Nuclear Reactors in a Box

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Why the Development of Nuclear Reactors ?

When Graham changed the name of my presentation from “Mini Nuclear Reactors” to “Reactors in a Box”, I wasn't sure whether he wanted to hear how to bury Nuclear Reactors for ever in a box, or whether he was thinking of a Micro Nuclear Reactor which can be fitted in a box.

Large Nuclear Reactors range from 300 MW to 1,300 MW

Mini Nuclear Reactors range from 10 MW to 300 MW

Micro Nuclear Reactors range from 1 MW to 10 MW

Peaceful use of Nuclear Power

The peaceful use of Nuclear Power was developed, because it was needed to combat Climate Change. The World was becoming colder and colder, which started in the 1930’s.

In the 1940’s dark patches appeared on the sun surface which grew larger. The blood of wounded solders froze, saving them from bleeding to death, others froze to death.

In the 1980’s it started to get warmer again and Nuclear Energy was no longer needed.

However, an enormous population growth had started to occur on earth.

Development of Nuclear Power Plants

- Were we heading towards the next Ice Age, faster than we had anticipated?
- A new source of energy, to keep us warm, was desperately needed.
- The energy obtainable from 1 gm of Uranium 235 is equivalent to burning 3,000,000 gm (3 million gm- 3 tonnes) of Coal.
- USA, Great Briton, Russia and France stated to develop Nuclear Power Plants (NPP) in the 1950's. Initially to obtain Plutonium, later primarily for heat energy to produce electricity.
- The world's largest Nuclear Power Plant in 1965, with two 620 MW Reactors, was started in Kent , England.
- It was the first Advanced Gas Cooled Reactor, an improvement on the British Magnox Reactors, and the first with a concrete Pressure Vessel instead of a Steel Pressure Vessel. - This was 58 Years ago.
- A construction boom of Nuclear Power Plants followed, and the size of a single Nuclear Reactor became larger, and larger; increasing from 250 MW to 1,300 MW in the 1970's

History of Nuclear Power

- After the Climate Change that occurred in the 1940's, when large black patches appeared on the sun surface and the weather became colder and colder.
- Another Climate Change occurred in the 1970's when the weather became warmer again and the black patches on the sun surface disappeared.
- Only countries with high energy demand. expensive coal reserves, or in need of Plutonium, continued to build Nuclear Power Plants in the 1980's
- The "Greenies" successfully cleaned the European Rivers and reduced the Air Pollution.
- The "Greenies " now aimed, to save the earth from being polluted by radioactivity from Plutonium, produced in Nuclear Reactor.
- The two Nuclear accident at Chernobyl (1986)and Fukuyama (2011) provided the trigger to stop the construction of Nuclear Power Plants in most countries.
- The "Greenies" extended their reasoning for "Climate Change" and "Global Warming". It being caused by excessive CO_2 emission.
- Now, Nuclear, Coal, Gas and Oil were no longer to be used for electricity generation.
- The Australian Parliament condemned the use of Nuclear Power in 1998.
- The EU declares, Nuclear Power produces 'Green Electricity', in 2022.

The Chain Reaction in a Nuclear Reactor

- Uranium 238 is found in nature. It contains about 0.7% of U 235 atoms.
- U 235 is an unstable isotope of Uranium, and it emits neutrons.
  The neutrons are emitted at a high speed too high to split another U 235.
  The high-speed neutron cannot penetrate the electron rings surrounding the nucleus of the atom, acting like a shield.
- The speed of the neutron must be reduced, for it to split another atom.
  Water, or Heavy Water, and Graphite are good medias to reduce the speed of neutrons
- On splitting the U235 atom, two new substances are formed –
  Krypton and Barium - and energy is set free - plus two further neutrons, at high speed, are emited.
- When their speed is reduced, 3 neutrons split 3 further U235 atoms, causing 6 new electrons to be emitted. Now 9 neutrons can split 9 U235 atoms, emitting 18 electrons, 27 neutrons then multiply to 36, 108,324, 972, 2916, 8748 ….
- The Chain Reaction happens at the speed close to light at 300,000 km/sec., or 7 x around the earth in one second.

The Chain Reaction in Picture

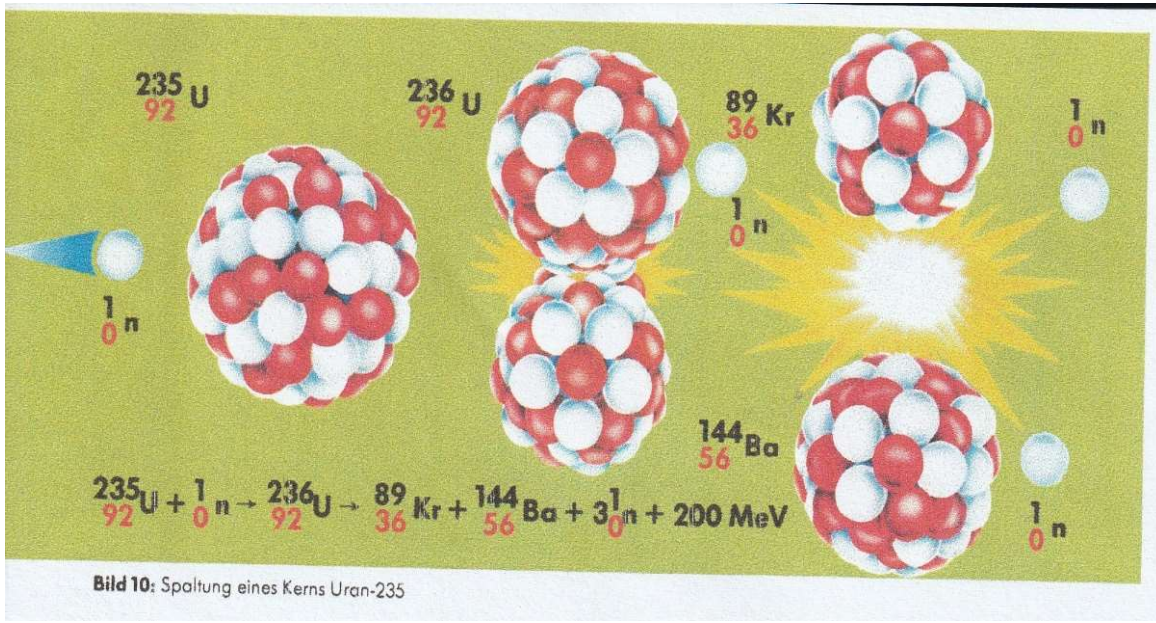


Bild 10: Spaltung eines Kerns Uran-235

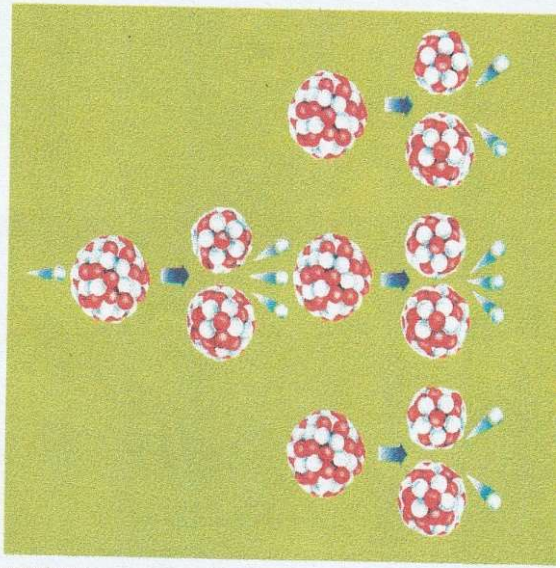


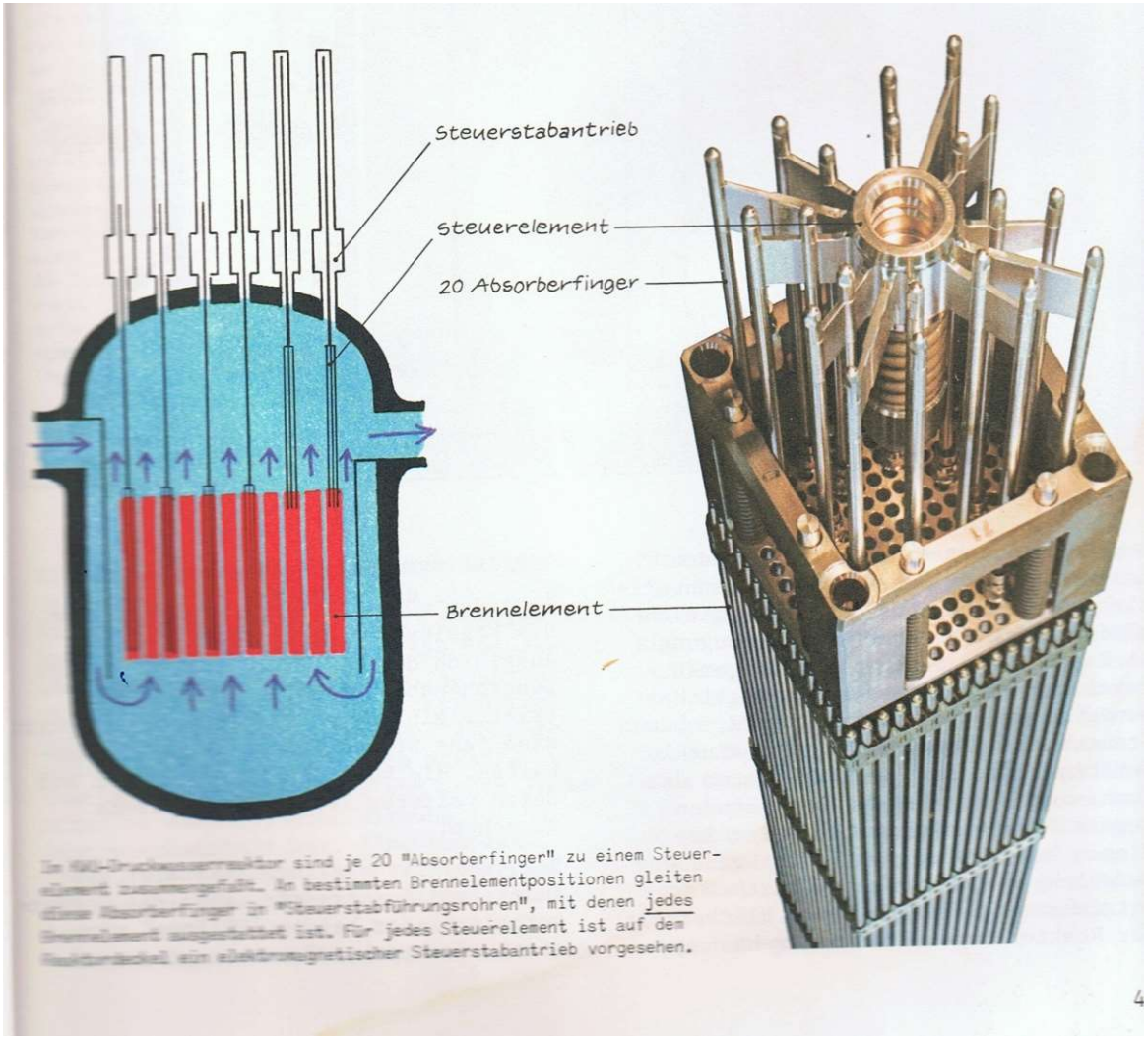
Bild 11: Kettenreaktion im Uran-235

The steel Reactor Pressure Vessel

It is the Primary Containment. The Uranium is placed in the fuel rods.

