Nuclear Power

Past, Present and Future

The Personal Perspective of a Nuclear Engineer

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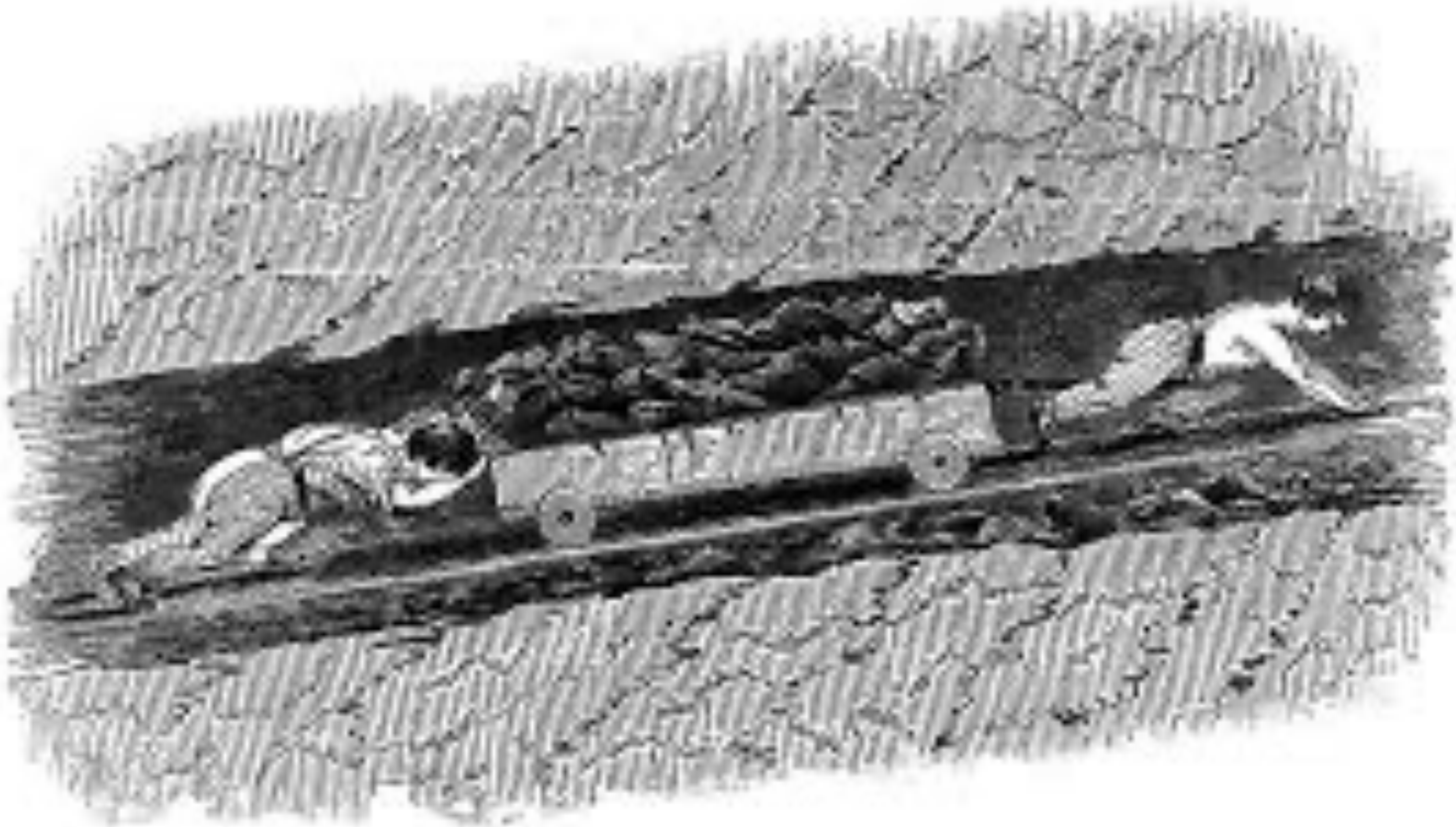
The Past - Victorian England



The Past - 1960s

The Past - 10 years ago

The Past - UK figures

UK coal production peaked
in 1913 at 287 MT

1300 deep mines and 92 surface mines
>1 million people employed

1957 >200 MT
2025 <100 kT

The Past - UK figures for workers

1850 and 1950
1400 deaths per year
in explosions, roof collapses and suffocation

1950 and 2000
320 deaths per year
in mine accidents

+untold suffering of millions of ex-miners
and 100,000s of deaths from lung diseases

The Present - wider issues

Deaths from respiratory illnesses amongst the population from airborne pollution

Global Warming caused by the CO_2 emitted when the coal is burned

~1,000,000,000 standard shipping containers full of fossil fuels are burned each year

2025 global fossil fuel CO_2 emissions 38 GT (up 1.1% on 2024)

