Nuclear Power

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IAEA
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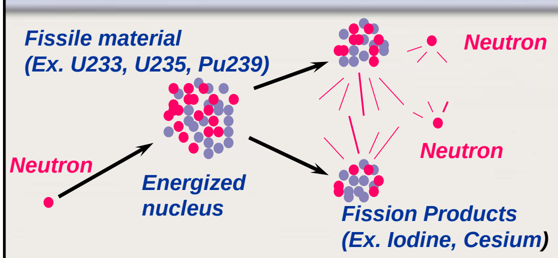
What is nuclear fission?



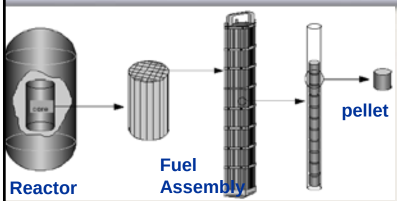
1 fission releases 200 Million eV (electron Volt)

Nuclear reactions are generated within the nucleus of an atom.

1 chemical reaction (burning fossil) releases several eV

Chemical reactions are the result of rearrangement of electrons in the orbits of an atom.

What is Nuclear Fuel?



LWR (Light Water Reactor) fuel

One pellet (1cm x 1cm) can produce 3000 KWhr of electricity

Equivalent to circa one ton of coal

World average per capita electricity consumption=2600 KWhr/year (in 2004)

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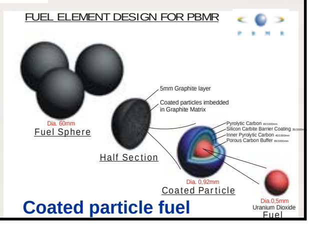
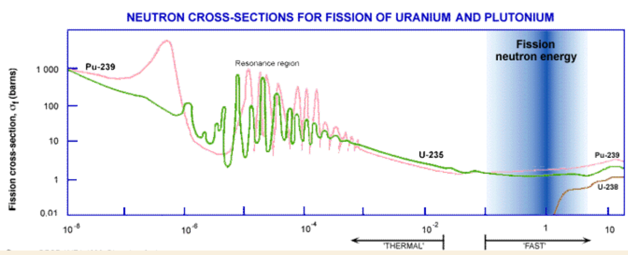


Coated particle fuel

Neutron interaction with fissile material depends on neutron energy



Higher rate of reaction with Uranium / Plutonium in low neutron energy (slow speed) region

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Neutron interaction with fissile material depends on neutron energy

(Light Water Reactor as an example)

High speed neutron emitted from fission reaction
→ Slow down ("moderation") by collision with other nuclide (such as with hydrogen in water)

In this "moderation" process;

- **Partly captured in slow-down process by U238…eventually becomes fissile material Plutonium**
  - ***→This is why non-fissile U238 can become resources***
- **Partly absorbed by structure material or water or control material**
  - ***→This is how reaction rate is controlled by control rod***
- **Partly absorbed by U235 for another fission reaction**
  - ***→This is why chain reaction can continue***

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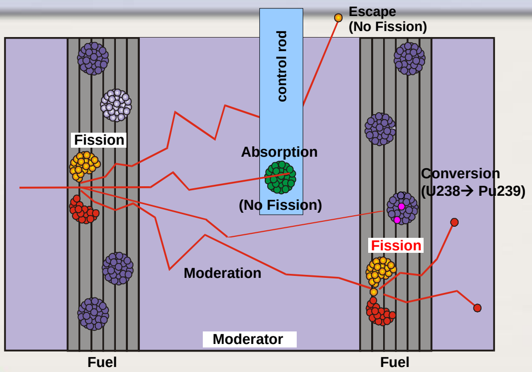
Could be illustrated like this….



