NUCLEAR ENERGY

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Plan

INTRODUCTION

Nuclear energy is a major topic in today’s world because it combines technical, economic, political, and environmental challenges. Understanding how nuclear power plants work, how much they cost, and how they impact global stability is essential for countries planning their future energy strategy. In this presentation, we will explore the key technical principles, economic factors, and geopolitical issues that shape the role of nuclear energy today.

PRINCIPLE OF NUCLEAR FISSION

Nuclear fission

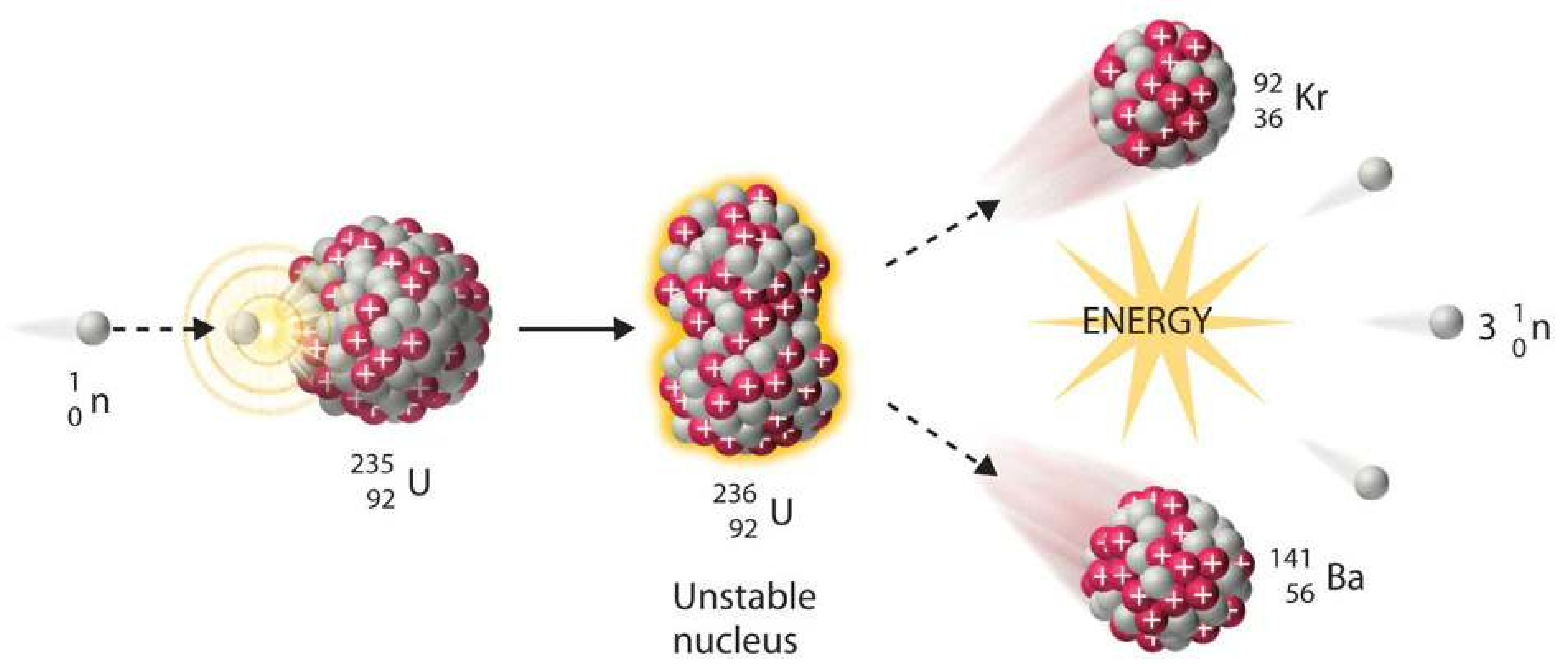
Spontaneous fission

Occurs without external intervention:
Some heavy nuclei are unstable and can naturally split into two lighter nuclei, releasing energy and neutrons.
This phenomen is **very slow and rare**

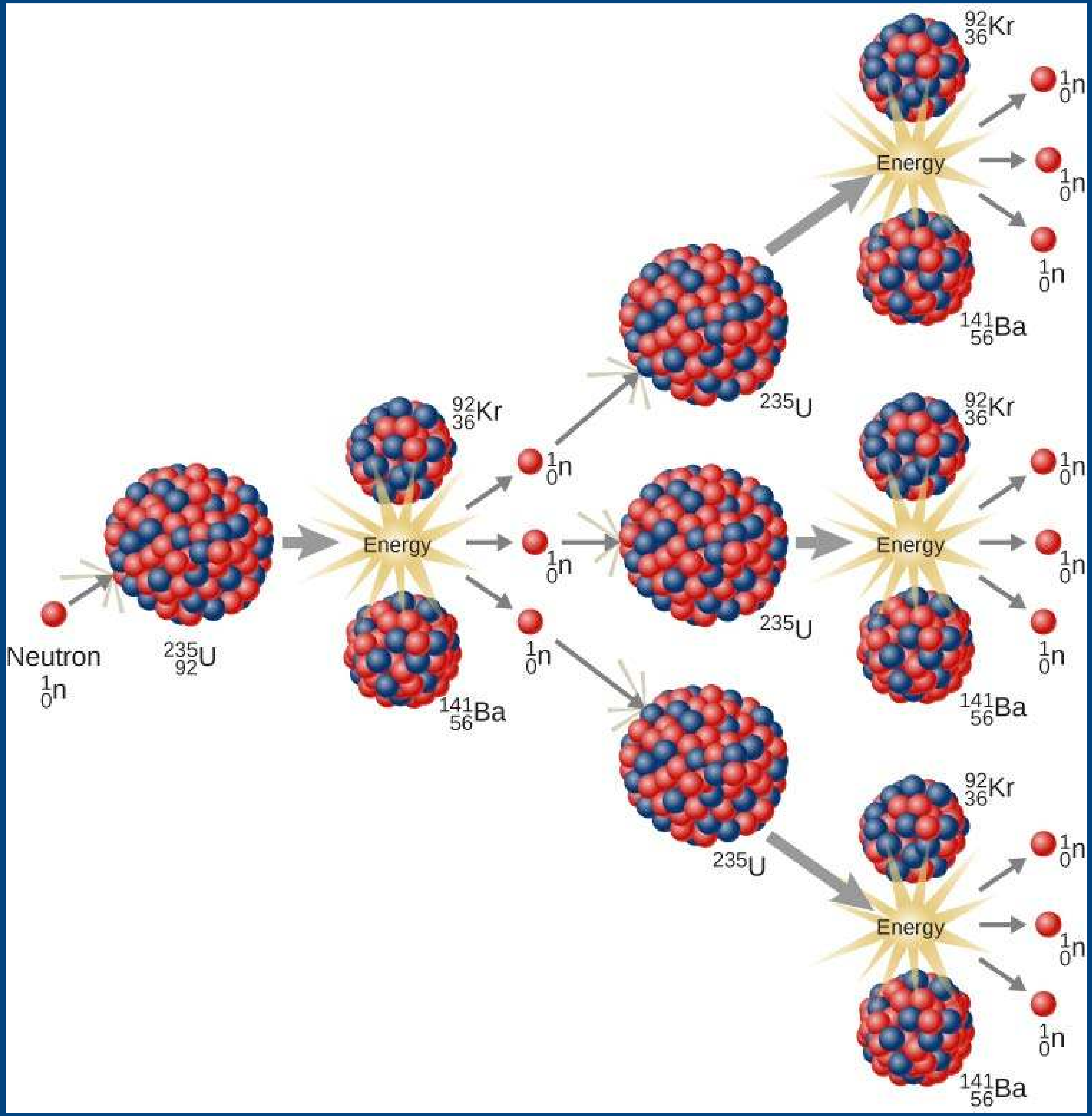
Induced fission

Occurs when a heavy nucleous captures a neutron and split into two fragments, accompanied by neutrons and a large amount of energy.
This type of fission is used in **nuclear reactors** and atomic bombs

