

NUCLEAR FISSION SUSTAINABILITY WITH HYBRID NUCLEAR CYCLES

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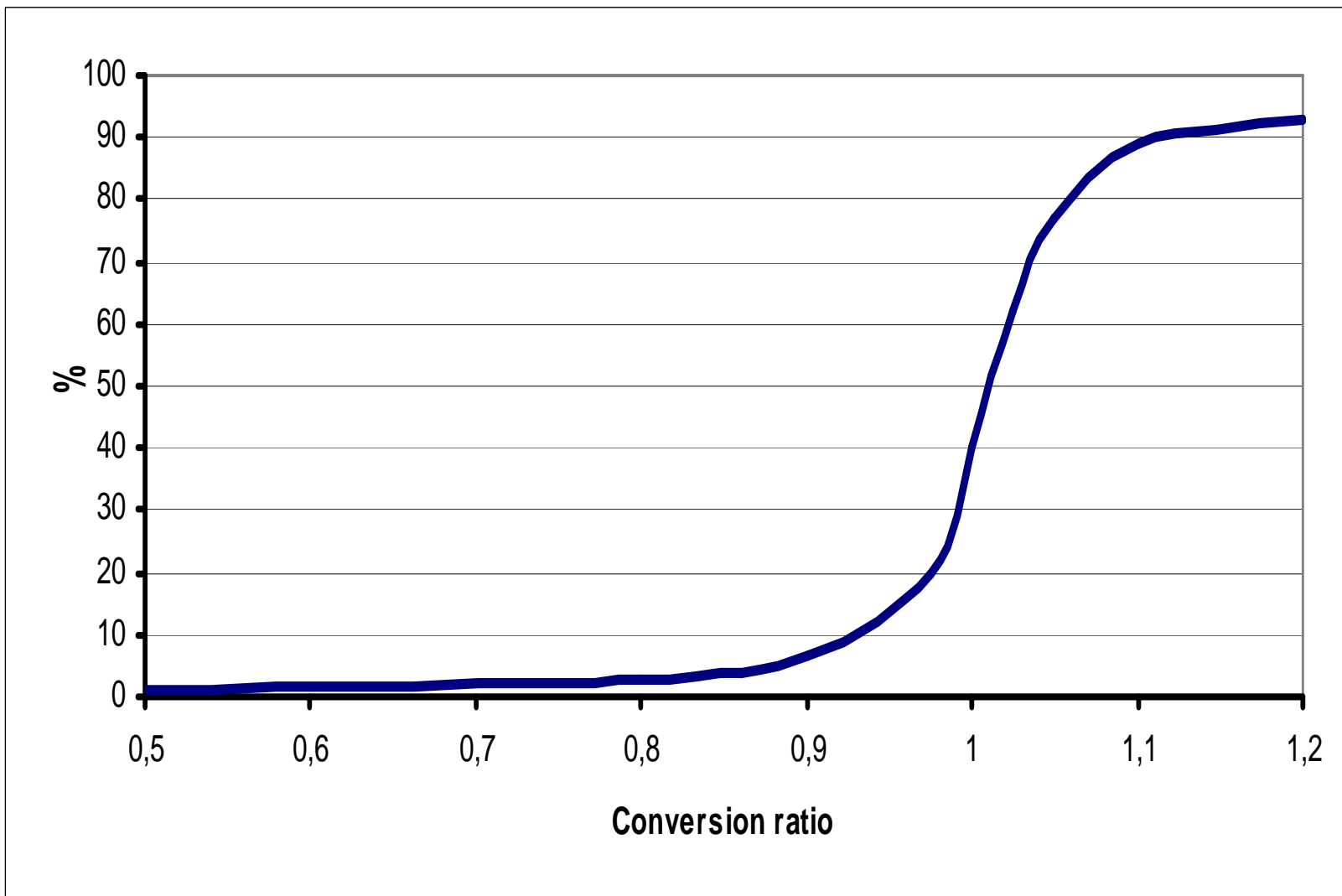
NUCLEAR FISSION SUSTAINABILITY