1960 to 2000

Nuclear Power - Magnox Reactors

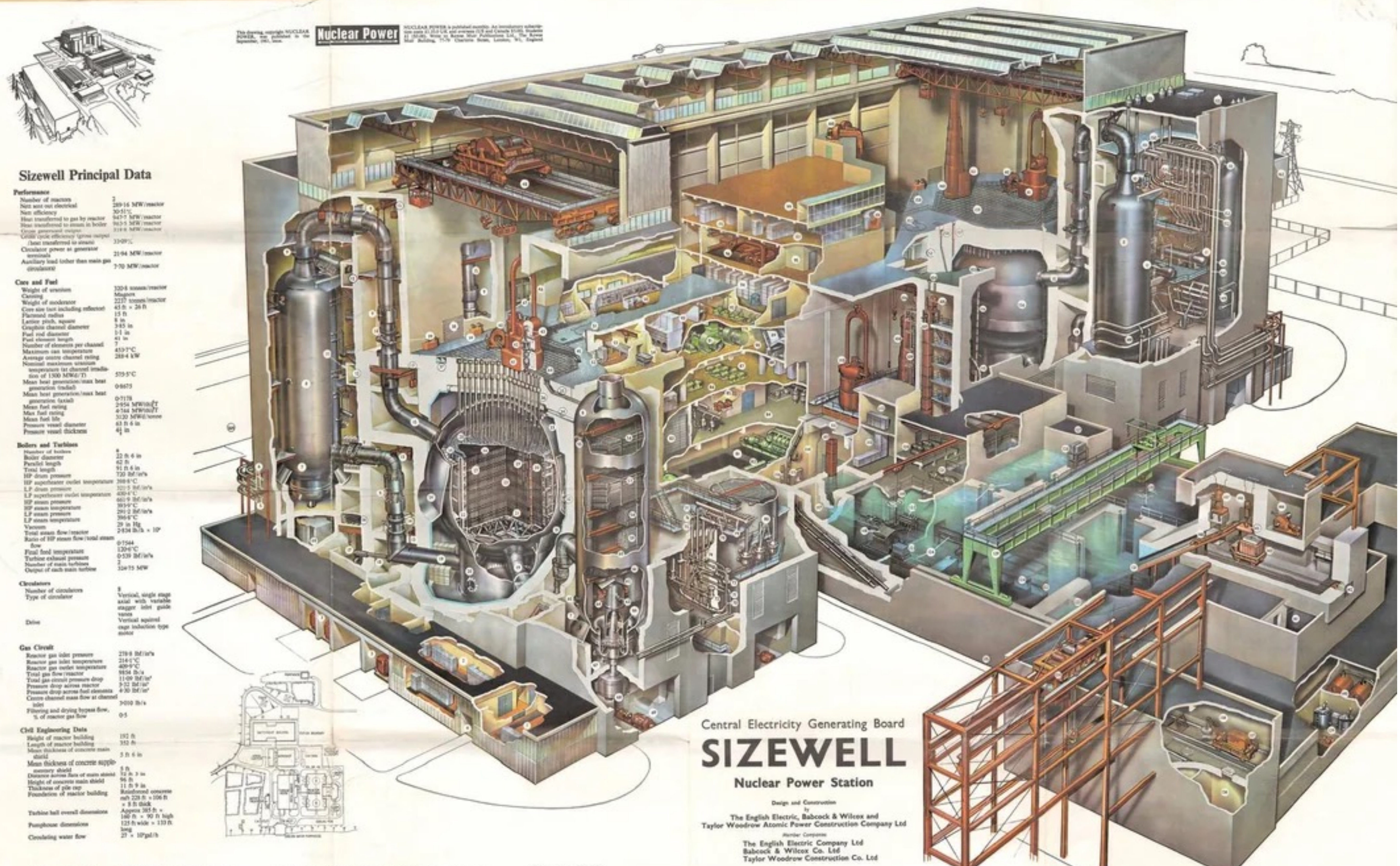
Civil nuclear power began in 1964 in the UK

Reactors optimised for electricity production run by the CEGB

8 Magnox power stations in the UK each with 2 reactors

Berkeley in 1964 and including Sizewell A in 1966

This design was exported by UK industry to Italy and Japan
France had similar a bit later at 3 sites



Sizewell Principal Data

Performance	
Number of reactors	2
Net sent out electrical	289·16 MW/reactor
Net efficiency	30·51%
Heat transferred to gas by reactor	947·7 MW/reactor
Heat transferred to steam in boiler	915·5 MW/reactor
Gross generated output	318·8 MW/reactor
Gross cycle efficiency (gross output/heat transferred to steam)	33·09%
Circulator power at generator terminals	21·94 MW/reactor
Auxiliary load (other than main gas circulators)	7·70 MW/reactor
Core and Fuel	
Weight of uranium	320·8 tonnes/reactor
Canning	Magnox
Weight of moderator	2237 tonnes/reactor
Core size (not including reflector)	45 ft × 26 ft
Flattened radius	15 ft
Lattice pitch, square	8 in
Graphite channel diameter	3·65 in
Fuel rod diameter	1·1 in
Fuel element length	41 in
Number of elements per channel	7
Maximum can temperature	453·7°C
Average centre channel rating	289·4 kW
Nominal maximum uranium temperature (at channel irradiation of 1500 MWd/T)	575·5°C
Mean heat generation/max heat generation (radial)	0·8675
Mean heat generation/max heat generation (axial)	0·7178
Mean fuel rating	2·954 MW/10³T
Max fuel rating	4·744 MW/10³T
Mean fuel life	3120 MWd/tonne
Pressure vessel diameter	63 ft 6 in
Pressure vessel thickness	4¼ in
Boilers and Turbines	
Number of boilers	8
Boiler diameter	22 ft 6 in
Parallel length	62 ft
Total length	91 ft 6 in
HP drum pressure	720 lbf/in²a
HP superheater outlet temperature	398·8°C
LP drum pressure	321·5 lbf/in²a
LP superheater outlet temperature	400·4°C
HP steam pressure	661·9 lbf/in²a
HP steam temperature	393·9°C
LP steam pressure	291·2 lbf/in²a
LP steam temperature	396·8°C
Vacuum	29 in Hg
Total steam flow/reactor	2·834 lb/h × 10⁶
Ratio of HP steam flow/total steam flow	0·7544
Final feed temperature	120·6°C
Turbine exhaust pressure	0·539 lbf/in²a
Number of main turbines	2
Output of each main turbine	324·75 MW
Circulators	
Number of circulators	8
Type of circulator	Vertical, single stage axial with variable stagger inlet guide vanes
Drive	Vertical squirrel cage induction type motor
Gas Circuit	
Reactor gas inlet pressure	278·8 lbf/in²a
Reactor gas inlet temperature	214·1°C
Reactor gas outlet temperature	409·9°C
Total gas flow/reactor	9854 lb/s
Total gas-circuit pressure drop	11·09 lbf/in²
Pressure drop across reactor	5·32 lbf/in²
Pressure drop across fuel elements	4·30 lbf/in²
Centre channel mass flow at channel inlet	3·010 lb/s
Filtering and drying bypass flow, % of reactor gas flow	0·5
Civil Engineering Data	
Height of reactor building	192 ft
Length of reactor building	352 ft
Mean thickness of concrete main shield	5 ft 6 in
Mean thickness of concrete supplementary shield	5 ft
Distance across flats of main shield	72 ft 3 in
Height of concrete main shield	96 ft
Thickness of pile cap	11 ft 9 in
Foundation of reactor building	Reinforced concrete raft 228 ft × 106 ft × 5 ft thick
Turbine hall overall dimensions	Approx 385 ft × 160 ft × 90 ft high
Pumphouse dimensions	125 ft wide × 110 ft long
Circulating water flow	27 × 10⁶gal/h

