Generation IV Reactors

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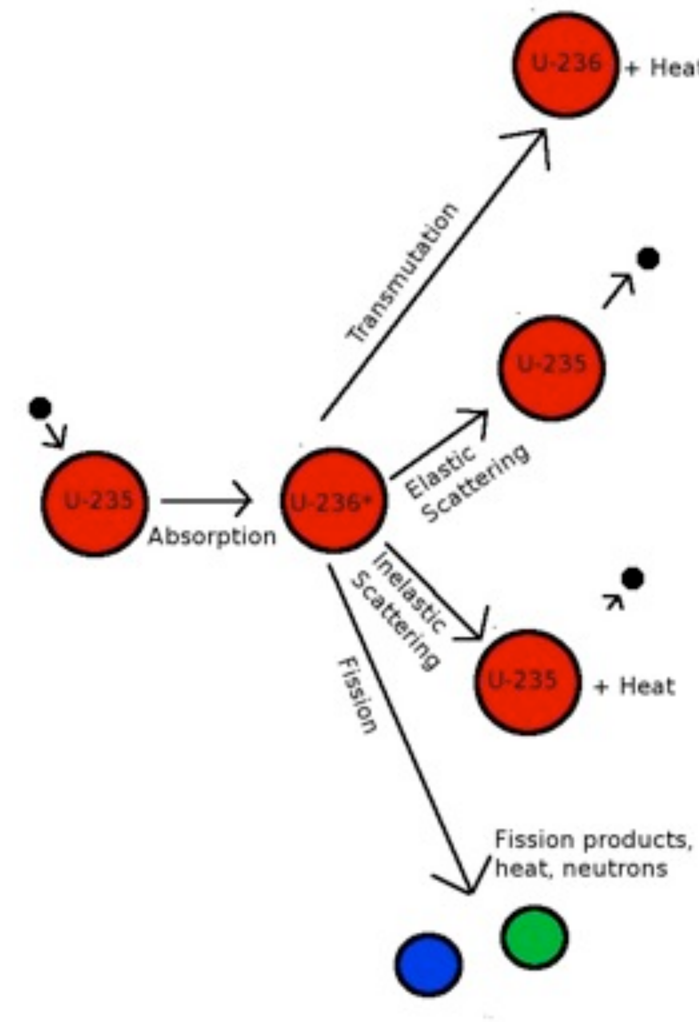
Outline

- Review and answering questions
- Nuclear waste
- Isotopic separation
- Chemical separation
- Plutonium
- Fuel predictions
- Gen IV reactors