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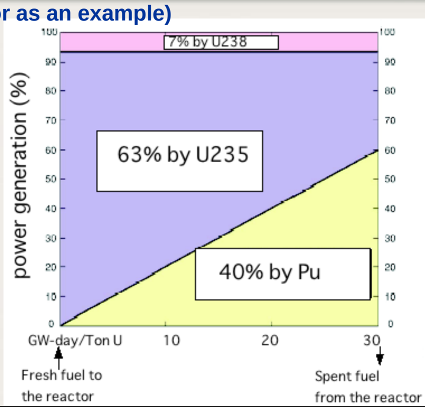
Fertile U238 can become resources

(Light Water Reactor as an example)

Fuel composition changes with burn-up



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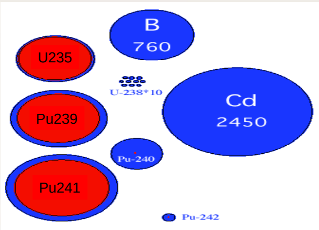
How to control the amount of chain reaction?

By absorbing neutron (Cadmium, Boron as control rod)
By creating void in water (reduce slow-down of neutron)
By increasing absorption by U-238 (by temperature increase) etc.



RED = fission
BLUE = absorption

The size of the area indicates absorption rate of thermal neutron

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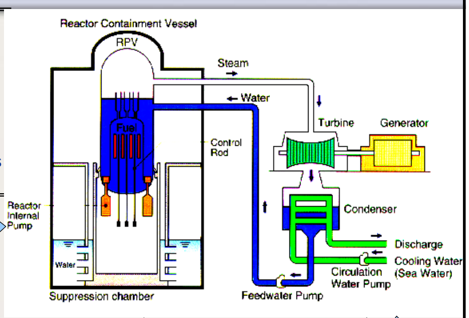
How Nuclear Power Plant produces electricity?

Nuclear Island
-Nuclear Reaction
- Fuel core
- Control system
-Heat transport
- Pumps & Valves
- Heat Exchangers
- Electrical, Controls
- Safety Systems



Turbine Island
Power conversion system
- Turbine & Generator
- Pumps, heat exchangers
- Controls

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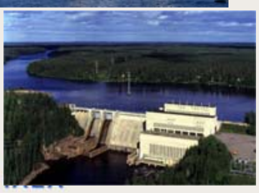
In most case, electricity is produced by turning an electric generator



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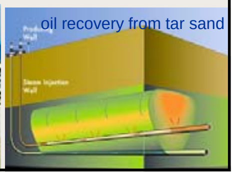
Other than just producing electricity, nuclear power can be used for

- ❑ Global demand for portable water increase: **desalination**
- ❑ Most of the world's energy consumption is for **heat and transportation**. NE has potential to penetrate into these sectors currently served by fossil fuels (price volatility and finite supply)
- ❑ Technology development is ongoing so that nuclear energy can help **chemical energy production**
  - Recovery of oil from tar sand (Canada)
  - Sweetening of oil by adding hydrogen
  - Coal Liquefaction (S. Africa, Australia)



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Reactor types

- ❑ **Classification by neutron energy spectrum**
  - **Fast neutron reactor**
  - **Thermal neutron reactor**
- ❑ **Classification by coolant**
  - **Gas-cooled (CO2, Helium)**
  - **Water-cooled (Heavy water, Light water)**
    Most of commercial reactor in operation (as of today) : Water-Cooled
  - **Liquid Metal-cooled (Sodium, Lead, Lead-Bismuth etc)**
  - **Molten salt-cooled**
    Other Non-conventional concepts;
    Gas-core reactor, Accelerator Driven System (sub-critical)
- ❑ **Classified by generation**
- ❑ **Classified by size**
  (Small<300MWe<Medium<700MWe<Large by IAEA)

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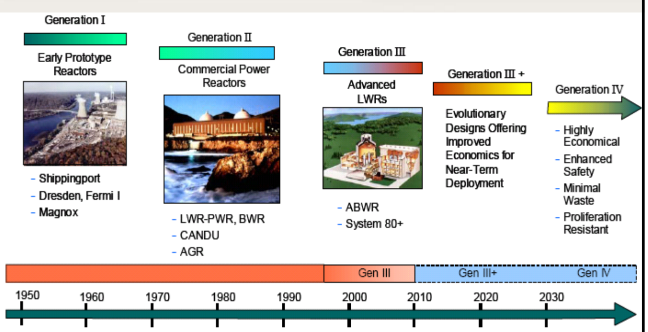
US classification of reactors by generation



