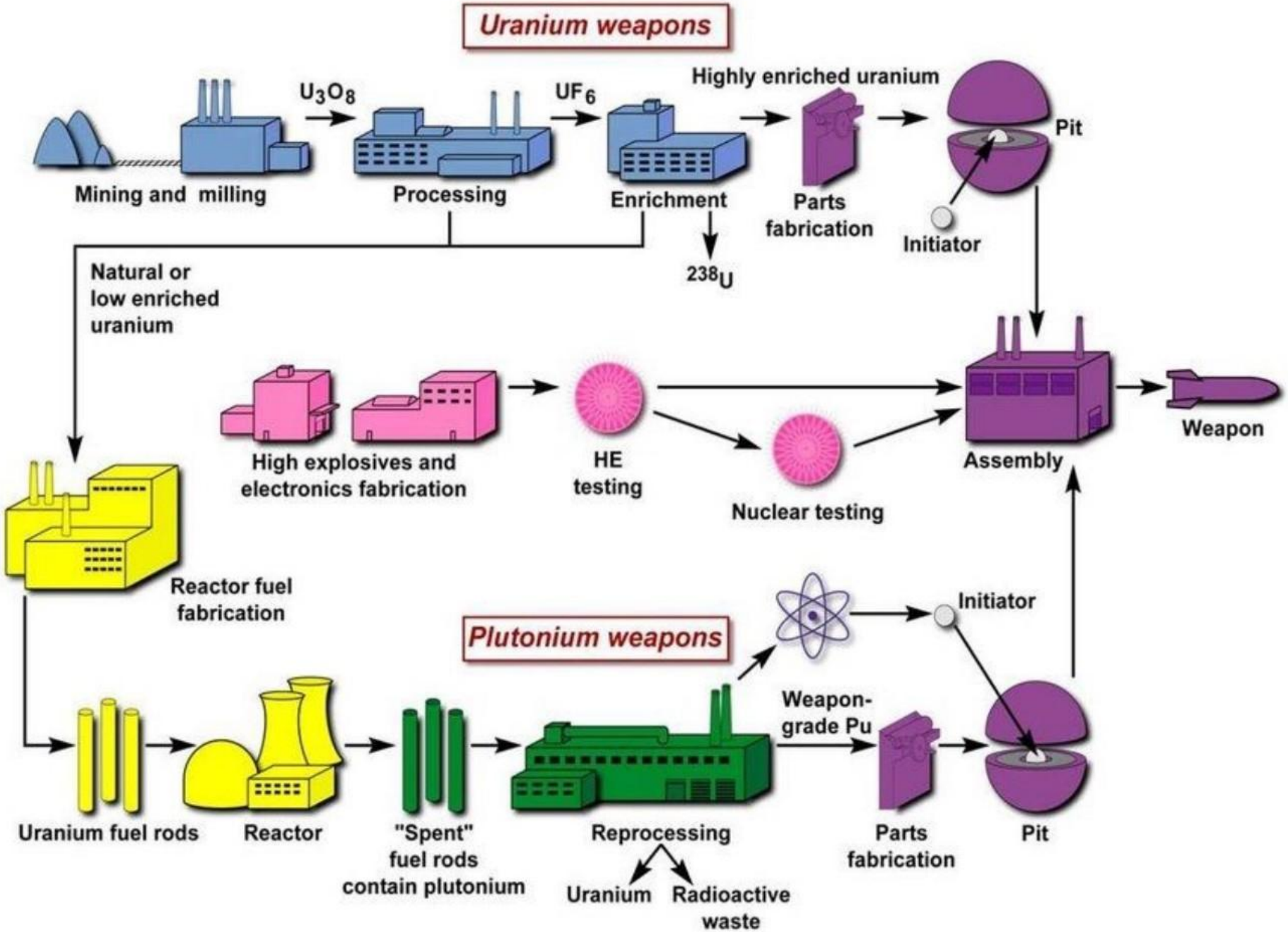
1

- Contribution to the proliferation of nuclear weapons.
- Countries such as Japan, South Korea and Germany are on the threshold of nuclearization.
- Countries with nuclear ambitions (Iran, Turkey, Saudi Arabia) intend to create a nuclear fuel circle.
- The geopolitical framework of limiting the spread of nuclear weapons (non-proliferation regime) has made nuclear energy less attractive.

Nuclear fuel cycle



**Spent fuel reprocessing* is omitted from the cycle in most countries, including the United States.


Uranium weapons
U_3O_8
UF_6
Highly enriched uranium
Pit
Mining and milling
Processing
Enrichment
Parts fabrication
Initiator
^{238}U
Natural or low enriched uranium
High explosives and electronics fabrication
HE testing
Nuclear testing
Assembly
Weapon
Reactor fuel fabrication
Plutonium weapons
Initiator
Weapon-grade Pu
Uranium fuel rods
Reactor
"Spent" fuel rods contain plutonium
Reprocessing
Parts fabrication
Pit
Uranium
Radioactive waste

For what reasons has nuclear power failed to meet initial expectations?

2

- High initial investment with a long payback period.
- Discouragement of private investors.
- The development of nuclear energy is easier in countries that invest with strategic criteria (Russia, China) than in terms of economic efficiency.

For what reasons has nuclear power failed to meet initial expectations?

3

- High, hidden costs due to

(a) long development time and

(b) changes in the regulatory framework towards stricter ones after a nuclear accident.

- The cost of decommissioning is extremely large but difficult to calculate.
- Such costs are not taken seriously by countries that invest in nuclear energy with a strategic rather than an economic rationale.

Very late and over budget: Why newest large nuclear plant in US is likely to be the last

BUSINESS | FINLAND

Finland's much-delayed nuclear plant launches

03/12/2022

Nuclear reactor Olkiluoto 3 has gone online in Finland some 12 years behind schedule and on a massively inflated budget. Finland now hopes to cut back on energy imports from Russia, Sweden and Norway.

The Olkiluoto 3 was developed and built by a joint venture between France's Areva and Germany's Siemens

Image: Antti Yrjonen/NurPhoto/picture alliance

For what reasons has nuclear power failed to meet initial expectations?