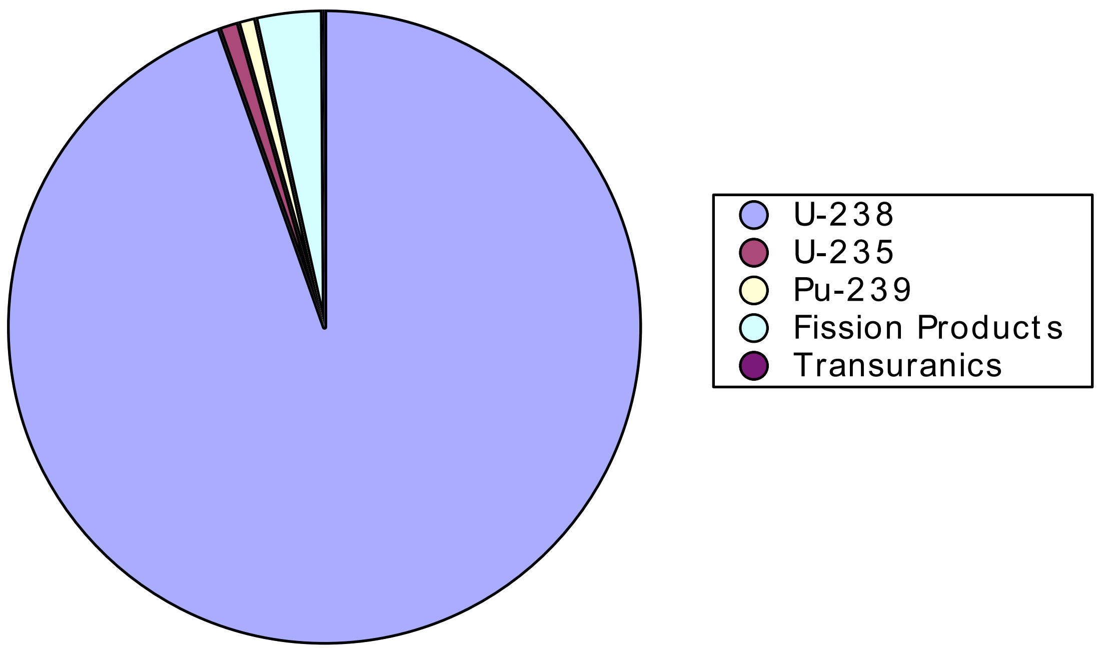
Recap

- Values for Uranium 235 (0.025 eV):
- Fire a neutron beam at a single atom (1/s)
- Wait ~50 hours for at least one fission
- Wait ~5 hours for scattering

Source: http://canteach.candu.org/library/20041801.pdf



Nuclear Waste

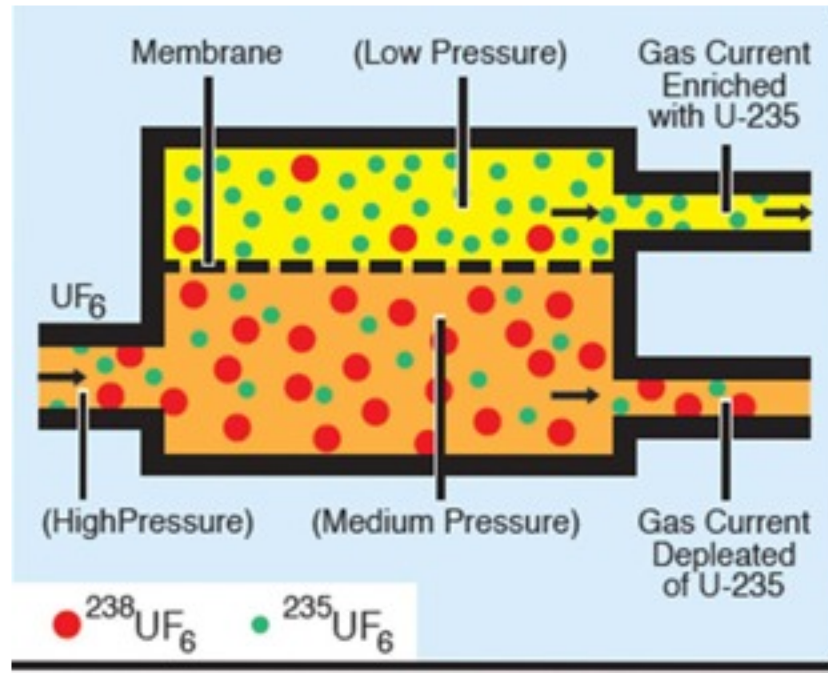


- ~1% U-235, Pu-239 after burning
- 3.4% fission products (short lived isotopes heavier than tin)
- Fission products are strong gamma emitters (very dangerous)
- Waste generally contains all of this

Source: Sustainable Nuclear Power. Suppes, Galen; Storvick, Truman.