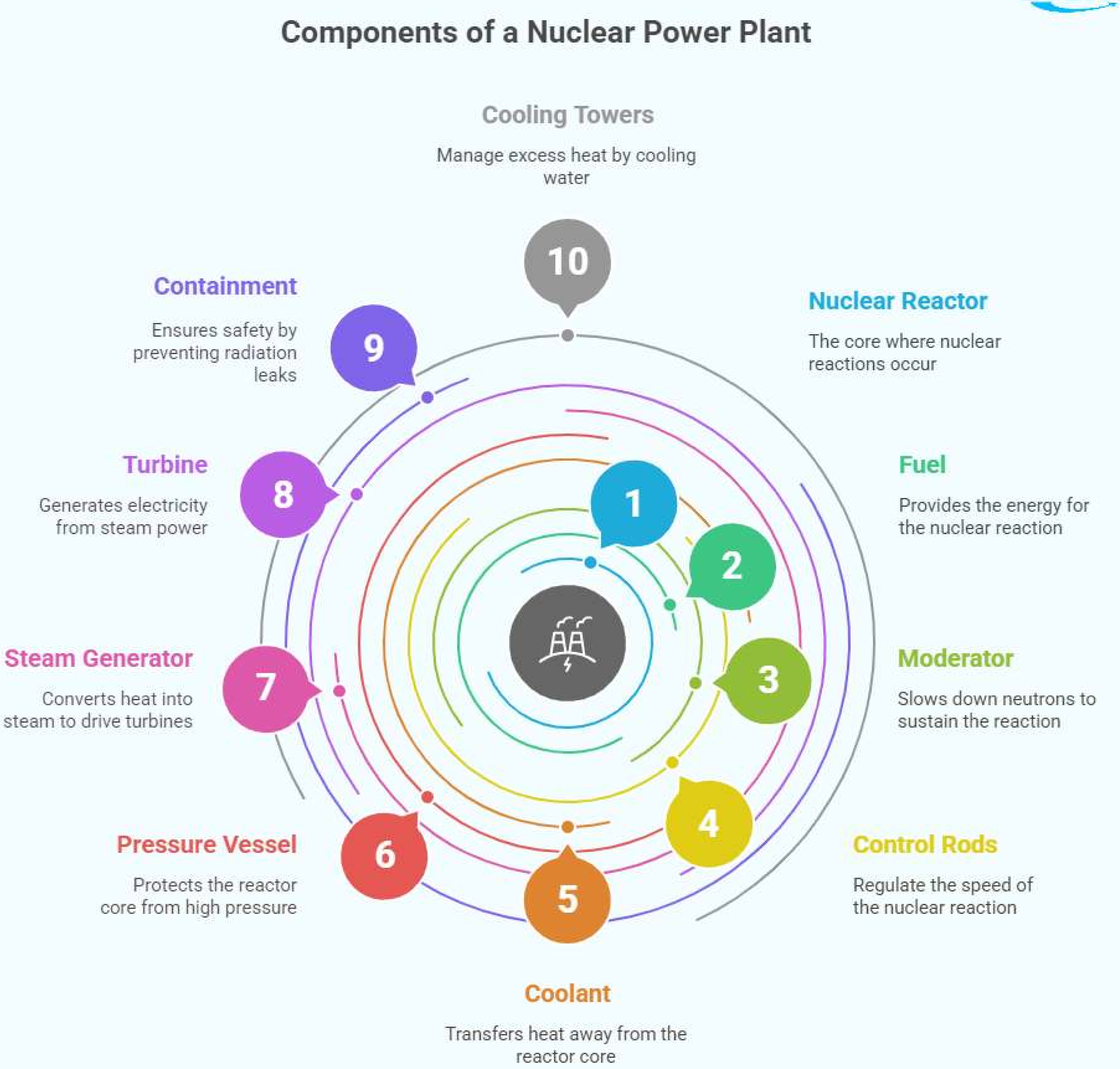
PRINCIPLE OF NUCLEAR FISSION



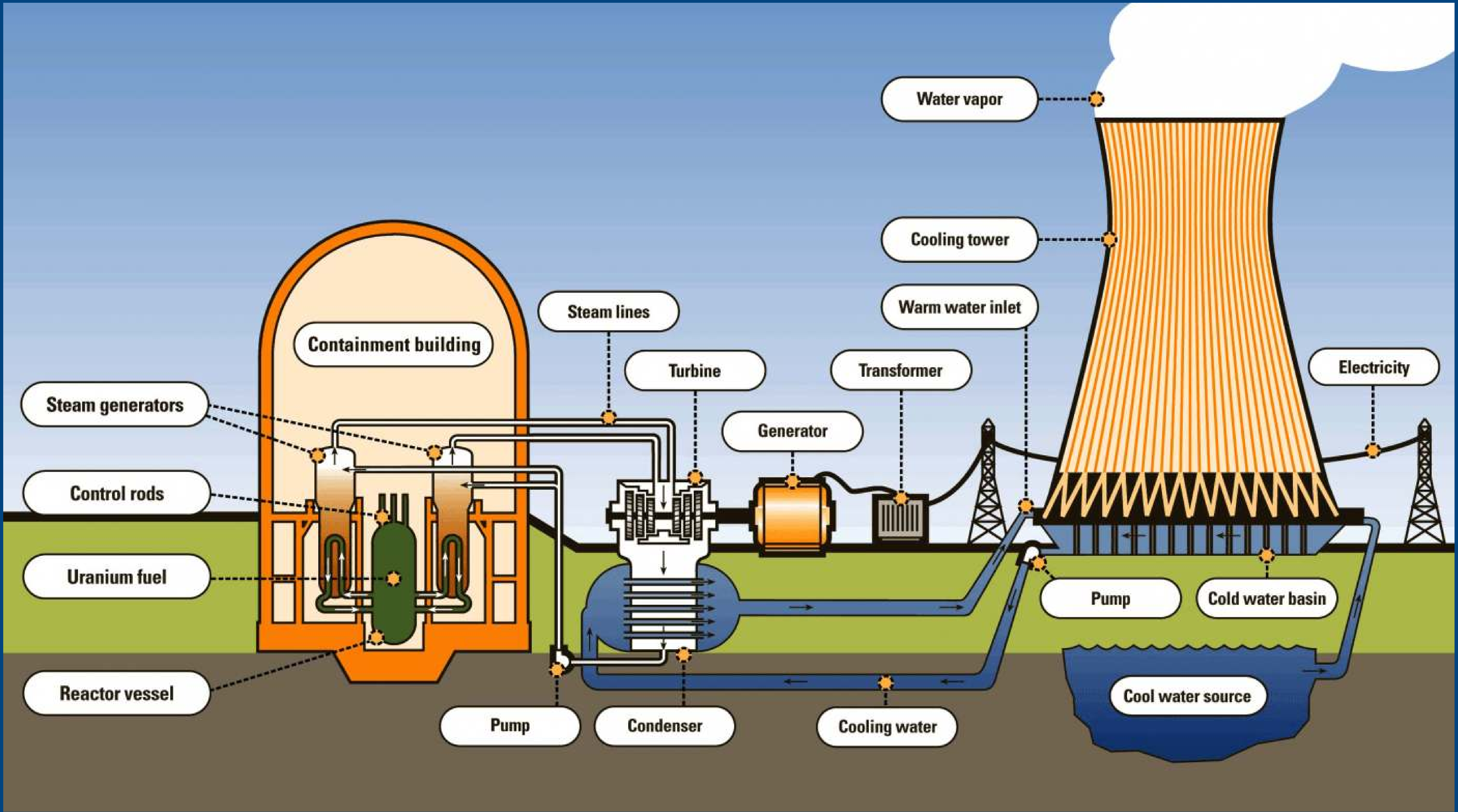
PRINCIPLE OF NUCLEAR FISSION



Structure of a nuclear power plant