4

- The cost of electricity production is more expensive than competing solutions (e.g., natural gas and RES).
- Countries that invest in nuclear energy with a strategic rather than economic rationale are favored.

For what reasons has nuclear power failed to meet initial expectations?

5

- Fears about the safety of nuclear power plants after high-profile accidents (Chernobyl, Three Mile Island, Fukushima).
- Decreased social acceptance in many countries (e.g.
- Germany, Japan) and in local communities (USA).
- Such fears do not seem to deter investment in nuclear power in countries with centralized political systems where social pressure on decision-making is less.

For what reasons has nuclear power failed to meet initial expectations?

6

- The consequences of the nuclear accidents were the relative deindustrialization in Western countries (USA, Germany, Japan).
- Leading nuclear energy companies either went bankrupt or changed their business sectors.
- This created a window of opportunity for companies from countries competing with the West (Russia, China).

For what reasons has nuclear power failed to meet initial expectations?

- Failure to find a solution to the issue of nuclear waste management.
- Nuclear waste is highly toxic and has a long lifespan.
- Its temporary storage usually becomes permanent, which exacerbates the lack of social and political acceptance of nuclear energy in the West.

For what reasons has nuclear power failed to meet initial expectations?

Supply chain management problems, which has favored countries with nuclear energy industrial infrastructure, such as Russia and China.

ANALYSIS

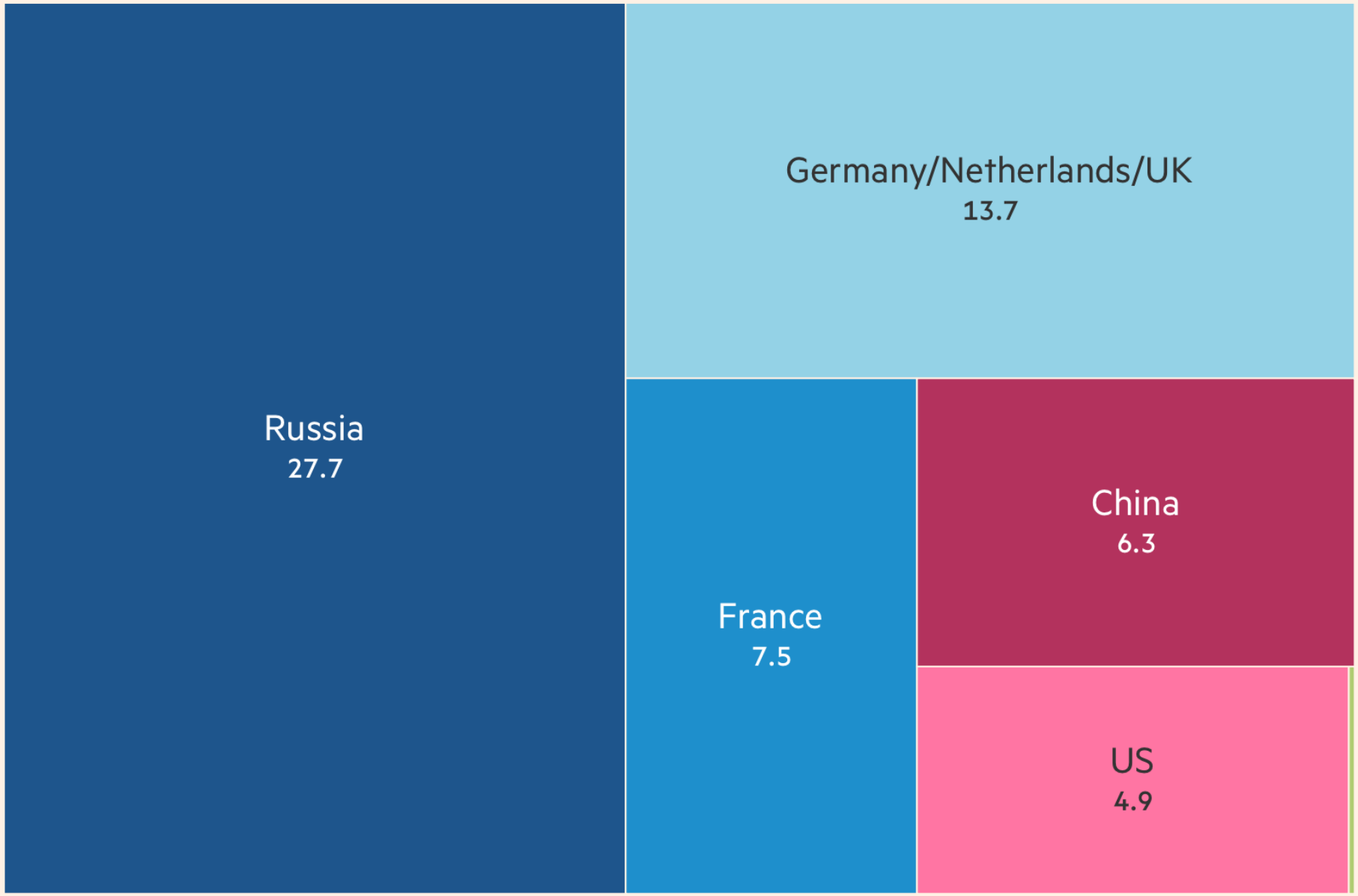
U.S. Reactors Still Run on Russian Uranium

But Washington and its partners are working to change that.

By **Keith Johnson**, a reporter at *Foreign Policy* covering geoeconomics and energy, and **Amy Mackinnon**, a national security and intelligence reporter at *Foreign Policy*.