Isotopic Separation

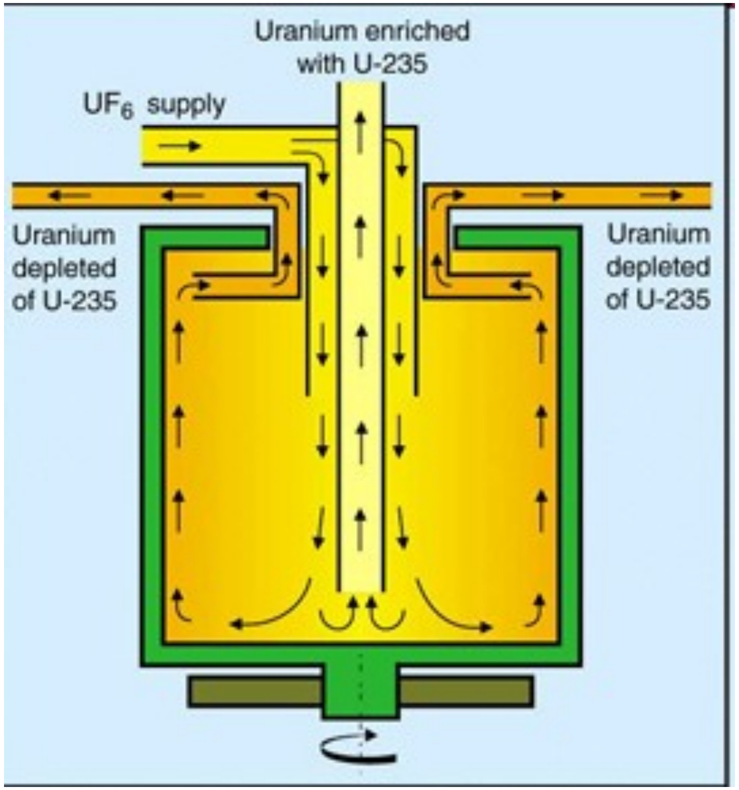
- Isotopic separation is hard (near identical chemical properties)
- Oakridge took two years and 1/7th US electricity to produce 64 kg for Little Boy
- Gaseous diffusion



Source: www.chemcases.com/images/8-fig.%201crop.jpg

Centrifuge

- Gaseous Diffusion uses 2400 kWh/SWU (4%)
- Centrifuge uses 60 kWh/SWU (0.1%)
- Laser separation is 3 times more efficient
- SWU (separative work unit)
- 100,000-120,000 SWU are needed to fuel a GW plant



Source: www.euronuclear.org/.../images/gascentrifuge.jpg

http://www.globalsecurity.org/wmd/intro/u-centrifuge.htm

Chemical Separation

- Takes advantage of solubility differences
- Formation of salts
- Aqueous/organic extraction
- Repetition leads to high purity

Plutonium

$$^{238}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \longrightarrow ^{239}_{92}\mathrm{U} \xrightarrow[23.5\ \mathrm{min}]{\beta^-} ^{239}_{93}\mathrm{Np} \xrightarrow[2.3565\ \mathrm{d}]{\beta^-} ^{239}_{94}\mathrm{Pu}$$

- Plutonium is a potential bomb material
- Plutonium is relatively safe to handle (alpha emitter)
- Fission products prevent proliferation from waste
- Plutonium can be chemically separated from uranium
- Fission products cause premature reaction
- Constantly produced in reactors

Fuel Reserves

Table 1. Ratios of uranium resources to present (2006) annual consumption, for different categories of resources, showing the impact of recycling in fast neutron reactors (in years)

	Known conventional resources	Total conventional resources	With unconventional resources
With present reactor technology	100	300	700
With recycling using fast neutron reactors	> 3 000	> 9 000	> 21 000

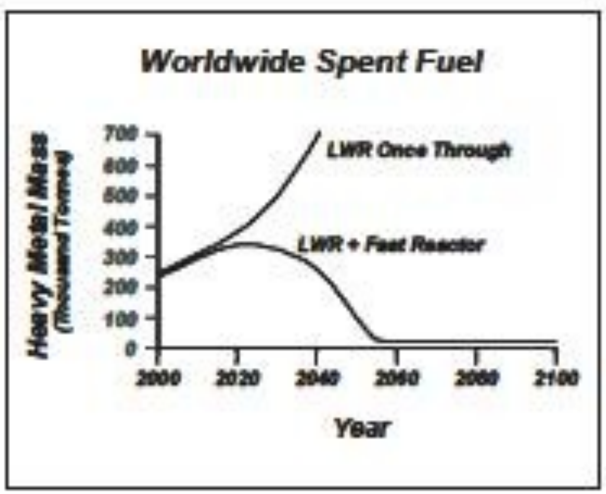
Source: *Nuclear Energy Outlook*, OECD Nuclear Energy Agency, 2008.