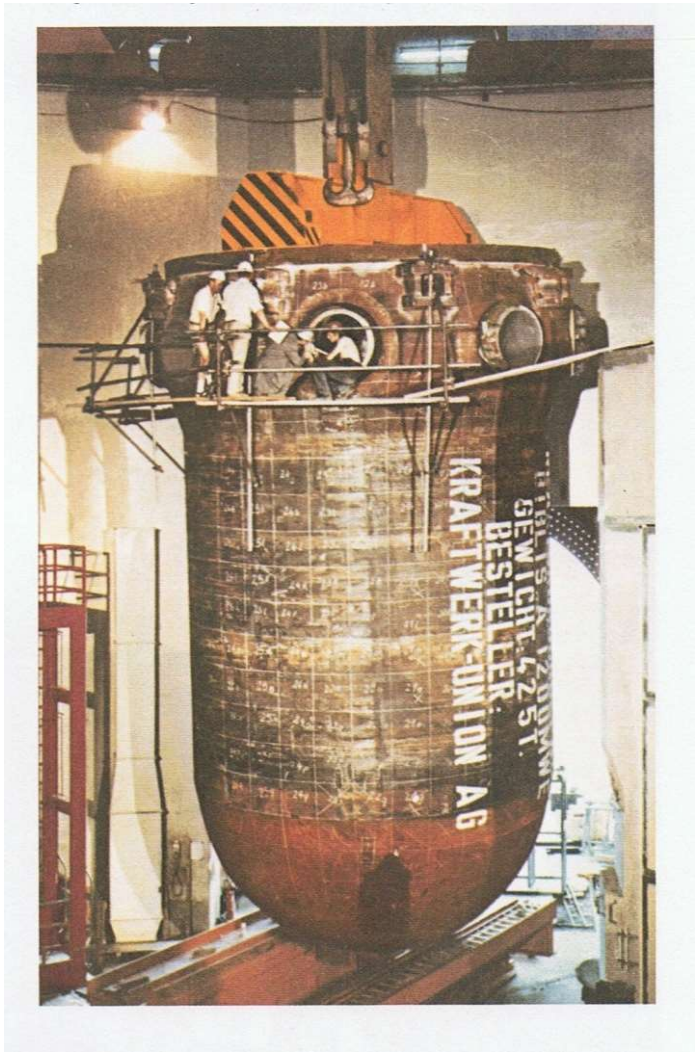
Boron is used to controlled the Chain-Reaction.

Boron absorbs the Neutrons like a sponge absorbs water.



In KKG-Druckwasserreaktor sind je 20 "Absorberfinger" zu einem Steuerelement zusammengefaßt. An bestimmten Brennelementpositionen gleiten diese Absorberfinger in "Steuerstabführungsrohren", mit denen jedes Brennelement ausgestattet ist. Für jedes Steuerelement ist auf dem Reaktordeckel ein elektromagnetischer Steuerstabantrieb vorgesehen.

The actual Steel Pressure Vessel for a small Nuclear Reactor.



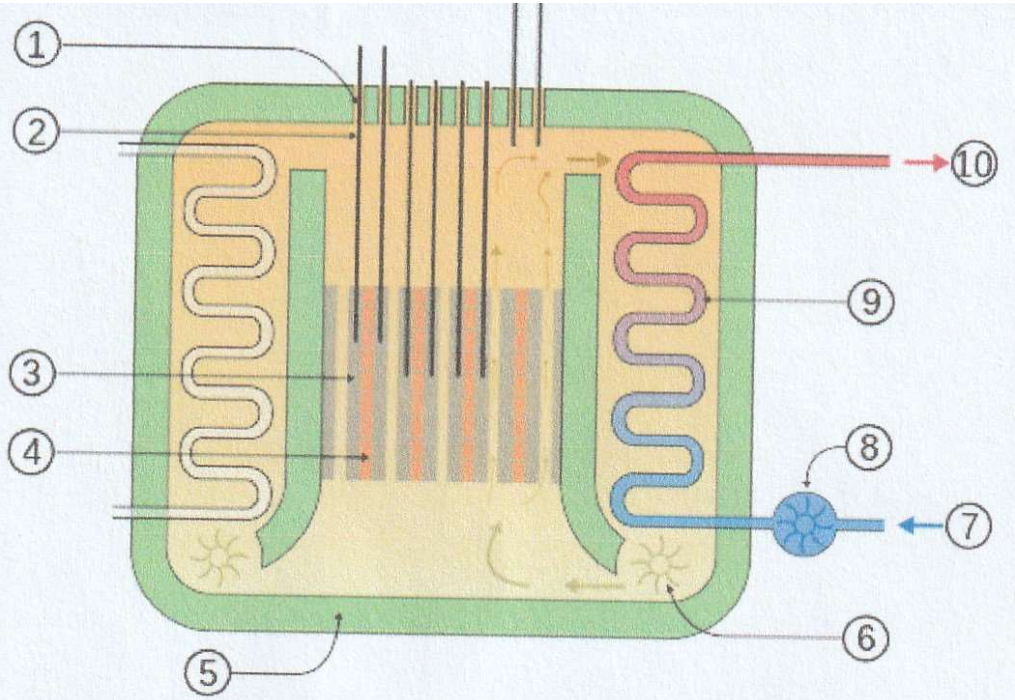
Development of Different Types of Nuclear Reactors

- **Light Water Reactor**, a US development in the 1950ties for Plutonium
- **Magnox Reactor**, a UK gas cooled Reactor, development in the 1950ties primarily for obtaining Plutonium
- **Pressurised Heavy Water Reactor**, an advancement on the Light Water Reactor.
- **Boiling Water Reactor**, commercially superior to Pressurised Reactors.
- **Advanced Gas Cooled Reactor** with Graphite as moderator, a UK development, very safe but not as efficient as Boiling and Pressurised Water Reactors
- **Russian Reactors**, a development combining Water and Graphite as speed reducing moderator.
- **Thorium Ball Reactor**, produces no Plutonium, but outer skin of the balls became brittle and broke.
- **Fast Breeder Reactor**, uses Plutonium as fuel and produces U235.
- **Mini Pressurised Water Reactors** were developed for Submarines, Aircraft-Carriers and Ice-Breakers, etc.
- **Micro Reactors**, for usage in space, about to become commercially available
- **Fusion Reactor**, will fuse 2H atoms to 1He atom. Will be available in decades.

The Advanced Gas Cooled Reactor build in Kent, UK

Concrete Nuclear Pressure Vessel with one Million tones compression force acting inwards .

Dimensions: Diameter 50m, Height 60m; Base 9m, Walls 5,5m, Top 12m thick



Schematic diagram of the Advanced Gas-cooled Reactor. Note that the heat exchanger is contained within the steel-reinforced concrete combined pressure vessel and radiation shield.

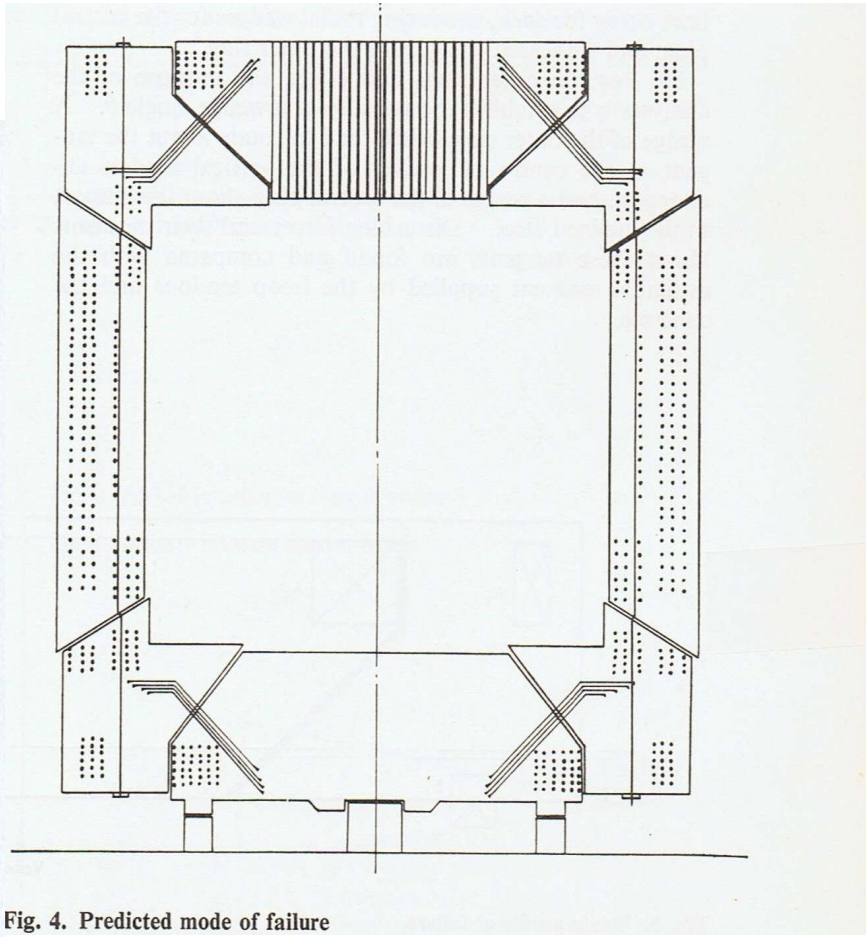
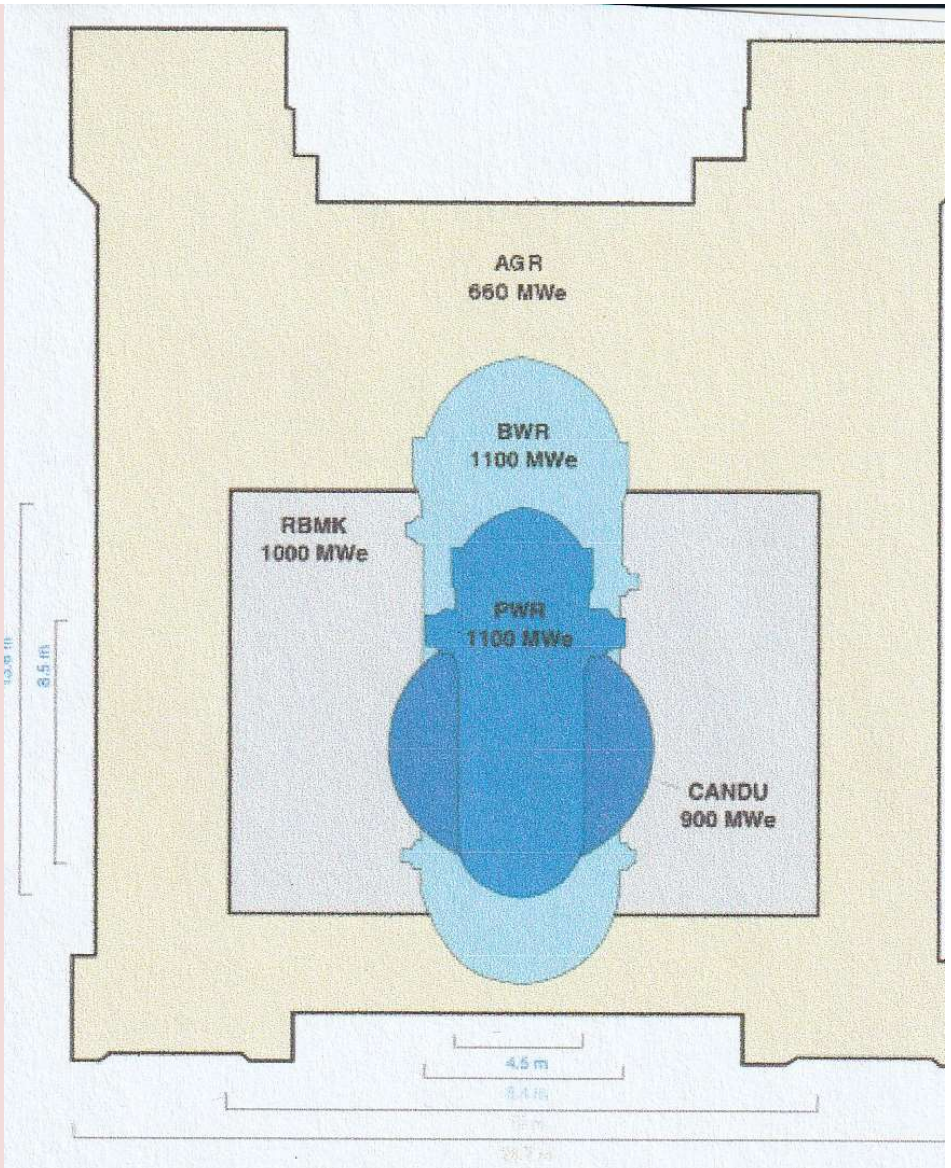