Russia dominates uranium enrichment worldwide

Global capacity, operational and planned (2020, mn SWU*)



Advantages of SMRs that create optimism for nuclear renaissance

1. Necessary solution to achieve environmental goals (net zero) based on forecasts for a significant increase in electricity demand (global South, EV, data centers)
2. Lower initial investment compared to traditional reactors
3. Easier to build
4. Easier to expand when needs increase (modularity)
5. Significantly shorter construction time without cost overruns (on time, on budget)
6. Safer than traditional reactors

Department of Energy

At COP28, Countries Launch Declaration to Triple Nuclear Energy Capacity by 2050, Recognizing the Key Role of Nuclear Energy in Reaching Net Zero

DECEMBER 1, 2023

Challenges that make nuclear renaissance difficult

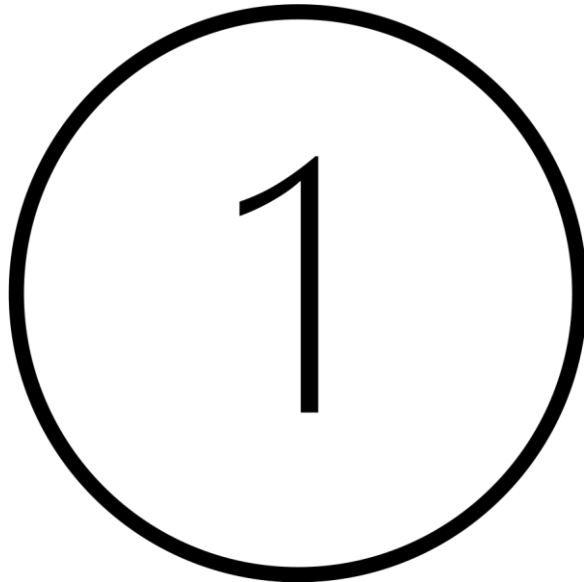
Challenges that make nuclear renaissance difficult

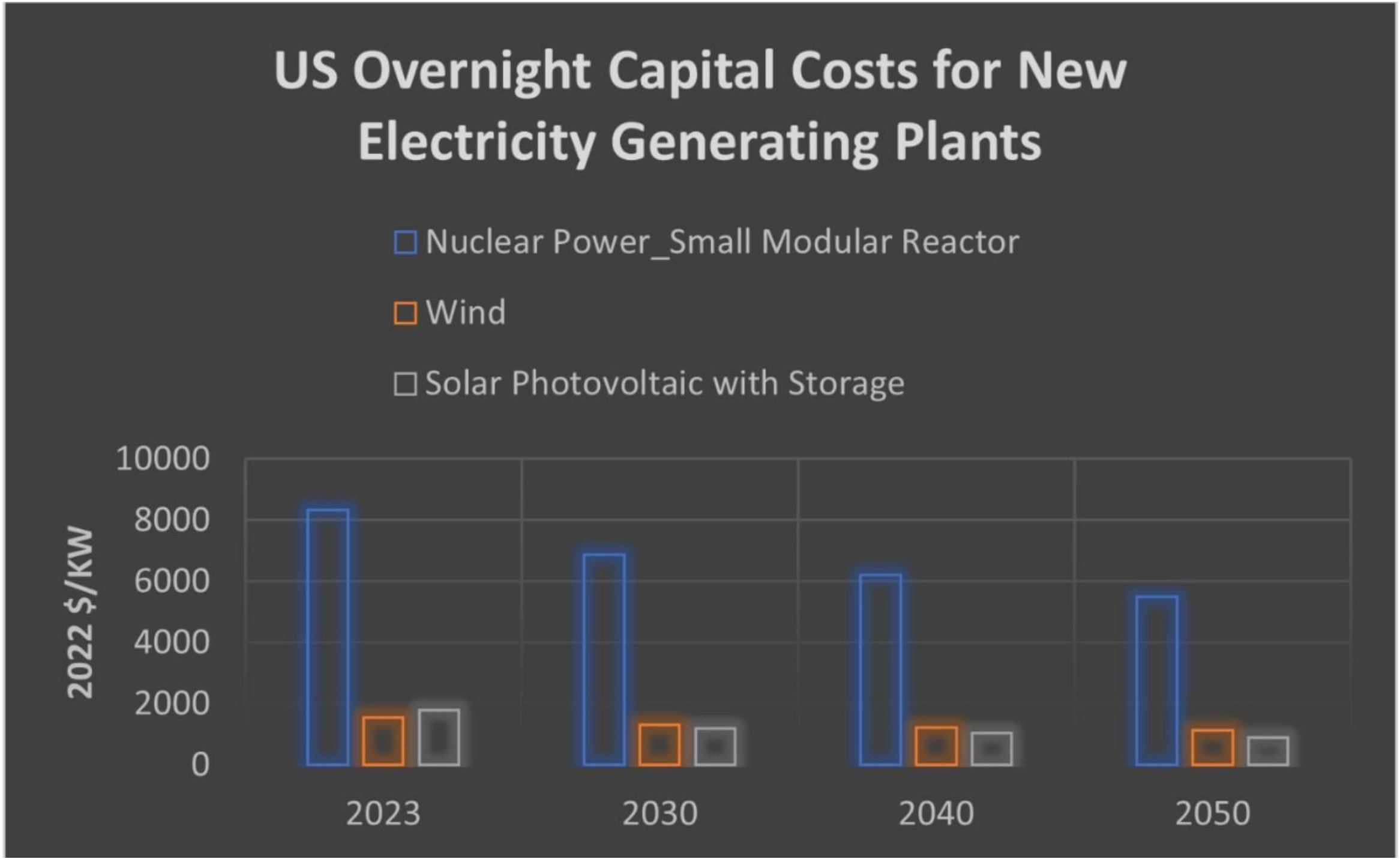
Efficiency

The cost of SMRs per MVh is higher than the corresponding cost of traditional reactors such as LWRs.

The cost of SMRs per MVh is higher than the corresponding cost of renewable energy sources and natural gas.

The use of SMRs will become more efficient if economies of scale (standardization) are created.