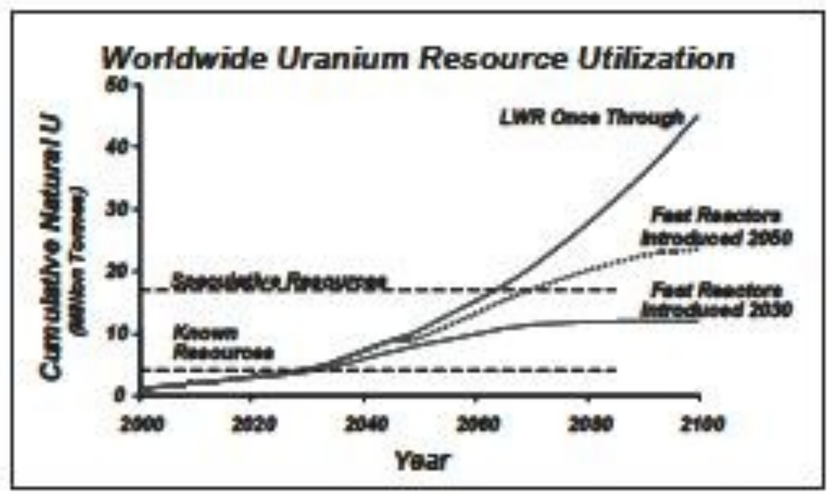
- Most economic uranium ores are simple oxides (pitchblende)
- Unconventional sources (phosphate rocks): (UOx) in fluorite
- Current consumption exceeds supply
- Recycling MUST occur

NEA Study (2009) - http://www.nea.fr/html/general/press/in-perspective/addressing-climate-change.pdf

Future Reactors

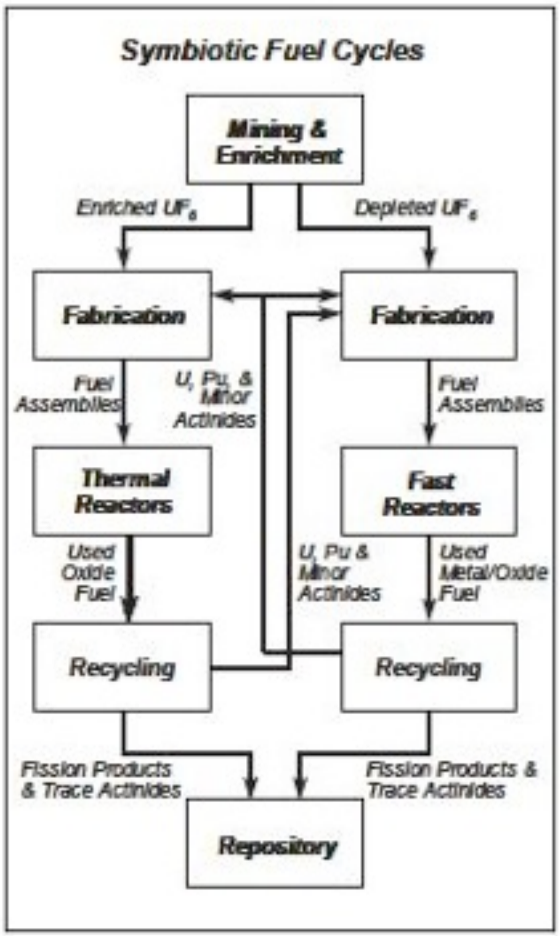
- Most commercial reactors are Gen II (PWR, CANDU)
- Gen IV will likely be ready by 2020
- These reactors will feature more recycling or higher utilization of once through fuel
- Reduces waste
- Decreases fuel requirements