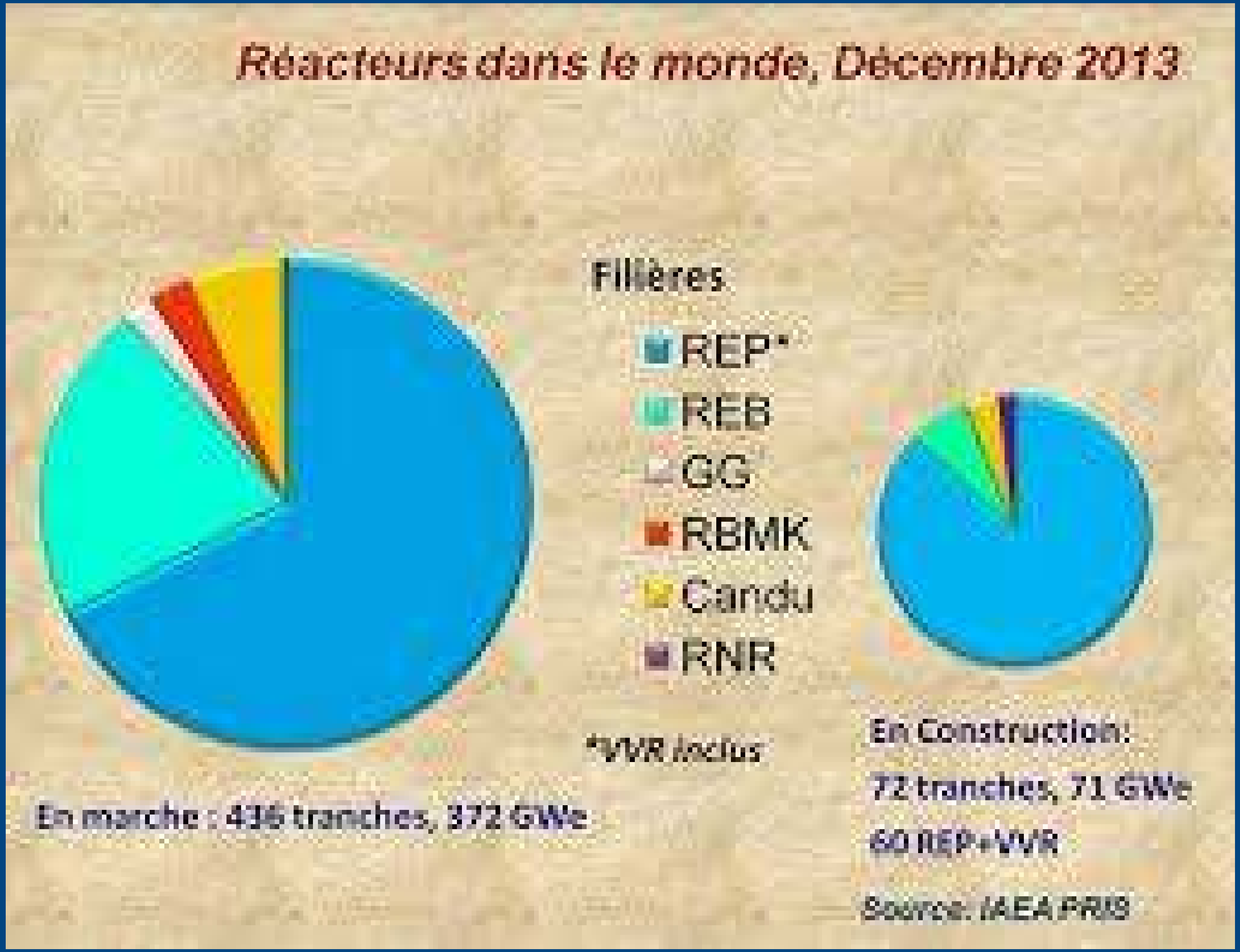
A typical nuclear reactor produces 1 gigawatt of power per plant on average.



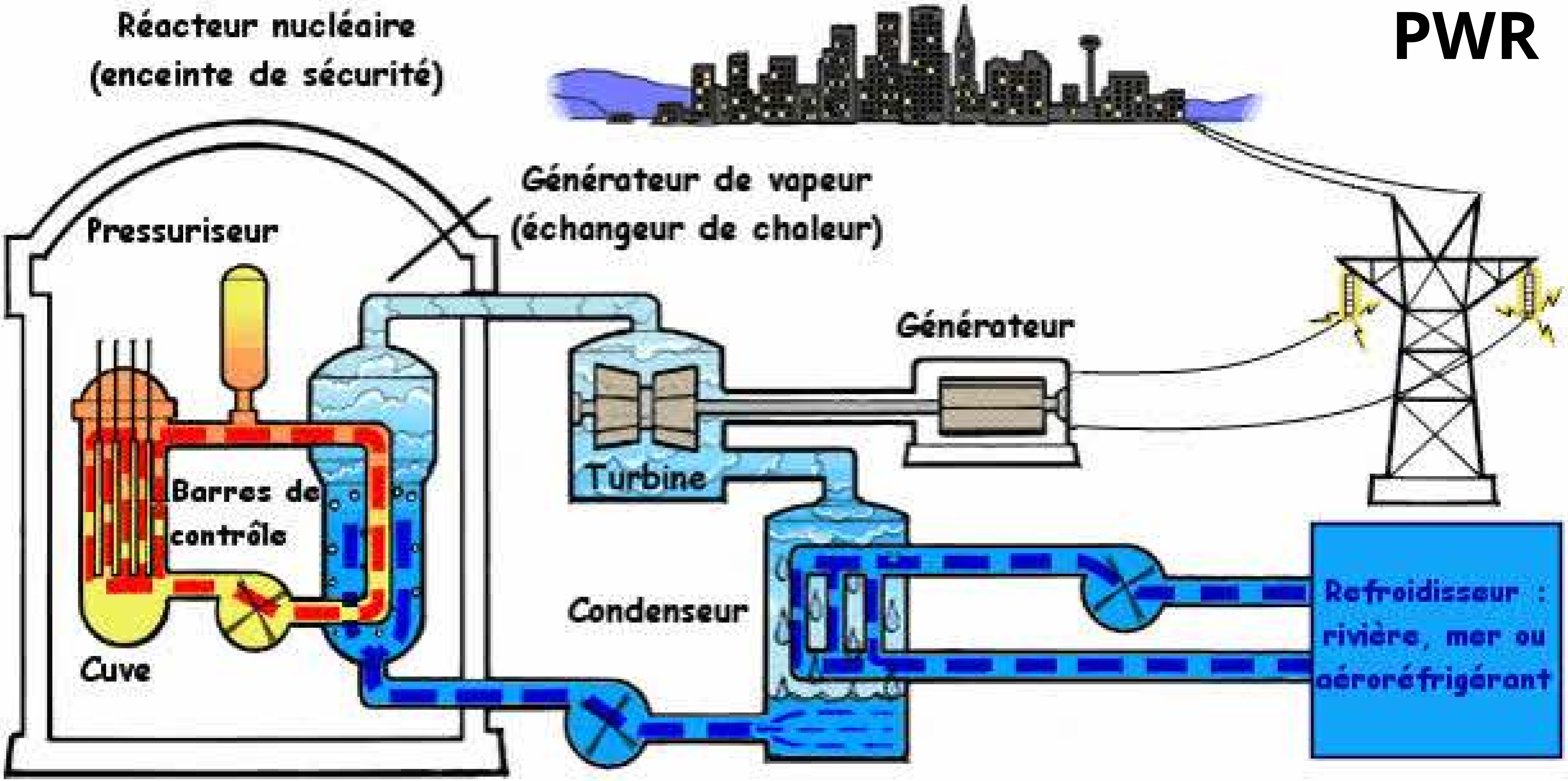
TYPES OF NUCLEAR REACTORS

We have:

- Pressurized Water Reactor (PWR)
- Boiling Water Reactor (BWR)
- Heavy Water Reactor (HWR or CANDU)
- Fast Breeder Reactor (FBR)
- Gas Cooled Reactor (GCR)
- etc ...

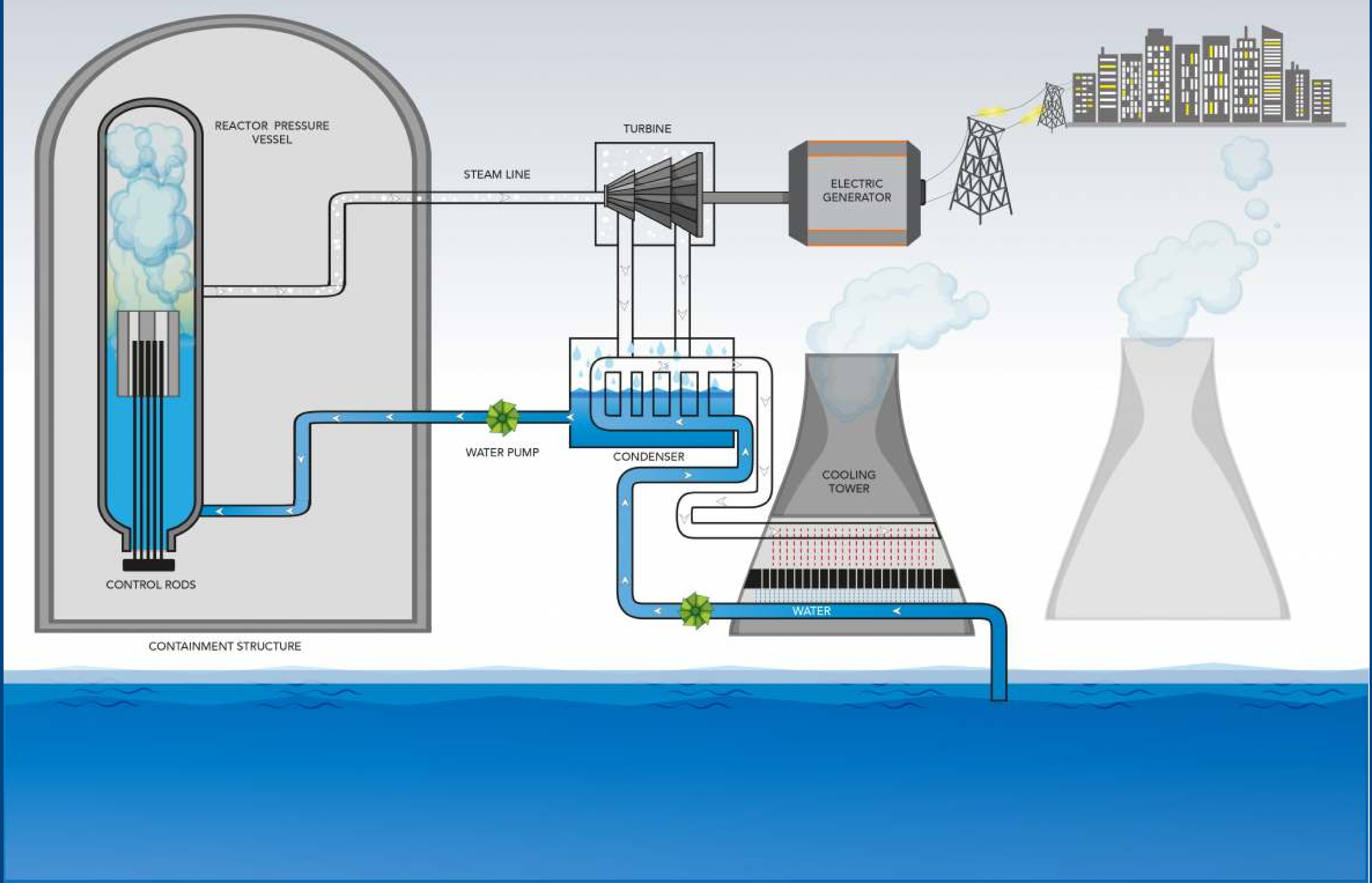


PWR

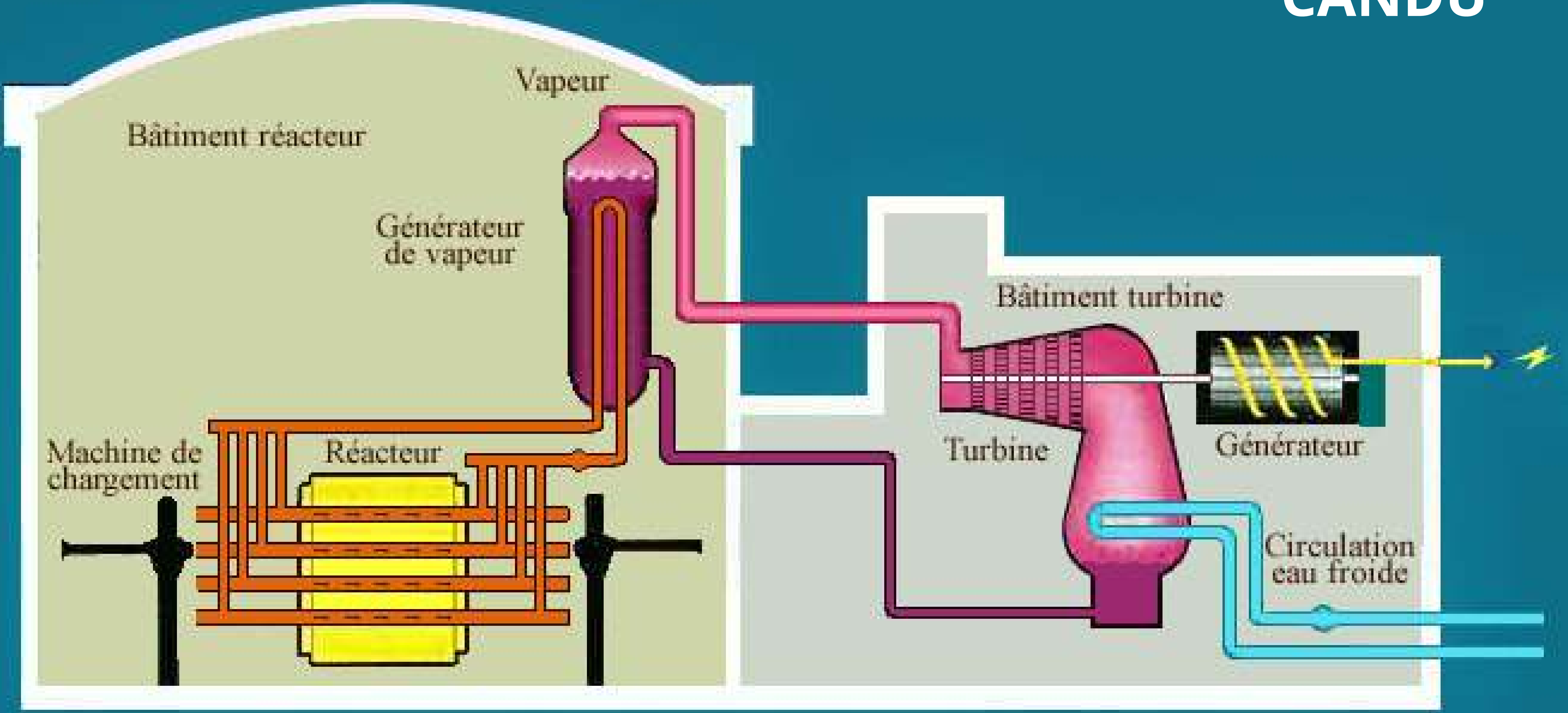


Réacteur nucléaire
(enceinte de sécurité)
Pressuriseur
Générateur de vapeur
(échangeur de chaleur)
Générateur
Turbine
Barres de
contrôle
Condenseur
Cuve
Refroidisseur :
rivière, mer ou
aéroréfrigérant

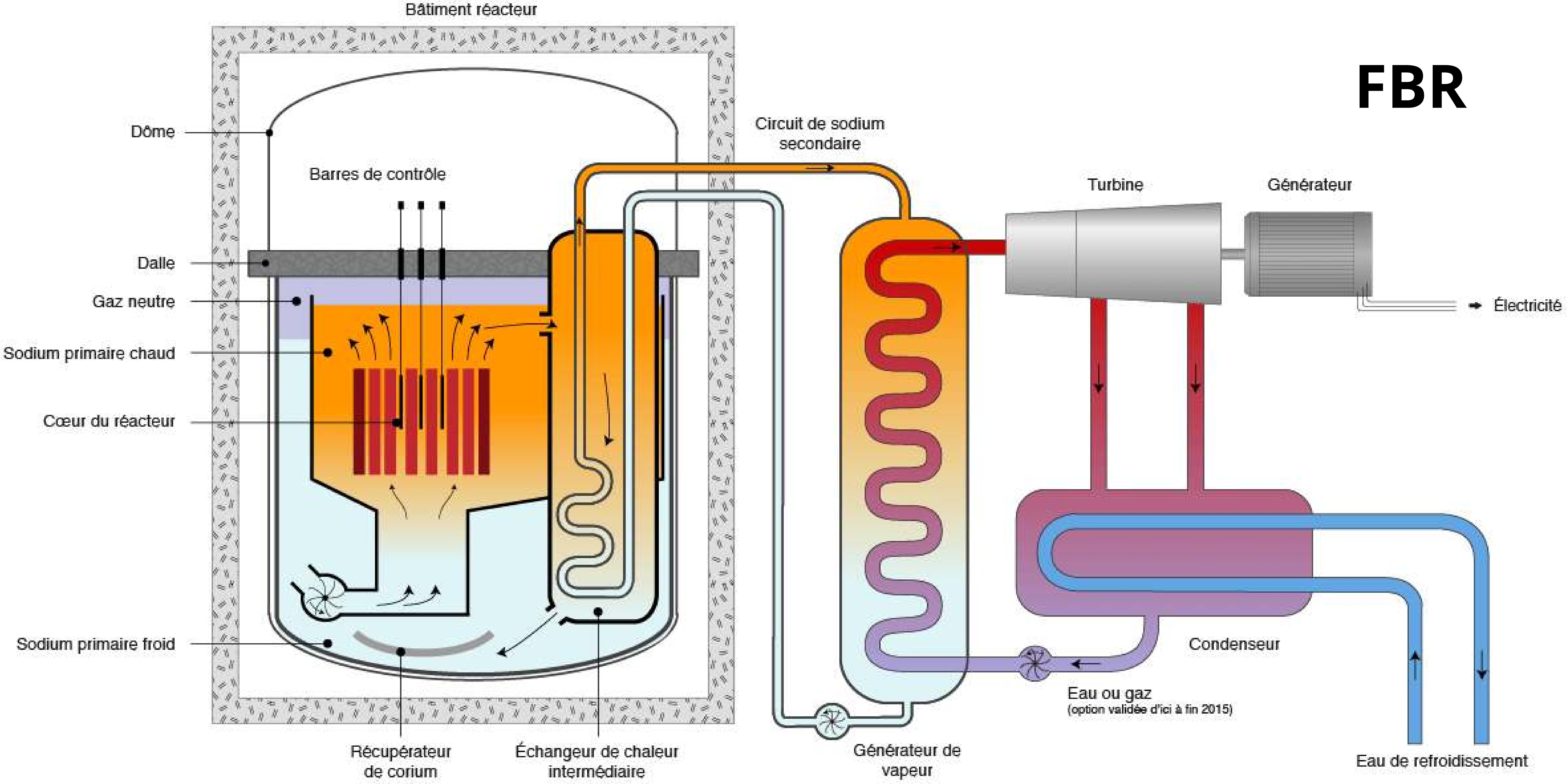
BOILING WATER REACTOR (BWR)



CANDU


Vapeur
Bâtiment réacteur
Générateur de vapeur
Bâtiment turbine
Machine de chargement
Réacteur
Turbine
Générateur
Circulation eau froide

FBR


Bâtiment réacteur
Dôme
Barres de contrôle
Dalle
Gaz neutre
Sodium primaire chaud
Cœur du réacteur
Sodium primaire froid
Récupérateur de corium
Échangeur de chaleur intermédiaire
Circuit de sodium secondaire
Générateur de vapeur
Turbine
Générateur
Électricité
Condenseur
Eau ou gaz
(option validée d'ici à fin 2015)
Eau de refroidissement

Safety Systems and Risk Management

Defense-in-Depth

- avoid failures,
- protect the reactor core,
- and contain radioactivity.

Main Safety Systems

- Reactor Protection System (RPS)
- Emergency Core Cooling System (ECCS)
- Containment System
- Hydrogen Mitigation System

Risk Management

- Passive Safety Systems:

Work automatically without electricity — reduce human error.

- Digital Monitoring:

Sensors and AI detect early warning signs.

- Continuous Learning:

Each incident worldwide helps improve safety rules everywhere.

- Safety Culture:

Everyone in the plant — engineers, technicians, management —shares the same mindset: Safety first, always.

Major Nuclear Accidents and Safety System Failures

Three Mile Island (USA, 1979)

- Cause: Valve failure + wrong human response.
- Problem: Operators misread signals and stopped coolant flow.
- Result: Partial meltdown, but no major radiation release.
- Lesson: Better operator training and clearer instruments are essential.