Fig. 4. Predicted mode of failure

Size Differences between various Reactor Vessels

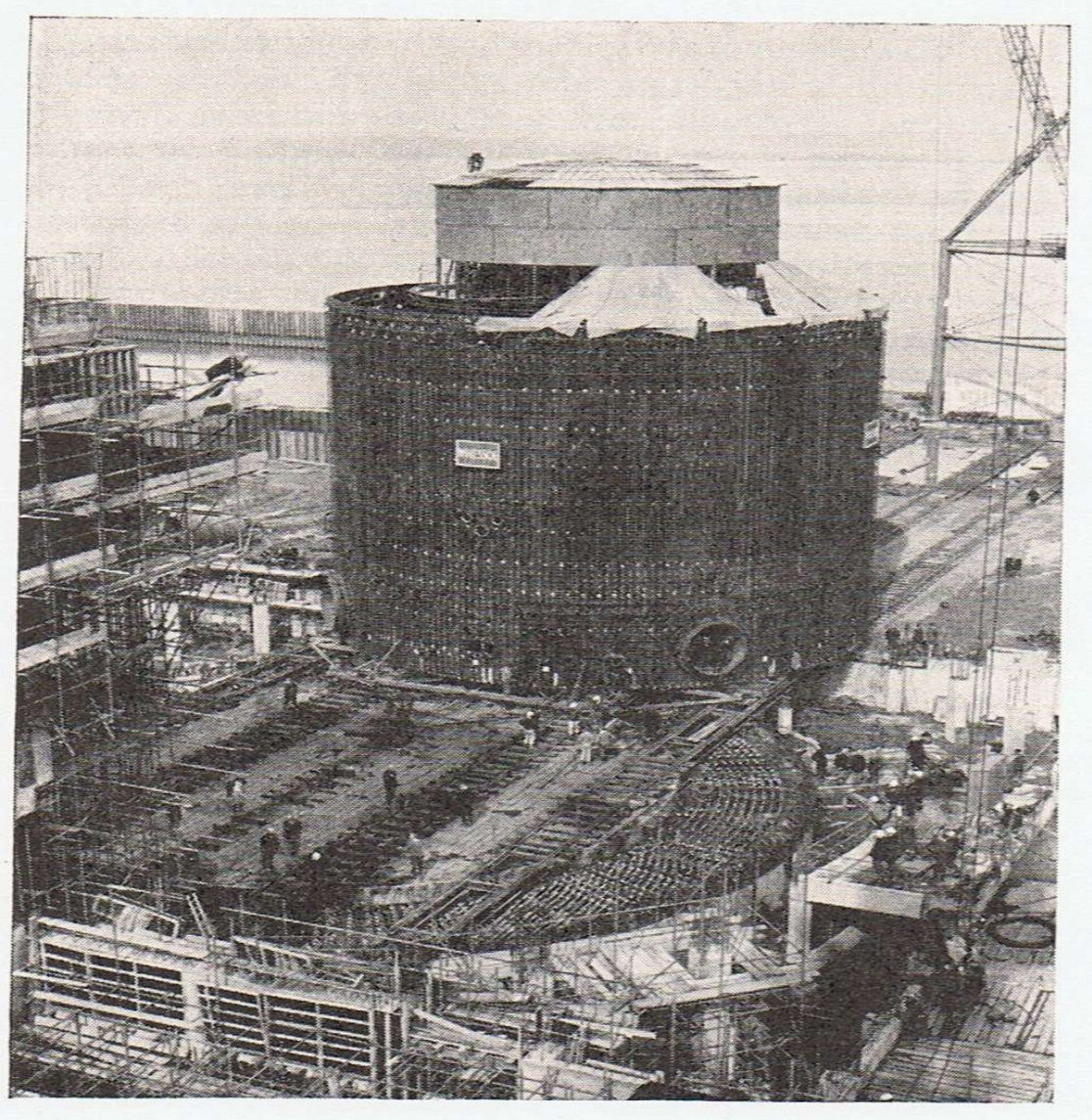
Gas cooled 660 MWe,
Candu 900 MWe,
RBMK 1000 MWe
BWR 1100 MWe,
PWR 1100 MWe



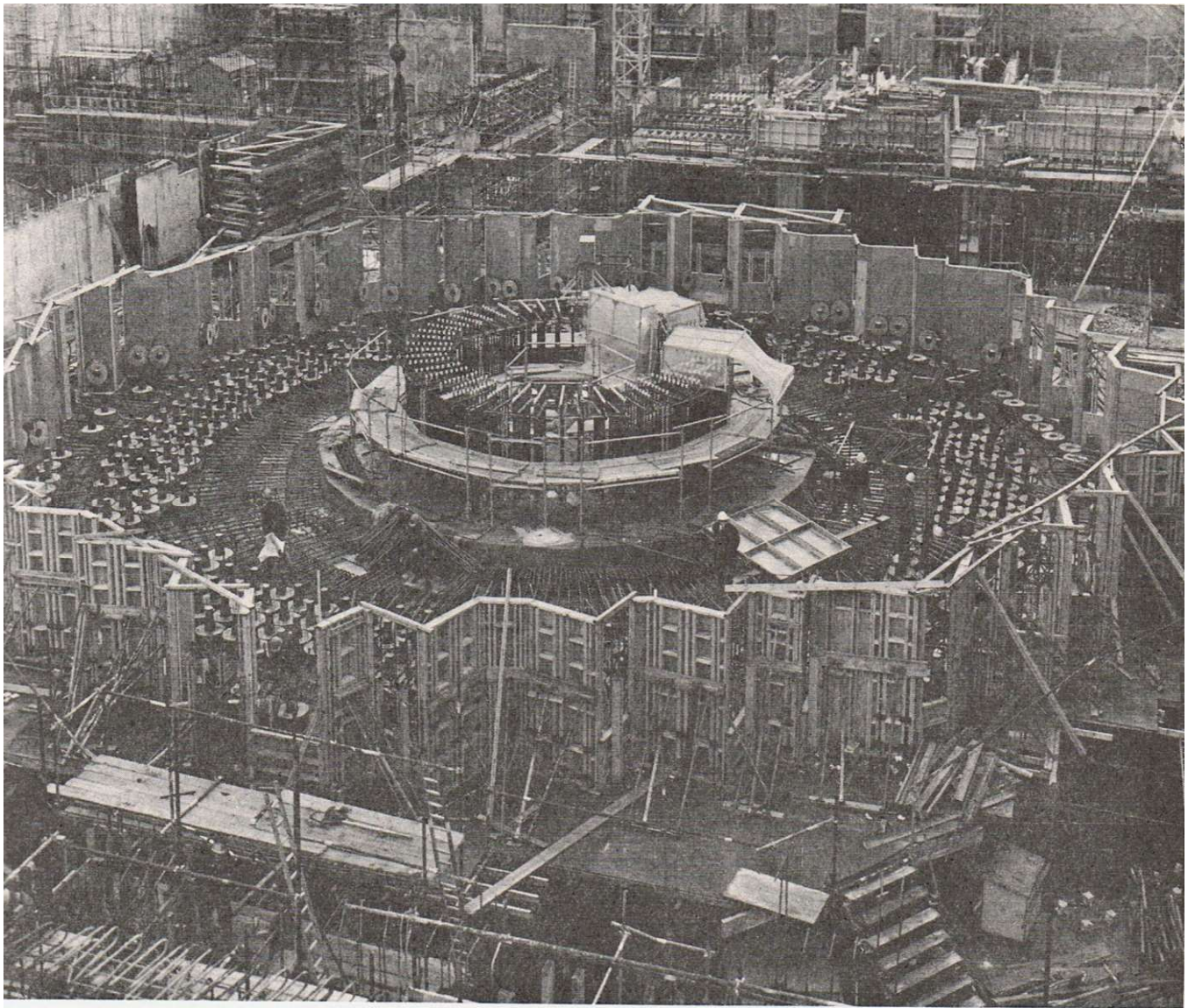
reactor size compared to other technologies