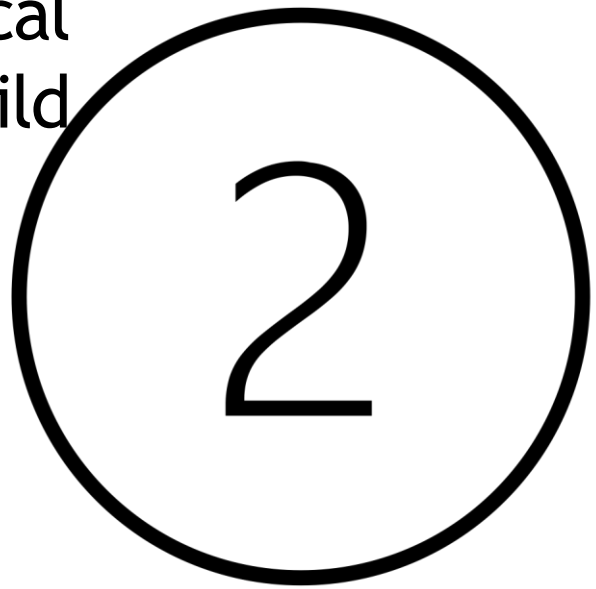



US Overnight Capital Costs for New Electricity Generating Plants
Nuclear Power_Small Modular Reactor
Wind
Solar Photovoltaic with Storage
2022 $/KW
10000
8000
6000
4000
2000
0
2023
2030
2040
2050

Challenges that make nuclear renaissance difficult

Social and political acceptance

There remains the problem of social and political acceptance, which is made more acute by the need to build SMRs closer to cities.

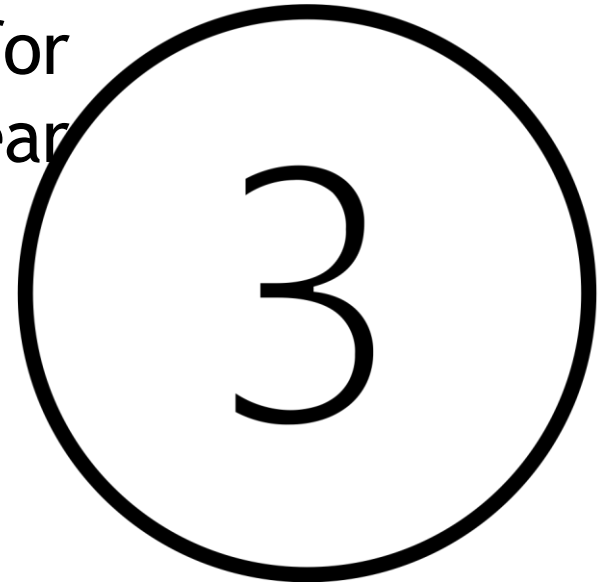


Challenges that make nuclear renaissance difficult

Nuclear waste storage

The problem of storing nuclear waste, which is usually stored on the perimeter of the plant, has not been solved, while a solution for permanent storage is being sought.

=> Toxic waste risks remaining next to residential areas for a long time, as is currently the case in existing nuclear plants in the USA and Germany.