Central Electricity Generating Board

SIZEWELL

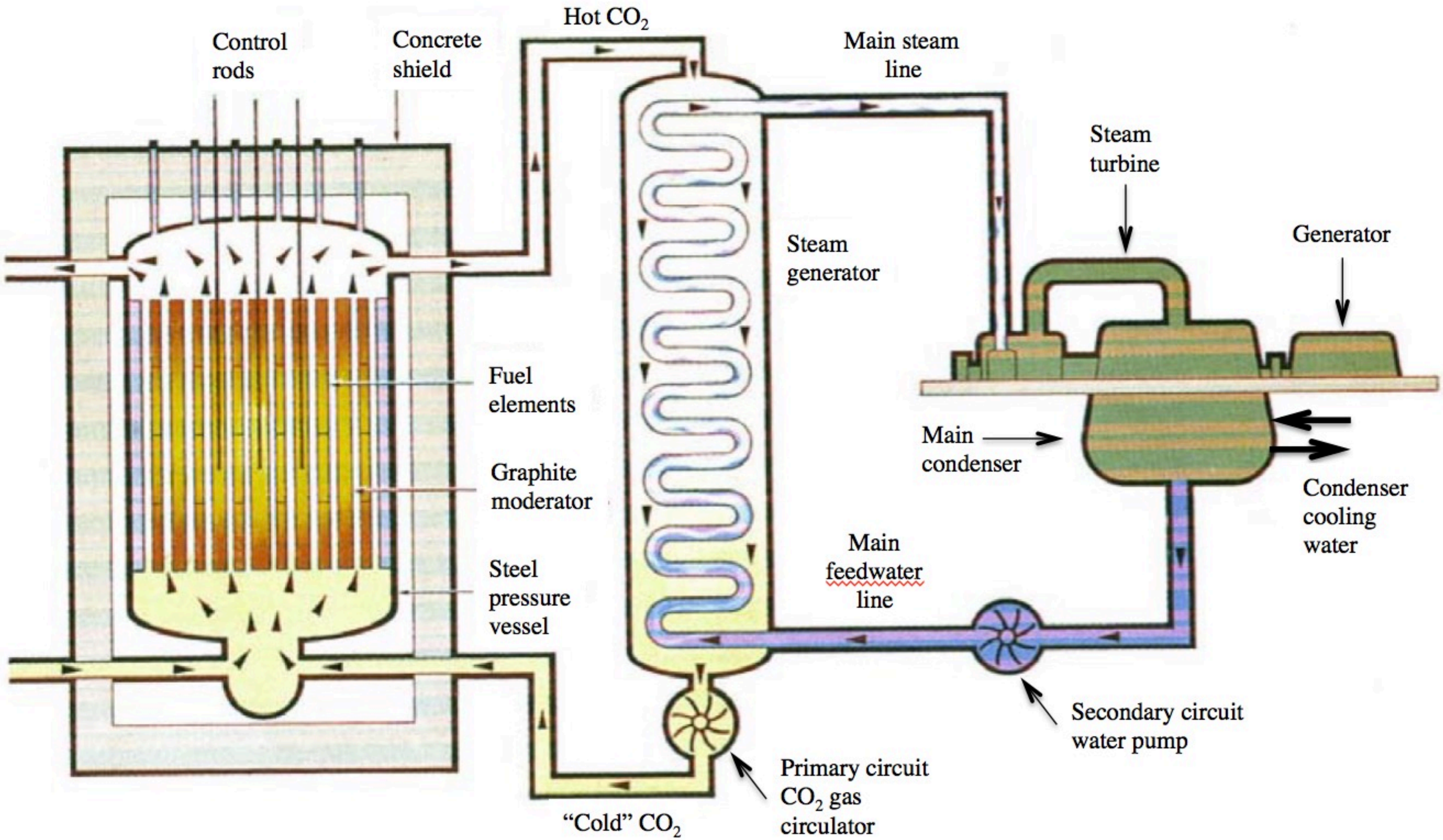
Nuclear Power Station

Design and Construction
by
The English Electric, Babcock & Wilcox and
Taylor Woodrow Atomic Power Construction Company Ltd

Member Companies
The English Electric Company Ltd
Babcock & Wilcox Co. Ltd
Taylor Woodrow Construction Co. Ltd

1960 to 2000

Nuclear Power - Magnox Reactors



1960 to 2000

Nuclear Power - Magnox Reactors

Natural Uranium fuel
Graphite as moderator
CO_2 gas as coolant
Steel Pressure Vessel

Steam at 400ºC
Thermal efficiency was around 30%
On-load refuelling

Stable 24/7 electricity throughout the year
often without any interruptions for many months

1975 Magnox produced 11% of the UK electricity

1975 - 2030

Nuclear Power - Advanced Gas Cooled Reactors

7 AGR stations designed and built starting in 1976

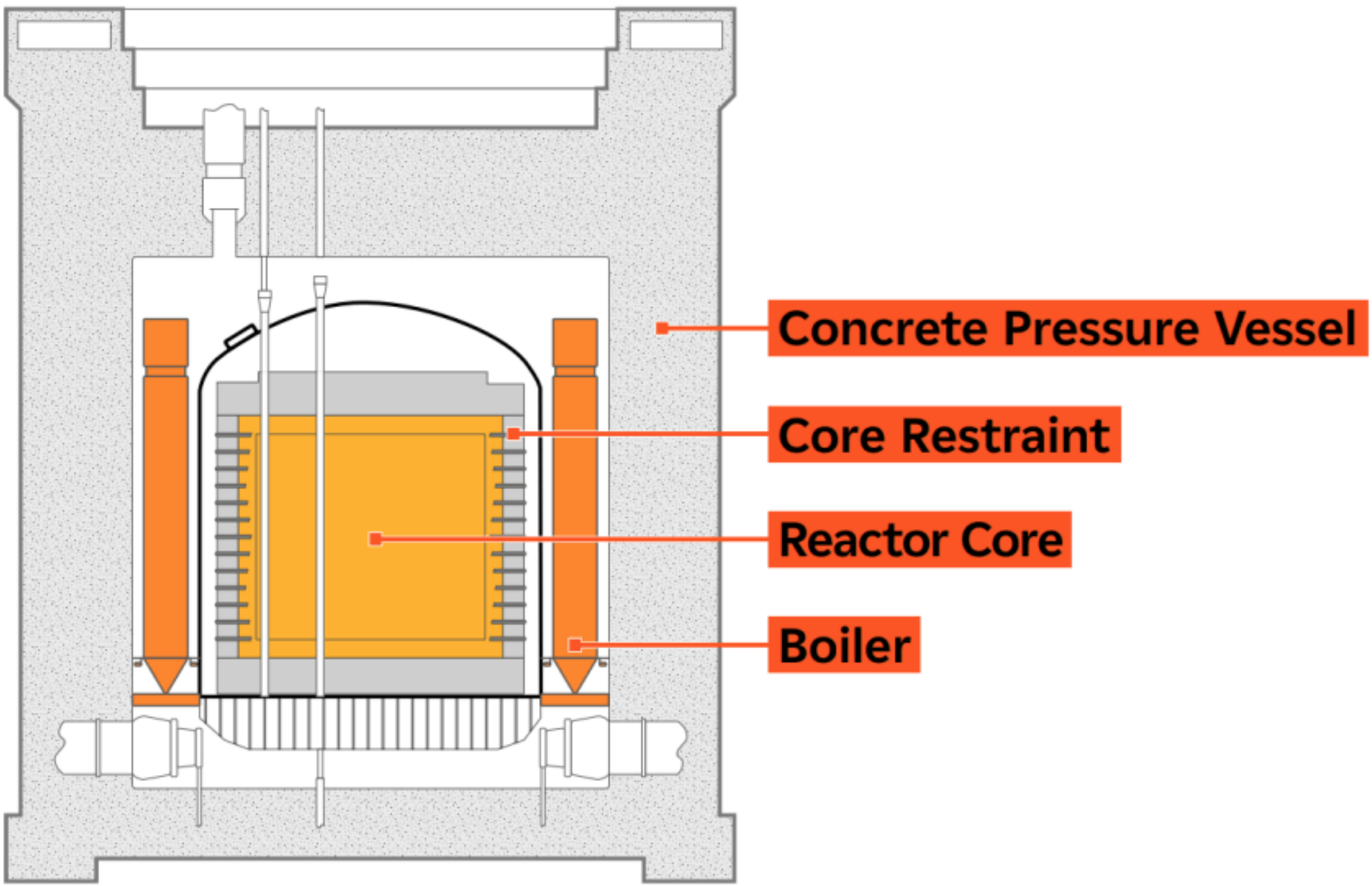
3% enriched uranium fuel
Graphite as moderator
CO_2 gas as coolant
Concrete Pressure vessel