Advanced Gas Cooled Reactor: Dungeness-B. Kent, UK

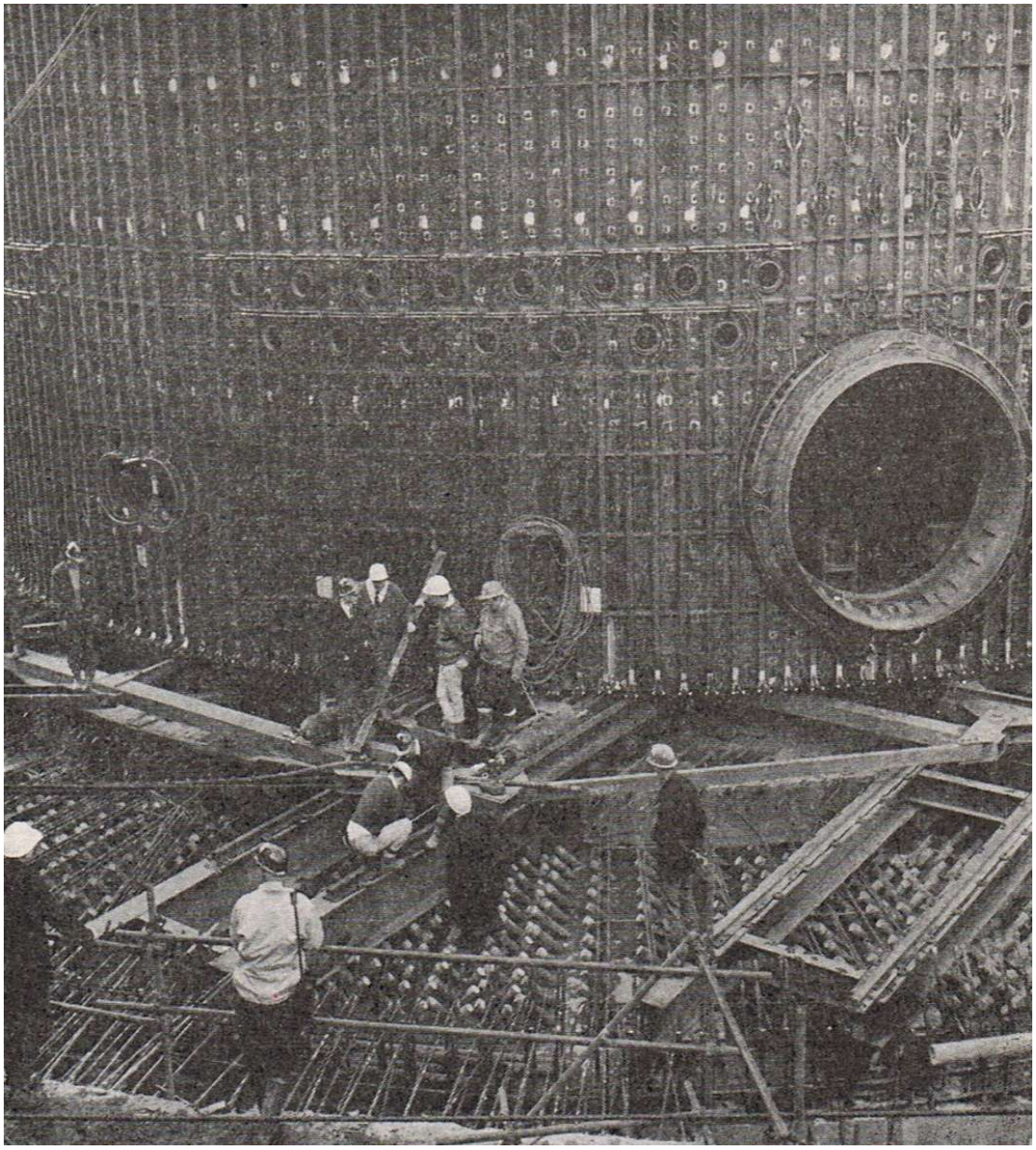
Steel Liner weighing 12,000 tons, against which concrete is poured , ensures that no CO2 gas can escape, through the concrete, from the inside of the Reactor Vessel.
It was constructed at the same time as reactor base slab and then pulled across.



The massive Concrete Reactor Pressure Vessel not only protecting the environment from the forces within the Reactor; but it also protects the reactor from the environmental forces like earthquake, gas explosion and aircraft accident.



It shows the enormity of this concrete Pressure Vessel
Unfortunately, many Problems were encountered with the boiler materials inside the vessel. It took 22 years to commissioning



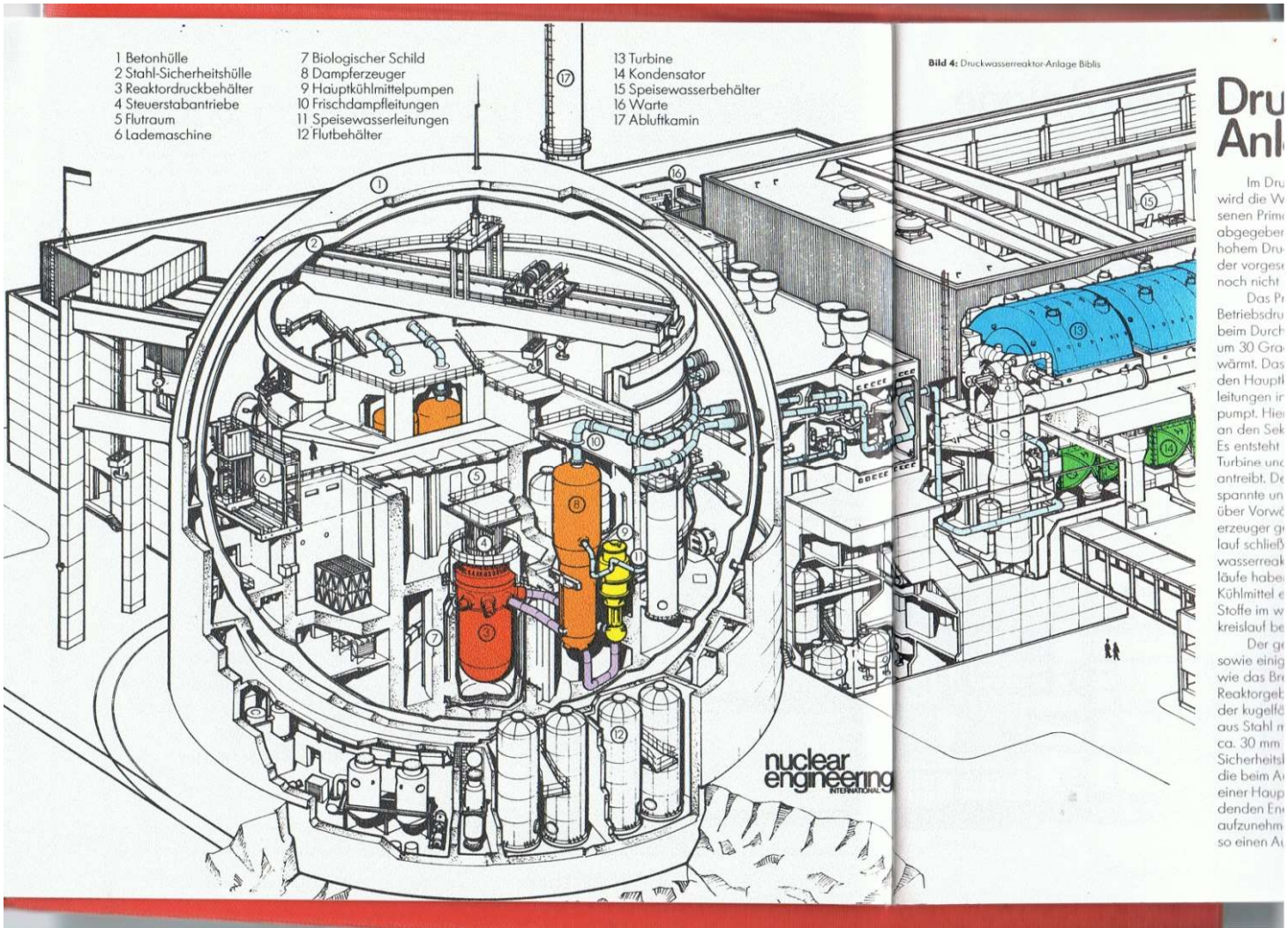
The Light Water Reactor

Build in the 1960ties had little protection against its environment, like Gas Explosions, Aircraft Accidents or Tsunamis

Pressurised Water Reactor

It uses Heavy Water to reduce the speed of the neutrons.

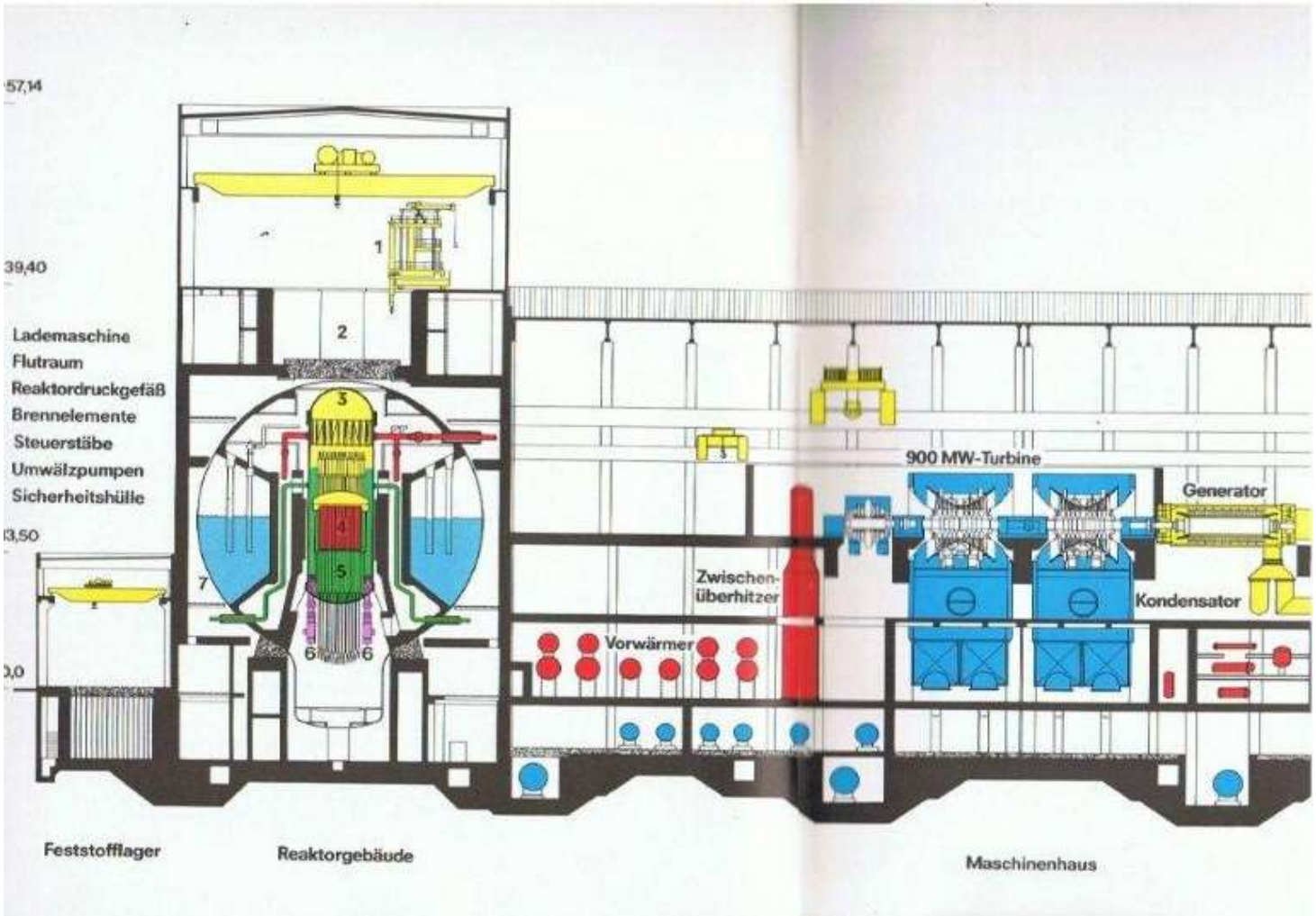
A **circular Secondary Containment** of Concrete with a Steel liner protects the reactor vessel, heat exchanger, cooling water pumps etc. from emitting radioactivity to the environment as well as giving protection against Earthquakes, Explosions and Tsunamis .