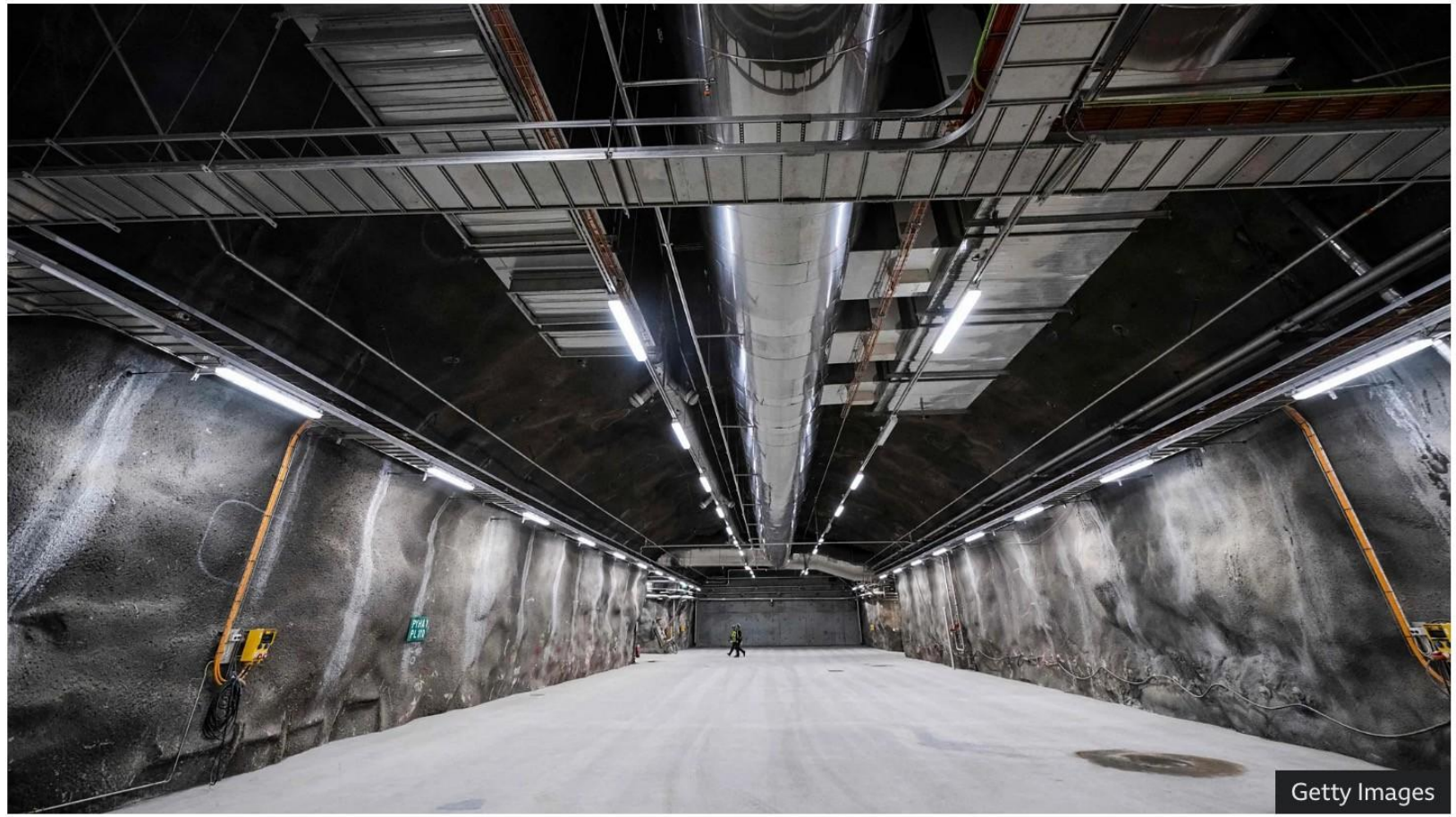


Finland's plan to bury spent nuclear fuel for 100,000 years

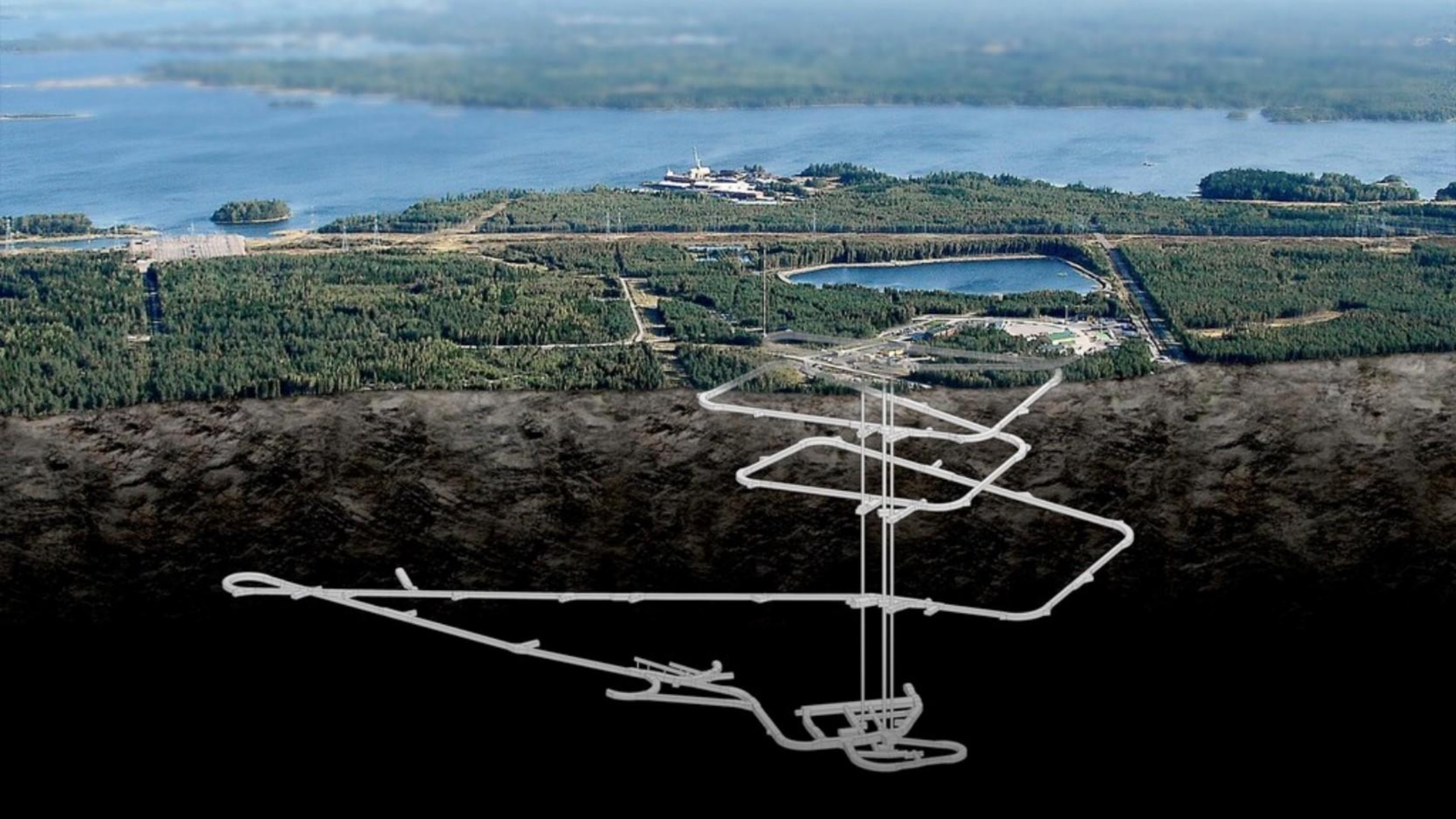
14 June 2023

Share

Erika Benke
Features correspondent



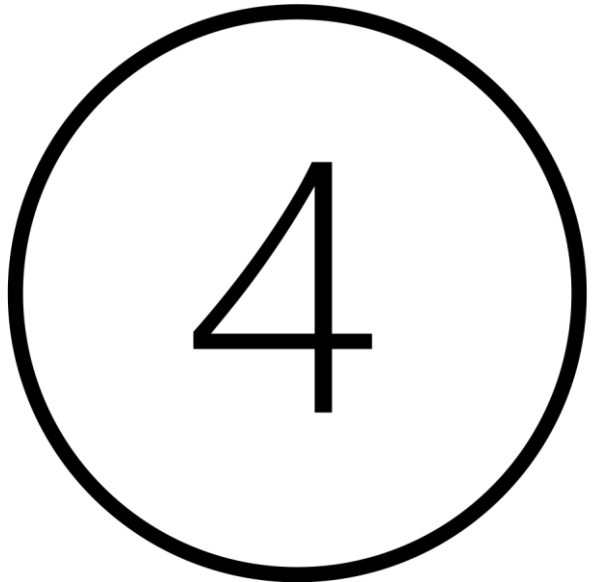
Finland plans to permanently bury its nuclear waste deep below the ground at its Onkalo site on an island near its coast (Credit: Getty Images)



Challenges that make nuclear renaissance difficult

Supply Chain

There is no reliable supply chain in the Western world that supports the operation of SMRs (uranium enrichment, fuel fabrication).