Non-proliferation

Operational safety of nuclear installations

Minimization of nuclear wastes

Efficient use of nuclear fission raw materials

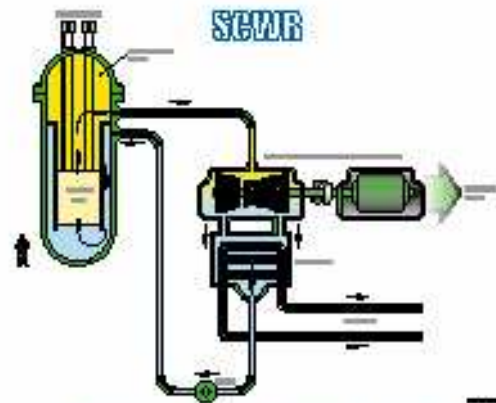


The need for nuclear breeding

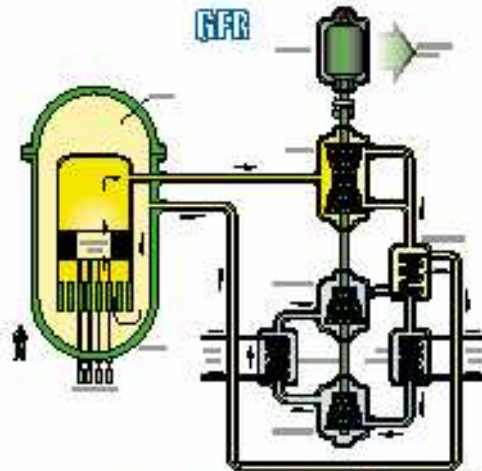
- Fast spectrum (properly tailored)
- Reactivity/stability problems: Doppler eff.
- LMFBR: + void reactivity coefficient?
- Chernobyl-type power trip
- Gas-cooled FBR: difficulties for Emergency cooling,
- and + reactivity by water ingress