Steam temperature is 540ºC
Thermal efficiency above 40%
(cf Magnox stations: 400ºC and 30%)

2x the electrical output

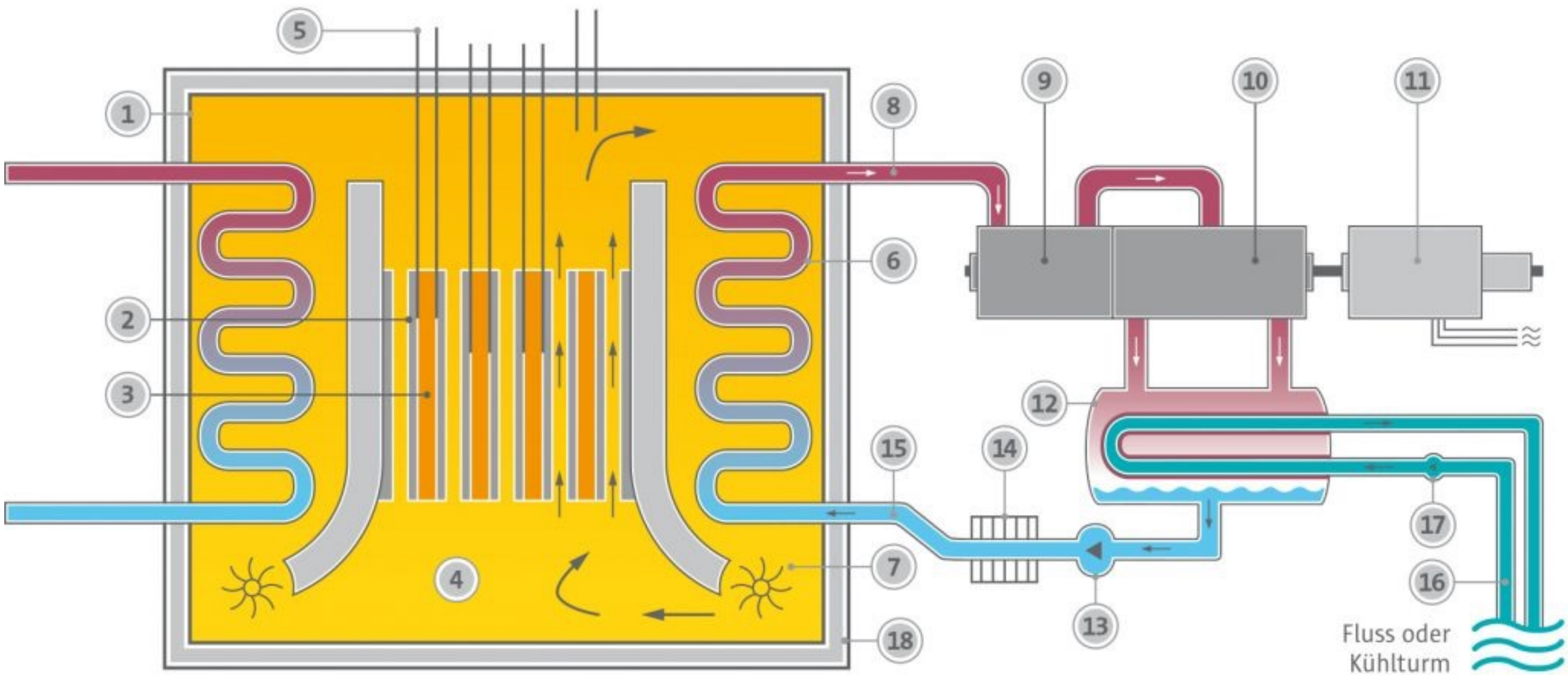
1975 - 2030

Nuclear Power - Advanced Gas Cooled Reactors



1975 - 2030

Nuclear Power - Advanced Gas Cooled Reactors



1975 - 2030

Nuclear Power - Advanced Gas Cooled Reactors

1975 - 2030

Nuclear Power - Advanced Gas Cooled Reactors

Despite some real advantages
no other country uses this reactor type commercially

AGRs produce base-load electricity

In 1995 AGRs and Magnox reactors
produced 25% of UK electricity

Of the original 7 stations, 4 are still operating in 2026

The Present

Nuclear Power - Pressurised Water Reactors

1960s USA chose Water Cooled Reactors

~1975 France, Germany, Japan, the USSR, Sweden and Belgium

Only the UK, Canada and the USSR developed other designs

In the 1970s and 80s European policy was to burn more coal
Following privatisation UK policy was to burn more gas

There was a dip in demand across the country

Nuclear power station building paused in the UK

The Present

Nuclear Power - Pressurised Water Reactors

Finally the UK chose PWRs in the early 80s

A programme of 4 stations was planned

There was a Public Inquiry lasting 3 years before building was given the go-ahead

