What is the role for nuclear power in achieving Net Zero?

Dame Sue Ion GBE FREng FRS
Hon President National Skills Academy for Nuclear

NSAN

EST. 1597
GRESHAM
COLLEGE

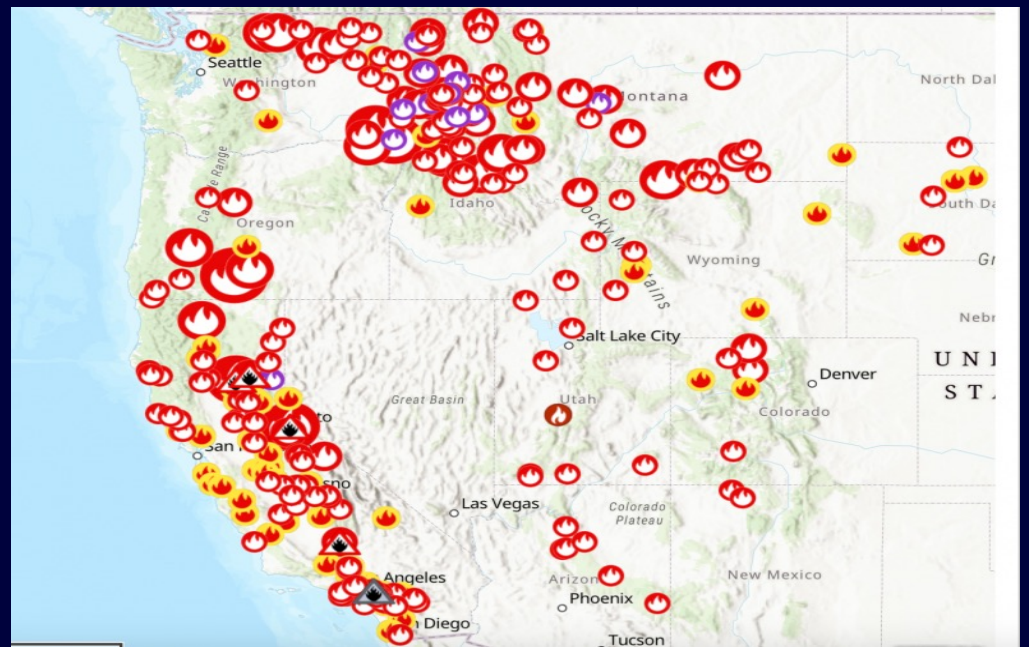
A Rapidly Changing World

- Unprecedented geopolitics

- Realisation we are not in control of
  - Energy Security
  - Energy Price
  - Material resources which affect both

Extreme Weather Events

Images of California Fires



Max Whittaker Freelance photographer for NY Times

Austrian flood damage

Floods in South Sudan

Getty images

Why do we care about whether energy is low carbon?

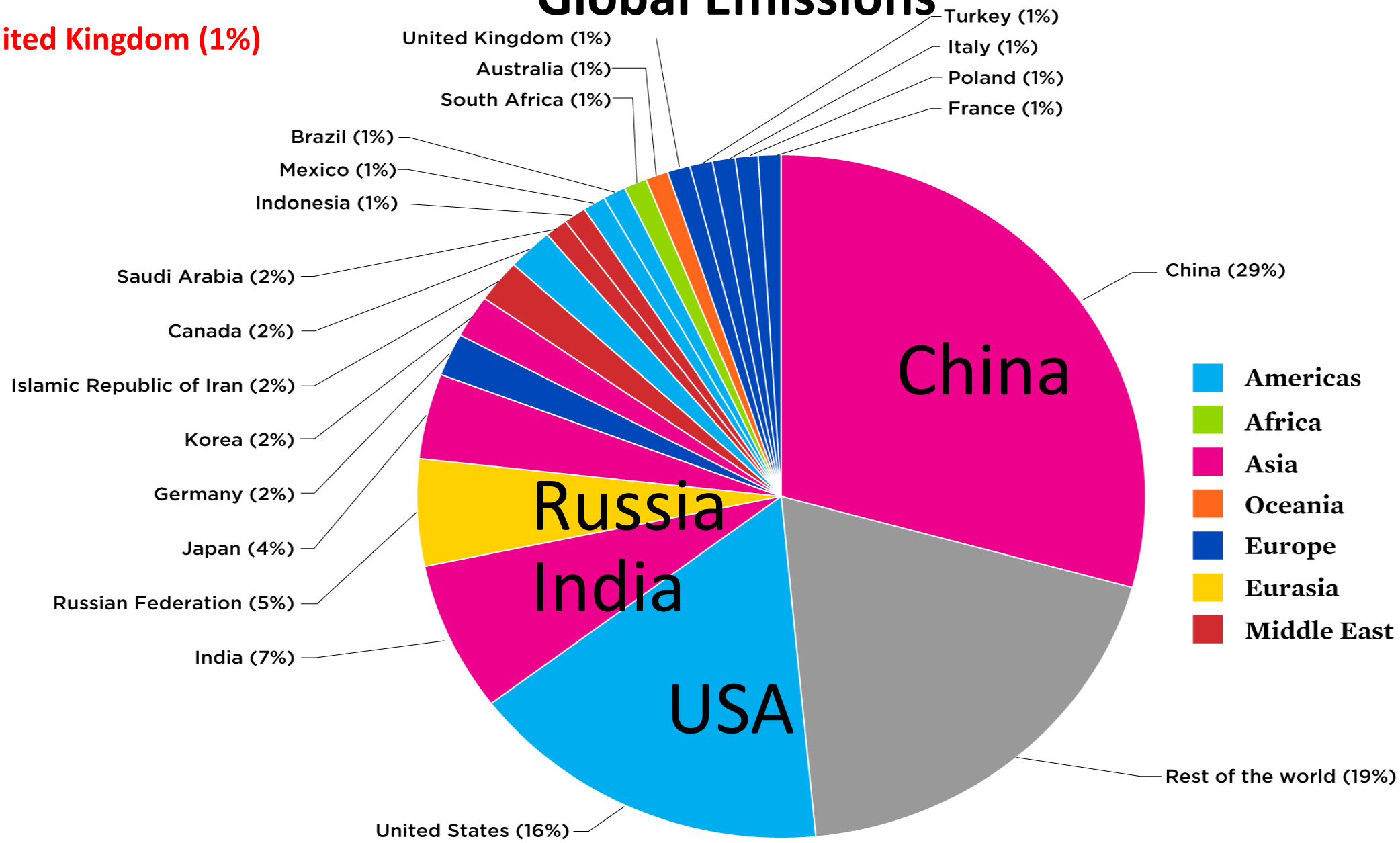
Because we are warming the planet up with greenhouse gas emissions and as a first world country we have to set an example

BUT

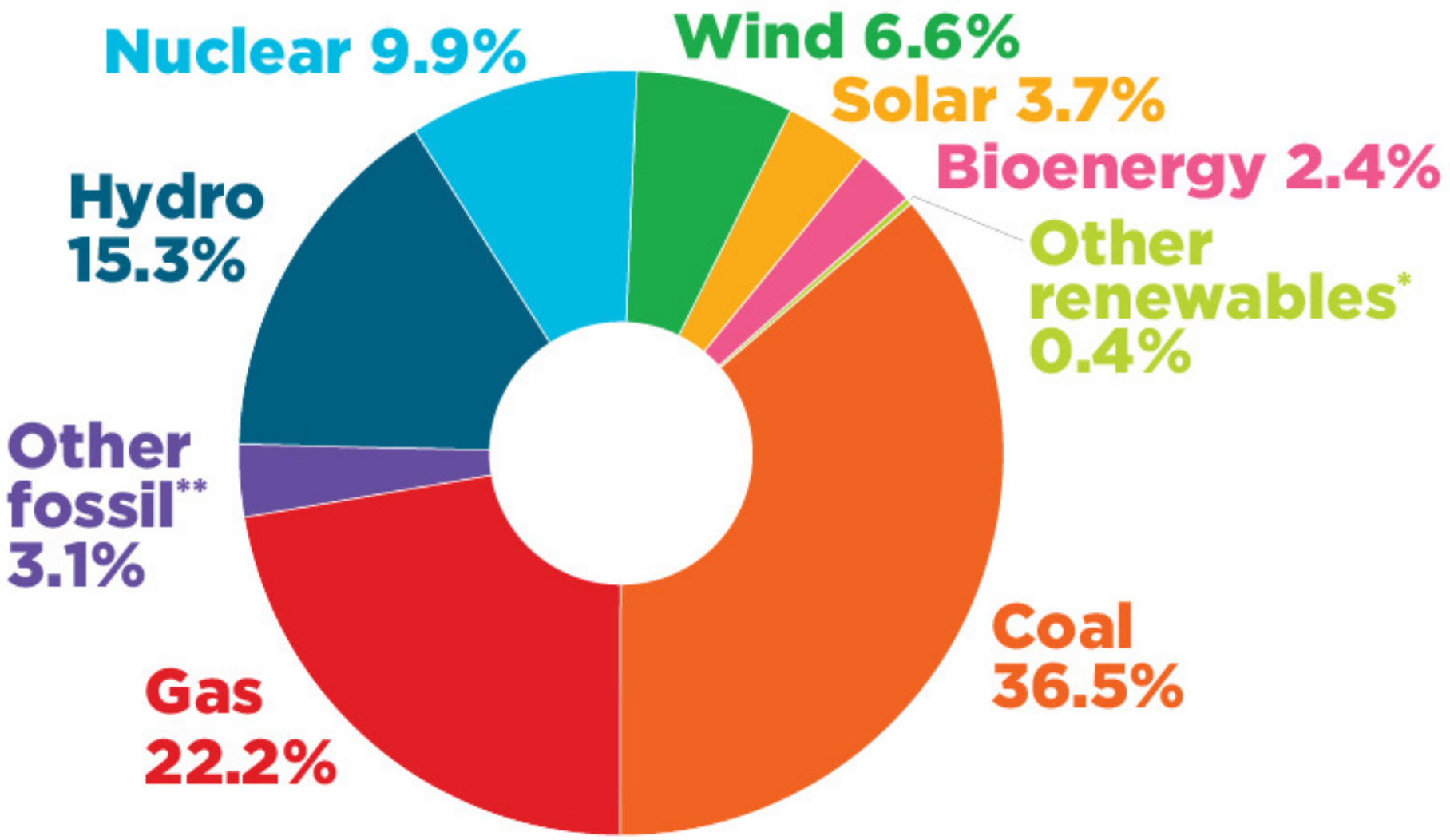
Do we still care when we are choosing between heating our homes and feeding our children?

Global Emissions

United Kingdom (1%)