The Boiling Water Reactor

Produces within the reactor the steam for the turbines.

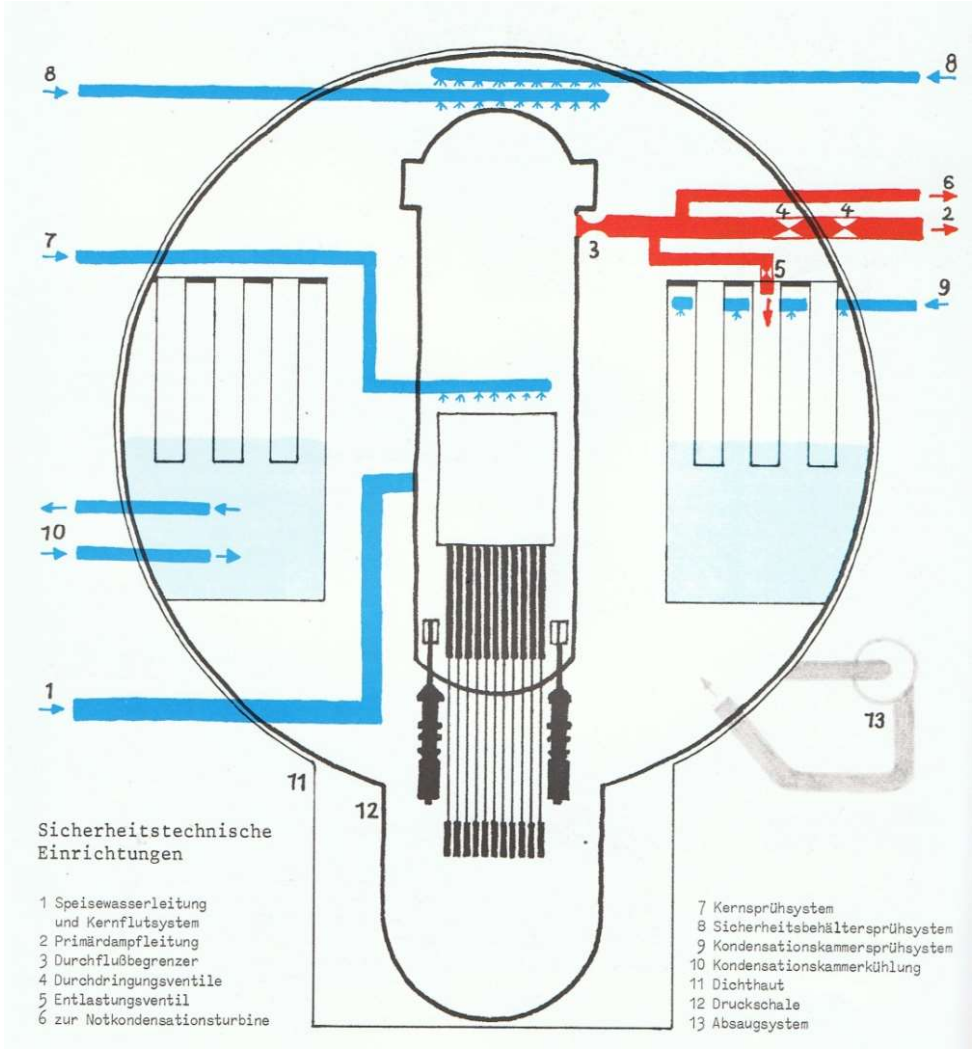
The smaller **Secondary Containment** has emergency cooling water is storage, which can condense the steam generated in the reactor, even after it has been shut down. This heat can melt the Reactor Pressure Vessel.



Seven Redundancies.

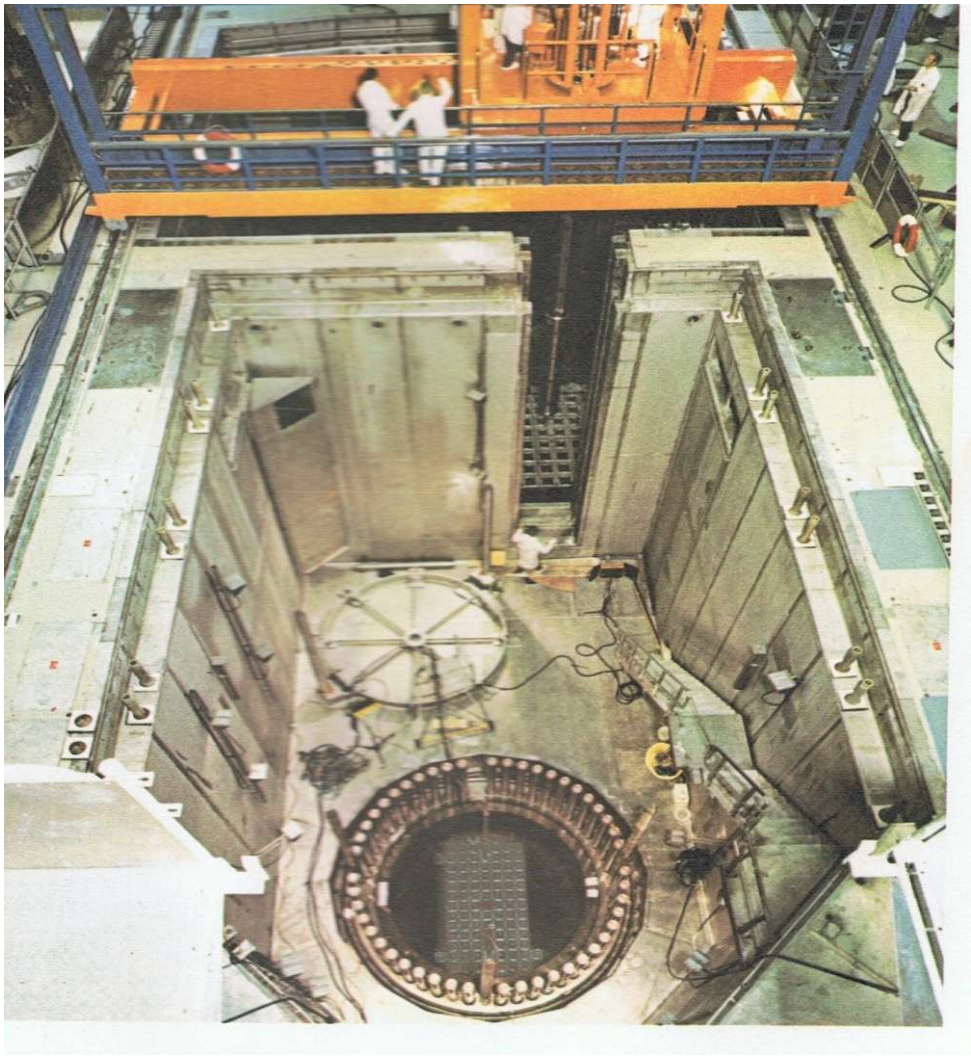
European Nuclear Power Plants have by Law the following Redundancies: **(i)** Additional feed water pumps, **(ii)**Additional Reactor cooling water pumps, **(iii)** Steam condensation facility **(iv)** Secondary Steam condensation facility **(v)** Pool water storage facility above reactor **(vi)** Three Secondary computer control Systems within and outside the Reactor Building **(vii)** five different emergency power supplies.

None of these existed at Chernobyl and Fukushima



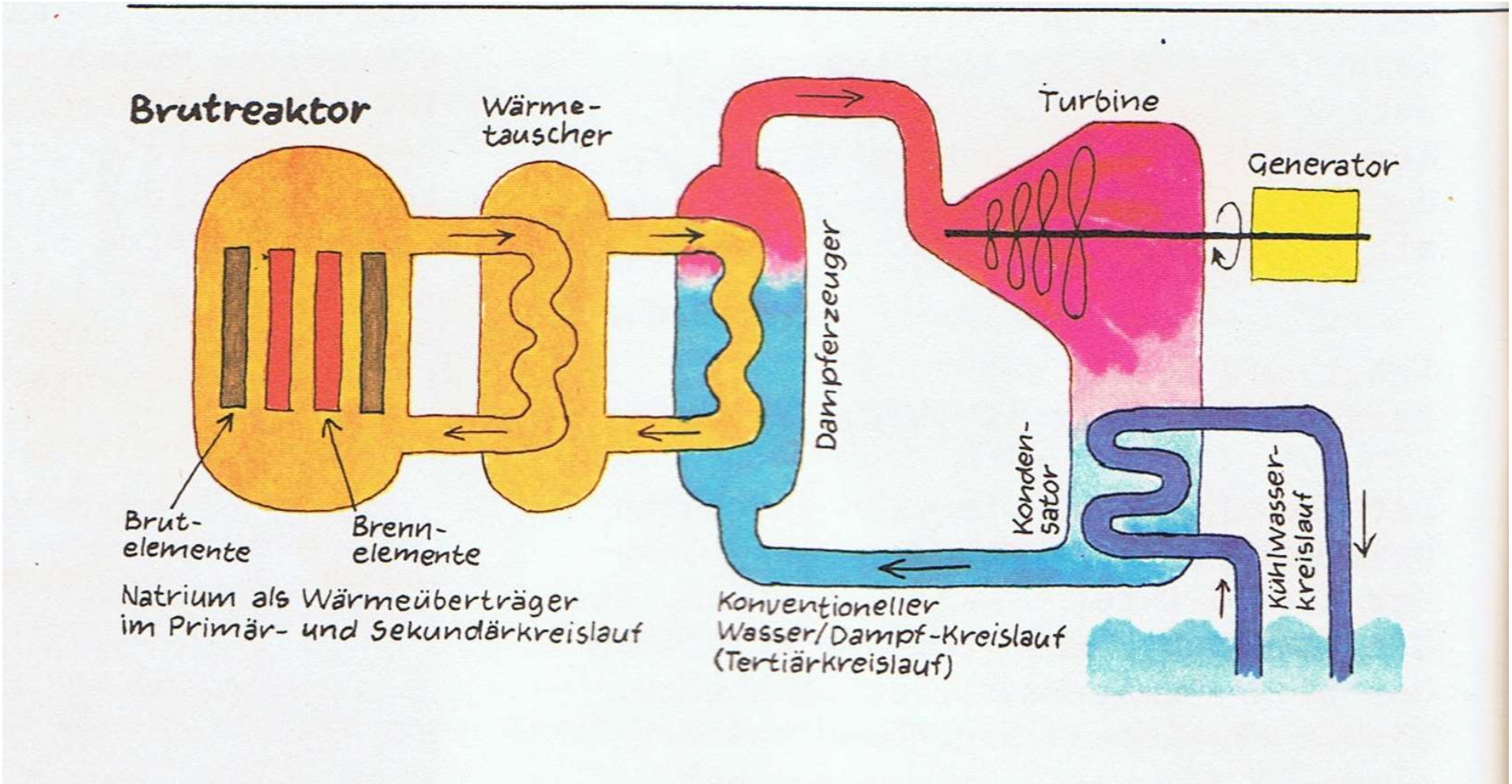
Redandance V : Fuel–Rod Water storage Pool