Challenges that make nuclear renaissance difficult

Workforce

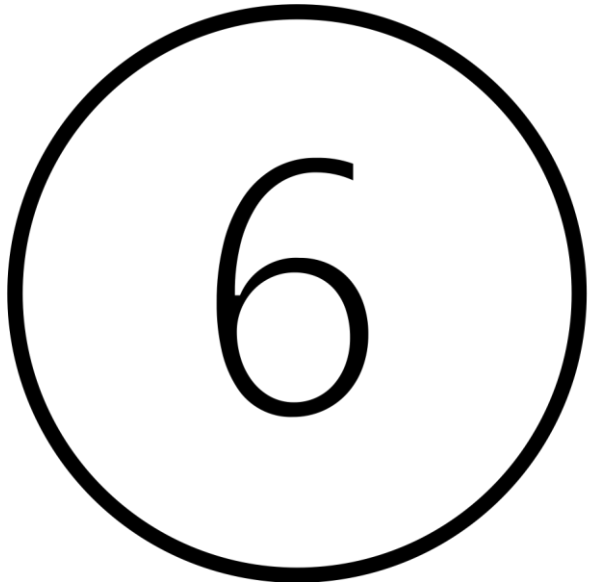
There is no workforce in the Western world that can support the revival of the nuclear industry, especially at a time when it is facing competition from the need of Western nuclear powers to modernize and expand their nuclear arsenals.

Challenges that make nuclear renaissance difficult

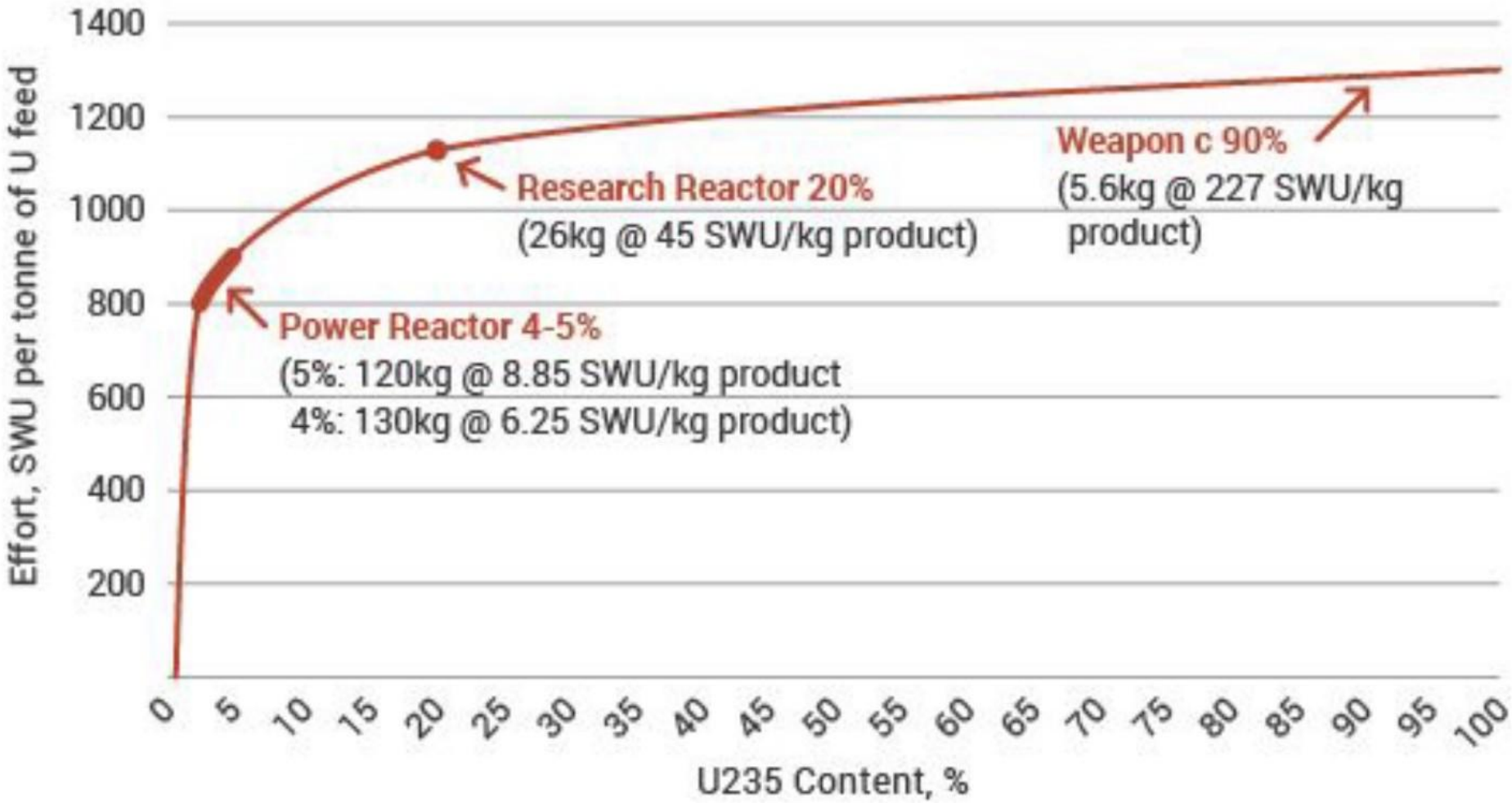
Nuclear weapons proliferation

The risks are greater because SMRs require more enriched uranium to operate efficiently than traditional LWRs.

It is also easier to provide security to a few large reactors than to many smaller reactors scattered across the country.