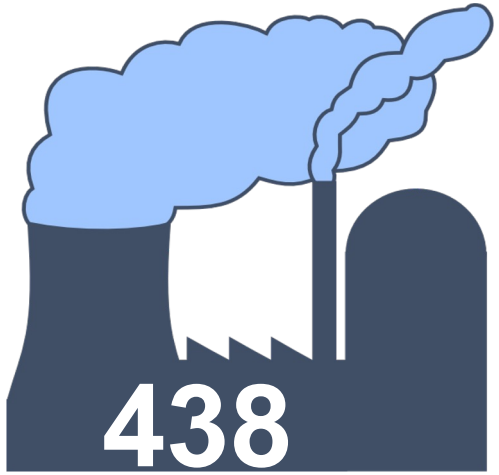


Worldwide Electricity Mix



Source: ember-climate.org

Nuclear Fission Around the World



Operational Plants

32

Countries

10%

Global Power Generation

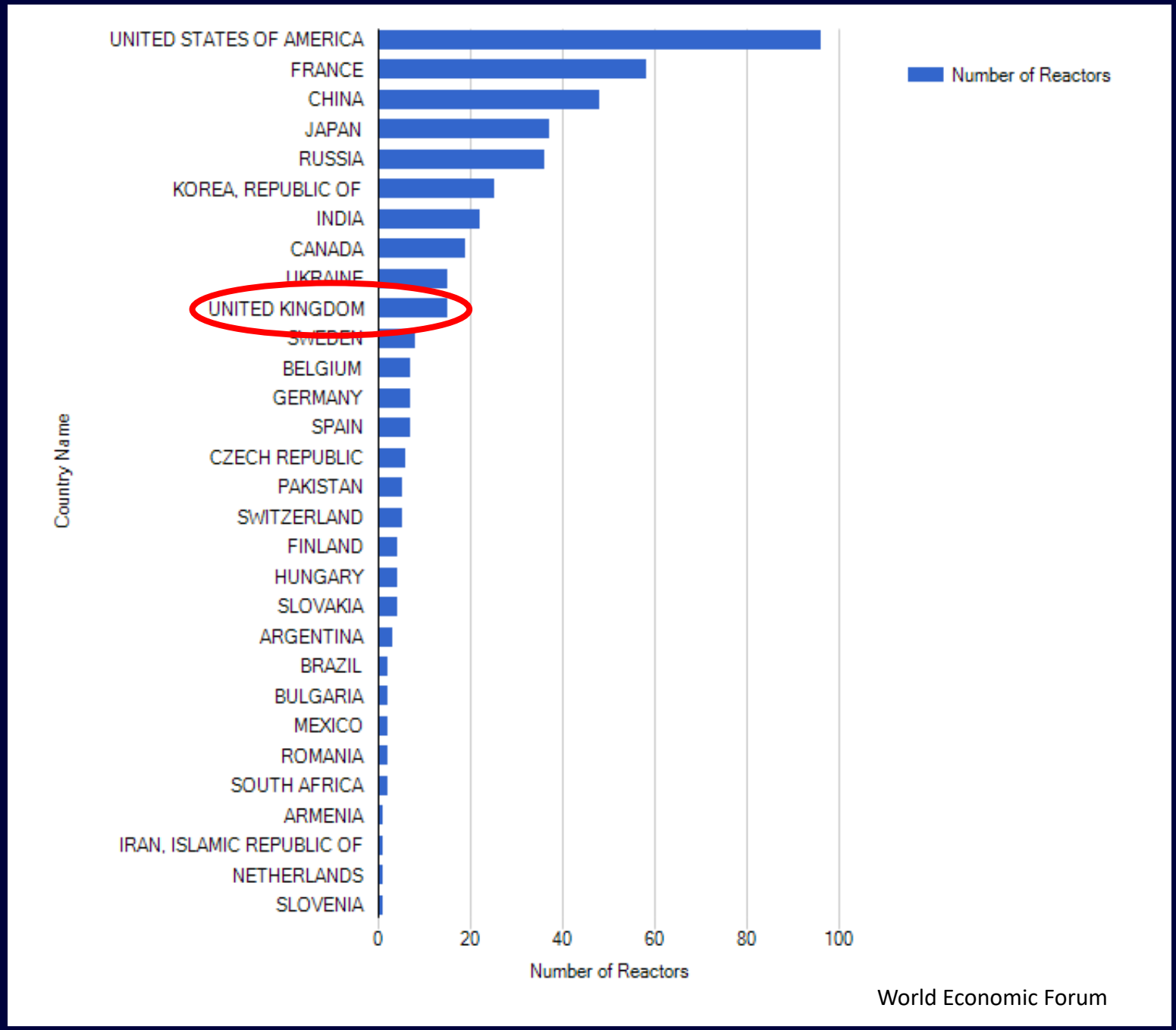
Plants Under Construction

Plants On Order / Planned

341

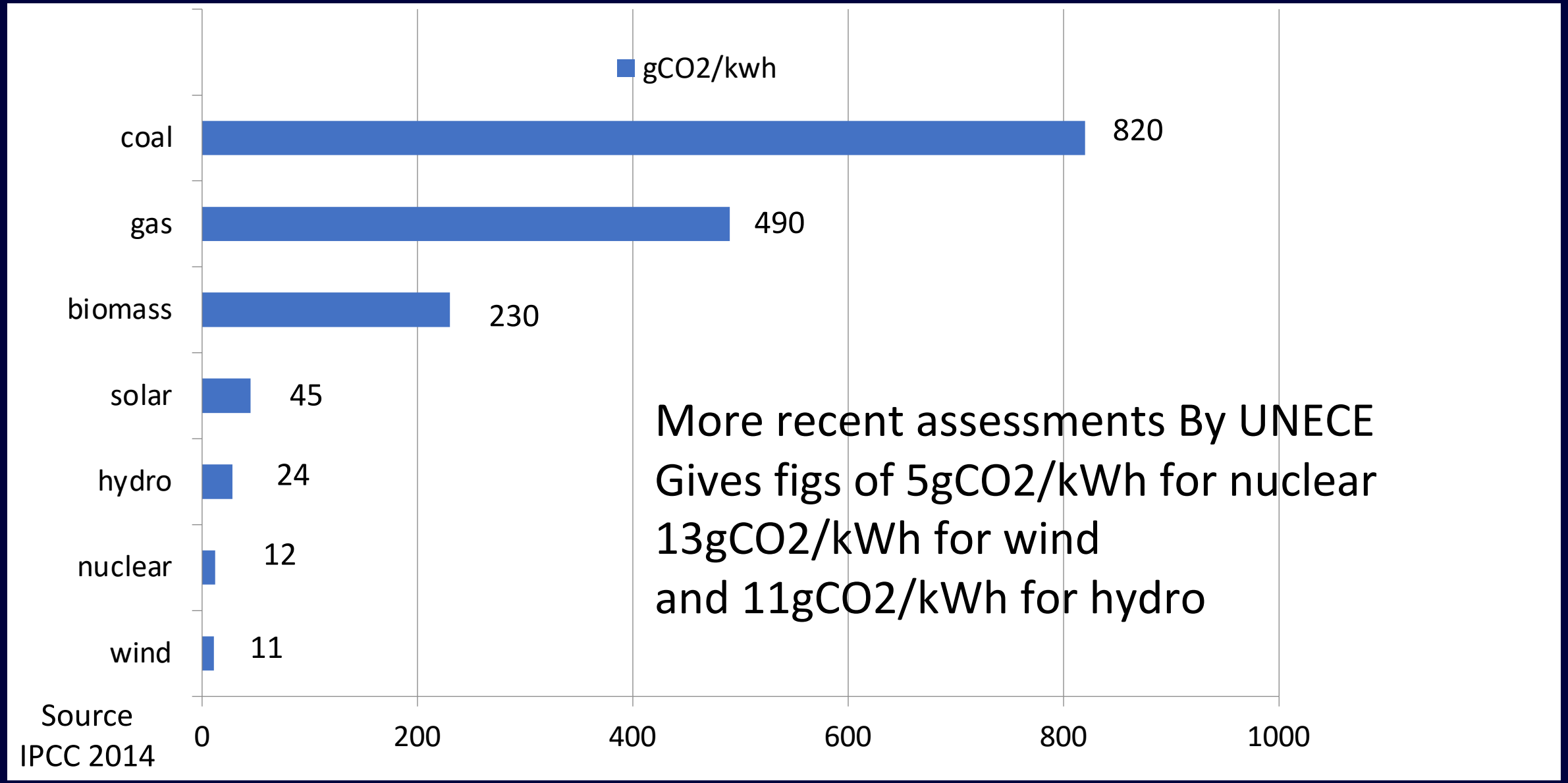
Plants Under Discussion / Proposed

Source: World Nuclear Association & IAEA PRIS database, as at 2023

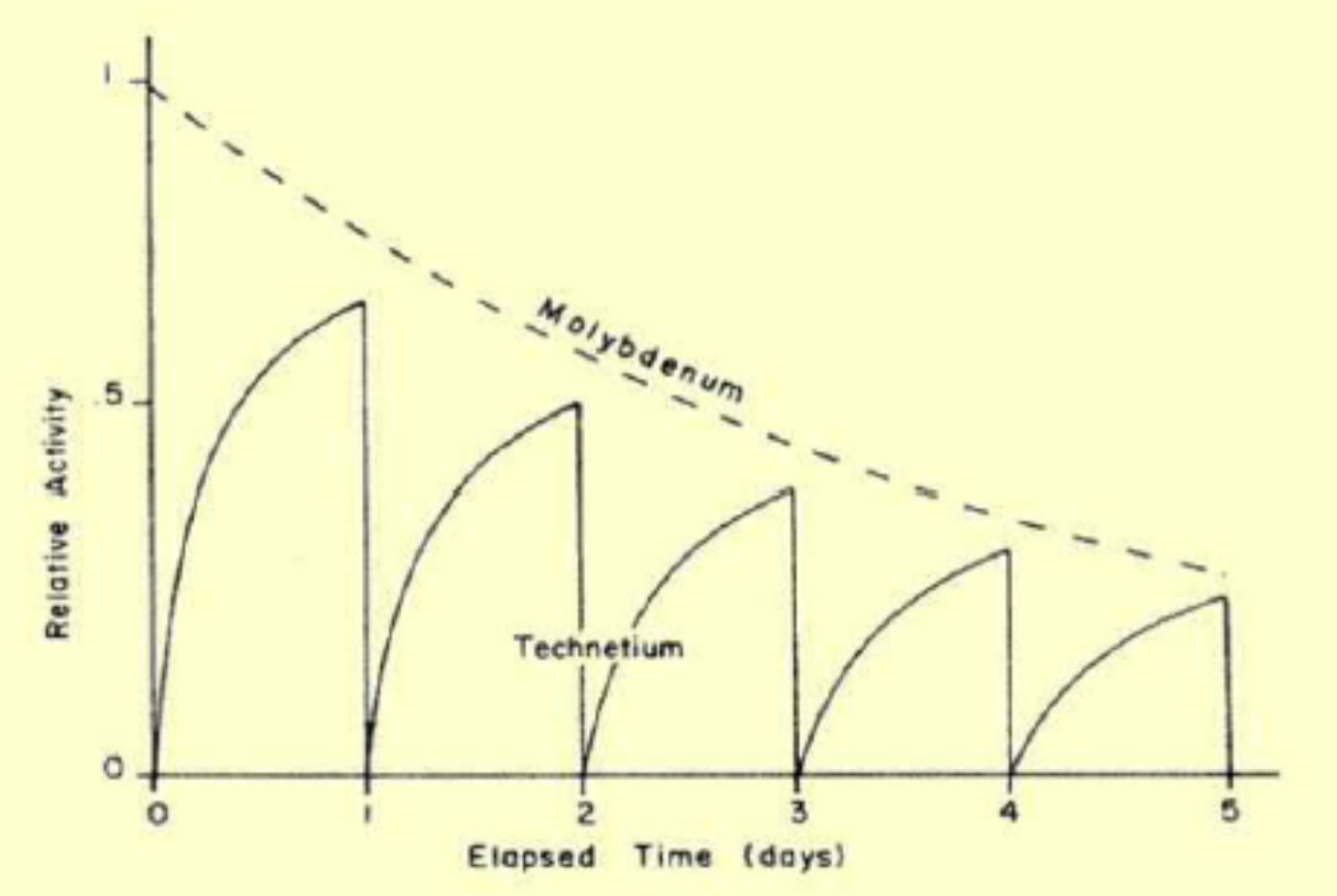

UNITED STATES OF AMERICA
FRANCE
CHINA
JAPAN
RUSSIA
KOREA, REPUBLIC OF
INDIA
CANADA
UKRAINE
UNITED KINGDOM
SWEDEN
BELGIUM
GERMANY
SPAIN
CZECH REPUBLIC
PAKISTAN
SWITZERLAND
FINLAND
HUNGARY
SLOVAKIA
ARGENTINA
BRAZIL
BULGARIA
MEXICO
ROMANIA
SOUTH AFRICA
ARMENIA
IRAN, ISLAMIC REPUBLIC OF
NETHERLANDS
SLOVENIA
Country Name
0
20
40
60
80
100
Number of Reactors
Number of Reactors
World Economic Forum

Nuclear
Biomass
Hydro
Marine
Solar
Wind Turbines

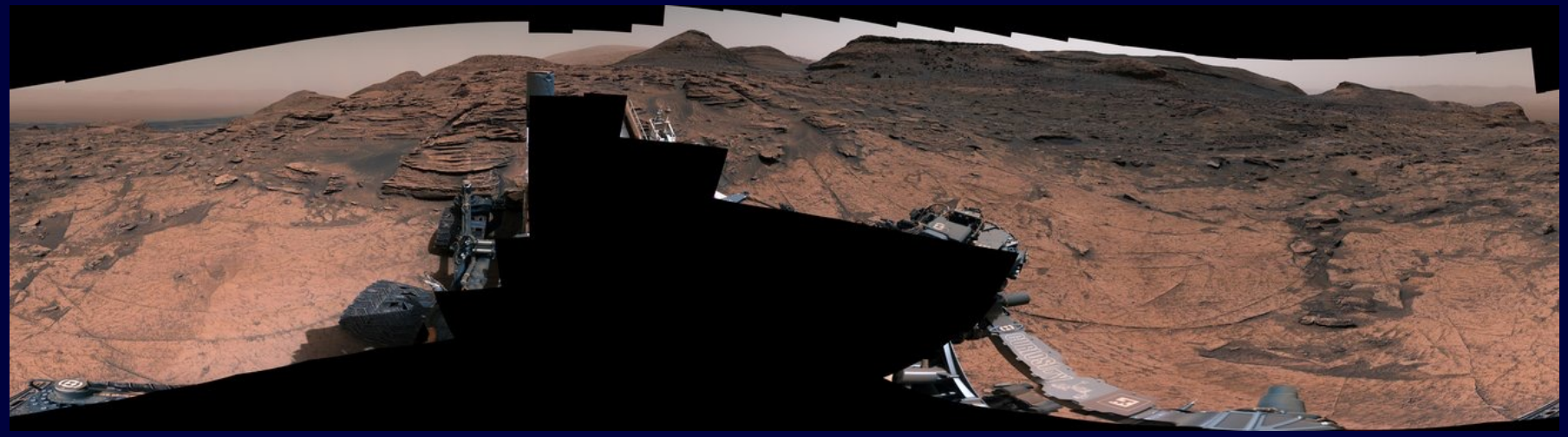
Carbon Contribution of Major Sources of Electricity



Need: Mo-99 every week.



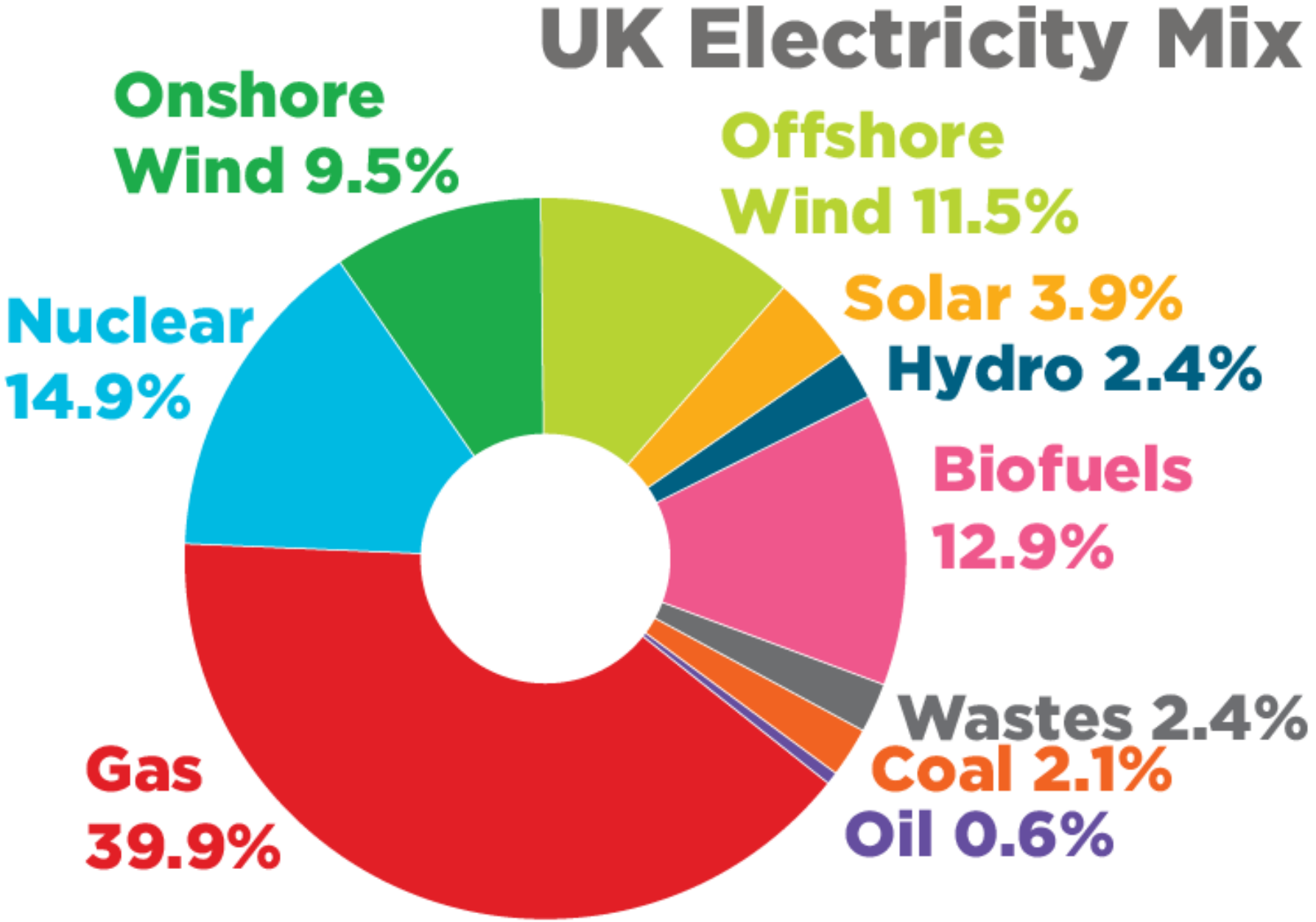
- Iodine-131: treat thyroid cancer
- Sr-89: treat bone and prostate cancer
- Iodine-123: Parkinson's disease detection
- PET scan
- Bone Scintigraphy



10 Years Since Landing, NASA's RPS-Powered Curiosity Mars Rover Still Has Drive

Voyager, NASA's Longest-Lived Mission, Logs 45 Years in Space

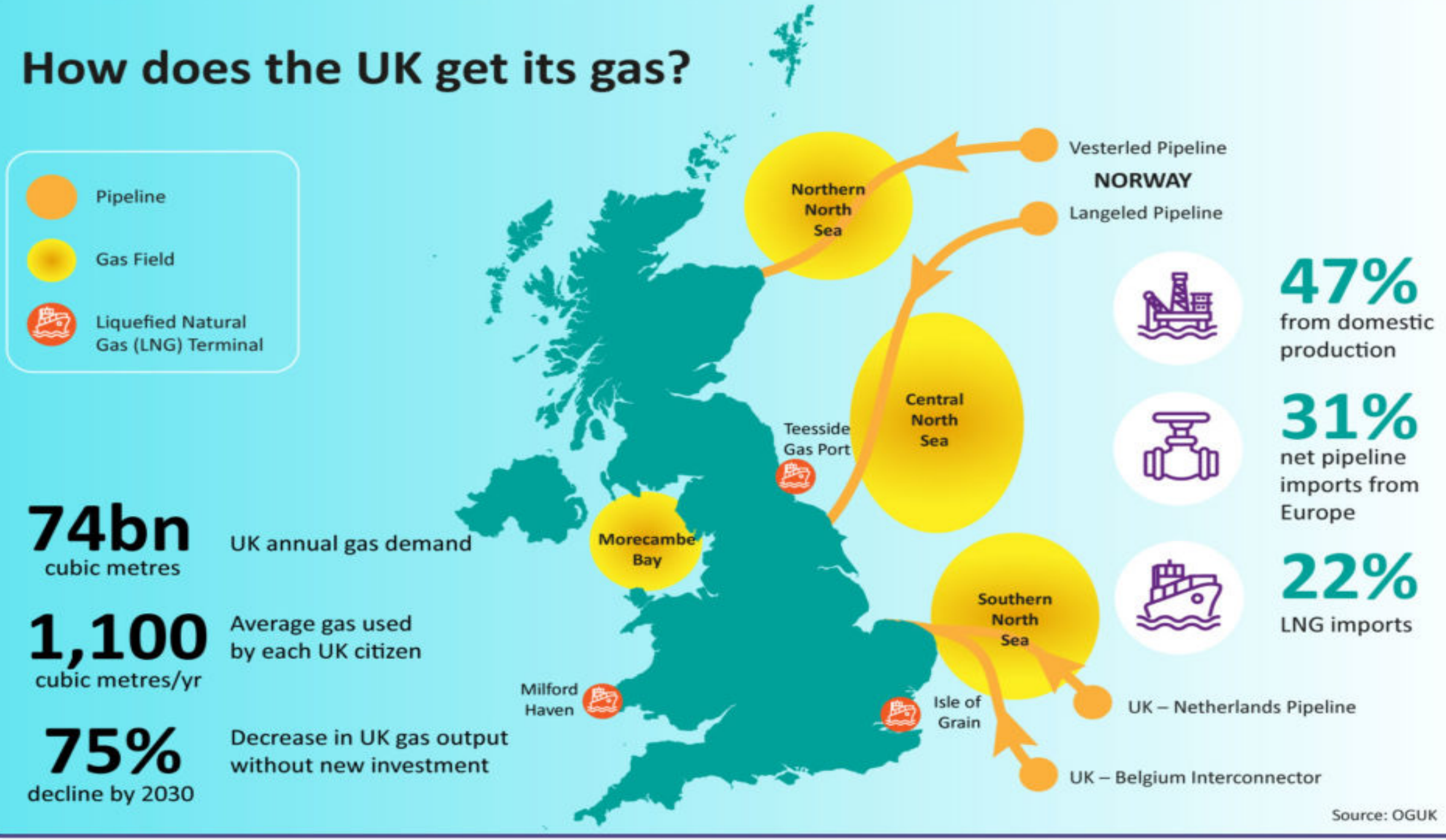
UK Electricity Mix



Source: 2022 Digest of UK Energy Statistics, BEIS

Gas Geopolitics

How does the UK get its gas?



74bn
cubic metres
UK annual gas demand

1,100
cubic metres/yr
Average gas used by each UK citizen

75%
decline by 2030
Decrease in UK gas output without new investment

47%
from domestic production

31%
net pipeline imports from Europe

22%
LNG imports

Source: OGUK

https://www.theguardian.com › business › sep › how-u...

'Relying on luck': why does the UK have such limited gas ...

24 Sept 2021 — The Rough storage facility, owned by Centrica, the parent company of British Gas, provided 70% of the **UK gas storage capacity** for more than 30 ...

https://www.newstatesman.com › 2021/09 › how-the-u...

How the UK's low gas storage capacity leaves it vulnerable

27 Sept 2021 — **Britain** has **storage capacity** for just 2 per cent of annual **gas** demand, compared with over 25 per cent in European competitors. By Polly Bindman.

https://www.ofgem.gov.uk › publications › gb-gas-stor...

GB Gas Storage Facilities 2021 | Ofgem

22 Jan 2021 — See information regarding the existing, operational **gas storage facilities** in GB.

https://www.storengy.co.uk › medias › news › expense-...