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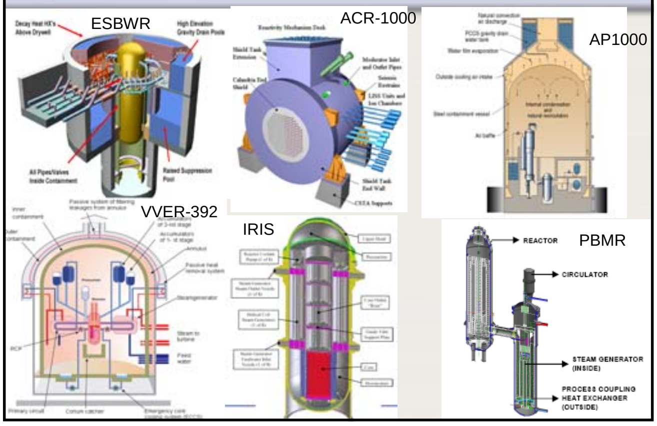
Various Designs for near-term deployment (Gen III+)



Fast neutron reactors

- ❑ Long history of development
- ❑ 4+ out of 6 systems in Gen-IV in 2030's: fast neutron reactors for effectively use of resources and burning long-life nuclides

France
- ✓ Tests of transmutation of long lived nuclides & use of Pu fuels at Phénix
- ✓ Design of 300-600 MWe Gen-V FR Prototype start operation in 2020
- ✓ R&D on GCFR

Japan
- ✓ MONJU restart planned for 2009
- ✓ R&D for Gen-V FR Systems: better economics by advanced systems and material

India
- ✓ 500 MWe Prototype FR in 2010
- ✓ Deploy 4 more 500 MWe FR afterward

Russia
- ✓ Operating BN-600
- ✓ Constructing BN-800
- ✓ Developing other cooled systems (Na, Pb, and Pb-Bi)

China
- ✓ Constructing 25 MWe CEFR criticality in 2009

Rep. of Korea
- ✓ Conceptual design of 600 MWe

USA
- ✓ In GNEP, planning development of industry-led prototype facilities:
  - ➢ Advanced Burner Reactor

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Trends in reactor designs for near-term deployment

- ❑ Designed considering "User requirements"
- ❑ Design considering 60 years life
- ❑ Design for maintenance – online or during outage
- ❑ Design for easier & shorter construction
- ❑ Use modern technologies
  - digital control, modern man-machine interface,
- ❑ Simplicity by reducing Nr. & rotating components
  - passive systems (gravity, natural circulation, accumulated pressure etc.)
- ❑ Build safety into the design
  - increased margins
  - severe accident measures
- ❑ Complete and standardized designs with pre-licensing

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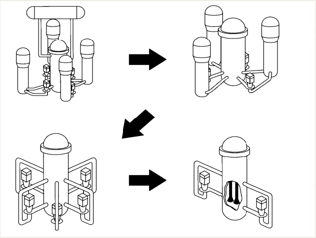
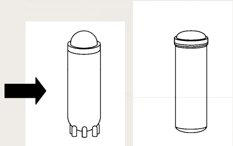
Simplicity - Evolution in case of BWR system-





Current or Generation 1 & 2 → Generation 3 & 3+

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Shorter construction period

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Modern man-machine interface

Old Control Rooms

Modern Control Room
- Large mimic display
- Trend display
- Operating console with touch screen
- Other ergonomic considerations

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SMR (Small and Medium-sized Reactor)

- **IAEA Definition**
  Small sized reactor: up to 300 MWe
  Medium sized reactor: 300-700 MWe
- **IAEA observation**

1. History of pursuit of economics of scale
2. Continued deployment of SMR (India)
3. (25 +108)/438 as of 2008/E
4. Current interest in Member States;
   - Developing countries: ***For use in a small grid***
   - Existing nuclear power countries : ***For local solution***
     (power source at isolated area, multi-purpose energy source)
   - Potentially in deregulated and unbundled electricity business environment : ***For incremental investment to avoid financial risk***

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SMR - challenges

- Development of regulatory standards for innovative designs
  - Claim for no-containment, no Emergency PZ due to "inherent safety"
- Economic competitiveness by innovation/learning
  Economic advantages of SMRs derived from
  - Multiple modules (common to all SMRs)
  - Passive safety : saving capital, O&M
  - Simplicity
- Technology
  - Without onsite refueling for small reactor by use of very long life core
- Institutional
  - non-stationary reactor