The fuel rod storage pool 12x12x12 m, provides also additional cooling water above the Reactor. When all systems fail, and pressure within the Secondary Containment rises to danger level, the membrane between pool and containment is pierce by the pressure and the pool-water flows into the Secondary Containment, cooling the Reactor, preventing the melt-down.



The Fast Breeder Reactor at KALKAR, Germany

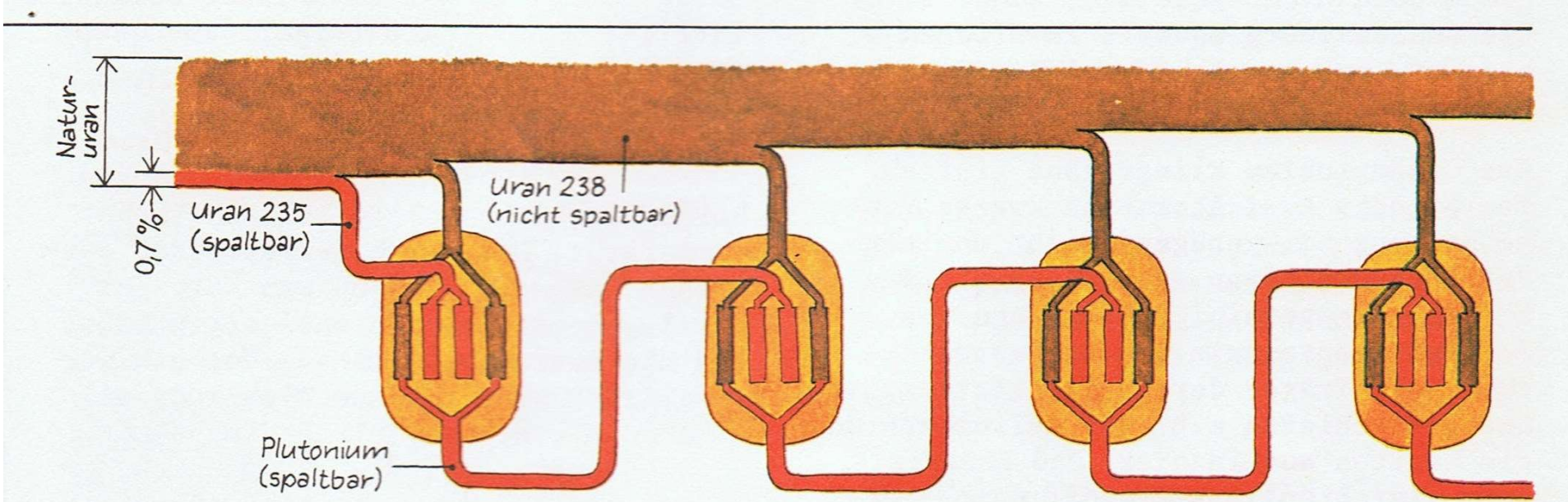
Plutonium is used as fuel. Splitting Plutonium into three different elements, releases enormous amount of energy.
The U238 placed in the reactor is changed to U 235.
Breeding U235 within this Reactor, makes it possible to use 100% instead of about 10%, of the natural ocuring Uranium.



The Plutonium Reactor is cooled with Liquid Metal .

Splitting the Plutonium Nucleus generates so much heat, that it needs to be cooled by liquid metal like Sodium or Potassium.
In Heat-Exchangers the heat of the liquid metal is passed on to water.

After the Chernobyl, Nuclear Technology got the stigma of being unsafe. The Chernobyl accident brought radioactive rainfall to Poland and Northern German. The radioactive harm was much exaggerated by the Press. the Water's radioactivity lasts 15 seconds, too short to do any harm.



Brutreaktoren erzeugen Nutzenergie aus spaltbarem Kernbrennstoff und erbrüten gleichzeitig neuen Spaltstoff (Plutonium) aus nicht spaltbarem Uran 238. Die Entfaltung dieser Brennstoffökonomie wird es ermöglichen, das Energiepotential des natürlichen, überwiegend aus dem Isotop 238 bestehenden Urans vollständig zu nutzen.

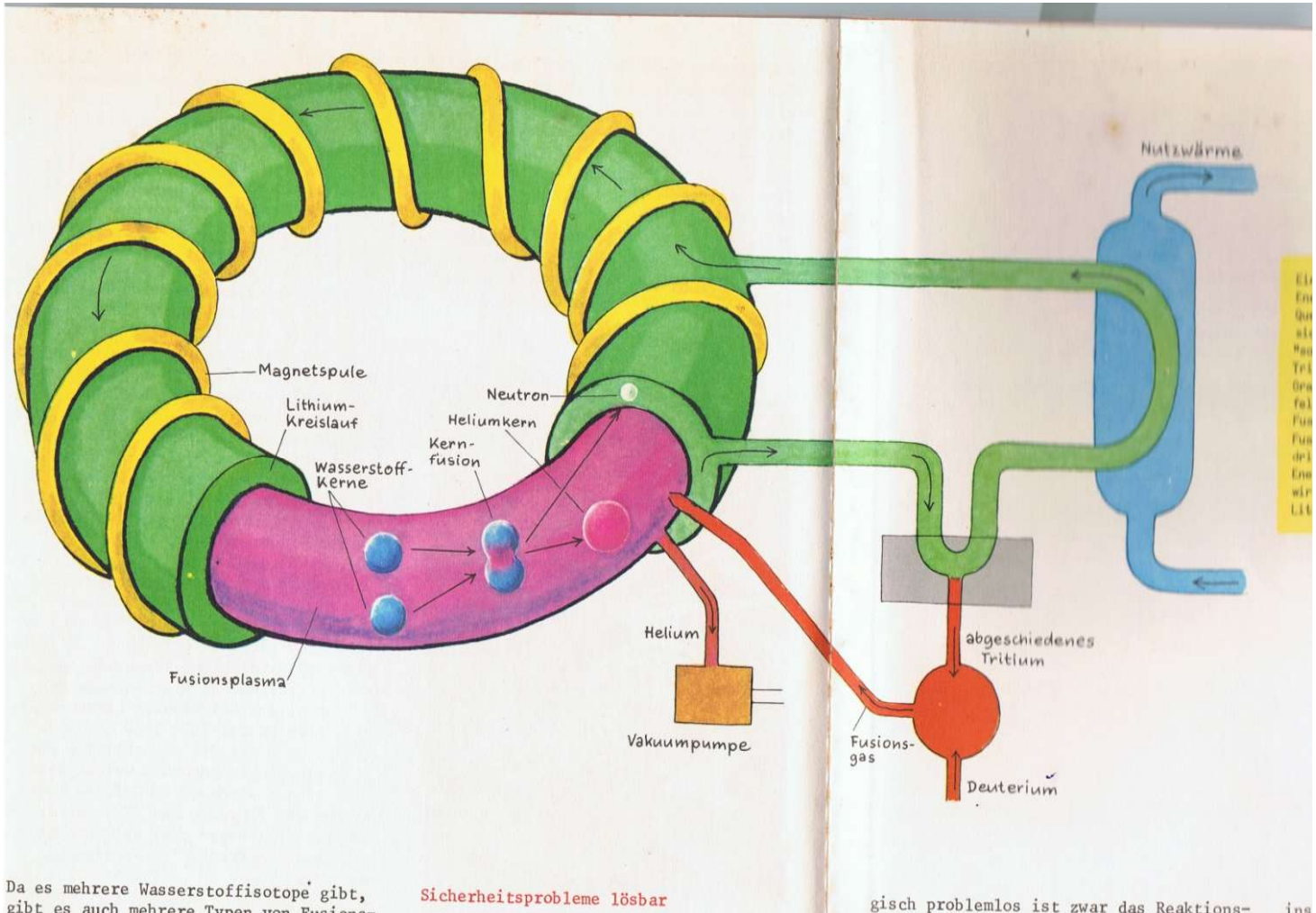
The 300 MW prototype station built at a cost of DM 7.5 Billion was prevented from being commissioned by the “Greenies”.
It was later sold to a Dutch Theme Park operator for DM 5 Million.
The cooling tower is now used as an alpine climbing experience.

The Experimental Fusion Reactor Station,

At Garching near Much was **Germany's first** Fusion Reactor. It achieved Nuclear Fusion for 1/10 second in 1982, with Energy input = Energy output. European Research continued in UK achieving 1 Sec.; and now in France aiming at 10 Sec.

Development of the Fusion Reactor

Two Hydrogen atoms (H) fuse to forming a Helium atom (He).
On earth this can only be achieved in a complete vacuum.
Magnetic forces guide the Hydrogen atoms around in a circle.
One Million times round in one Second..