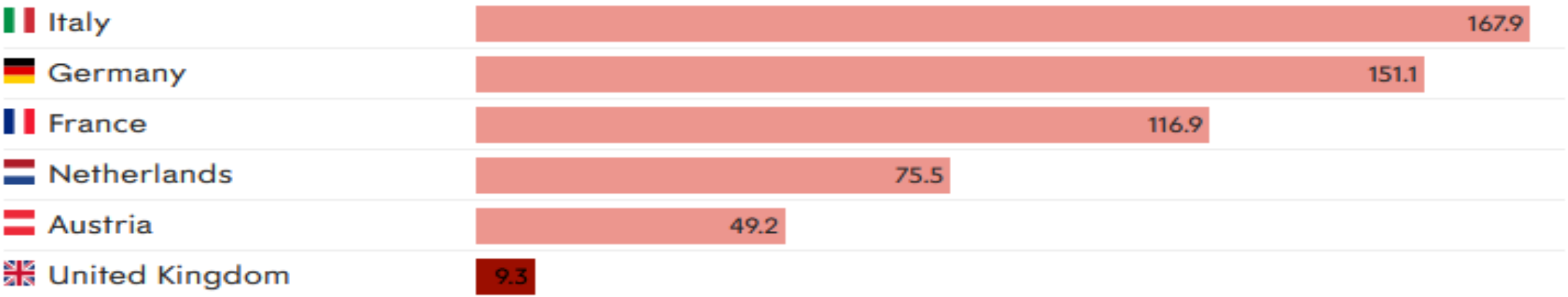
The expense of 'just-in-time' gas imports over gas storage

25 Jan 2021 — The **UK** stores under 2% of its annual **gas** demand on the **British** Isles vs. ... **Storage Capacity** in European countries vs annual **gas** demand.

The UK currently has around nine terawatt hours of stored gas reserves, compared to 168 in Italy and 151 in Germany, according to the latest figures from Gas Infrastructure Europe, meaning its capacity is equivalent to roughly 2 per cent of its annual demand, compared with 25 per cent to 37 per cent in Europe's four largest storage holders.

The UK has much less gas storage than other major European countries

Gas in storage in terawatt-hours, of selected European countries as of 25.09.2021