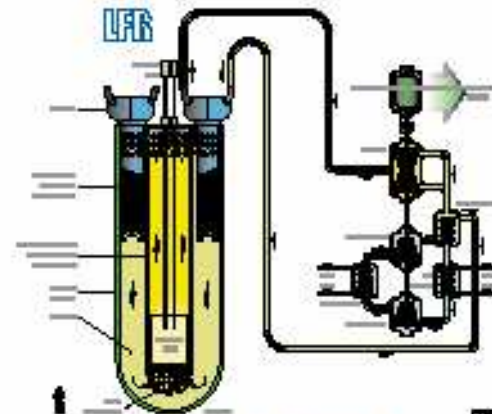
The next generation of nuclear reactors



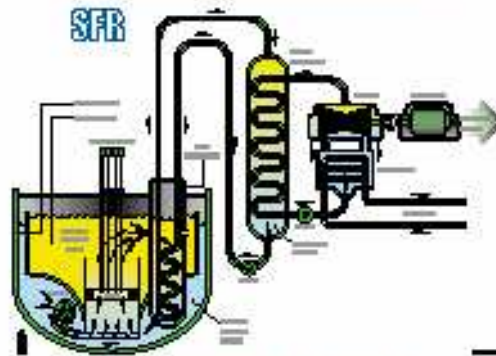
Supercritical-water-cooled reactor



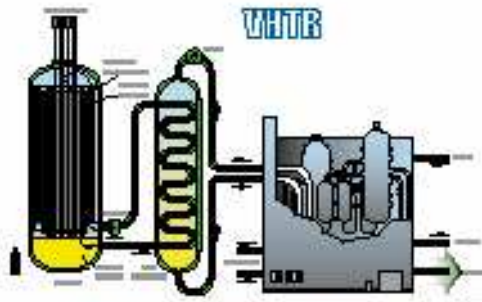
Gas-cooled fast reactor



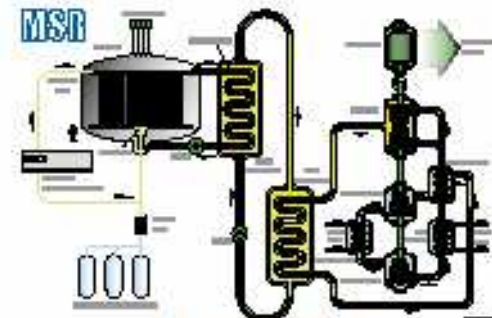
Lead-cooled fast reactor



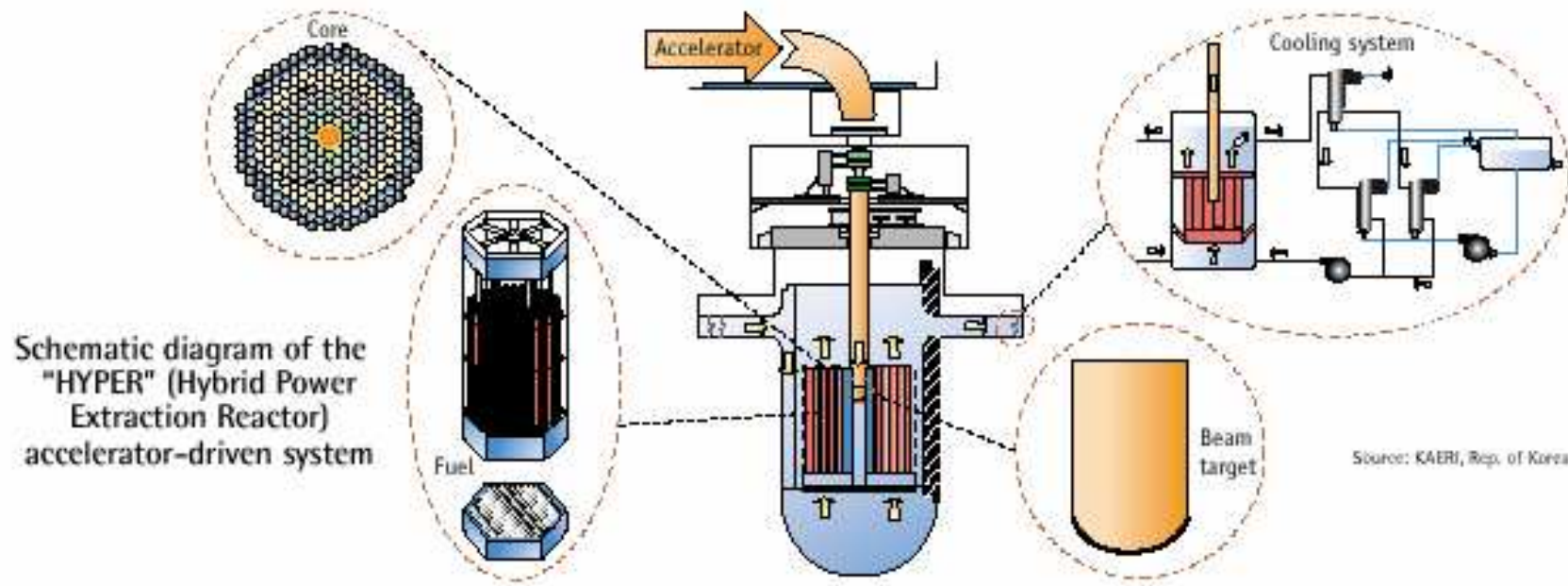
Sodium-cooled fast reactor



Very-high-temperature reactor



Molten salt reactor

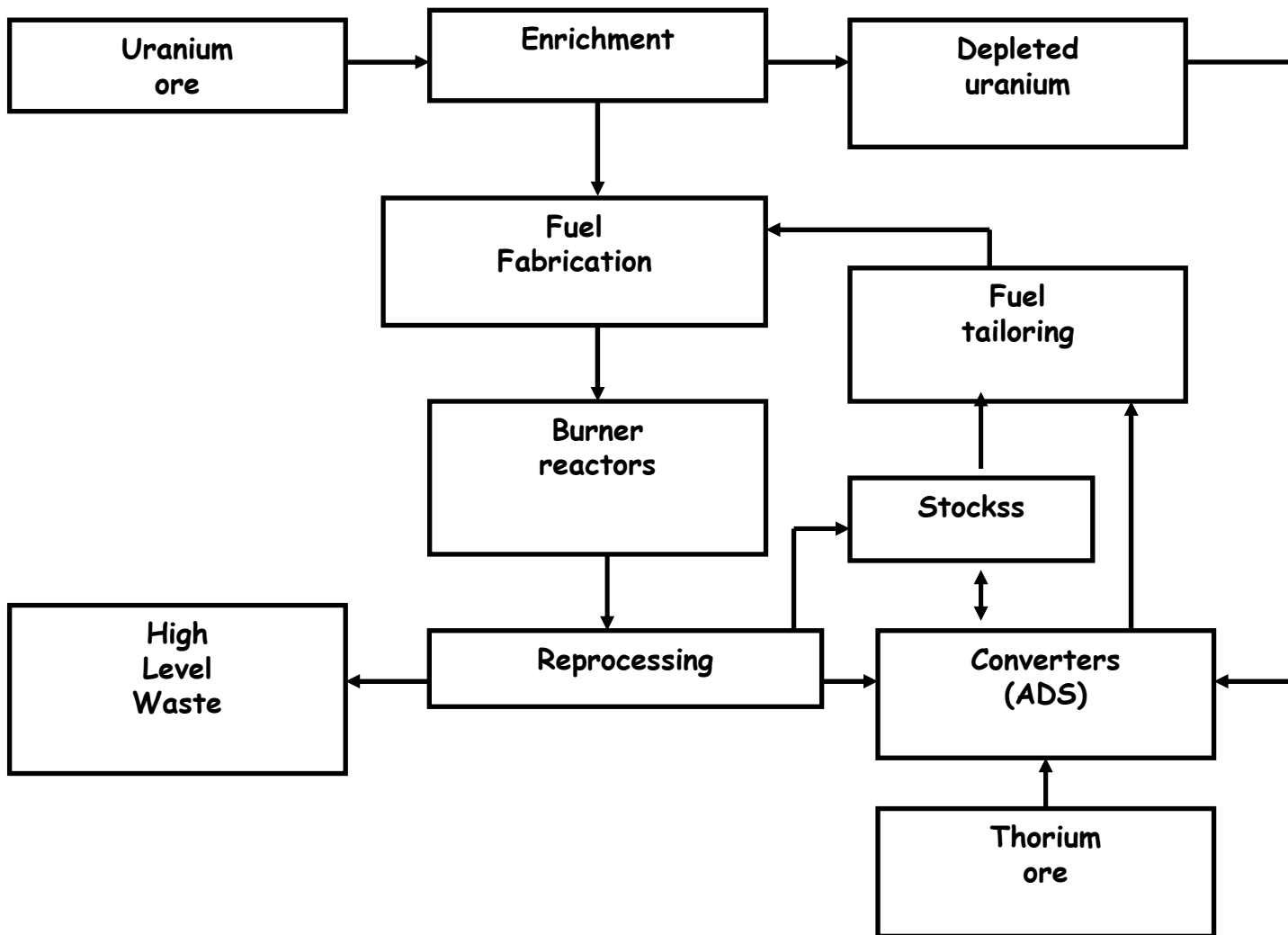


Schematic diagram of the "HYPER" (Hybrid Power Extraction Reactor) accelerator-driven system

Source: KAERI, Rep. of Korea

Nuclear hybrid cycles: synergism

- Good safety features of LWR, but very poor fertile conversion (0.5% of effective use)
- Subcritical systems: an additional degree of freedom to tailor the spectrum
- Sodium void worth lower than subcriticality