In the end only 1 reactor station at Sizewell B was built

By any standard, Sizewell B has been very successful over the the last 40 years

The Present

Nuclear Power - Pressurised Water Reactors

National energy independence is an issue that favours nuclear power

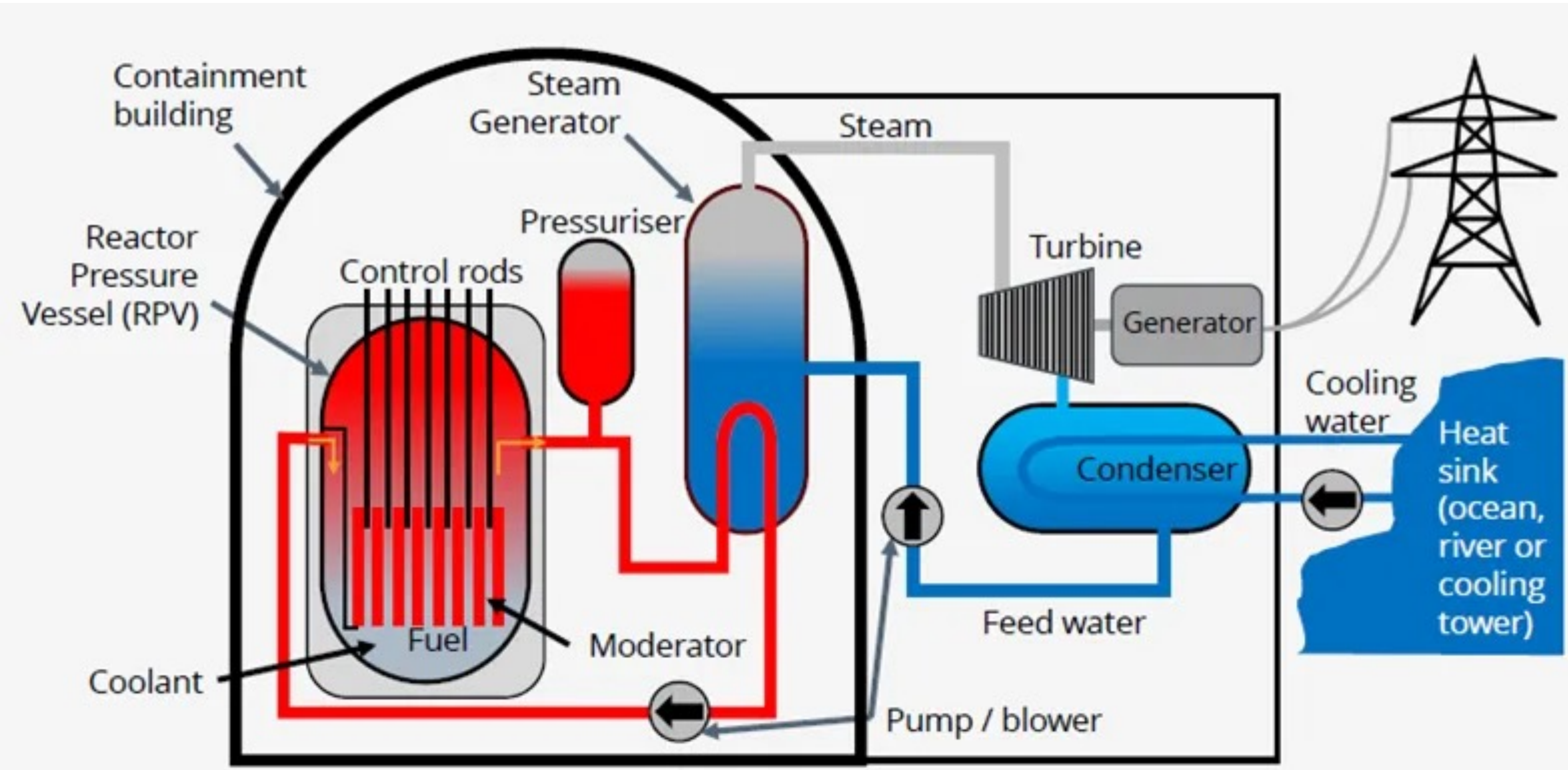
Global Warming became to be seen as more of a problem so there is a drive towards “Net Zero”

Also many environmentalists (who were previously opposed) came round to understand that well managed nuclear power should have a role in the energy mix in the UK

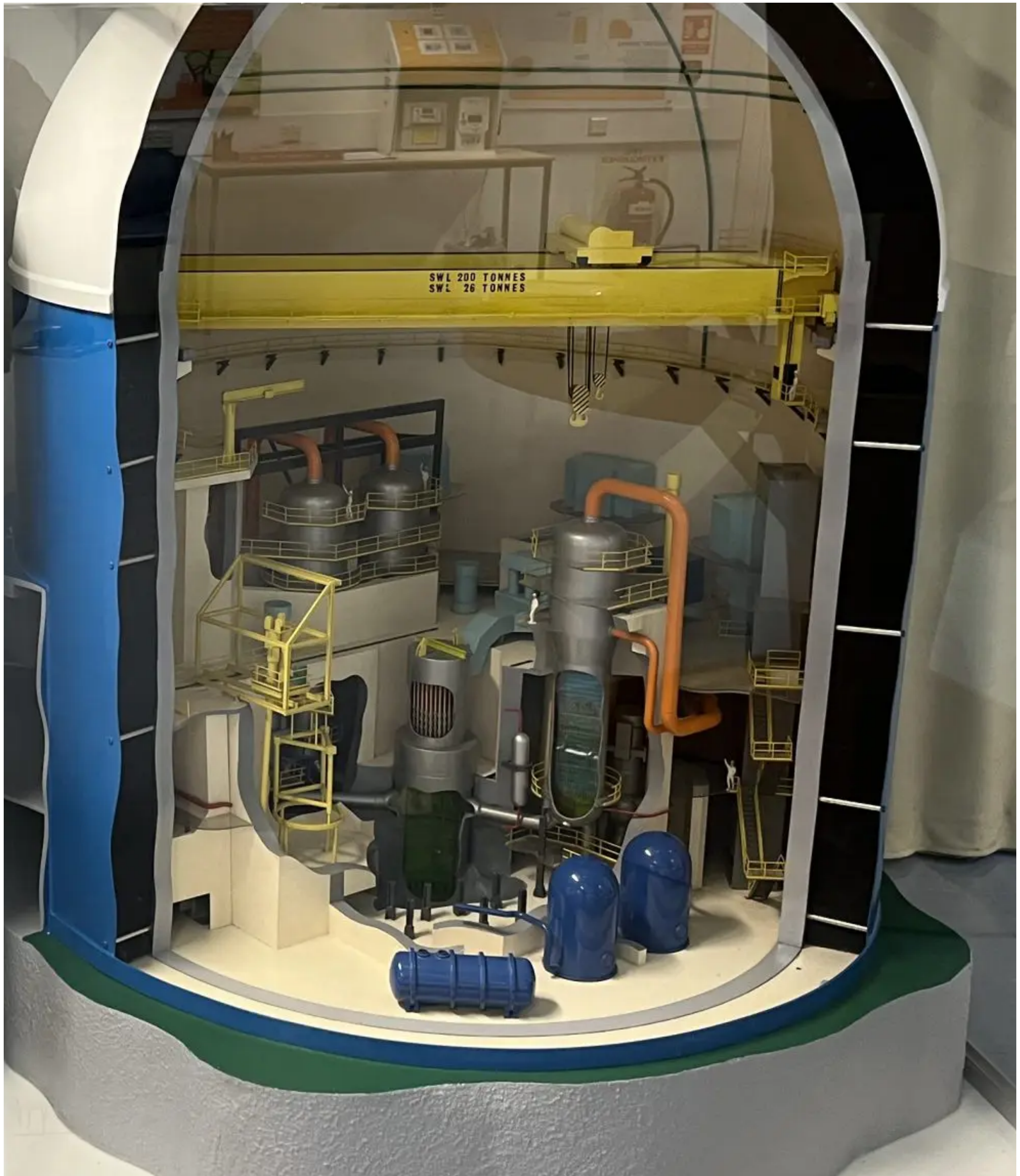
So, in the 2020s work began on an upgraded PWR design