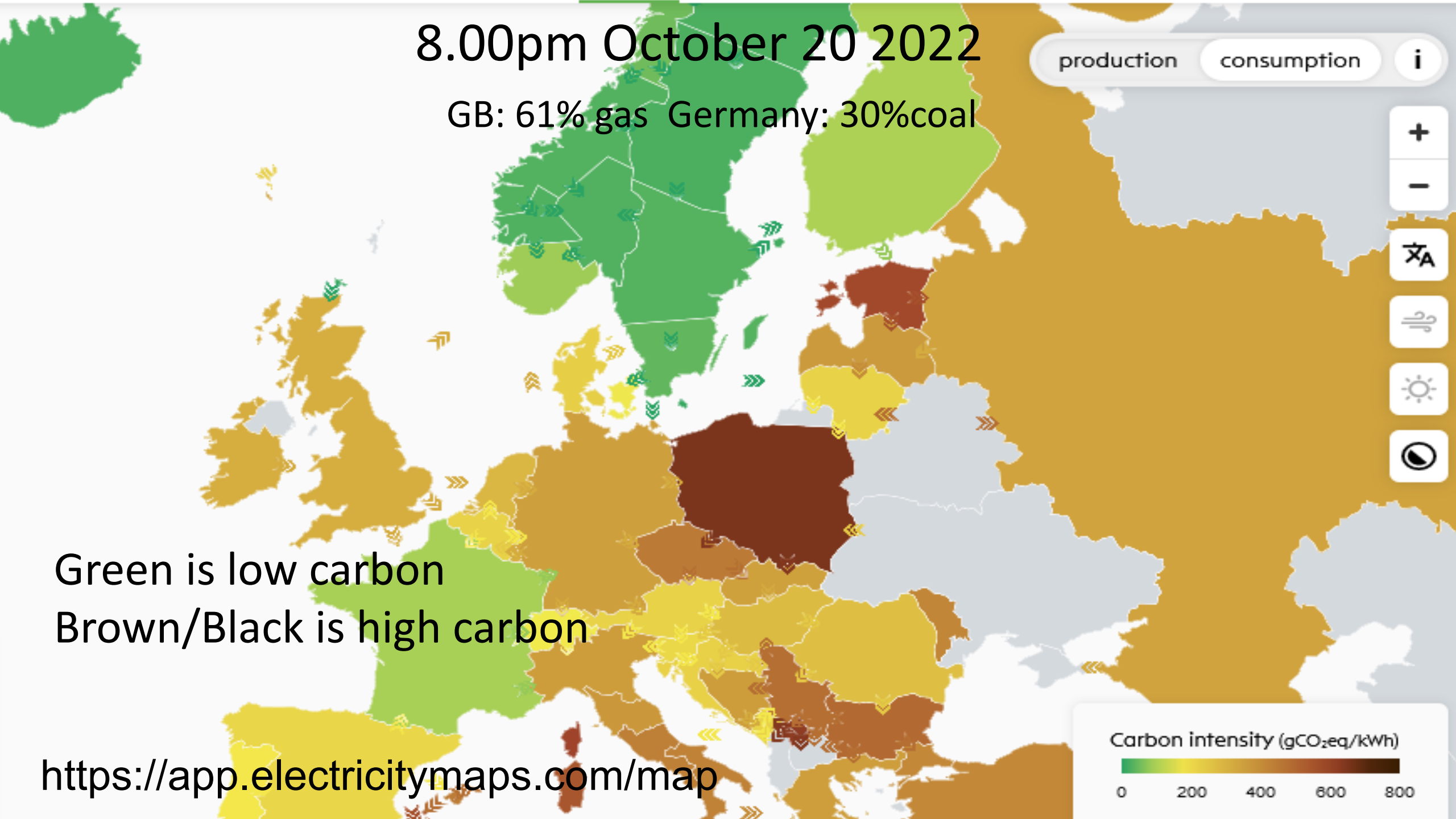


Source: Gas Infrastructure Europe

THE NEW STATESMAN

8.00pm October 20 2022

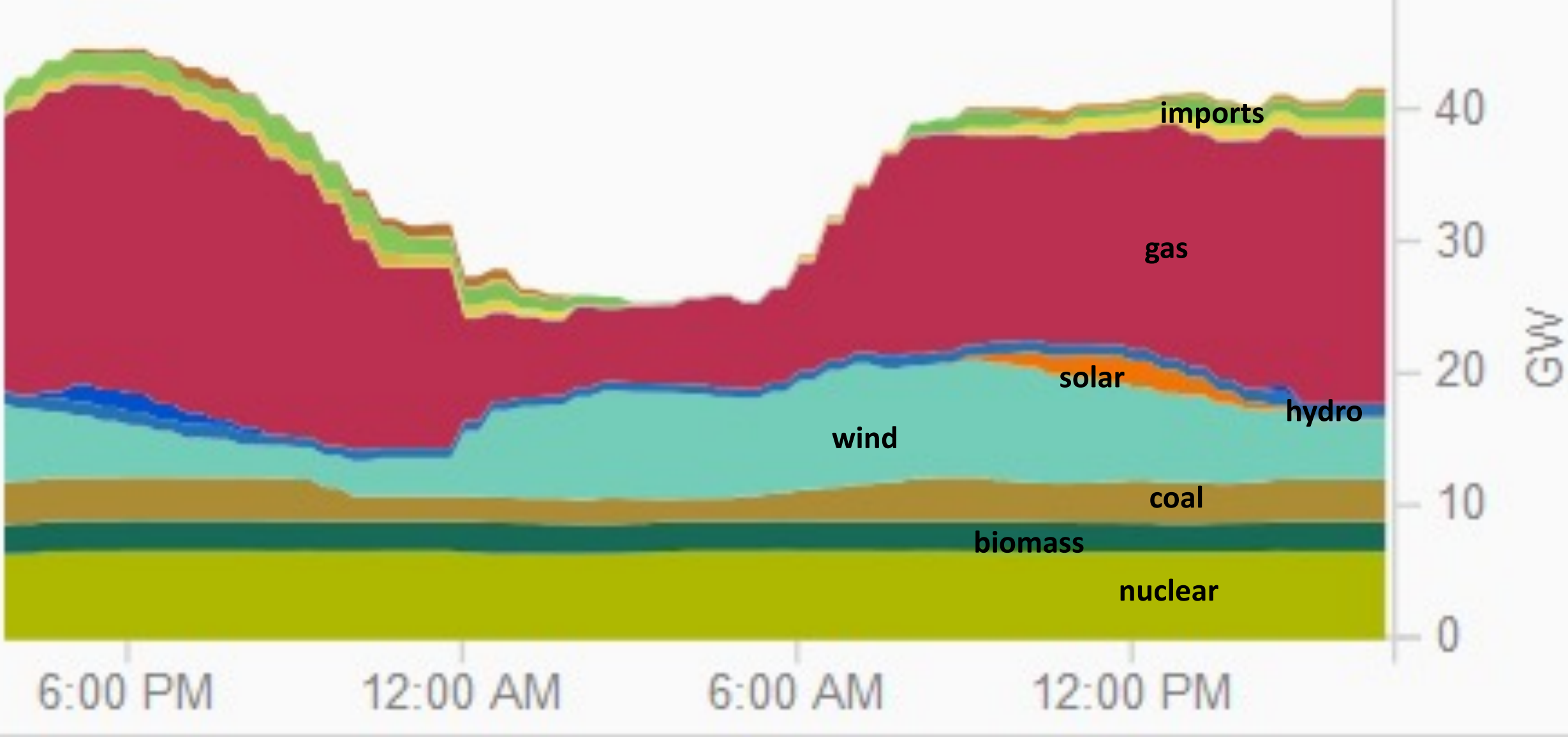
GB: 61% gas Germany: 30%coal



Green is low carbon

Brown/Black is high carbon

https://app.electricitymaps.com/map

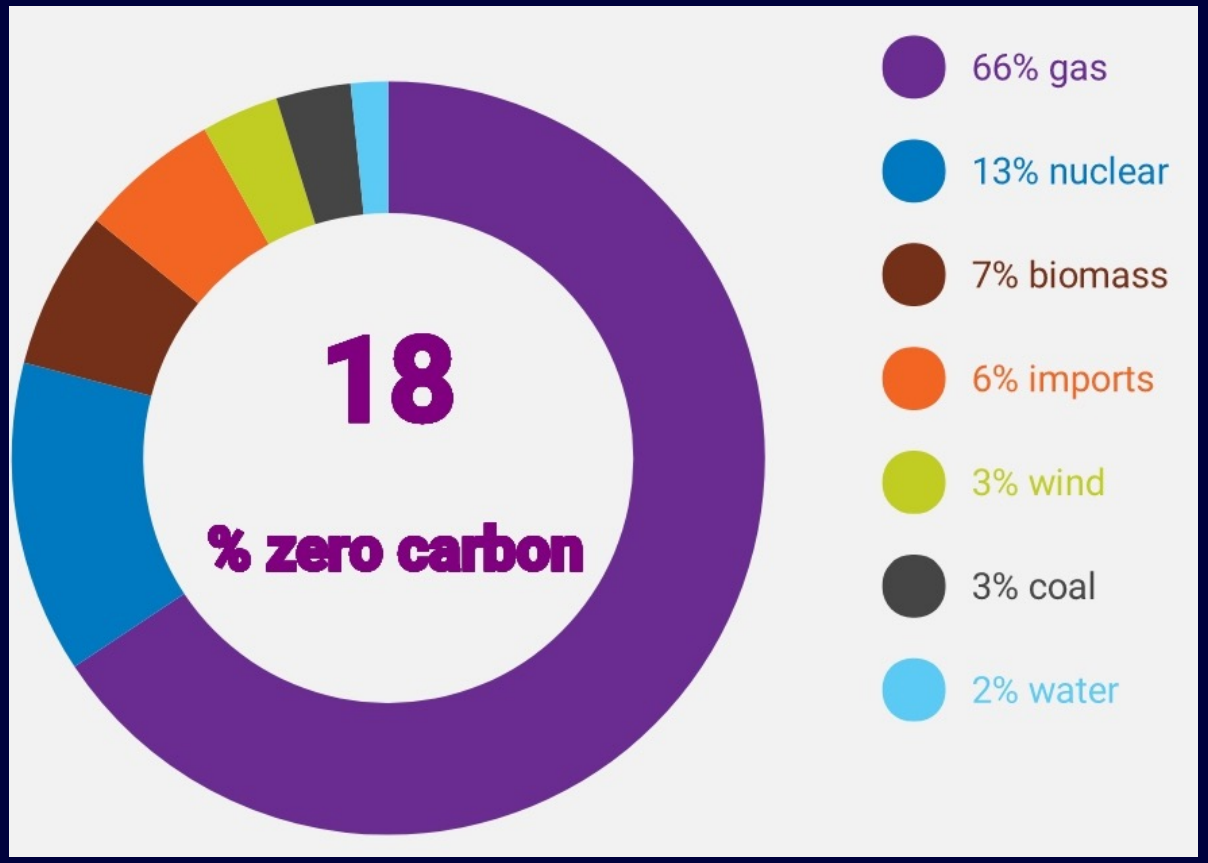


GB Electricity Demand Varies Widely during 24 hour periods

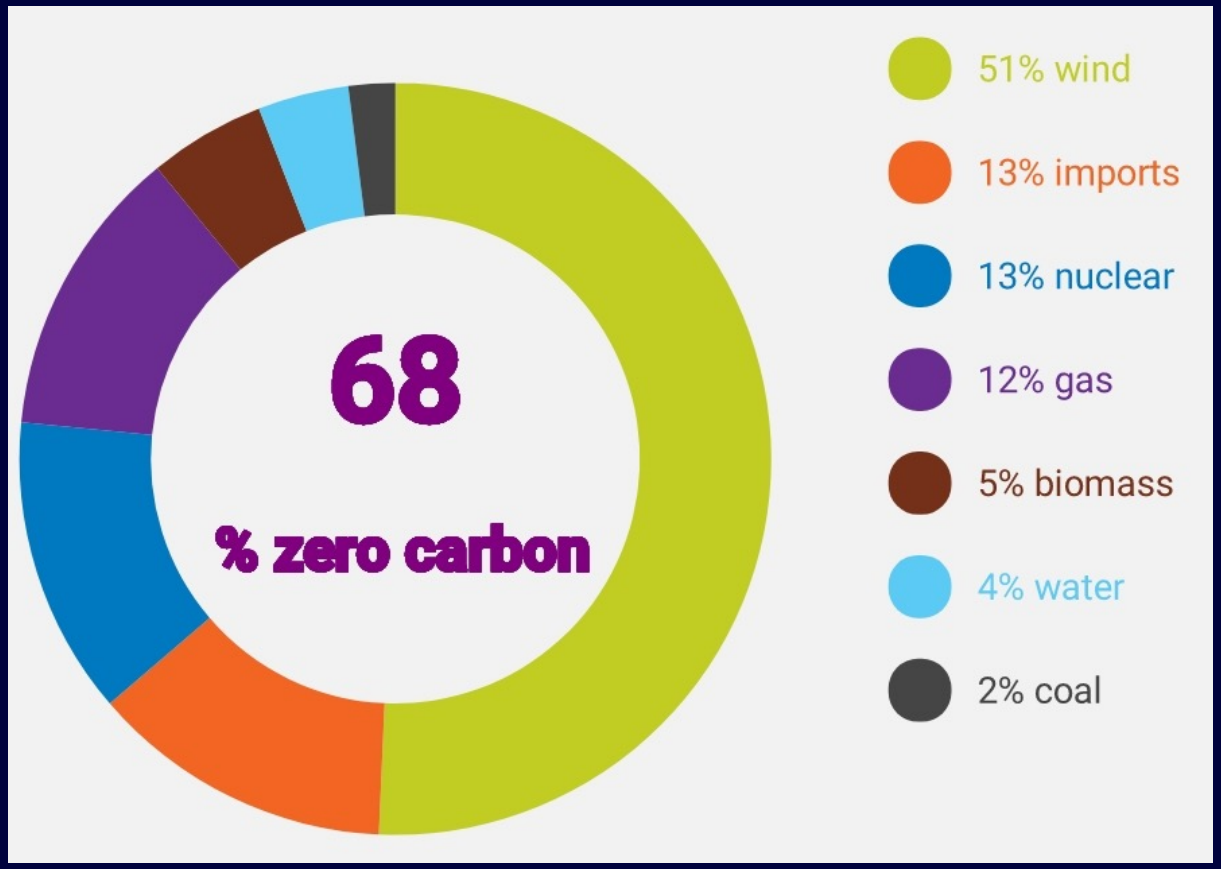
Typical winter day during the week

GB Generation mix from National Grid ESO app

29 November 2022

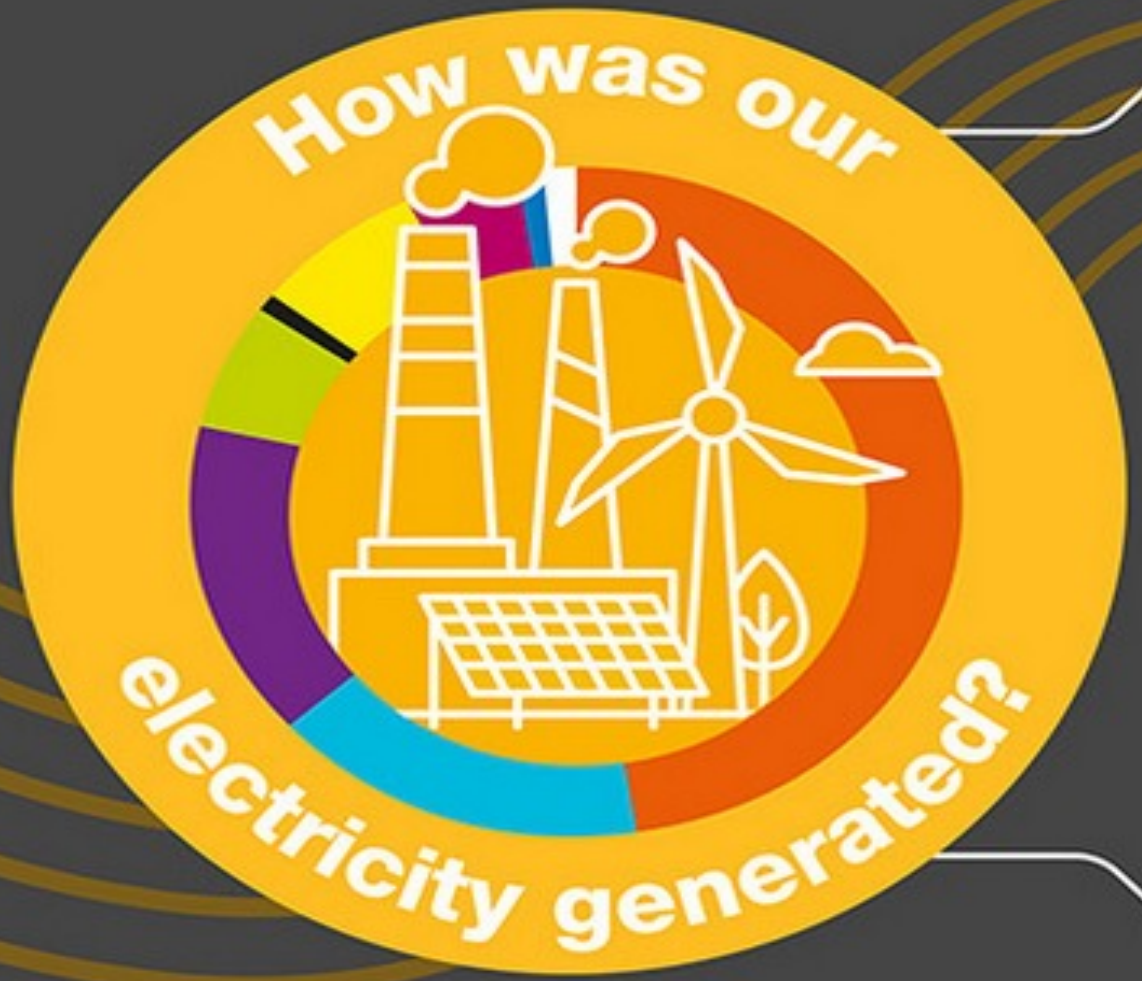


10 January 2023



nationalgridESO

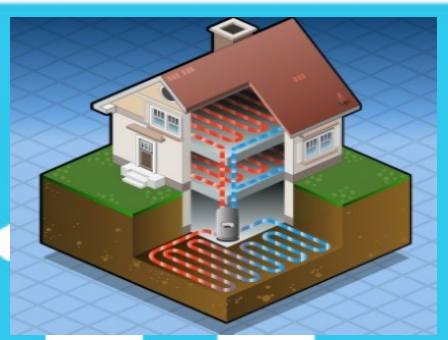
August 2022



Gas	47.7%
Wind	15.9%
Nuclear	15.1%
Biomass	6.2%
Coal	0.9%
Solar	7.2%
Imports	4.5%
Hydro	1.2%
Storage	1.3%

UK needs low carbon energy supplies

Business
17 %

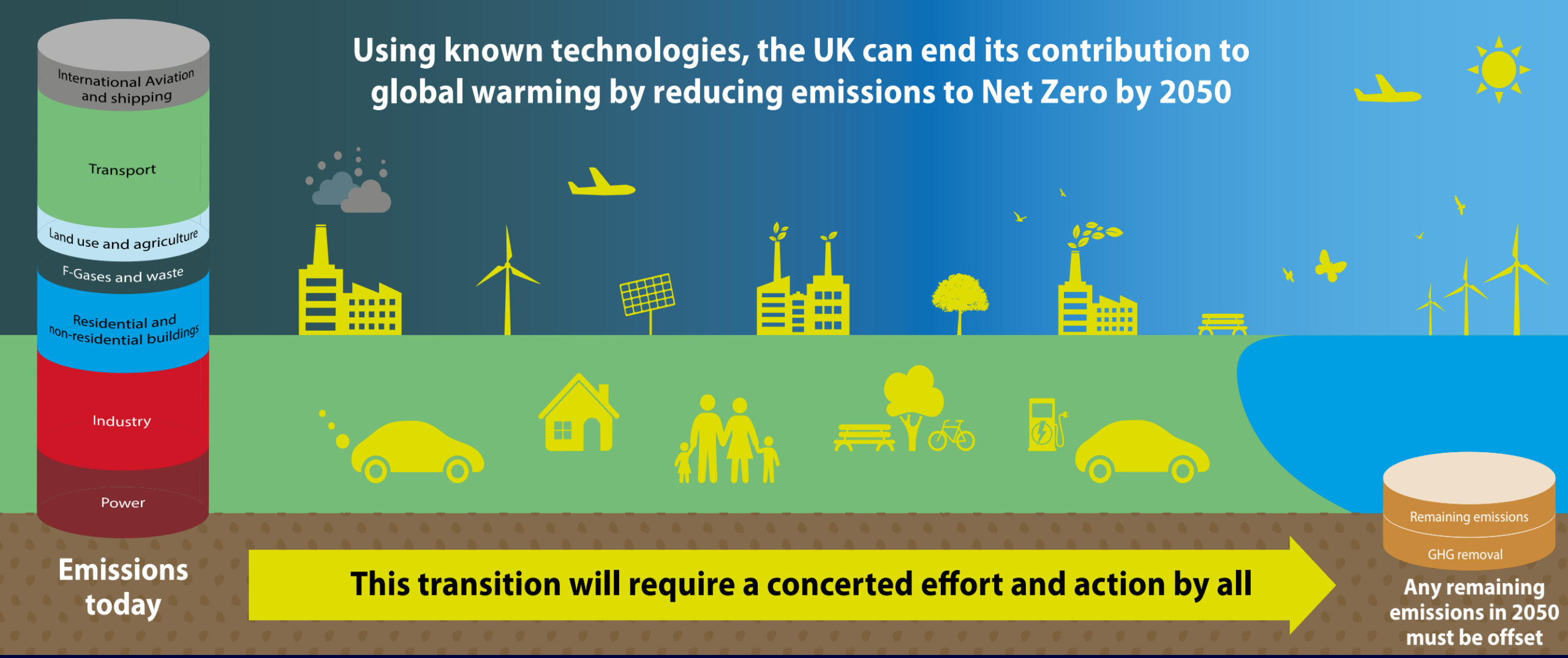


Agriculture
10 %

Energy supply
25 %

Waste management
4 %

Other
4 %

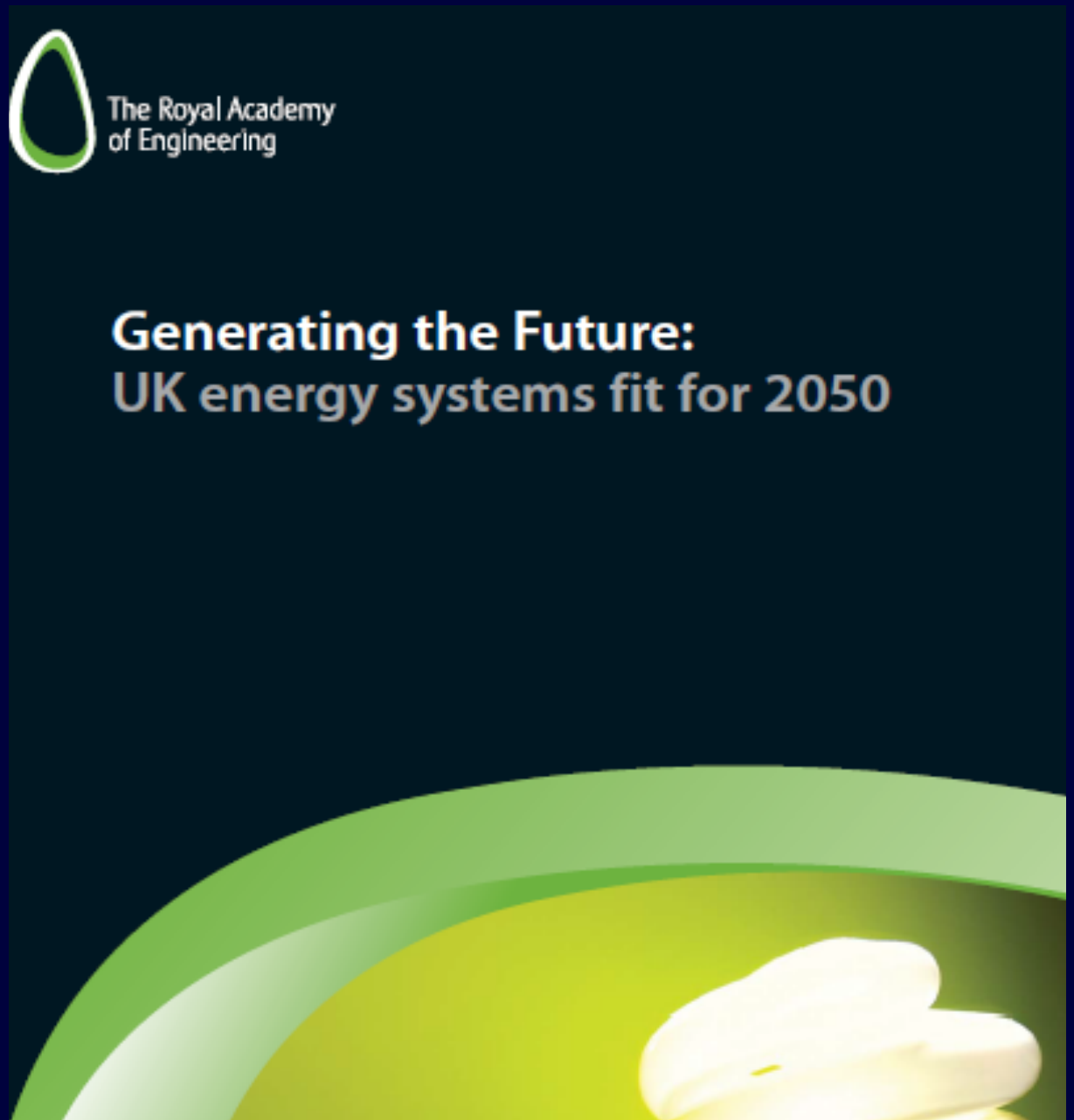


This is what the Committee on Climate Change says

But is it really possible?

And will the lights go out as we try?

Report issued by the Royal Academy of Engineering in 2010

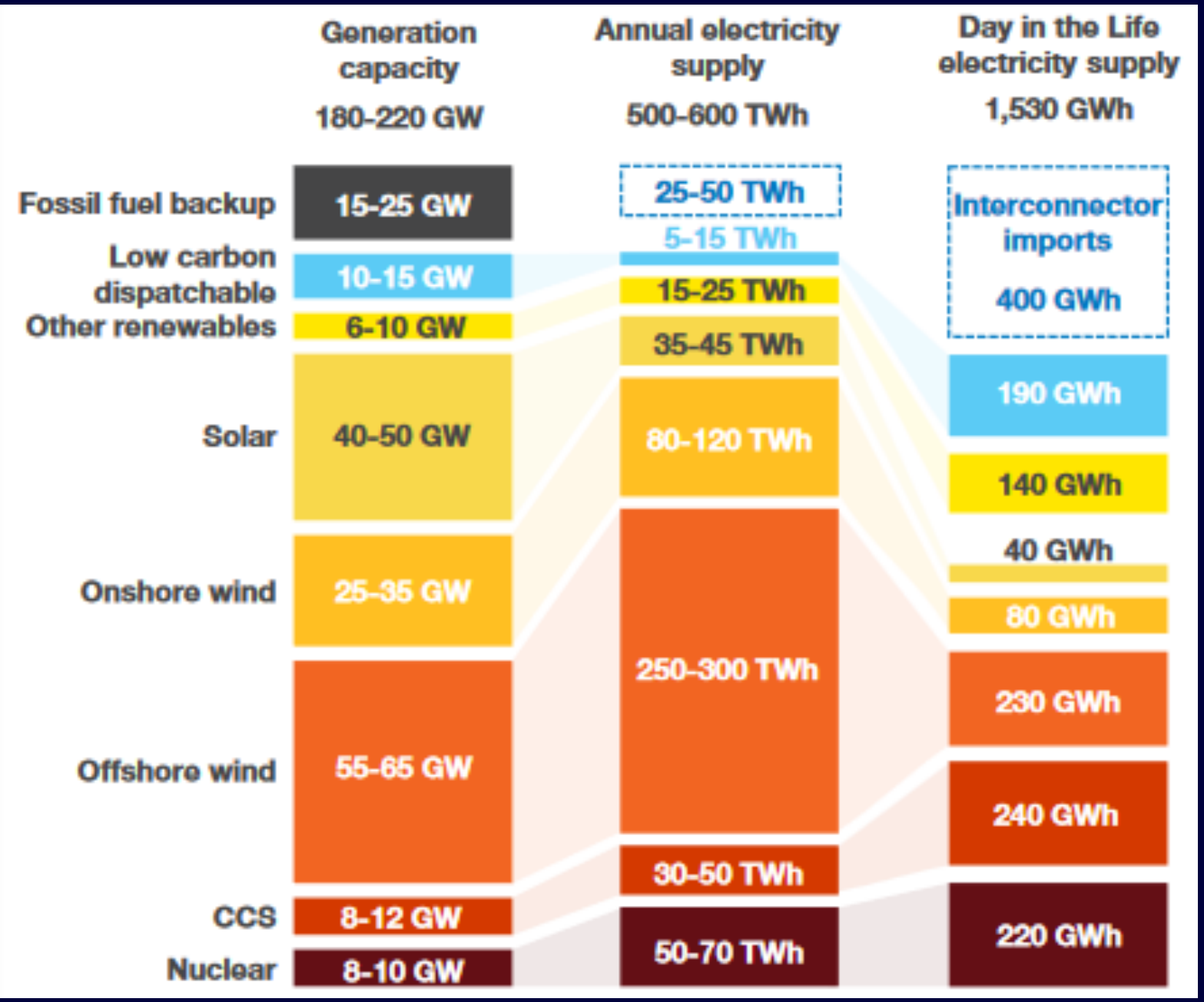


What we needed to meet a target of 80% reduction by 2050 compared with 1990 levels

Onshore wind	9600 2.5MW turbines
Offshore Wind	38 London Arrays
Solar Voltaics	25million 3.2kw solar panels
Wave	1000 miles of Pelamis m/c
Tidal Stream	2300 SeaGen Turbines
Tidal Barrage	1 Severn Barrage
Hydro	1000 hydro schemes
Nuclear/Fossil with CCS	**80 new power plants**
Demand reduction	**At least 30%**

What was thought necessary to meet the target	The average amount of GWe the max amount produces	Max amount thought possible to build (GWe)	**What we have built so far (GWe)**
Onshore Wind	6.5	24	14.3
Offshore Wind	11.4	38	10.4
Solar Voltaic	7.2	72	13.5
Wave	3.8	9.4	None
Tidal Stream	1.4	2.8	None
Tidal Barage	2.0	8.5	None
Hydro	0.9	2.3	Small local schemes 4.7 :2.8 pumped
Total	**33.2**	**157**	**43**

No new nuclear power stations or fossil with CCS



Annual electricity supply is dominated by renewables. However on the winter Day in the Life with low renewable output and high demand, supply draws heavily on carbon capture and imports alongside energy storage and demand side flexibility.

Source: National Grid: Bridging the Gap - A Day in the Life of 2035

New 10 point plan for Green Industrial Revolution

UK Government Position

- Ten Point Plan 2020
- Energy White Paper 2020
- British Energy Security Strategy 2022

- Reduce the cost and the role of nuclear to support carbon net zero targets and energy security, including novel design.
- Target of 24GW generating capacity by 2050.

Nuclear Energy: a major contributor to the UK’s low carbon electricity but for how long?