Source: DOE: A Technology Roadmap for Generation IV Nuclear Energy Systems (DOE)

Two Types of Reactors

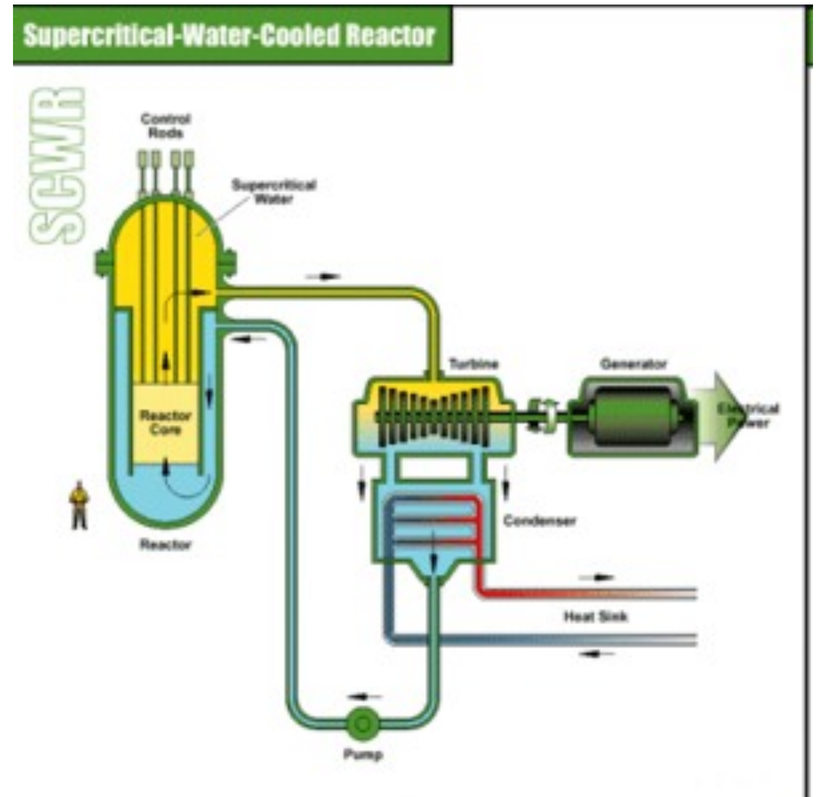


- Thermal reactors consume more fissile fuel than they use
- Fast reactors (breeders) produce fissile material from fertile U-238
- Fast reactors do not use a moderator to slow neutrons (thus large surplus for transmutation)

Source: DOE: A Technology Roadmap for Generation IV Nuclear Energy Systems (DOE)