The Mini Reactor

1. Mini Reactors were developed at the same time as the large Reactors

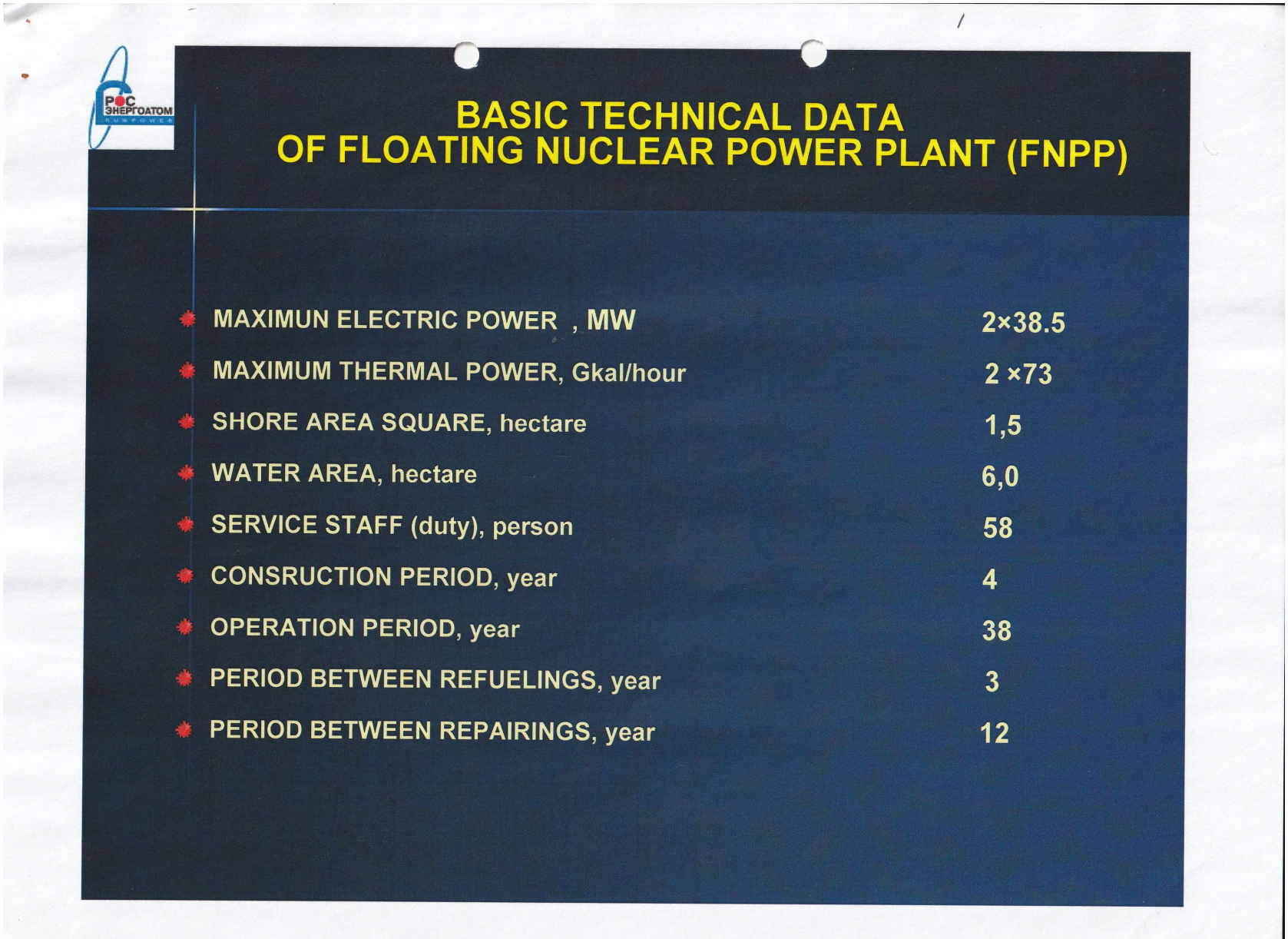
- They were developed for the energy supply of Marine Vessels
- They are much smaller than large Nuclear Reactors and can be transported as a single unit.
- They can generate electricity with 95% availability for 40 to50 years
- When decommissioned, they can be returned, with their radioactive content, to the place of origin, where they were made.
- They require refueling only every 2 to 3 years, by using a higher concentration of U235 in their fuel.
- Refueling and maintenance of the Mini Reactor could be subcontracted to the supplier of the Mini Reactor.
- Mini Nuclear Reactors are not as efficient as large Reactors; therefore, no commercial land usage took place until the present condemnation to use Coal for our 24/7 electricity generation
- The first use of Mini Reactor for commercial electricity supply was built by Russia on a ship in 2012.
- Canada, the USA, and South Korea are now also developing commercial Mini Reactors, using Water Cooled Technologies.

Developing Commercial Mini Nuclear Reactors

- In 2012 the Russians built a ship, that could generate electricity from two Mini Pressurised Water Reactors of 34 MW each on board. The ship could be located close to a town's habour and supply the township with reliable day and night electricity for 40 years, with refueling every 2-3 years.
- Modular Mini Nuclear Reactors, as a single unit, suitable for large scale production started to be development by private industry using various Reactor types, like Light Water Reactors, Pressurised Water Reactors, Boiling Water Reactors, Gas Cooled Reactors, even Breeder Reactors.
- These Mini Reactors can be used in small Nuclear Power plants, that could replace old and inefficient Coal fired Power Plants.
- Development proceeding in USA, UK, Canada, Russia, North Korea, China.
- Placing a Mini Reactor configuration at the location of a former coal fired power station, has the advantage, that existing services can be used and no extensions to the Nation Electricity Grid, are need.
- There is no need to bring sunny Queensland electricity to NSW and Victoria, with a 10% electricity loss, for every 300km the electricity travels.
- Mini Nuclear Reactors are small, and likewise are their Power Plants.It is possible to construct the entire power plant underground, enhancing the environmental protection from and on to the Mini Reactor.
- When their live-spans are exsouced, the Mini Reactor can be retured to their place of manufacture.

Floating Mini Nuclear Power Plants

The Russian Floating Nuclear Power Plant



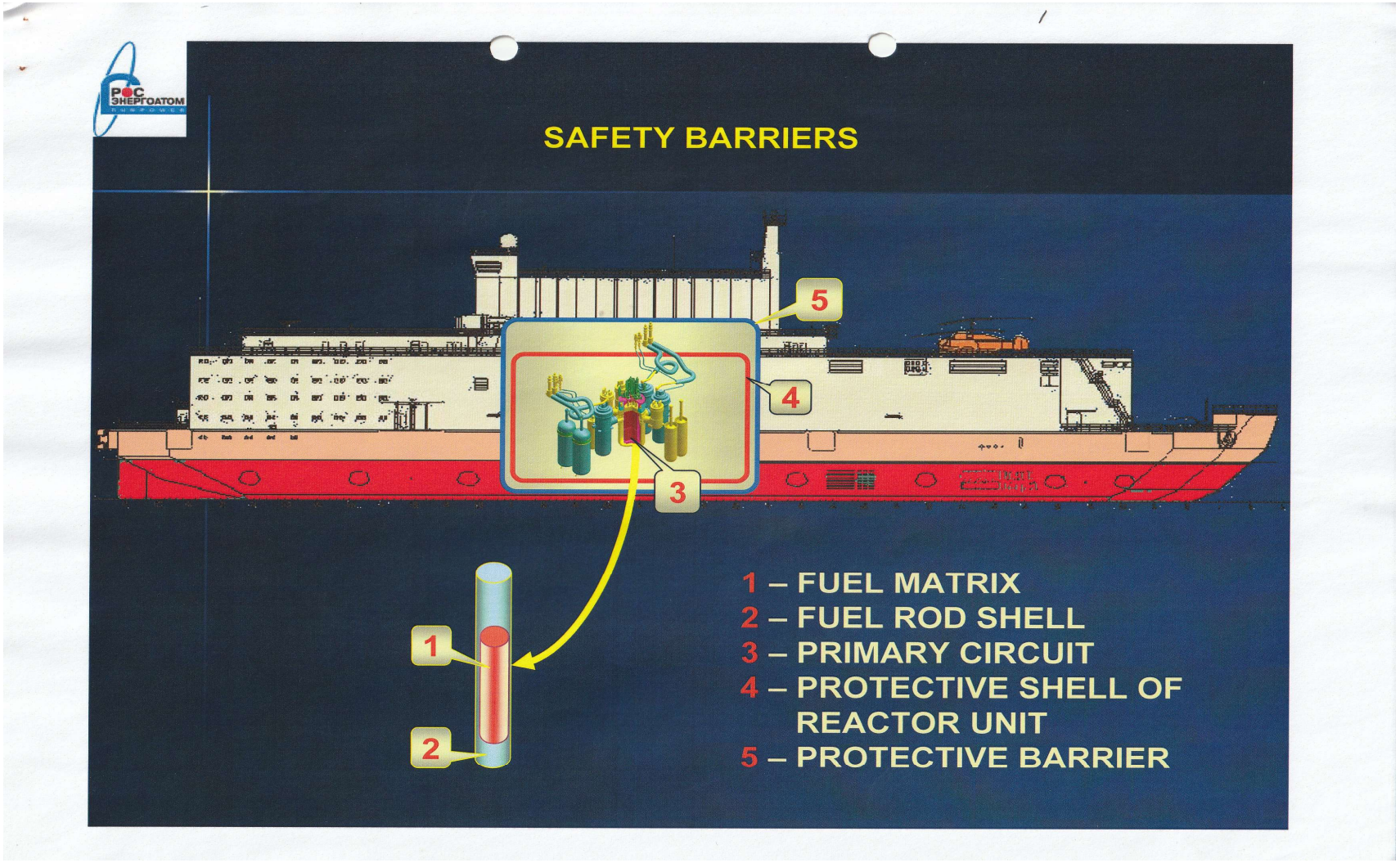
BASIC TECHNICAL DATA OF FLOATING POWER UNIT

TYPE - NON-SELF-PROPELLED VESSEL

LENGTH , M	140,0
WIDTH, M	30,0
BOARD HEIGHT, M	10,0
DRAFT, M	5,6
DISPLACEMENT, T	21 000

- VARIANTS OF STATIONING:
  COASTING (NEAR THE BERTH)
  SEA (ROAD STATIONING)

Mini Nuclear Reactor has three outer Safety Layers



Safety Areas around the Nuclear Reactor Ship

RADIATION AND ECOLOGICAL SAFETY

- All operations with spent nuclear fuel and radioactive wastes are taking place only onboard or at the special Russian shipbuilding facility in full compliance with approved technical and safety procedures and under the supervision of special authority
- Dose load for population under normal operation and project accidents is 100 times less than the same resulted from the natural radiation background
- Outboard water activity inside sanitary protective zone resulted from nuclear unit operation is 100 times less than the regulated value of portable water activity

Development of Mini Modular Reactor Units, halted.

- Envisaged was single Unit Mini Reactor, which could be mass produced, to be transported to Power Plants anywhere in the world
- Pursuing the aim of economies of series production of 50 -100 Units, and short construction times of 4 years, to be competitive to coal.
- After the Fukushima accident, the popular resentment towards Nuclear Power grow very strong, and the risks to plan a series production of Mini Nuclear Reactors, became too great for the private industry.
- While this development has started now again, there are vast differences in the costs estimates for their future costs of their electricity production.
- CSIRO estimated that by 2030 their costs could vary between $129/MWh and $336 /MWh; The $129/MWh would be cheaper that solar electricity make it available 24/7 at $245/MWh.