Hartlepool

Hinkley B

Heysham1

Hunterston B

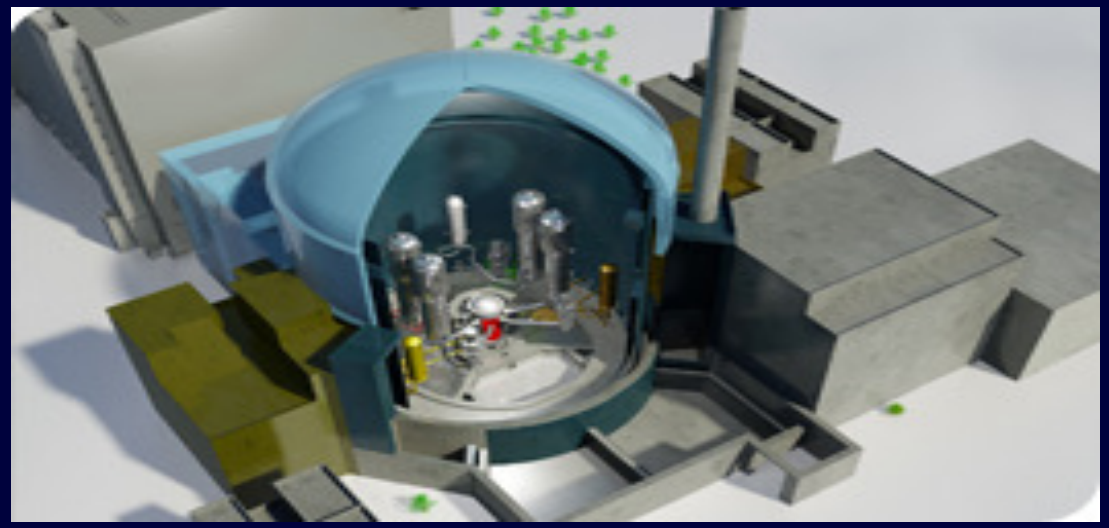
Heysham 2

Dungeness

Sizewell B

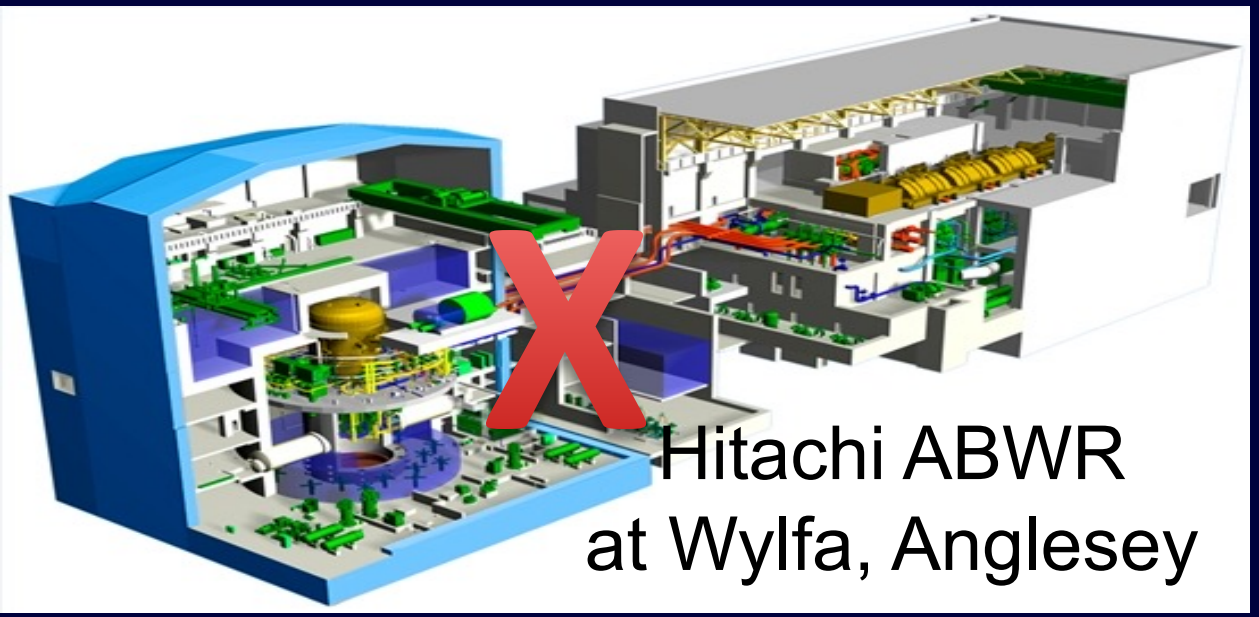
Torness

The UK's ambitions for new build



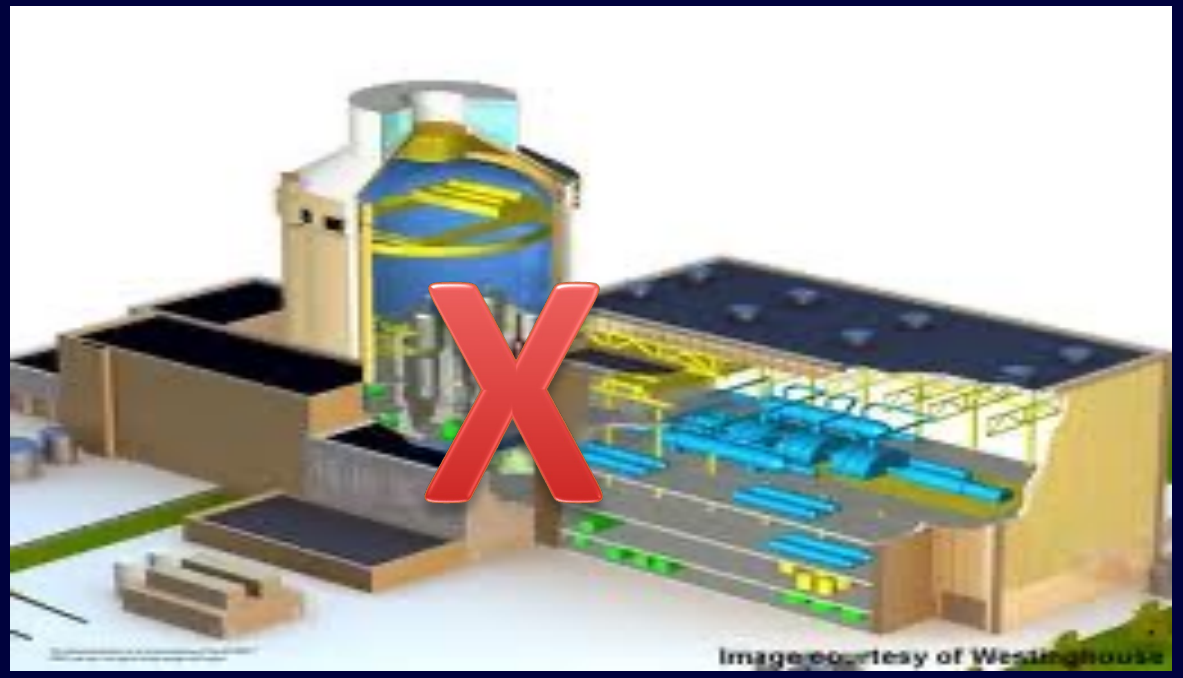
EdF deploying French EPR
at Hinkley Point and Sizewell

Westinghouse AP1000
at Moorside Cumbria



X

Hitachi ABWR
at Wylfa, Anglesey



X

Even before Ukraine the USA and France had begun a major push for new nuclear power investments

https://www.world-nuclear-news.org/Articles

EDF teams up with Italian partners on SMR development

BWRX-300 selected for Estonia's first nuclear power plant

Contract signed with Westinghouse for pre-design work for first Polish plant

ČEZ identifies two further preferred SMR sites

Canadian and Polish regulators announce SMR collaboration

14 February 2023

Poll finds record support for Japanese reactor restarts

Siting permit requested for new Slovak plant

Poland's Industria selects Rolls-Royce SMR for green energy plans

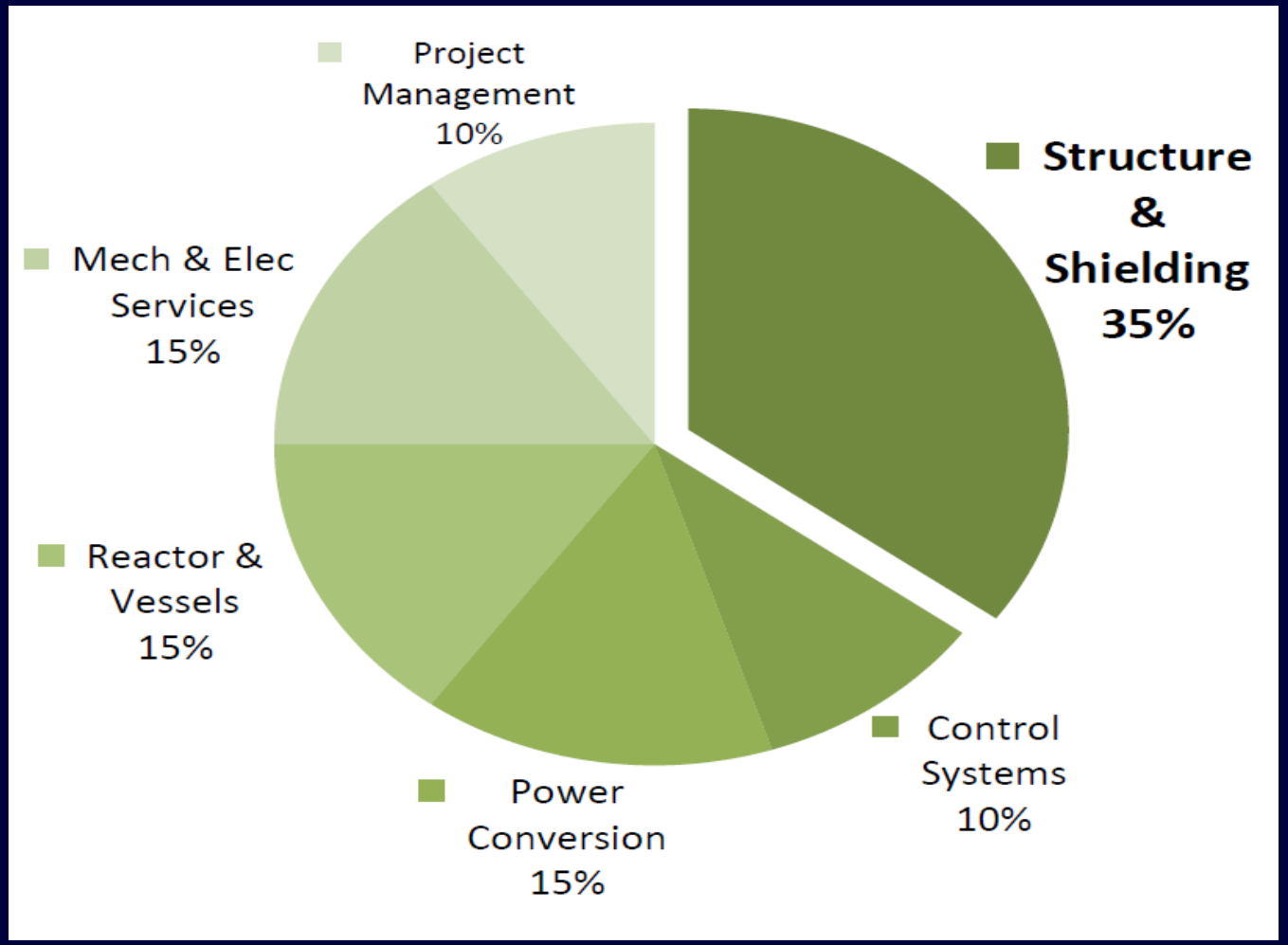
French ministerial council prepares for nuclear revival

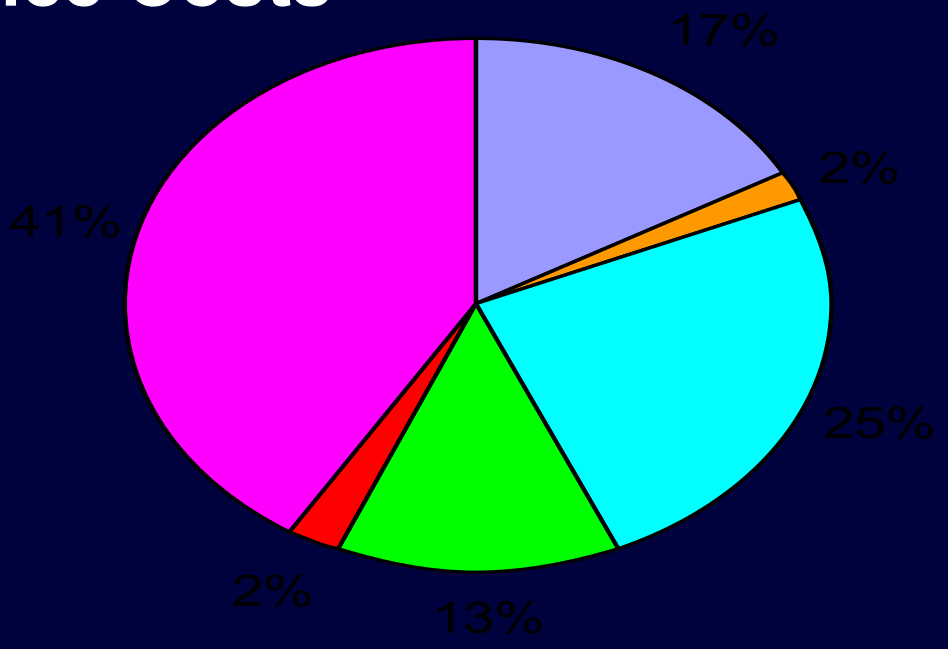
Nuclear plants vital for Spain, manifesto says