A twin reactor station at Hinkley Point C in Somerset is now under construction and an identical twin reactor station at Sizewell C is being built. When complete in Sizewell B and C will together produce 10% of the electricity needed in the UK

The Present - Sizewell B



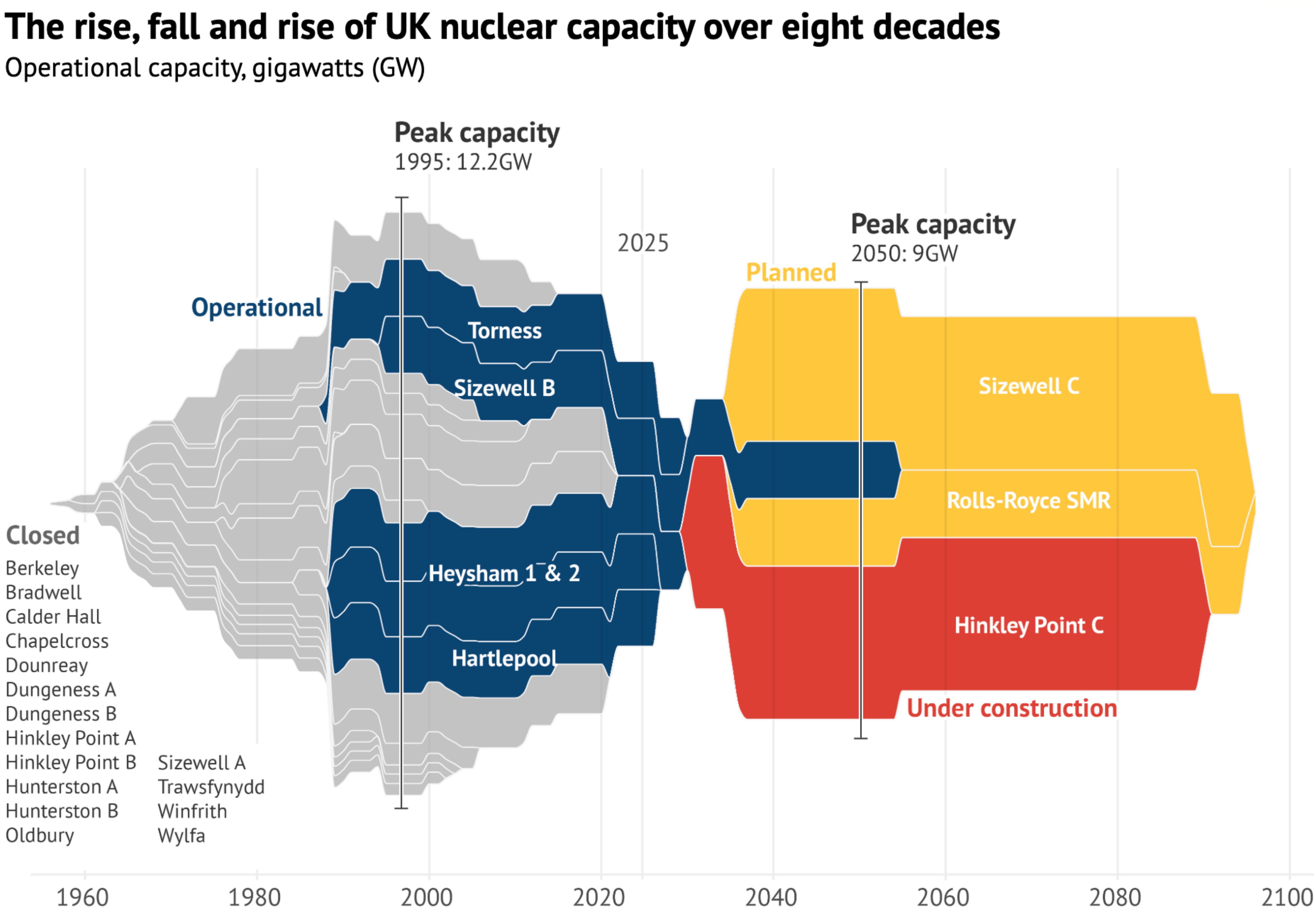
The Present - Sizewell B



Future - Nuclear Power

Hinkley Point C

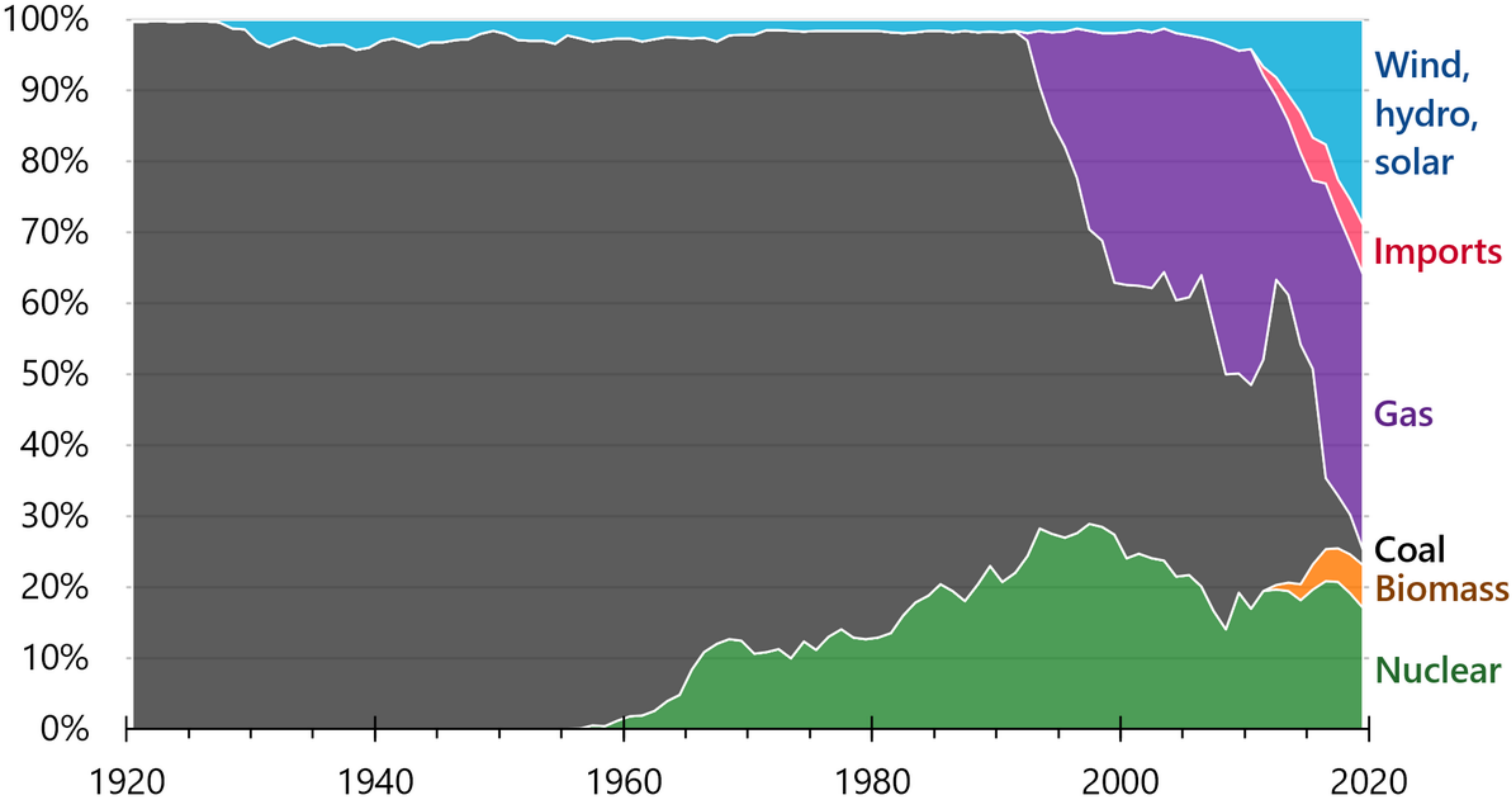
Past/Present/Future - Nuclear Power



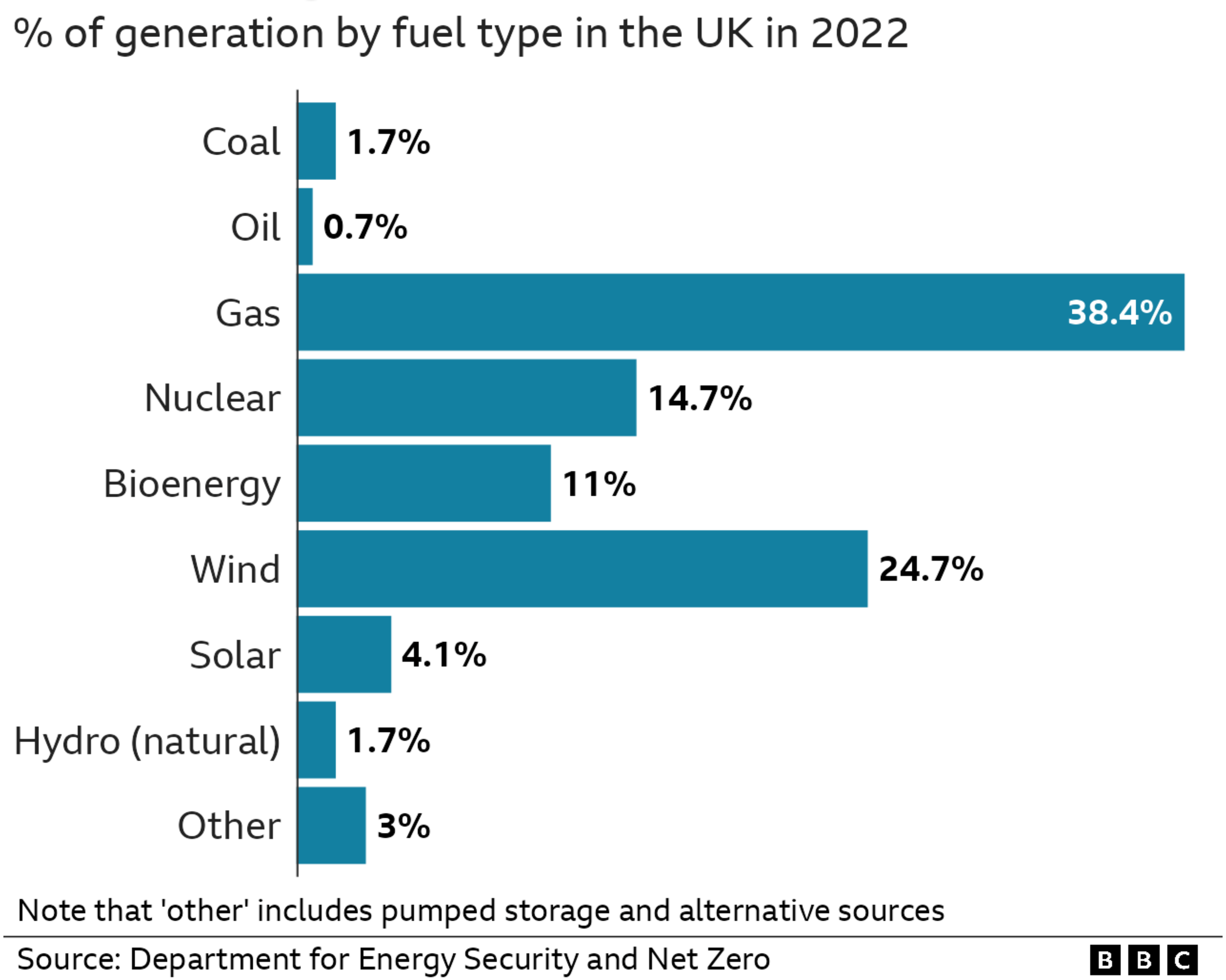
Source: World Nuclear Association and Carbon Brief analysis