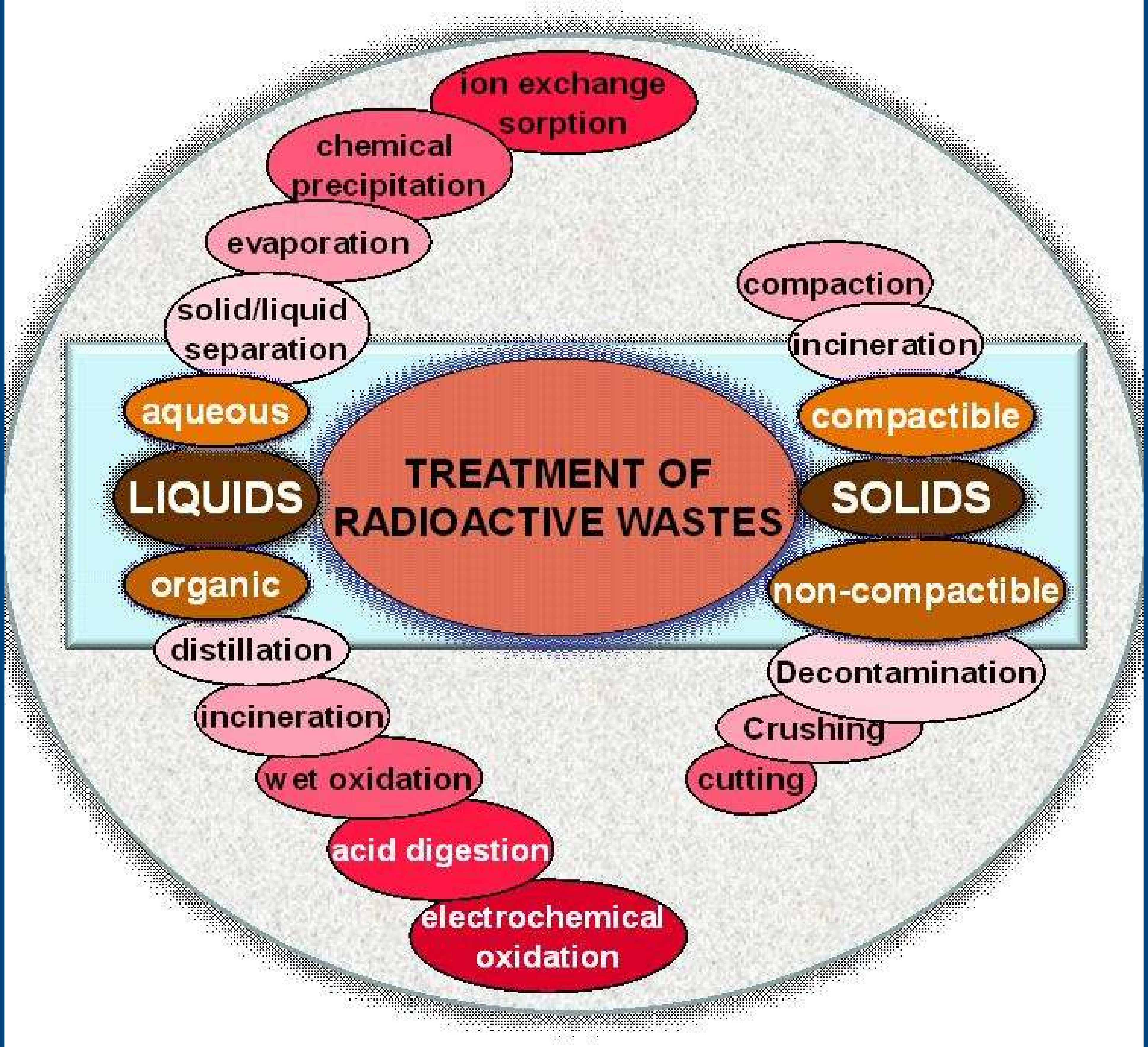
Chernobyl (Ukraine, 1986)

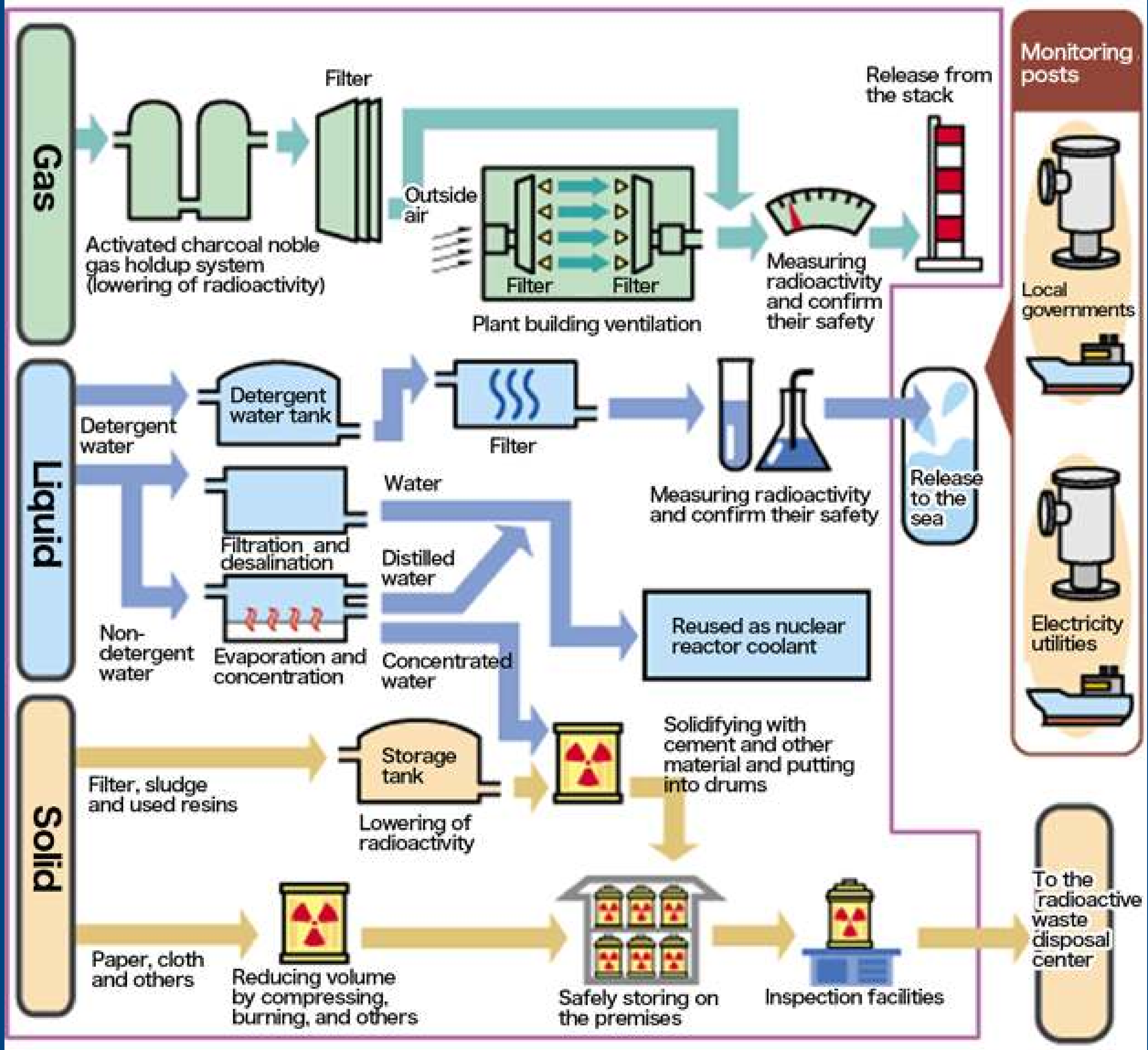
- Cause: Unsafe test + safety systems turned off.
- Problem: Reactor became unstable and exploded.
- Result: Massive radioactive release, thousands affected.
- Lesson: Never disable safety systems; always follow strict procedures.

Fukushima (Japan, 2011)

- Cause: Earthquake followed by a huge tsunami.
- Problem: Flooding cut off all electricity — no cooling for reactors.
- Result: Core meltdown and hydrogen explosions.
- Lesson: Design plants to resist extreme natural events and ensure backup power.