Changes to Swedish law proposed to enable nuclear new build

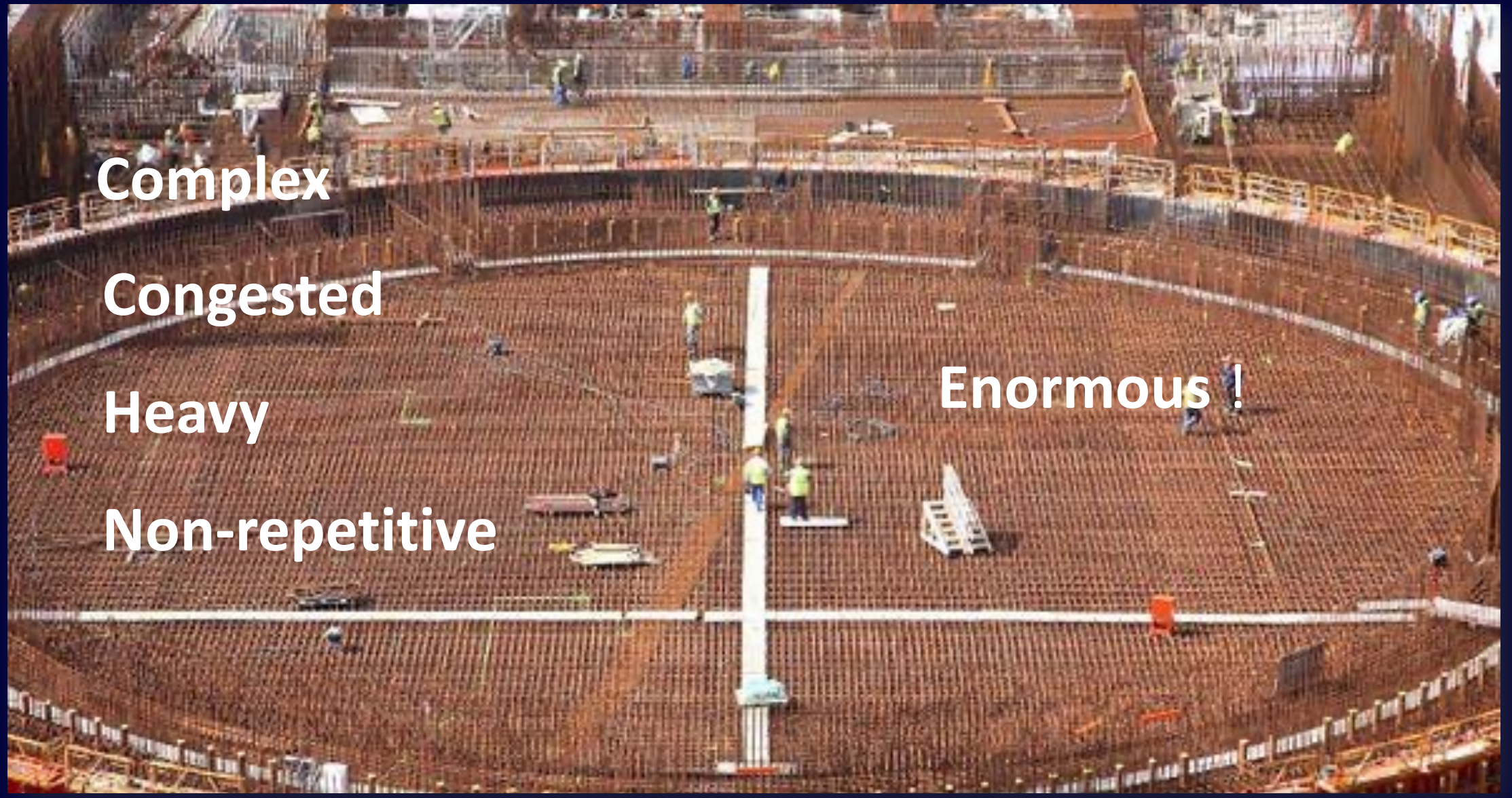

Vast amounts of cash before you get power
£/$ bn

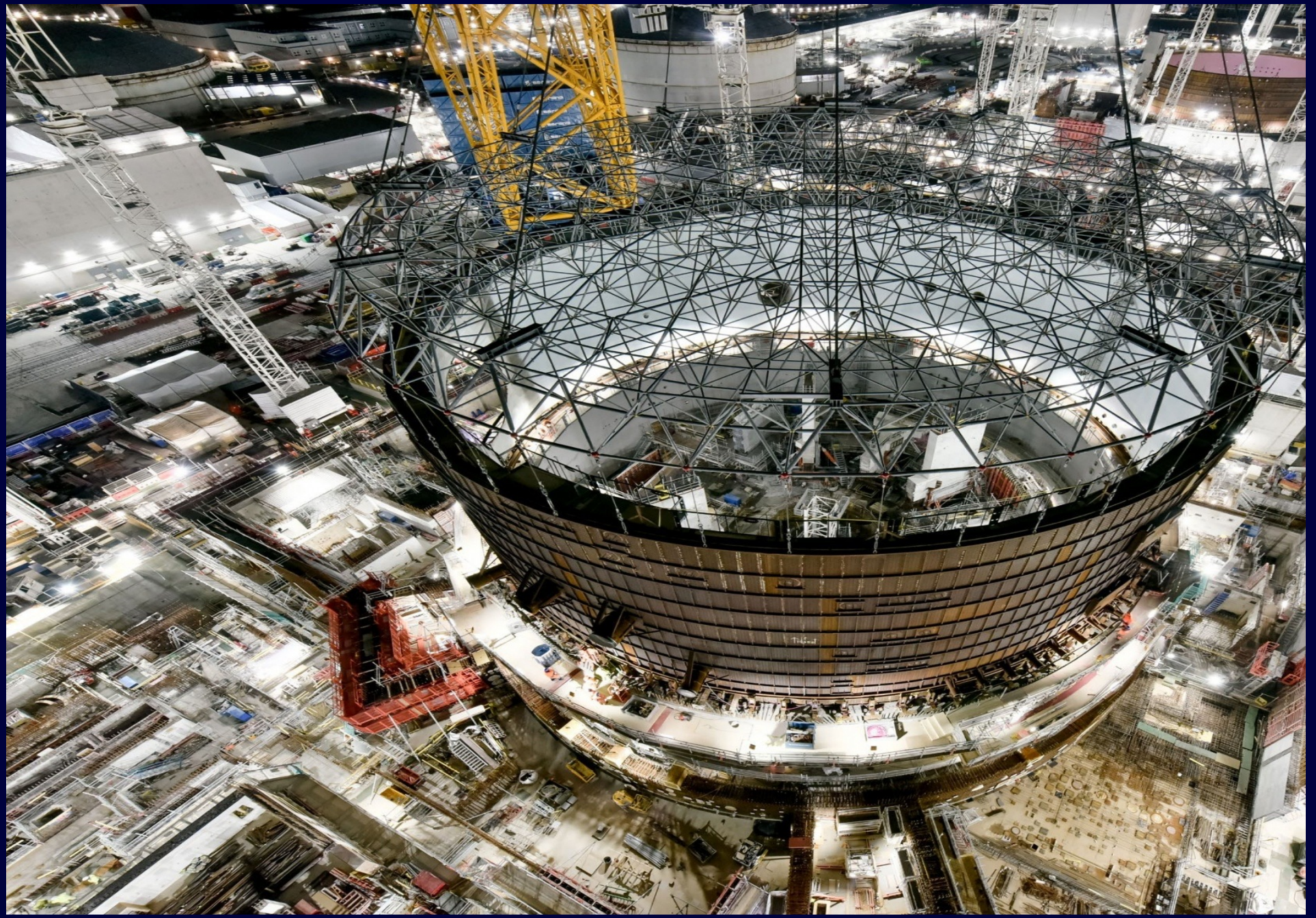
Reactor Capital and Finance Costs





The Challenge of Hinkley Point C





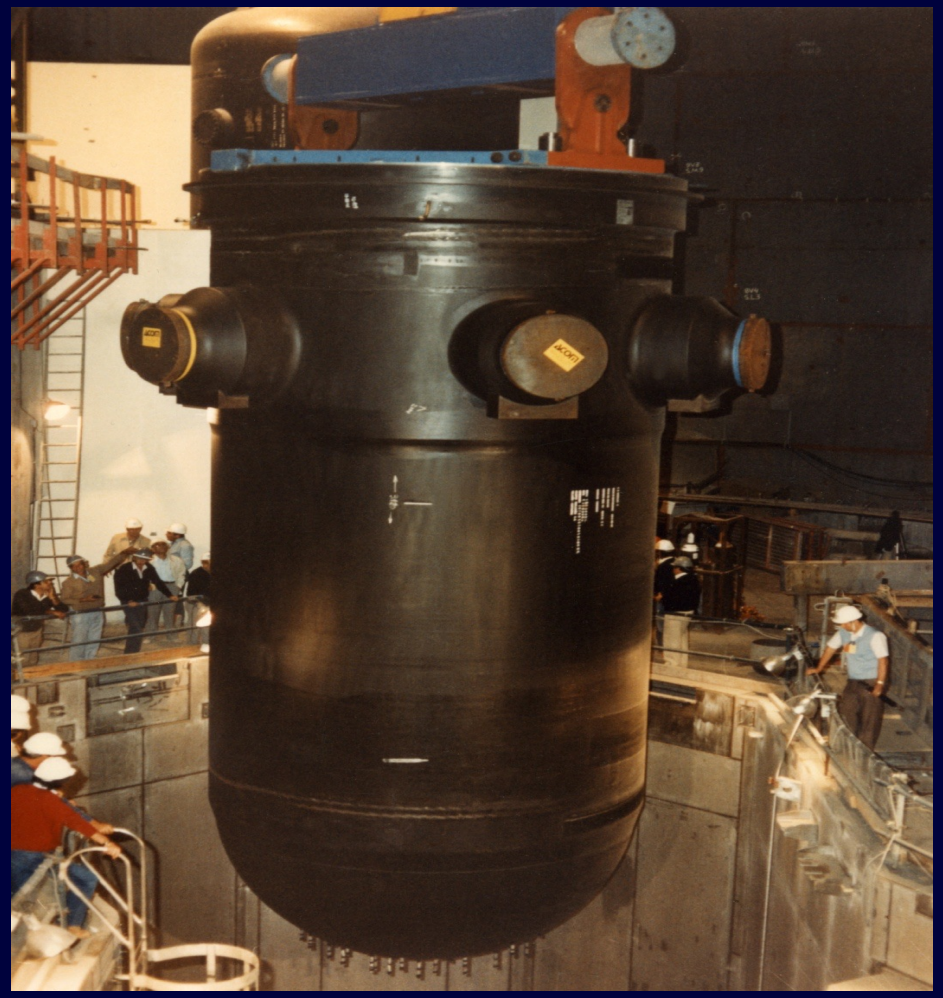
Hinkley Point pressure vessel
on last leg of its journey to Site at the end of February 2023

Units 3 and 4 of the Vogtle Nuclear Plant in the United States

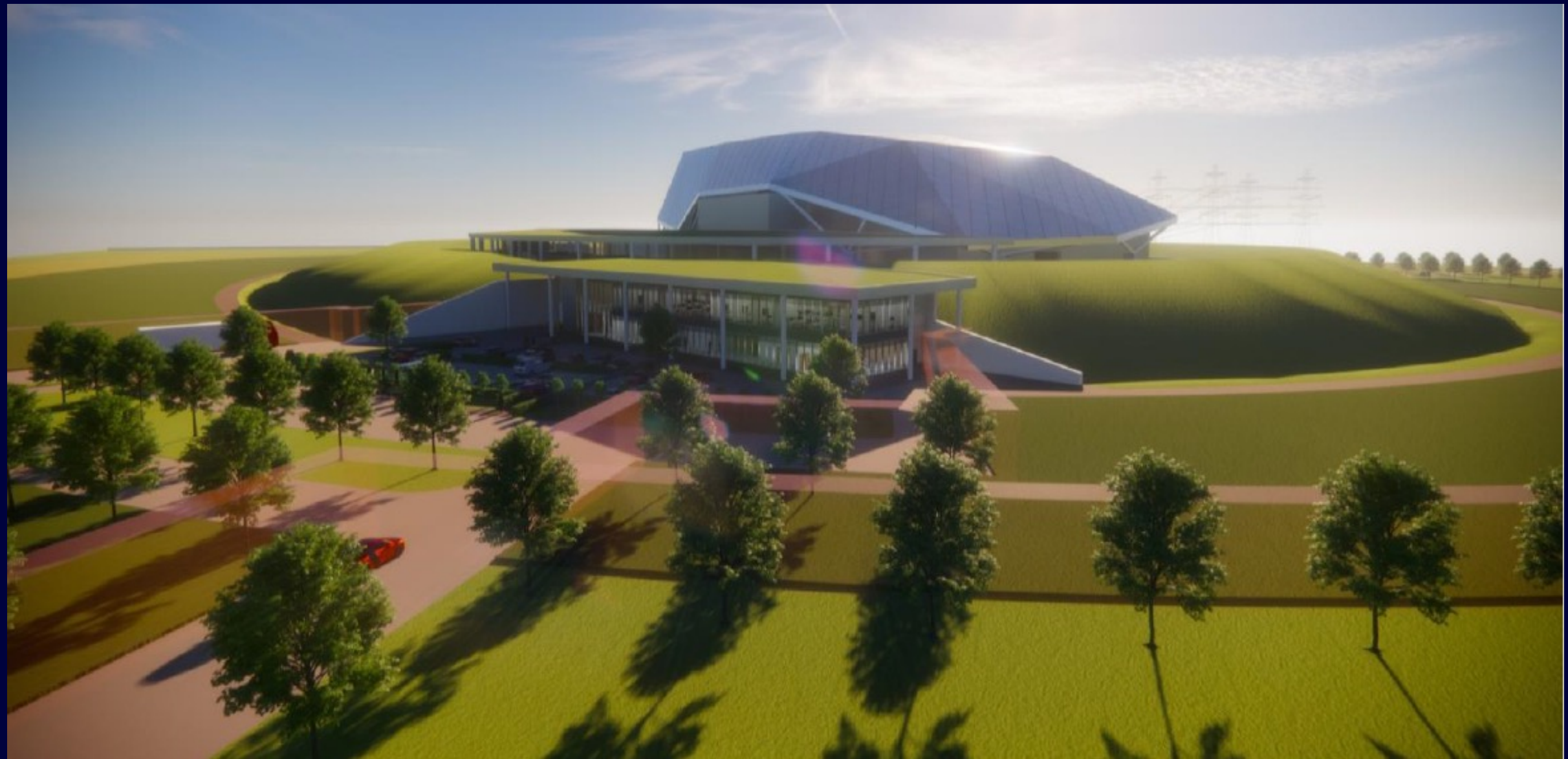

(Image: Georgia Power)

March 6th 2023 Vogtle 3
Celebrated first criticality

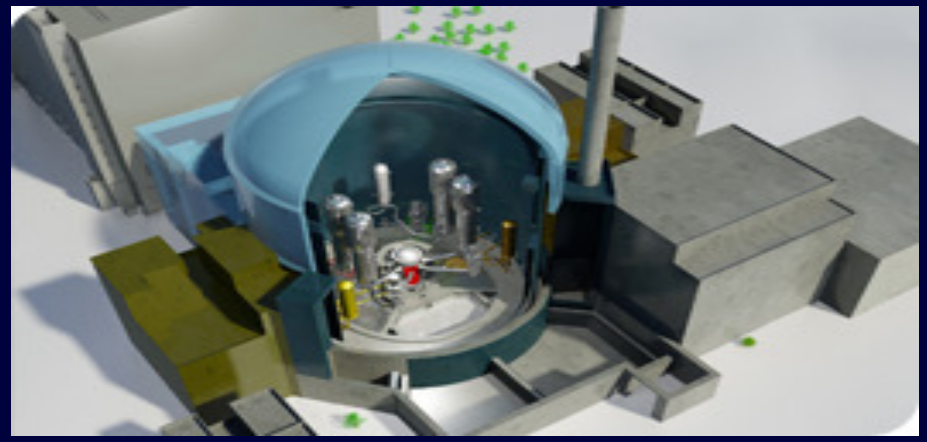
Reactor Pressure vessel



Rolls Royce SMRs – Low cost, Deliverable, Investable Low Carbon Power

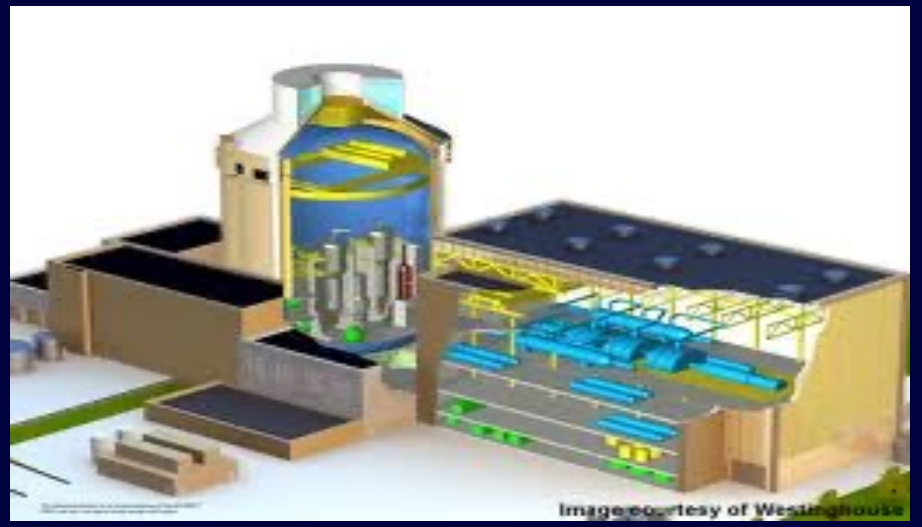


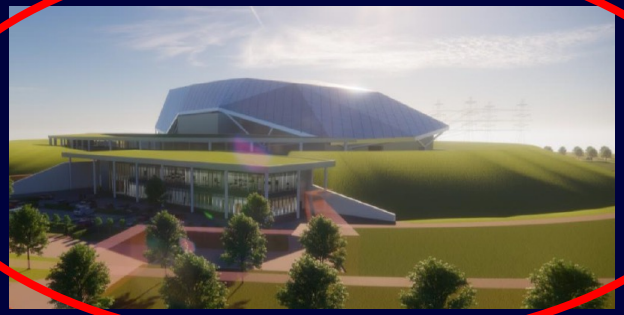
The UK's ambitions for new build?



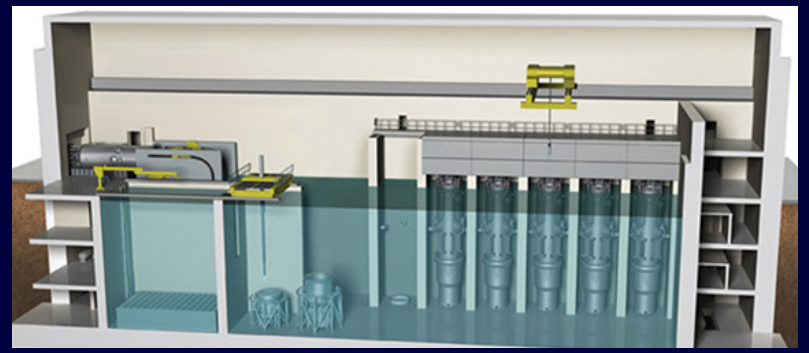
EdF deploying more French EPRs?

Westinghouse AP1000?





RR SMR

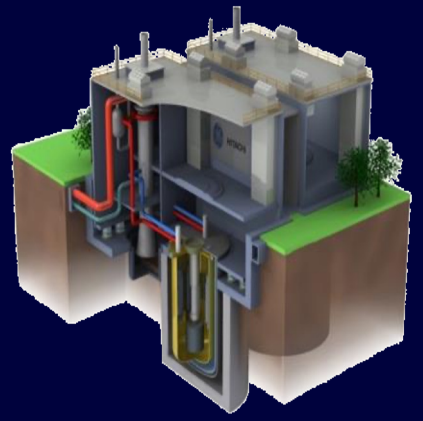


GE BWRX-300

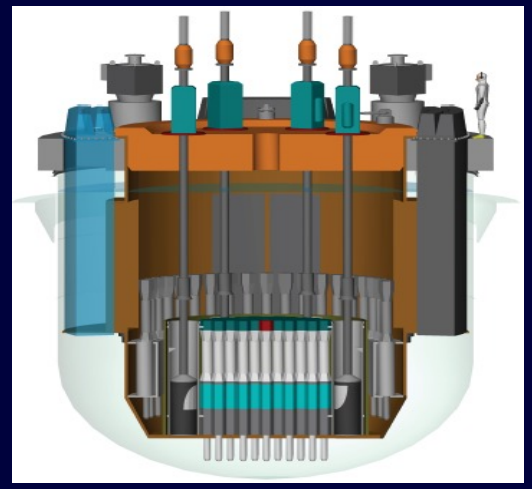
NuScale SMR

Innovation from Major Traditional Vendors GE-H and WEC in non-LWR Systems

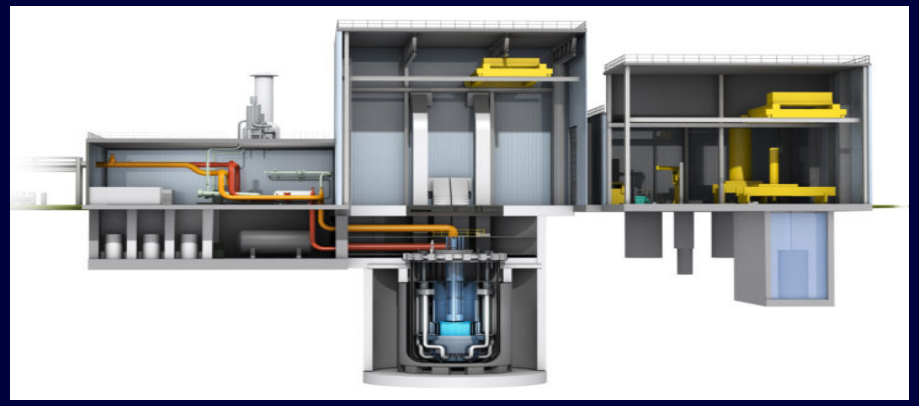
PRISM



- 165 MWe and 311 MWe
- 12-24 month fuel cycle
- Power gen, heat, used nuclear fuel & Pu disposition