Uranium Enrichment and Uses



Challenges that make nuclear renaissance difficult

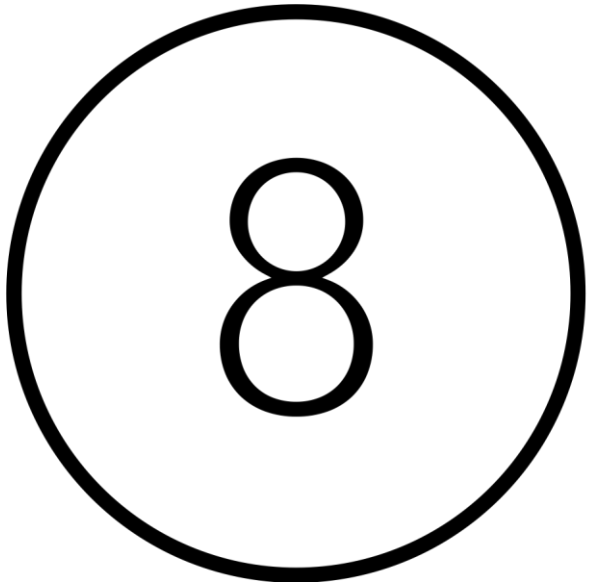
Financing

Private financiers are reluctant to finance nuclear facilities without government subsidies and guarantees.

Challenges that make nuclear renaissance difficult

Environmental challenge of operation

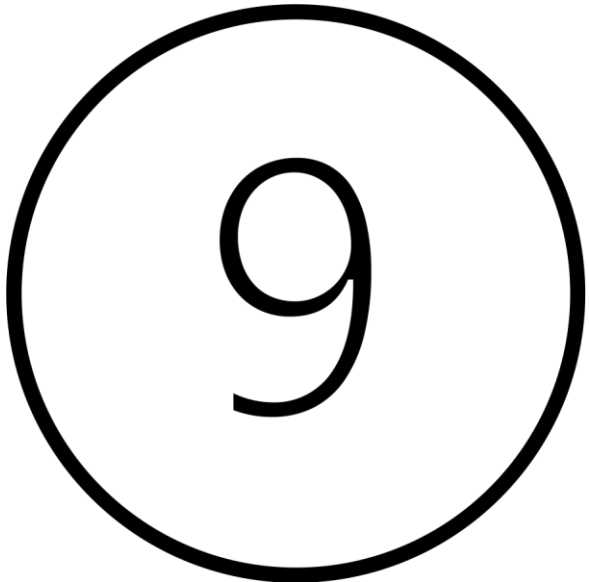
Most SMR reactors require large amounts of water for cooling (water-cooled) in an era when water supply is limited (water scarcity).



Challenges that make nuclear renaissance difficult

Regulatory framework

Installing SMRs near cities or on commercial ships (e.g. containers) creates additional safety requirements that complicate the work of regulatory authorities (e.g. port access permits).



New Geopolitical Order in the Age of Nuclear Rebirth

Three major suppliers

Russia China USA



TABLE 1: Civilian Nuclear Power Sector Comparison: The United States, Russia, and China

COUNTRY	REACTOR UNITS (DOMESTIC)		INSTALLED CAPACITY	NUCLEAR SHARE IN NATIONAL POWER SUPPLY (2018)	FUTURE NET INSTALLED CAPACITY	SECTOR STRUCTURE	EXPORT UNITS UNDER CONSTRUCTION	PUBLIC FINANCING FOR NUCLEAR EXPORT
	ONLINE	UNDER CONSTRUCTION						
USA	96	2	98 GW	19.32%	92 GW[1]	Multiple private companies	None	Loan terms per OECD restriction; no equity
Russia	38	4	28 GW	17.87%	44 GW [2]	Vertically and horizontally integrated under 1 state corporation	7 (Belarus, India, Bangladesh, Turkey)	Loans & equity
China	48	11	45 GW	4.22%	120-150 GW [2]	Vertically integrated under 3 state corporations	2 (Pakistan)	Loans & equity

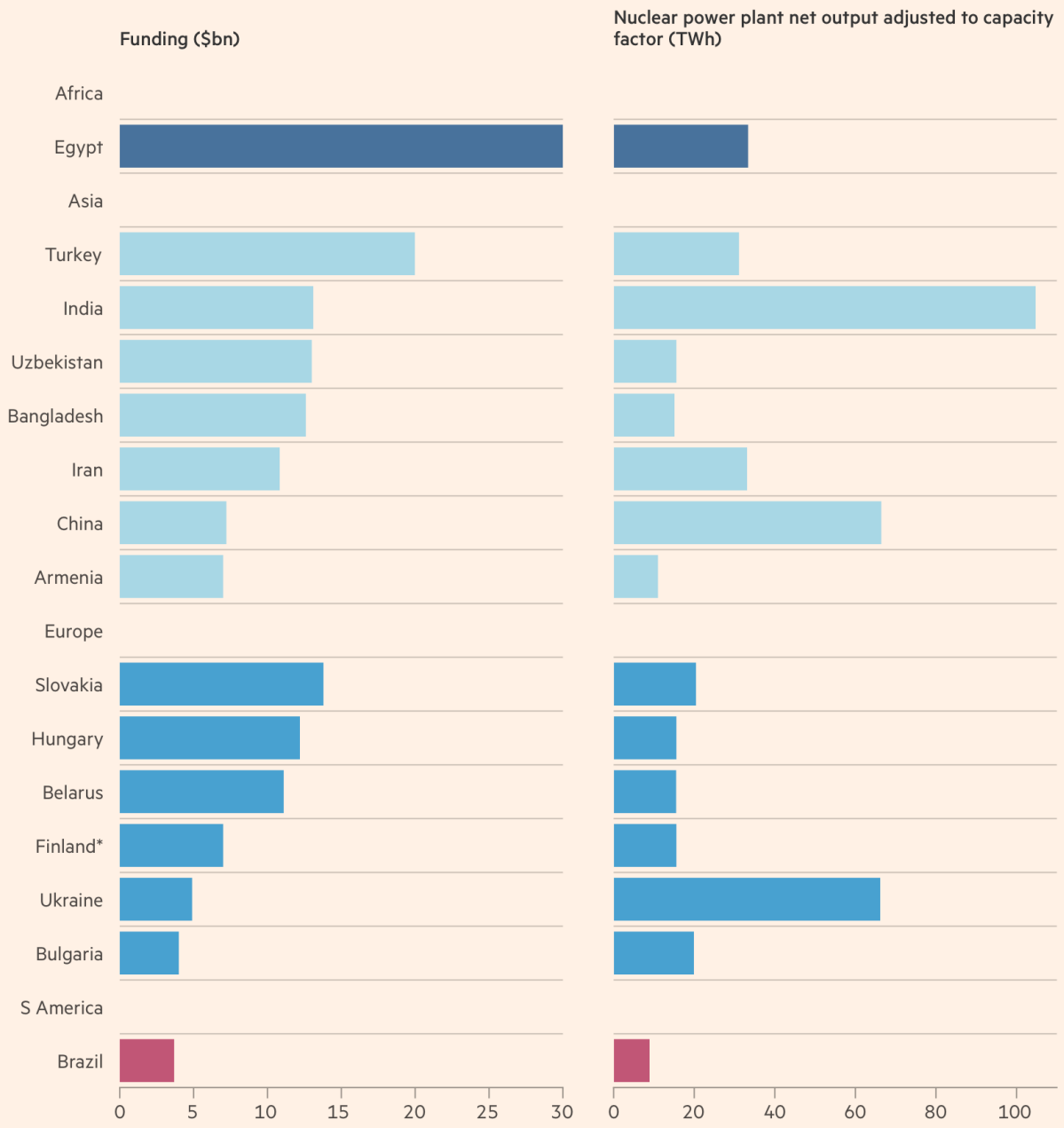
Source: "Reactor Database," World Nuclear Association, HYPERLINK "https://urldefense.com/v3/__https:/www.world-nuclear.org/information-library/facts-and-figures/reactor-database.aspx__;!!KRhing!NJduRuozGelokCC-SZ2urQCauracicX9IwSGOCISJKRfoXIY8EeK2Z_oOWmP$"https://www.world-nuclear.org/information-library/facts-and-figures/reactor-database.aspx. The sources for Future Net Installed Capacity are "Annual Energy Outlook 2020," U.S. Energy Information Administration; "Nuclear Power in Russia," World Nuclear Association; and various media reports for the China figure.