CarbonBrief
CLEAR ON CLIMATE

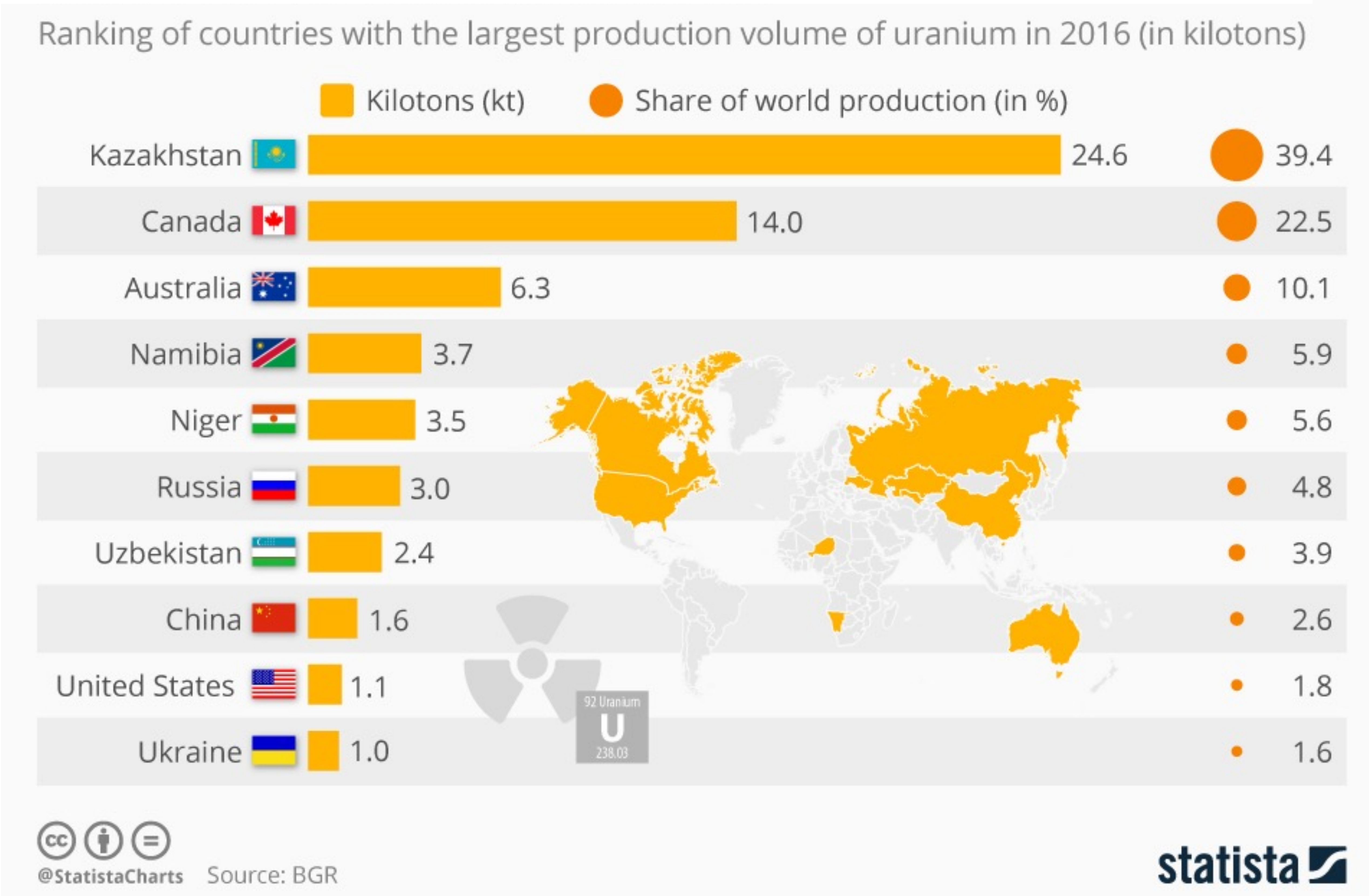
The Present - UK Generation Mix



The Present - Electricity Generation



The Present - World Uranium Supply



The Present

Nuclear Power - Safety - Radioactive Waste

Nuclear Power - Safety Concerns

1a. Nuclear accidents

People fear a **reactor accident** in which:

- Radioactive material escapes into the air and water
- Large areas become unsafe for people
- Cleanup is difficult and expensive

How avoided:

All operations and maintenance work follows approved procedures
carried out by highly trained staff
Very positive open safety culture in the industry

Strong government regulation
International cooperation and information exchange

Reality:
Very few nuclear accidents in many decades

Nuclear Power - Safety Concerns

1b. Nuclear accidents

Very few nuclear accidents in many decades …

Three Mile Island - USA 1979 - A steam leak in the reactor building wrote the power station off and making the plant safe has been very costly. However the reactor building containment worked as designed, and only a minuscule amount of radioactive material was discharged. Although a massive financial loss no one was hurt.

Chernobyl - Soviet Union - 1986 - this was a big one! An unauthorised commissioning test was performed by operators. I see this as a result of the political/management/cultural system at the time which in so many respects is anathema to UK/ Western European/ USA culture… the reactor design was not built anywhere else; the testing that was done was completely reckless and so different to the robustness of UK operations procedures; and the response was slow and again contrary to UK management culture.

Fukushima - Japan - 2011. The reactors shut down correctly when the near record Richter 9 magnitude seismic event occurred, however, some minutes later the 14m tsunami overtopped the 10m high protection wall. Water ingress disabled some safety systems and the operators were not able to keep the reactors and fuel cool in the hours following shutdown. Some radioactive material was discharged to the atmosphere and this required the emergency evacuation of more than 100,000 people. Although a massive financial loss no one was hurt by radiation (although there were deaths in the evacuation process and by the stress caused). Some villages are still in an exclusion area. The recovery is costly but well managed with international involvement. (Unconnected with the power station, on the day of the tsunami elsewhere along the coast around 20,000 people were killed and 200,000 people lost their houses and more lost their livelihoods.)

Nuclear Power - Safety Concerns

2a. Radioactive waste

People fear **radioactive waste** because it stays dangerous for a long time

How to avoid harm:

- Efficient controls at source
- Storage and isolation
- Long-term storage underground in engineered sites

Reality:

Little waste produced considering the amount of electricity produced
All of it is managed (only minuscule amounts discharged to air and sea)
The hazard of radioactivity diminishes with time

Nuclear Power - Safety Concerns

2b. Radioactive waste categories

Low level - hazard equivalent to domestic waste
steel drums and sent to a special engineered landfill site

Intermediate level - needs isolation for 50 years or so
concrete canisters and sent to a special engineered landfill site

High level is stored at site until the heat given off and its radiation level diminishes and is then vitrified to stabilise it for underground burial

Note:
Radioactivity is all around us
All rocks are radioactive - some dangerously so
The fuel comes from mining *naturally occurring* radioactive rocks
High level waste is processed into *artificial* radioactive rocks for burial

Nuclear Power - Safety Concerns

3. Risk of radiation exposure
People fear exposure to radiation and getting cancer if something goes wrong

How avoided:
All operations and maintenance work follows approved procedures
carried out by highly trained staff
Very positive open safety culture in the industry

Strong government regulation
International cooperation and information exchange

Plants built to survive earthquakes, floods, etc.
Systems used to protect against terrorism, cyber attacks, theft, etc.

Reality:
Very few nuclear incidents in many decades

Future - Nuclear Power

Hinkley Point C but Sizewell C will be similar