RADIOACTIVE WASTE TREATMENT AND STORAGE


ion exchange sorption
chemical precipitation
evaporation
solid/liquid separation
aqueous
LIQUIDS
organic
distillation
incineration
wet oxidation
acid digestion
electrochemical oxidation
TREATMENT OF RADIOACTIVE WASTES
compaction
incineration
compactible
SOLIDS
non-compactible
Decontamination
Crushing
cutting


Gas
Filter
Activated charcoal noble gas holdup system (lowering of radioactivity)
Outside air
Filter
Filter
Plant building ventilation
Measuring radioactivity and confirm their safety
Release from the stack
Monitoring posts
Local governments
Liquid
Detergent water
Detergent water tank
Filter
Measuring radioactivity and confirm their safety
Release to the sea
Water
Filtration and desalination
Distilled water
Non-detergent water
Evaporation and concentration
Concentrated water
Reused as nuclear reactor coolant
Electricity utilities
Solid
Filter, sludge and used resins
Storage tank
Lowering of radioactivity
Solidifying with cement and other material and putting into drums
Paper, cloth and others
Reducing volume by compressing, burning, and others
Safely storing on the premises
Inspection facilities
To the radioactive waste disposal center

Future of Nuclear Energy: Technologies and Innovations

New Classes of Advanced Reactors

- Small Modular Reactors
- Molten Salt Reactors (MSRs)
- High-Temperature Gas Reactors (HTGRs)

Advances in Nuclear Fuel Technology

- Accident Tolerant Fuels (ATFs)
- High-Assay Low-Enriched Uranium (HALEU)

Nuclear-Powered Clean Hydrogen Production

Quick expansion

Employment and Industrial Impact

JOB CREATION

1) Total effort : up to 12,000 labor-years
2) Permanent Jobs : 600 – 1,000 Jobs per Plant (50+ years)
3) Multiplier Effect

Industrial Impact

1) Grid Stability: (24/7 Reliability)
2) Economic Output
3) New Markets

QUALITY OF EMPLOYMENT

1) Wages : 30-36% Higher than local average
2) Skills Pipeline : High Demand for STEM (Engineers) and Certified Trades

Investment costs

Cost of investment

The estimated costs of building a nuclear power plant vary from $14 billion to $30 billion.

- ⅓ INDIRECT COST (land, licensing, engineering, construction...)
- ⅔ DIRECT COST (reactor and turbine equipment...)

Nuclear power plants are relatively cheap to run, but they are expensive to build. Delays in project delivery may double the costs in less than five years.

Ways for financing

Broadly, there are two main ways in which a nuclear power project and its ownership can be structured:

- Government (public) Government directly finances a project through a mix of equity and debt (i.e Qinshan 1 in China) .

- Corporate (private) Most commonly the corporate entity is a large utility. The corporate entity arranges credit from lenders and takes on the full risk related to the project and in some cases it can be also a groupe of investors (i.e Widely used in France, Korea, Russia, the UK and USA).

2023 Cost Summary ($/MWh)

Category	Plants / Sites	Fuel	Capital	Operating	Total Generating
All U.S.	54	$5.32	$7.06	$19.38	$31.76
Plant Size[2]					
Single-Unit	18	$5.50	$10.72	$25.40	$41.62
Multiple-Unit	36	$5.27	$6.23	$18.03	$29.53
Type					
BWR	20	$5.26	$6.30	$20.57	$32.13
PWR	34	$5.35	$7.46	$18.76	$31.56

Source: EUCG

Cost of electricity generation

The economies of scale allow plant operators to spread costs over more generation, resulting in a lower total generating cost. In 2023, the average total generating cost at multiple-unit plants was $29.53 per MWh compared to $41.62 per MWh for single-unit plants.

Economic Lifespan and Maintenance

Typical Lifespan

- **Originally designed for:** 30–40 years of operation
- Often extended to 50–60 years or even 80 with some life-extansion programs mainly in the US

Common Major Maintenance Operations

Refueling

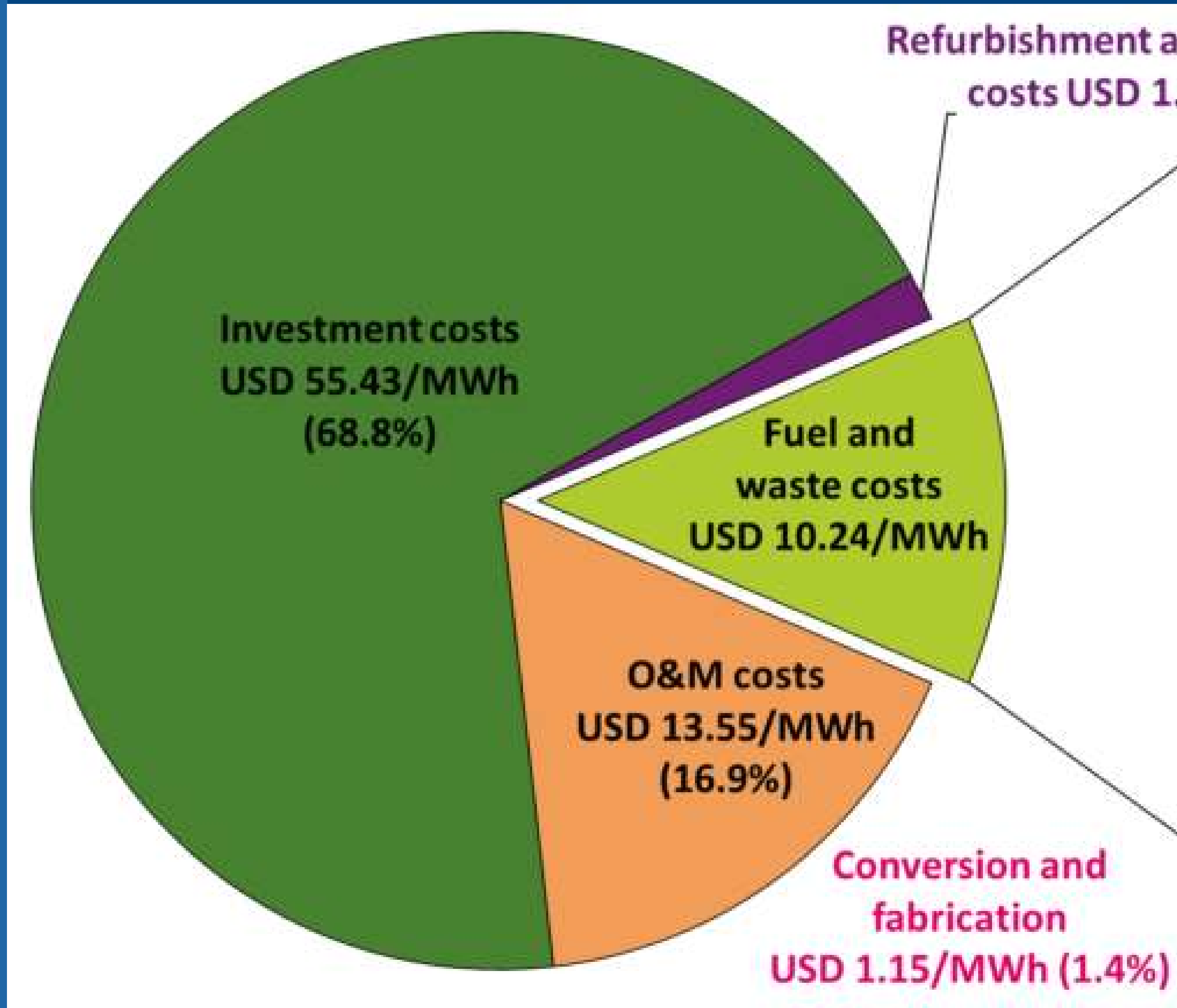
- Happens every 1–1.5 years
- Takes about 20–40 days