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Grid-appropriate design

- Historical evolution by preference to *large size*, because NPP (nuclear power plant) is capital intensive but fuel cost is small
  - large size unit operated in base load
- **NPP's Influence on grid** **:**Sudden disconnection of a large scale NPP from the grid (reactor trip) creates serious disturbance to the connected grid
  - Frequency change allowance 0.2-0.5Hz depending on the characteristics (load shedding capability, customer etc)
    → Maximum size of one unit < 5-10% of the grid size as first order approximation (though depends highly on specific conditions)
- **Grid Influence on reactor**: Reliability/quality of the grid influences transient/safety of NPP.
  - Frequency drop→ reduced coolant flow → change in power
  - Isolation from grid →Reactor transient & Potential safety issue if emergency power supply does not come in

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Global trend of nuclear power generation

- **Current worldwide nuclear generating capacity**
  - ✓Commercial NPPs in Operation **438** (2008/End)
  - ✓Share of nuclear electricity **14-15%** (2008, no statistics yet)
- **Slowdown of capacity addition since late 80's**
  - ✓Electricity market deregulation
  - ✓Slow growth of electricity demand in advanced countries
  - ✓Public Perception
- **Nuclear electricity increased due to availability increase**
  - ✓ Best practice prevailing
  - ✓ Consolidation to those who perform best
  - ✓ Risk-informed regulation
  - ✓ Continued operation by life extension
- **Rising expectation to the role of nuclear power**
  - 1)energy supply security, 2)volatile fossil price, 3)environment

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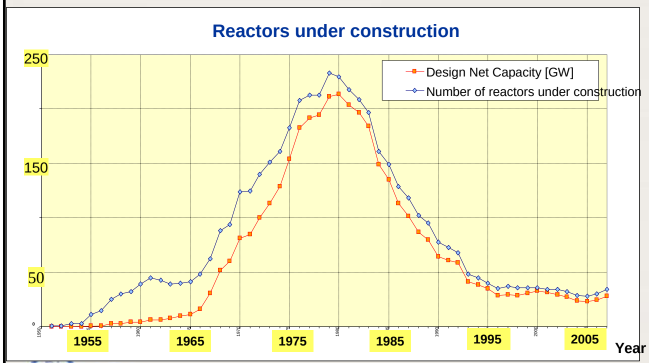

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Challenges of expansion

1. Safety and reliability
2. Economic competitiveness and financing
3. Public acceptance
4. Uranium resources
5. Fuel and waste management
6. Human and industrial resources
7. Proliferation risk and security
8. Infrastructures, especially in new countries

Phased approach using Milestones for infrastructure building

Declaration of interest in nuclear as an option
ENEGY PLANNING

Phase 1: 1-3 years
Development of knowledge of commitment/obligation & Assessment
viability of NP, national capability, what needs to be done
Milestone 1 Formal Intention To Implement Nuclear Power Program

Phase 2: 3-7 years
Start implementation of INFRASTRUCTURE BUILDING PLAN
Milestone 2 Invitation To Bids Issued

Phase 3: 4-6 years
First Project Contract Signed
CONSTRUCTION of the FIRST NPP
Milestone 3 Ready for Criticality and Operational Testing

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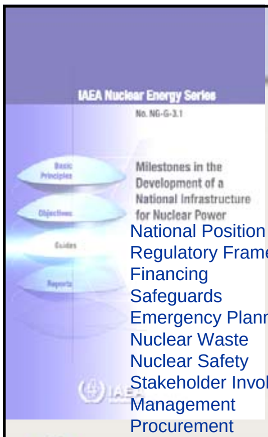
Milestone document



Clarifies:
- 19 major issues to consider
- Conditions to achieve the milestone for each issues

For use in self-assessment

National Position
Regulatory Framework
Financing
Safeguards
Emergency Planning
Nuclear Waste
Nuclear Safety
Stakeholder Involvement
Management
Procurement

Legal Framework
Radiation Protection
Human Resource Development
Security and Physical Protection
Nuclear Fuel Cycle
Environmental Protection
Sites & Supporting Facilities
Electrical Grid
Industrial Involvement

(Nuclear Energy Series NG-G-3.1)

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…Thank you for your attention

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