- Reduced power densities in subcritical systems not intended to generate energy at high T; intended to breed fissile fuels



Neutronic characterization of a hybrid reactor

$$E = \frac{P}{U}$$

$$z + \frac{\eta'}{\nu'} \leq 1$$

$$T = \zeta \frac{\psi^*}{1 - k}$$

$$w = \frac{\sigma_{cU}}{\sigma_{aP}} = EB$$

$$K = \eta' x$$

$$B \geq \frac{z}{1 - z}$$

$$E^* = w$$

Fissile production (breeding)

$$\epsilon = \frac{\zeta \psi^*}{1 - \eta' x} z x$$

$$\epsilon \approx \frac{\zeta \psi^*}{1 - v'(1 - z)x} z x$$

Neutron subcritical multiplication

$$\gamma = \frac{Q_f}{Q_s} \zeta \frac{\psi^*}{v} \frac{k}{1 - k} \frac{1 + \frac{Q_{n,2n}}{Q_f} \frac{\Sigma_{n,2n}}{\Sigma_f} + \frac{Q_{n,3n}}{Q_f} \frac{\Sigma_{n,3n}}{\Sigma_f} + \frac{Q_c}{Q_f} \frac{\Sigma_c}{\Sigma_f}}{1 + \frac{2}{v} \frac{\Sigma_{n,2n}}{\Sigma_f} + \frac{3}{v} \frac{\Sigma_{n,3n}}{\Sigma_f}} + 1$$

$$\gamma = \zeta \frac{\psi^*}{v} \frac{\eta' x}{1 - \eta' x} \frac{Q_f}{Q_s} + 1$$