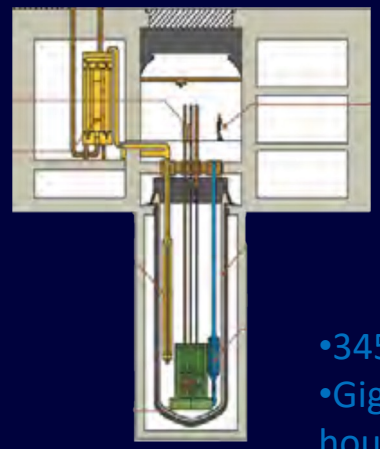
Westinghouse
Lead Cooled Fast Reactor



Natrium
TerraPower and GE

ARC-100

- 100 MWe
- 20 year fuel cycle
- Power generation & industrial heat

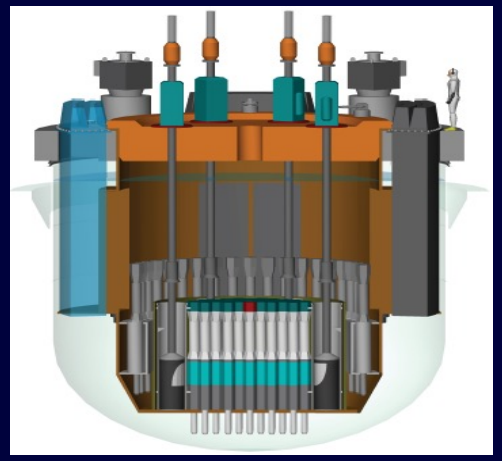


- 345 MWe reactor
- Gigawatt-hour-scale energy storage (capacity of 500 MWe output for 5.5+ hours)
- Four times more fuel efficient than light water reactors
- 80% less nuclear-grade concrete per MWe

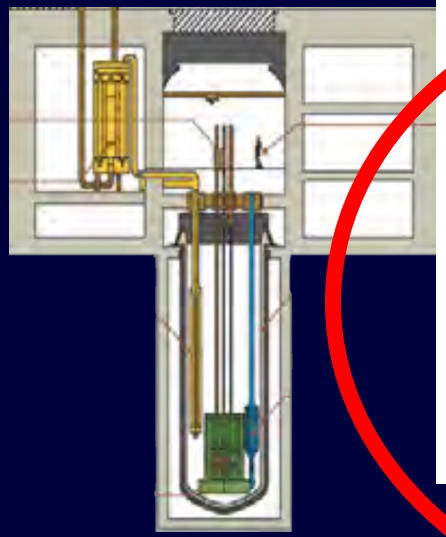
eVinci™
Micro reactor

UK AMR Landscape

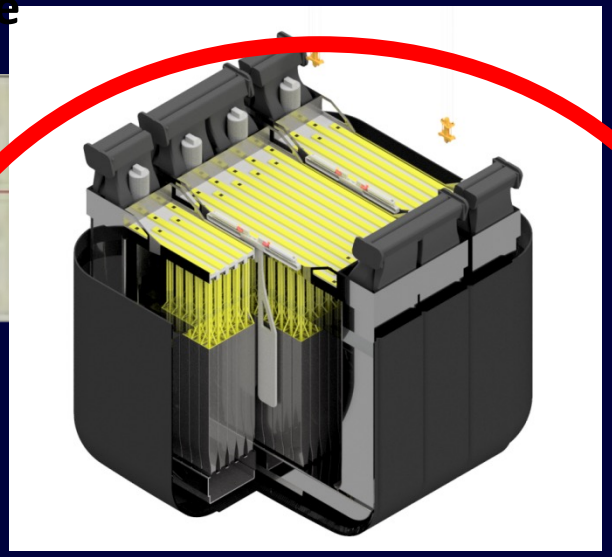
SEALER
LeadCold



Westinghouse LFR

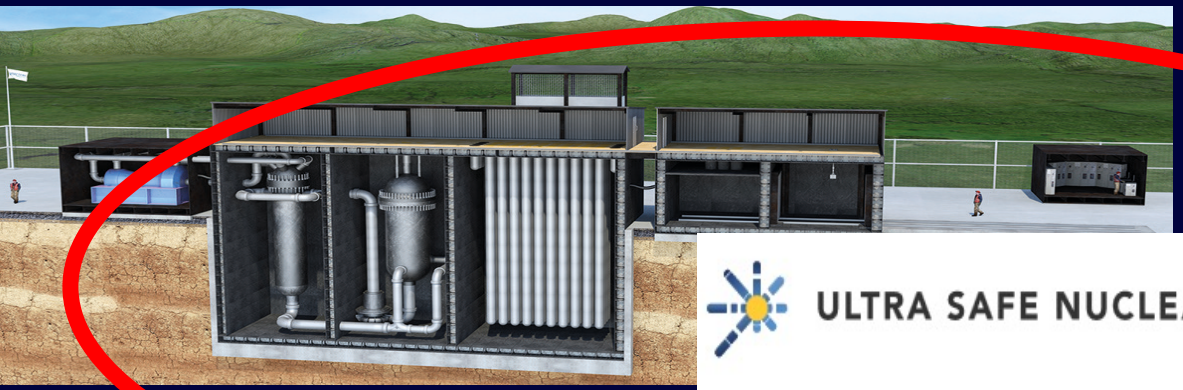


ARC100
Na FR



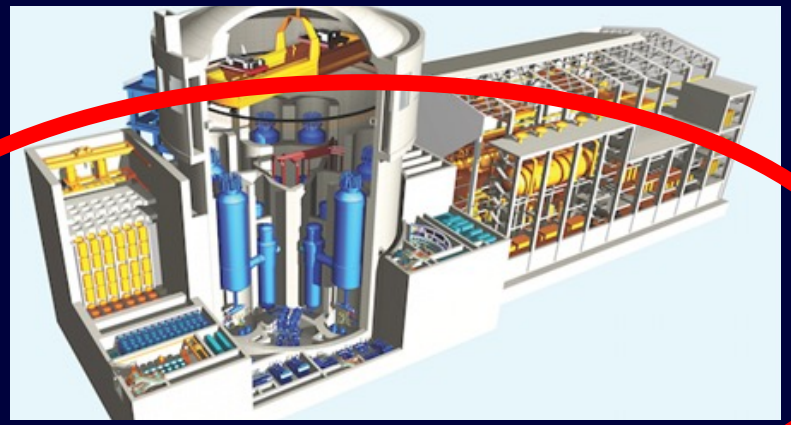
MOLTEX MSR

Tokamak Energy
Fusion Device



URENCO led U-Battery™

ULTRA SAFE NUCLEAR CORPORATION



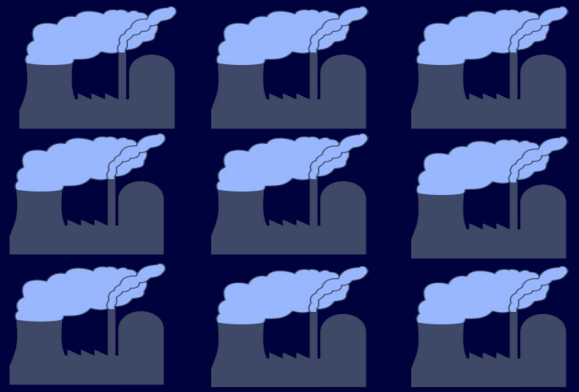
X-Energy HTR

What do we need to do?

Use Fewer Bits

Use Less Time

Once upon a time HMG set Energy Policy…….
Energy was too important to national security and security of energy supplies to leave it to the international marketplace…..



Fleet Approach

Borrow the Money Cheaply

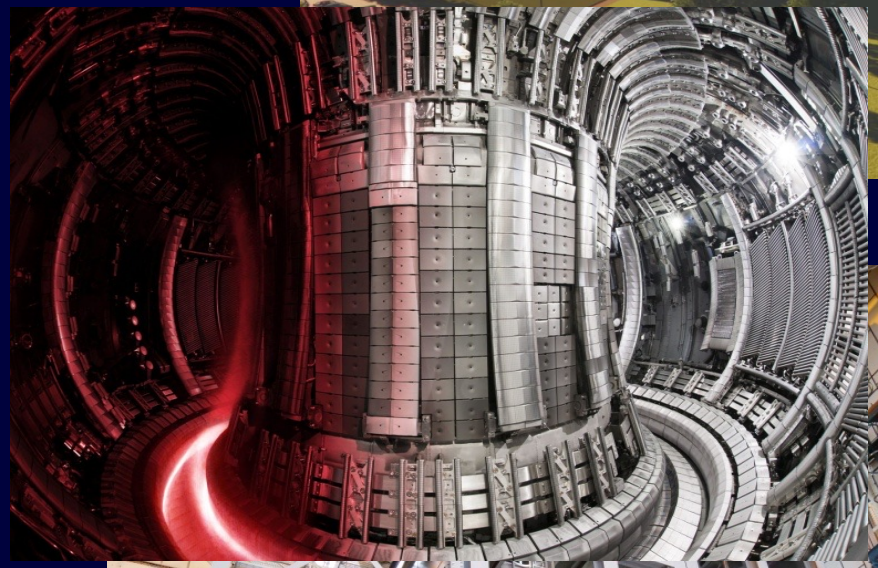
Nuclear gets green label backing and Great British Nuclear launched in huge step forward for the industry: budget 15 March

Does Nuclear Energy have some additional functionality?

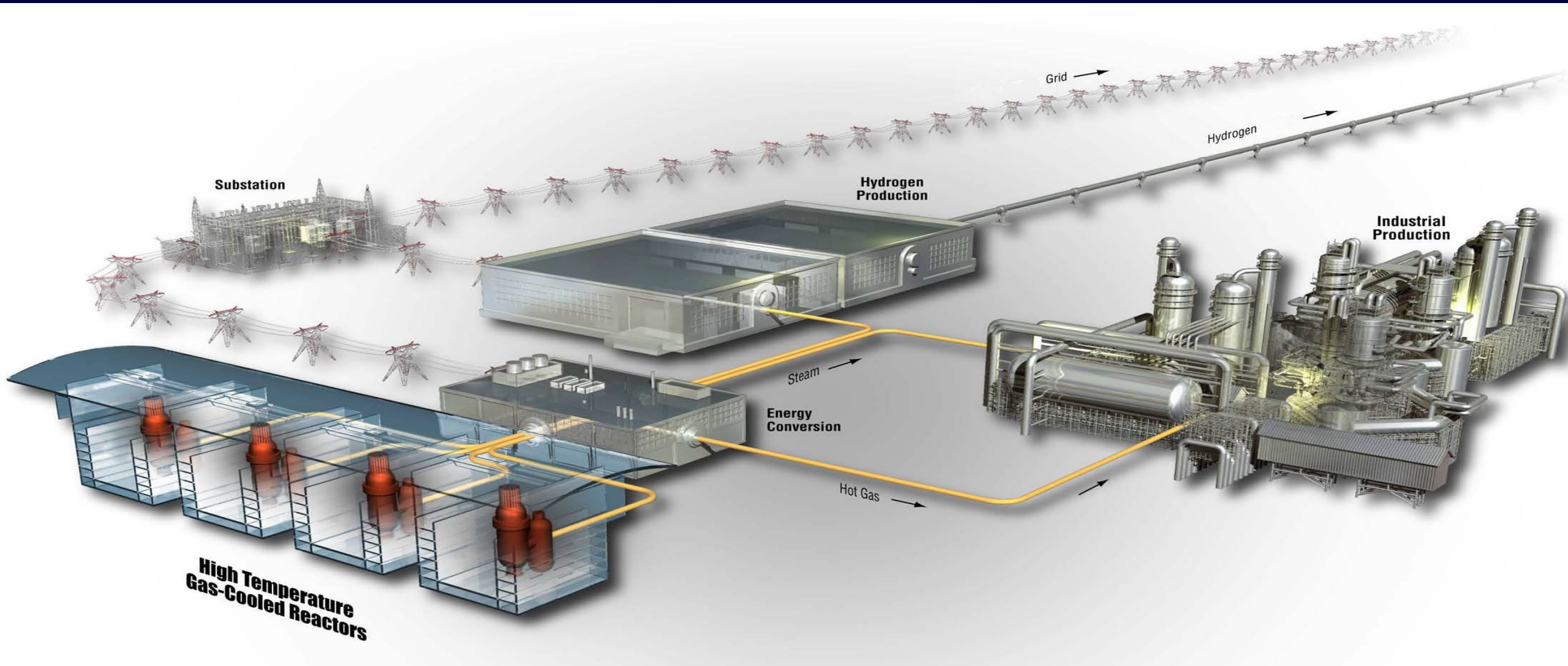
How about coupling nuclear with heat and hydrogen generation?

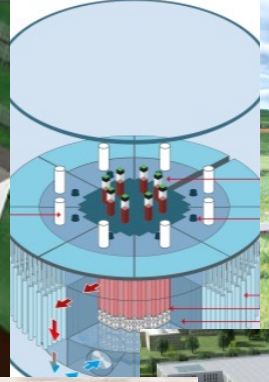
Nuclear Hydrogen Advantages

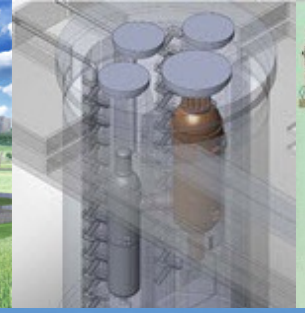
- Nuclear provides stable electricity output which allows electrolysers to run more efficiently
- Nuclear is the only clean energy source that produces low-carbon heat as a primary output
- Heat from reactors can make electrolysis more efficient and thus cheaper
- Only advanced reactors can produce high enough temperatures for thermochemical processes, the most efficient hydrogen production method
- Efficiency = cost competitive, comparable to CCS, but without the carbon emissions:



Advanced Nuclear Systems
High Temp Reactors coupled with Hydrogen Generation?
Small (micro) off grid systems?

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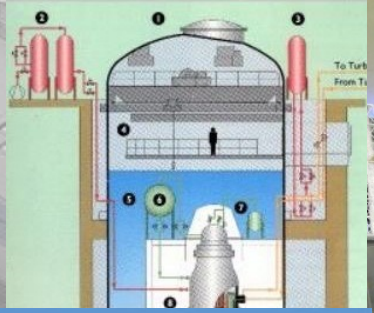

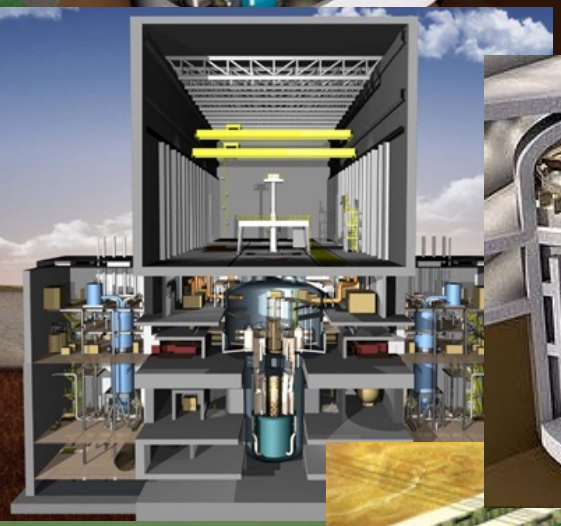
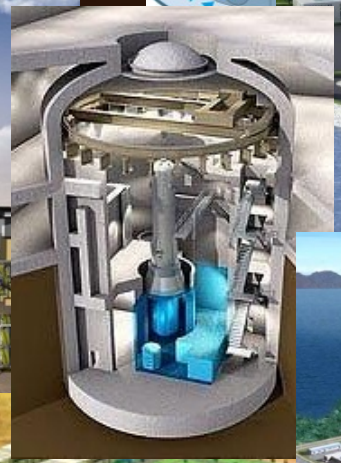

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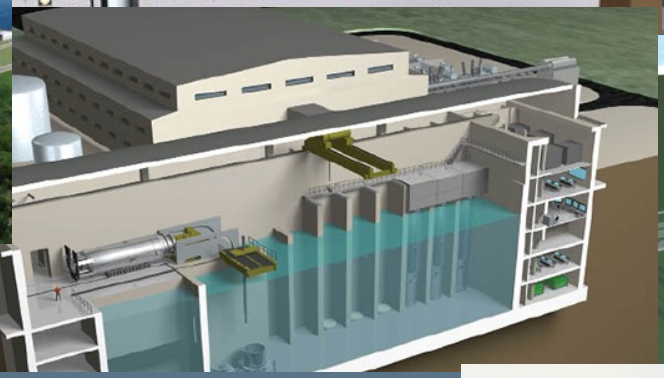
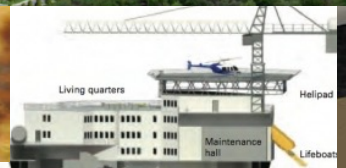
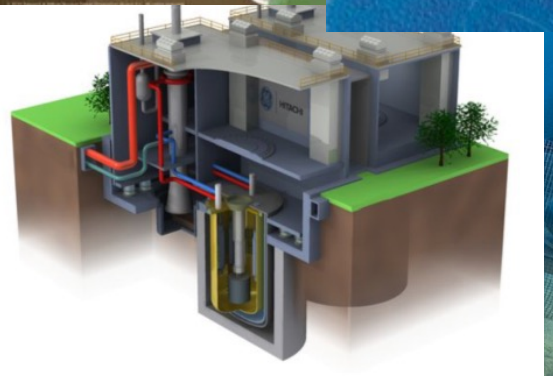
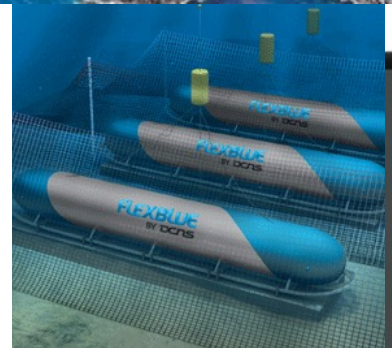
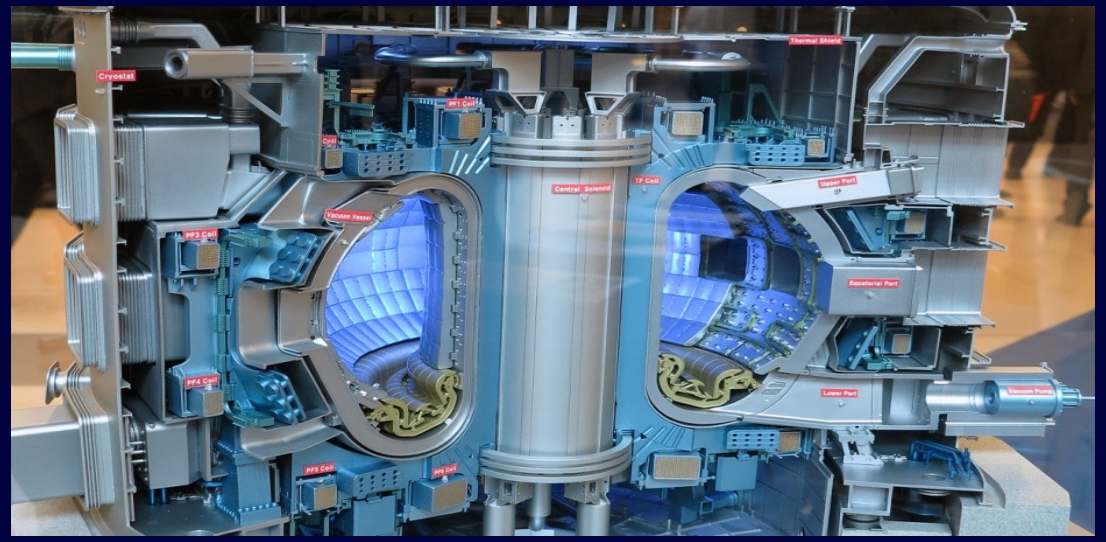