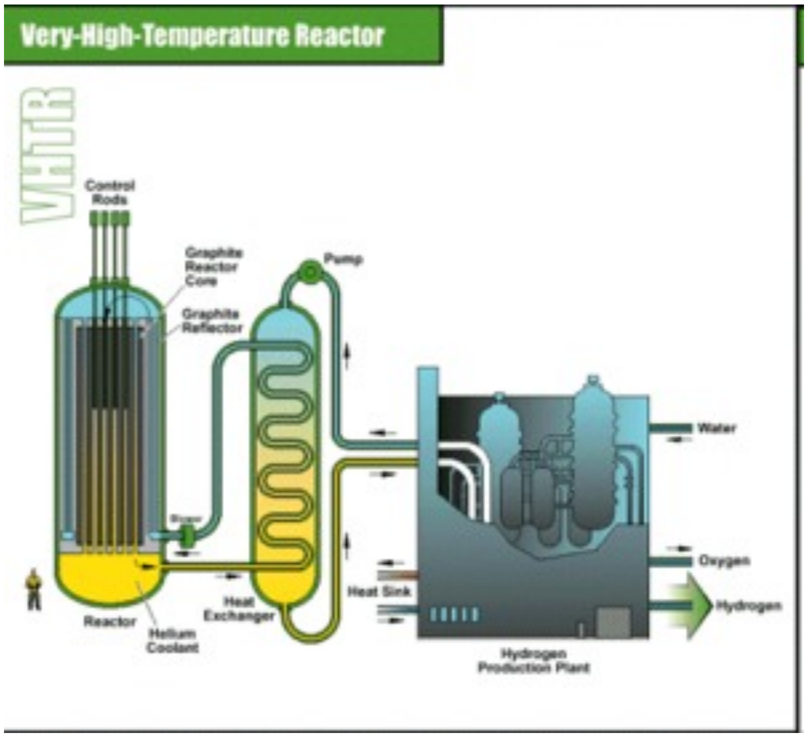
Supercritical Water Reactor

- Combines two proven technologies
- Light water reactor
- Supercritical water is working fluid
- Higher thermal efficiency (45%)
- Could use thermal or fast neutrons
- Deployed by 2025