Steam Generator Replacement

- Major operation in pressurized water reactors
- Done after ~20–30 years

Cooling System Upgrades

- Ensures efficiency and thermal performance
- Often required during life-extension programs



IV Political and environmental dimensions

01. Global nuclear landscape

02. Energy Policy and National Strategies

01. Strategic Objectives and Energy Mix

02. Regulatory Framework and Security

03. Technological and Industrial Choices

04. Fuel Cycle Management

05. Human Capital and Social Acceptability

01. Strategic Objectives and Energy Mix

- Supply Security
- Decarbonation and climate action
- Economical competivity

02. Regulatory Framework and Security

- Establish Independent Oversight
- Prioritize Safety and Security
- Adhere to Global Treaties

03. Technological and Industrial Choices

- Define Reactor Strategy
- Support Domestic Industry
- Invest in R&D

04. Fuel Cycle Management

- Secure Fuel Supply
- Make Enrichment Decisions
- Define Waste Strategy

05. Human Capital and Social Acceptability

- Develop Skilled Workforce Enrichment Decisions
- Ensure Transparency
- Obtain Social License

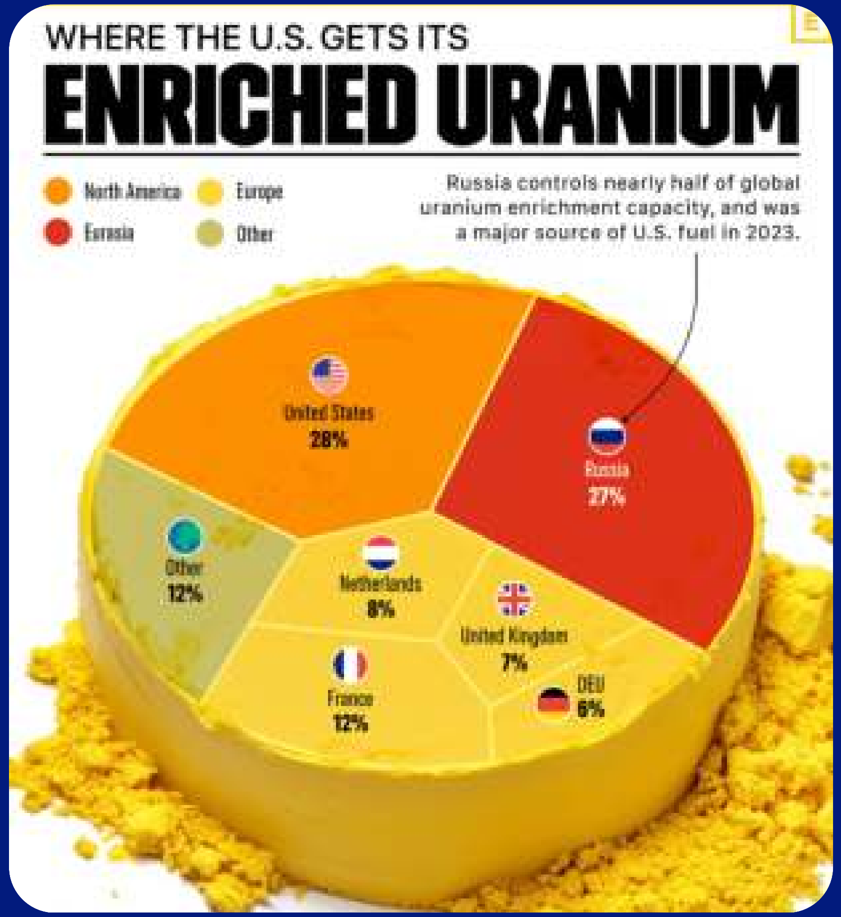
03. Energy Policy and National Strategies

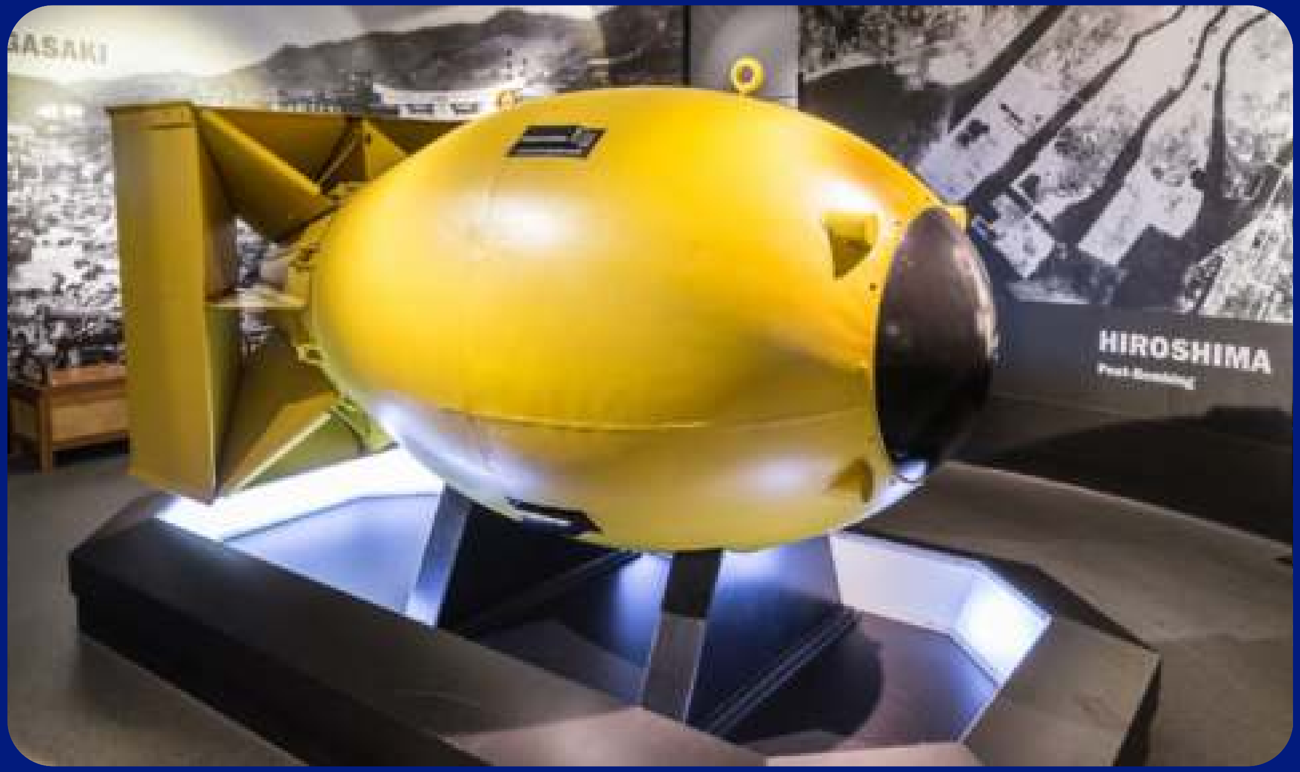
🌍 **Decarbonation contribution**

⚡ **Energetic security and complementarity**

Geopolitical and Security Issues

- Energy Dependence and Geopolitical Influence
- Proliferation Risk
- Nuclear Power in Conflict Zones
- Cybersecurity and Physical Protection
- International Regulations and Safeguards





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THANK YOU