CSIS | ENERGY SECURITY AND CLIMATE CHANGE PROGRAM

[1] Projected for 2025 (EIA) [2] 2030 target

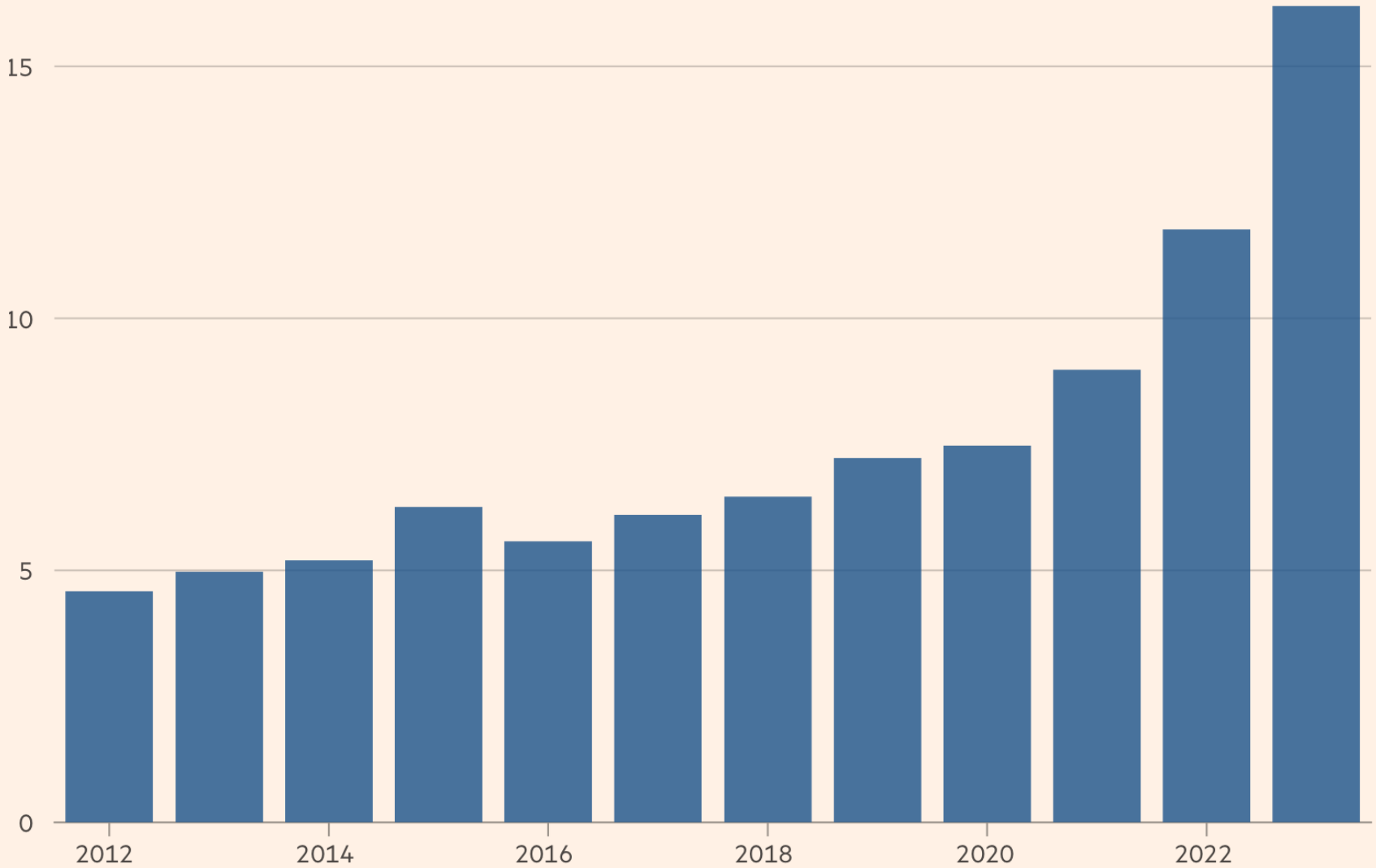
The breadth of Russia's nuclear energy empire

By country



Rosatom has seen a surge in its overseas revenue

Revenue from foreign projects ($bn)



Operable nuclear power capacity