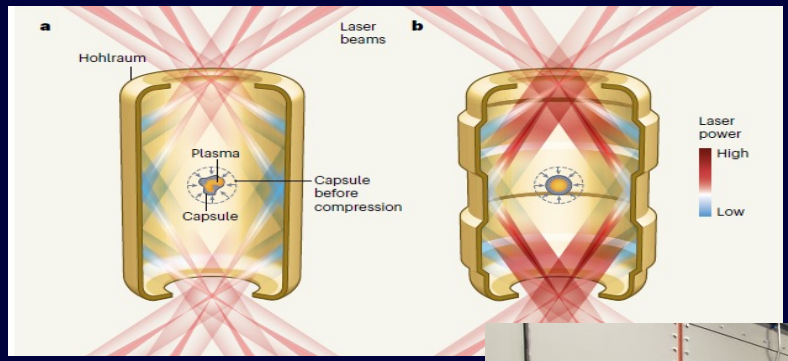


Living quarters
Helipad
Maintenance hall
Lifeboats
Adjustable ballast
Adjustable ballast
Turbine sector
Control room
Spent fuel pool
Steam drum
Platform double hull
RPV
Reactor hull
Containment
Flooded with seawater
Skirt
Ballast

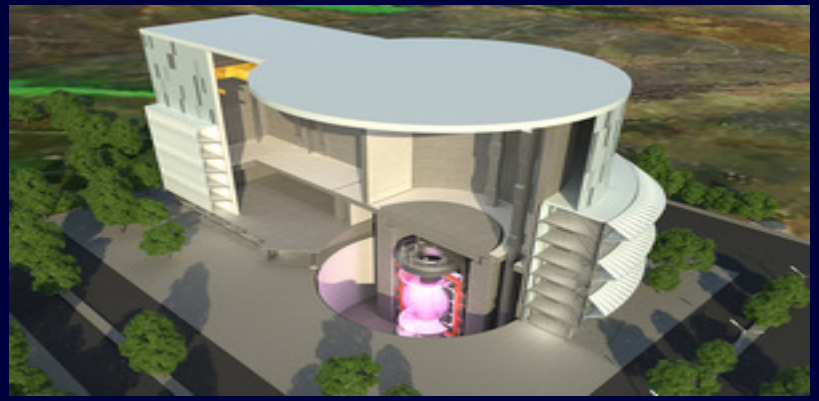



FLEXBLUE
by DCNS
FLEXBLUE
by DCNS
FLEXBLUE
by DCNS

Overground Maintenance Hall
Low Profile Cooling Tower
Electrical Output
Generator
Removable Access Covers
Removable Access Covers
Removable Access Covers
Removable Access Covers
Turbine
Intermediate Heat Exchanger
Reactor
Spare Fuel Cartridge Store
Spare Fuel Cartridge Store
Underground Reactor Building


What About Fusion?







UKAEA STEP Project

First Light Fusion

Late December 2022 Major Fusion Breakthrough Announced

This illustration provided by the National Ignition Facility at the Lawrence Livermore National Laboratory depicts a target pellet inside a hohlraum capsule with laser beams entering through openings on either end. The beams compress and heat the target to the necessary conditions for nuclear fusion to occur.

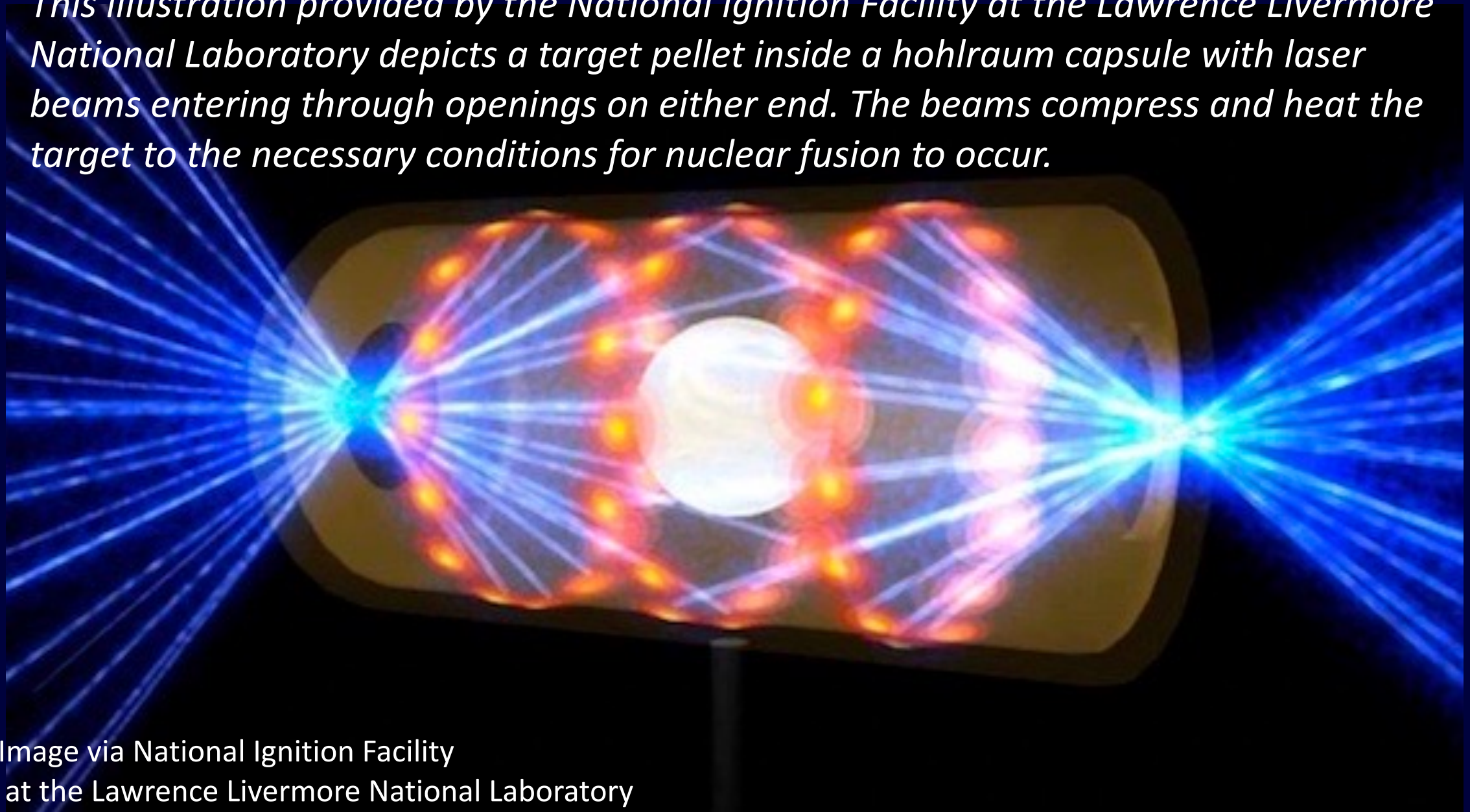
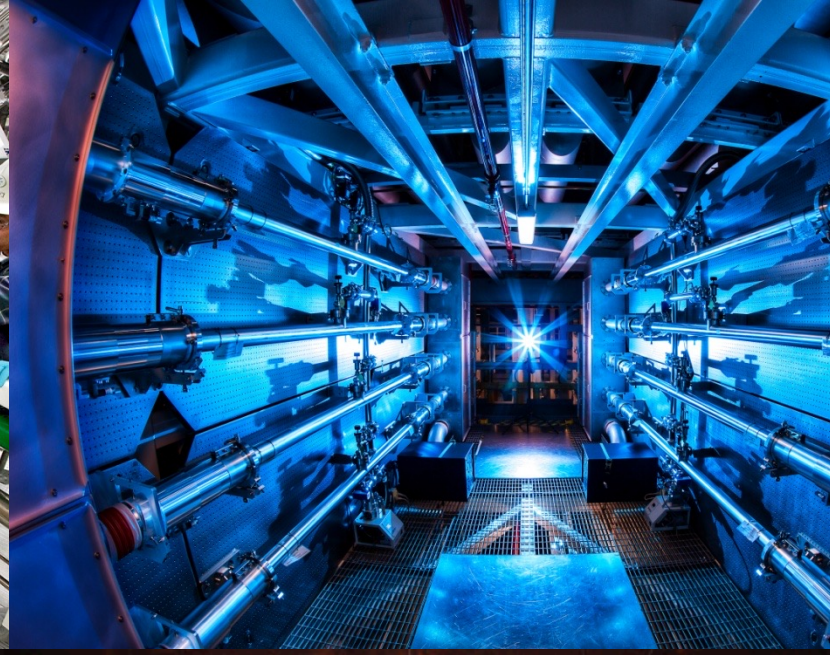
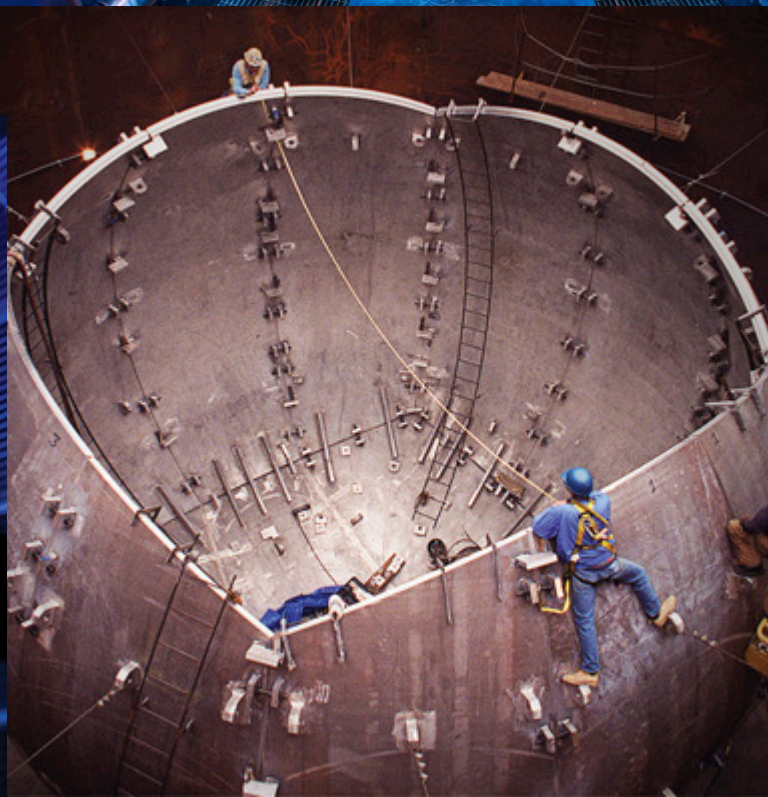


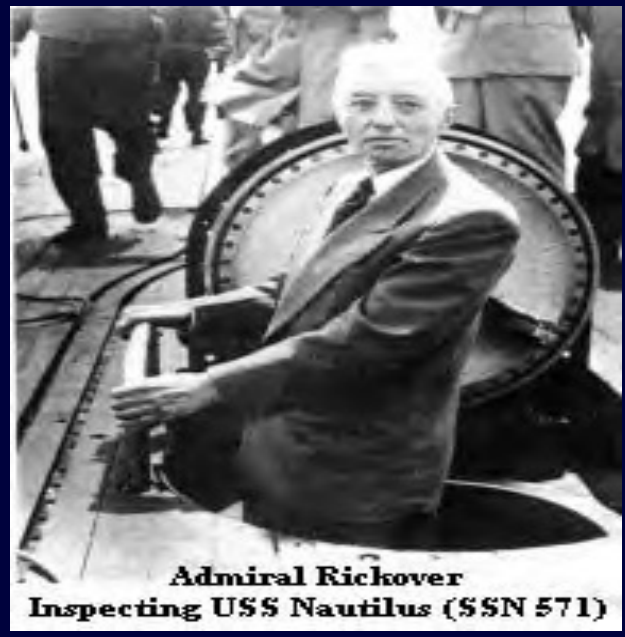
Image via National Ignition Facility
at the Lawrence Livermore National Laboratory



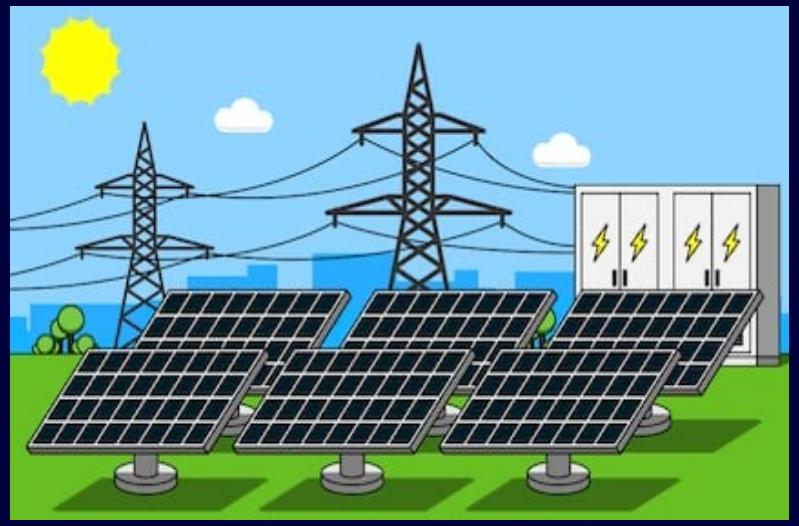


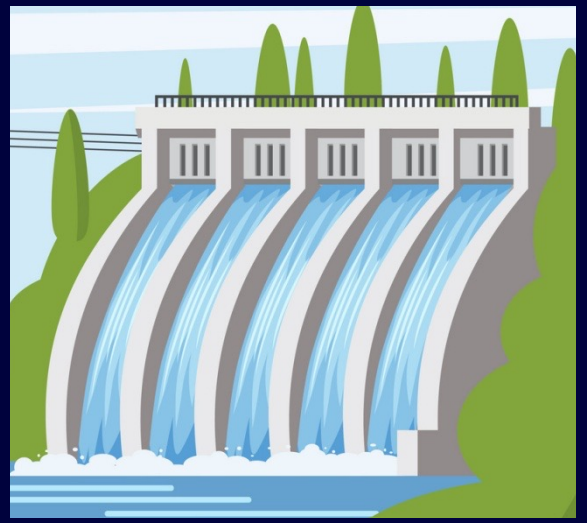
Images courtesy of LLNL and Wikipedia

Admiral Rickover

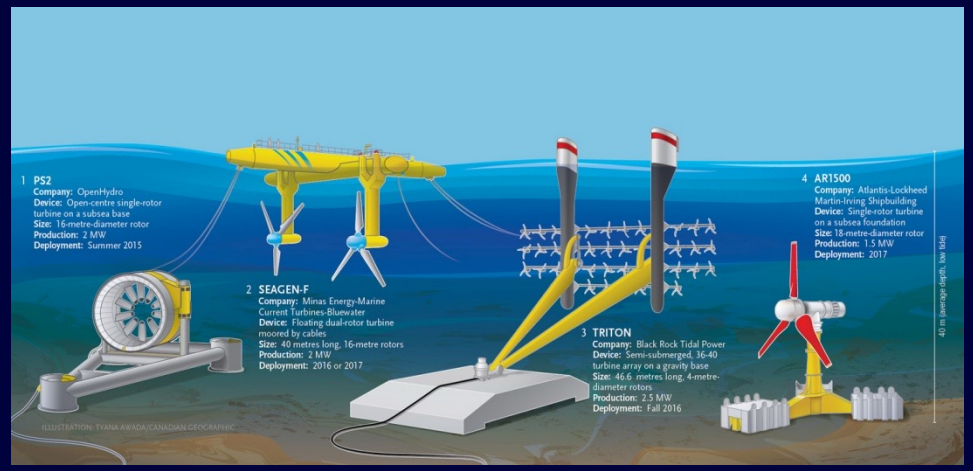


Admiral Rickover
Inspecting USS Nautilus (SSN 571)





What is the role for nuclear power in achieving Net Zero? Will the lights go out without it?



United Nations Economic Commission for Europe, highlighting nuclear energy's superb green credentials:

- The lowest lifecycle carbon intensity *of any electricity generating technology*
- The lowest lifecycle land use *of any electricity generating technology*
- The lowest impact on ecosystems *of any electricity generating technology*

Thank You and Questions?

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