Cost of Solar Energy made available 24/7 , including electricity storage when the sun does not shine

- Solar and Wind energy are highly variable during the day, and they need to be supplemented, to become a consistent supply 24/7.
- Pumped Hydro Power Plants, large Batteries and Gas fired Power Plants are used to store solar energy to produce electricity when the sun does not shine.
- It requires an up-grade of the Australian Electricity Grid, to transport 25,000 MW Alternative Energy from places of generation to the end consumers. It has been estimated by CSIRO to cost $100 Billion on the East Coast, equivalent to $4 million/MW
- Solar panels have a life span of 20 years, Batteries of 10 years., Pumped Hydro Power Plant, loss about 25% of supplied energy during operation, but last for more than 50 years.

Capital Cost of Solar made available 24/7

- The capital cost to provide 1MW of solar electricity for permanent consumption for 40 years requires the following cost components:

1) Solar plant costing $1.5 Mill/MW + new glass panels @ $1.0 Mill/MW = $ 2.5 Mill/MW
2) Additional sole panels to produce electricity for the nighttime supply = $ 2.5 Mill /MW
3) Additional sole panels for 25% energy loss at Pumped Hydro Plant = $ 0.61 Mill/MW
4) Additional solar panels, 25% to charge Batteries to stabilize network = $ 0.61 Mill/MW
5)Construction Costs of the Pumped Hydro Power Plant for night power = $ 2.0 Mill /MW
6) Construction of Battery Set for 0.25 MW at $3.6 Mill/MW = $ 0.9 Mill/MW
7) Three replacements of batteries at $ 0.9 Mill x 3 = $ 2.7 Mill = $ 2.7 Mill/MW
8) Additions to East Coast National Grid extensions ($100 bn/25,000 MW) = $ 4.0 Mill/MW

Total **$ 15.82 Mill/MW**

Estimated capital costs to construct a Mini Nuclear Power Plant **$ 9.0 Mill/MW**
to capital cost estimates of MNPP with 20 years to construct time $ 26.0 Mill/MW

Electricity Production Costs per MWh

Listed are the general electricity production cost of different types of electricity generation within a variable range.

Solar at full sunshine …… $ 40 to $ 60/MWh

Wind at average good wind speeds …….. $ 70 to $ 90/MWh

Coal fired Power Plants …….. $ 80 to $100/MWh

Hydro Power Plants …….. $ 40 to $ 70/MWh

Pumped Hydro Power Plant for min. 24 hours …… $ 80 to $ 160/MWh

Gas fired Power Stations at normal gas prices ……. $120 to $200/MWh

Battery Power for at least 4 hours …….. $300 to $500/MWh

Solar made available 24/7..(40+40+10+80+300/4) .. $ 245 to 320/MWh

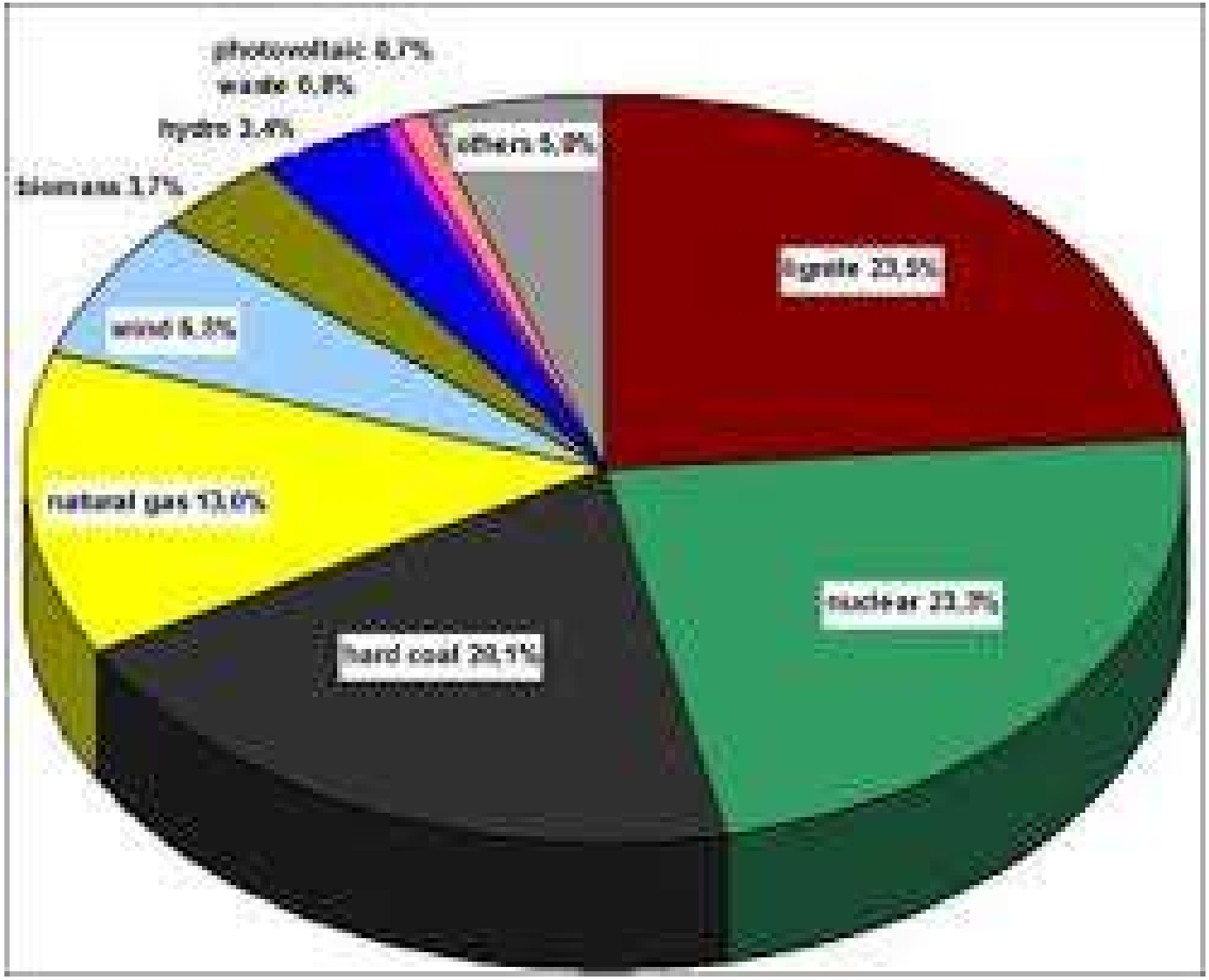
Large Nuclear Reactors …….. $ 80 to $120/MWh

Mini Nuclear Reactors (CSIRO by 2030) …… $129 to $336/MWh

Germany's Problems with Alternative Energy

- Germany was the first highly industrial nation to embrace the idea to stop producing electricity using Nuclear and Fissile Fuels for its electricity generation, after 'Green' protests started in the 1980ties.
- About 80% of Germany's 110,000 MW electricity generation was produced by Black Coal (20%), Lignite (20%), Nuclear (25%) and Gas (15%) in 1983.
- Natural Gas could be used to supplement the intermittent electricity generation by Wind and Solar. Gas would later be replaced by Hydrogen.
- Germany constructed Wind Farm and Solar Plants, with the capacity to replace 70% of its Electricity consumption, which had already reduced to below 90,000MW by 2011.
- The lack of good Sunshine and Wind in Germany, however, reduced the electricity generation from Wind and Solar often to a poor 8%.
- Cheap Russian Gas and additional Gas fired Power Plants covered-up the deficiency of Germany's move to its Alternative Electricity production.
- **Germany now admits, the move to Sun and Wind Energy, does not give the cheap electricity 24/7, required in Germany. It urges electricity companies to construct Geo-Thermal power plants, drilling into the earth crust 5 to 7 km deep, to produce the 'Electricity Base Load' .**

Germany's 110,000 MW Electricity Generation in 1983, prior to closing down its Nuclear Power Plants.



Germany has 16,000 Wind Poles with a Capacity of 40,000 MW, generating often only 8,000 MW – 20 %.

Environmentalist demand, that more Wind Poles are built, out of sight, in the North Sea and Baltic Sea.

The blades use up the wind power, which once blew rain clouds over to the fertile lowlands of northern Europe. They are now in draught !

German Solar and Wind Energy.

Solar power is being subsidised by the German Government with annually Euro 17 Billion, for it to be competitive to Coal, Gas and Hydro.

In May 2011, about 250,000 Germans protested against the use of Nuclear Power in Germany.

Pressured by the Public with: “Let Fukushima be a Warning, Switch off all Nuclear Power Plants”

The Government agreed to shut-down all Nuclear Power Plants by 2022/23, 10 to 20 years ahead of their design life.

Usage of Nuclear Power in Europe

France produces 80% of its electricity by Nuclear Power.
Germany produced once 25% with 26 Nuclear Plants. Now 0%.
New Nuclear Power Plant are being constructed in most European countries. World-wide, 485 Nuclear Reactors are presently operating.

Germany's failed cheap Alternative Electricity

- Germany has admitted now, that their transition to Alternative Energy of Wind and Solar has failed. Having no longer cheap Russian gas to cover-up the very low electricity production from 'Alternative Energy'; they now had to un-mothball 27 Coal fired Power Plants, to avoid "Black-Outs",
- The German people pay now 75 Cent/kWh for their Electricity, three times the amount we pay in Queensland, 24.9 Cent/kWh, that is till 30/6/2023.
- Even though the European Parliament has declared, that Nuclear Power produces 'Green Electricity', Germans will demolish their Nuclear Plants.
- Laws have been passed in Germany, by the Green Coalition Government; that oil and gas no longer can be used for home central heating. It needs to be replaced by Wood-Pellets, Electricity or Heat-Pumps.
- Houses need to be 100% insulated or will be demolished within 10 years.
- Car manufacturer need to change their production to 50% electrical cars or pay penalties of Billion Euros.
- The Electricity Companies are being strongly urged to build larger off-shore Wind Farms in the North-Sea and Baltic Sea; and to construct large Geo-Thermal Power Plants, drilling 5 to 7km into the 'Earth Crust' to replace the switched-off base load of Nuclear Power Plants.

Conclusions for Australia‘s Alternative Energy Program

- **Do we really want to pay 300% more for our electricity supply, like Germans?**
- **Is there not a better solution. Replacing our Coal fired Power Stations with Mini Nuclear Reactors ?**
- **Or even better with new modern Coal fired Power Stations, when the large black patches on the sun surface will re-appear in 20 years, according to the100 year cosmic climate change circle. It would confirm, that Climate Change is not primarely caused by CO2 emissions produced by humans.**
- **China constructs annually as many new Coal fired Power Stations, as are in operation in Australia. Being an under developed Nation, China is allowed to do so until 2060.**
- **At the same time China is building 50 new Nuclear Power Plants, and have a further 25 in the planning stage.**
- **China has bought the German Fast Breader Reactor plant design from Siemens.**
- **It is time for Australia to re-consider seriously their condemnation of Nuclear Power, and replace their Coal fired Power Plants with Mini Nuclear Power Plants. Electricity from Mini Nuclear Reactors is cheaper than from Solar and Wind made available 24/7.**

- Thank You for your Time and Attention
- Any Questions?