Source: http://nuclear.inl.gov/gen4/scwr.shtml

Very High Temperature Reactor

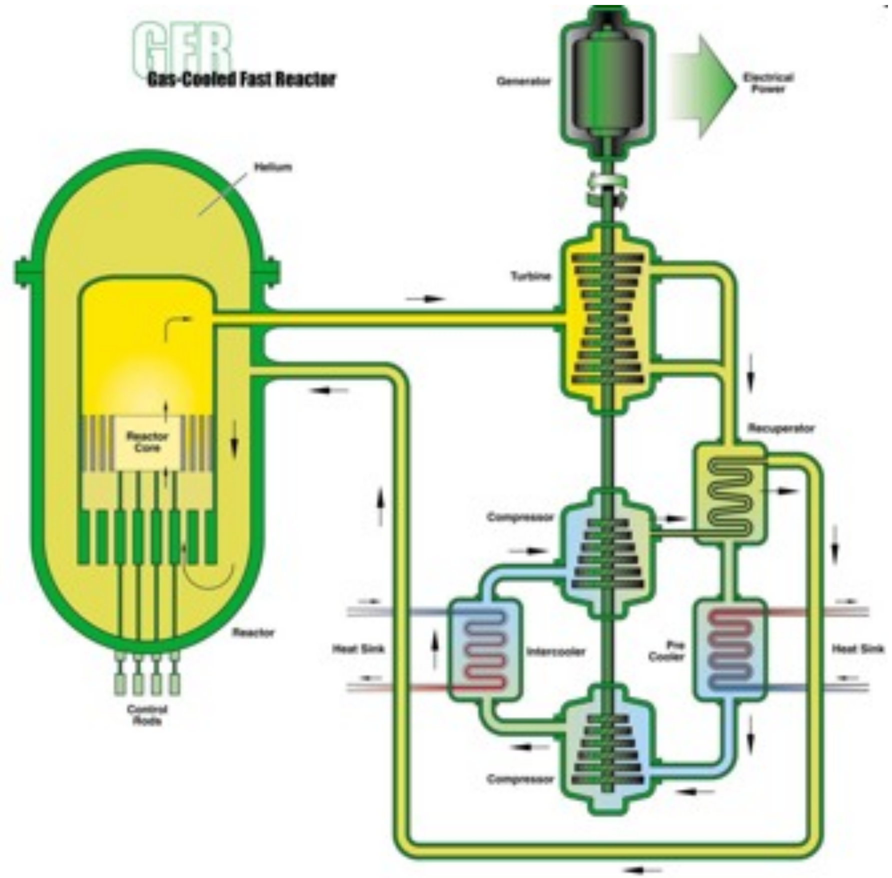


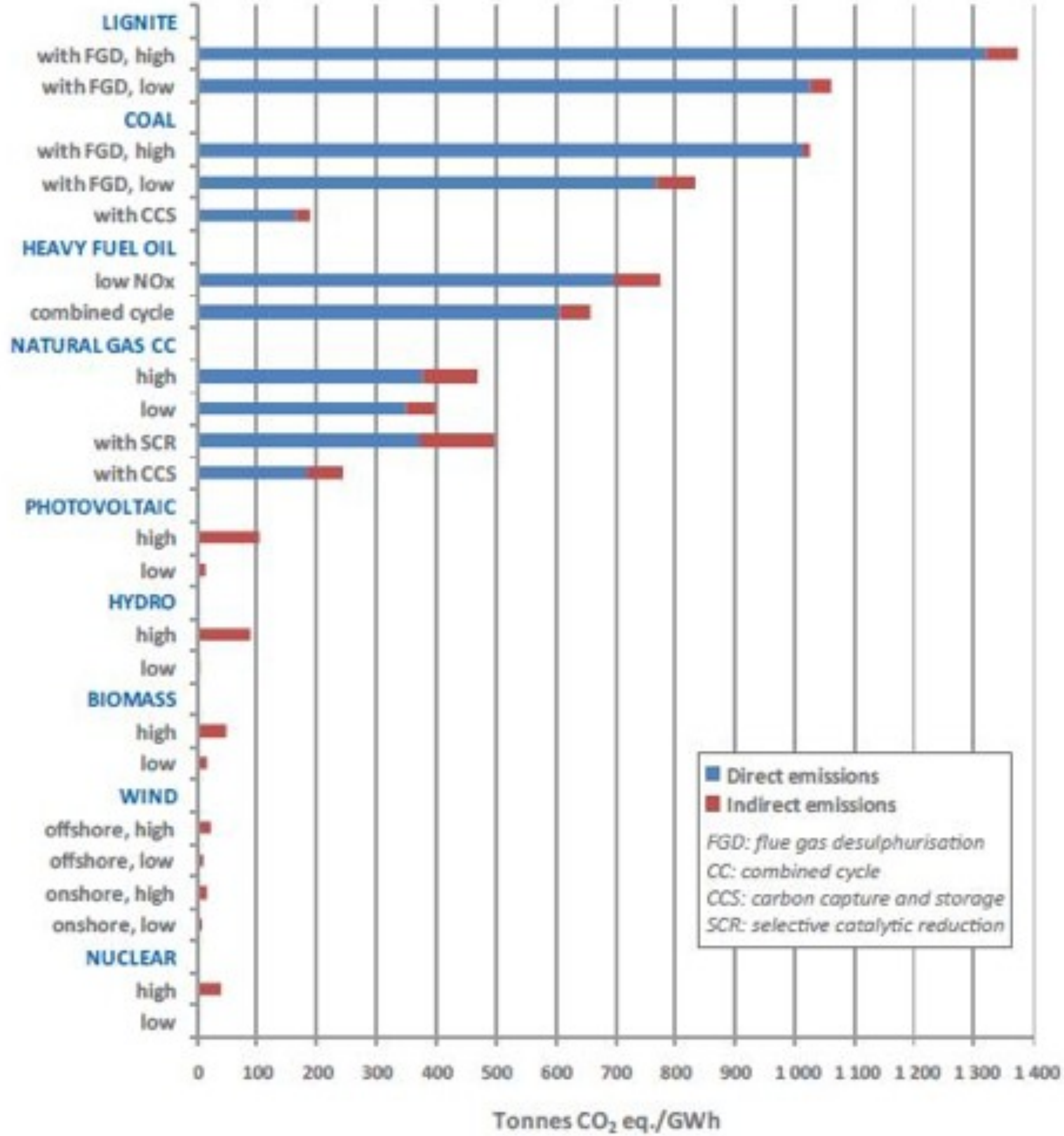
- Thermal neutrons, once through fuel
- Pebble bed reactor
- Produces heat for industrial processes
- Could be used for coal gasification or thermochemical hydrogen
- Deployable by 2020

Source: DOE: A Technology Roadmap for Generation IV Nuclear Energy Systems (DOE)

Gas-Cooled Fast Reactor

- Fast neutron, high burn
- Helium cooled (low cross section
- Fuel could be removed and recycled
- Electricity production
- Deployed by 2025





Source: *Mitigation of Climate Change*, Intergovernmental Panel on Climate Change, 2007.