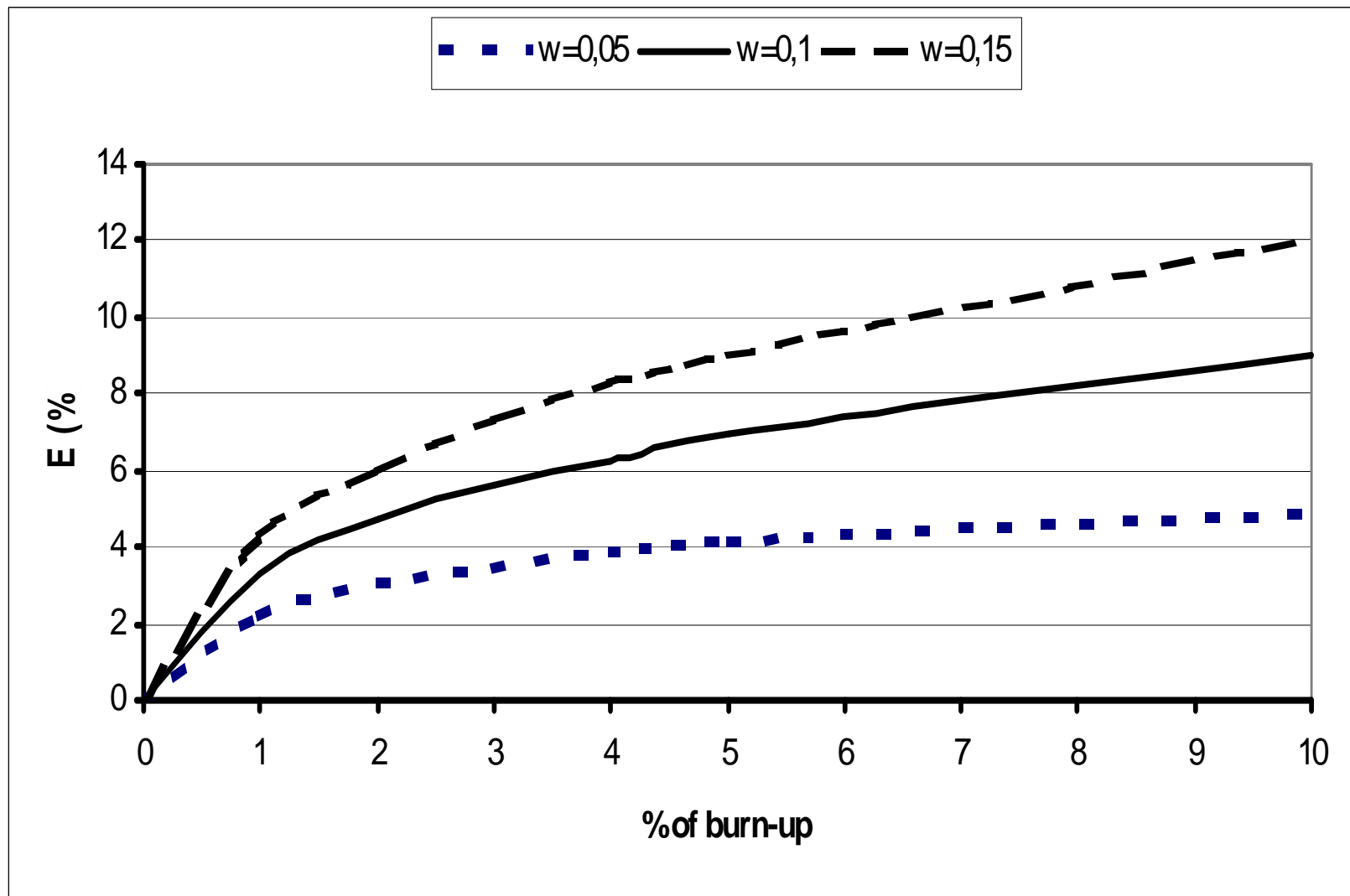
Effective fissile production

$$S = \frac{Q_f \varepsilon}{Q_s \gamma} = \frac{\xi \psi^* z x v' Q_f}{\xi \psi^* k Q_f + v'(1-k)Q_s}$$

$$S = \frac{z v'}{\eta'} \quad z = 1 - \frac{\eta'}{v'}$$

$$S = \frac{v' - \eta'}{\eta'}$$

For a fast spectrum subcritical blanket, one can have $v'=3$ and $\eta'=1$. This means that S will be close to 2.



The proposal is based on using LWR for electricity generation (as burner reactors) and subcritical hybrid blankets, driven by intense neutron sources, as breeders.

Those breeders would not be intended for energy production, so that safety standards could rely on very low values of the thermal magnitudes, so allowing for very large safety margins for emergency cooling

Similarly, subcriticality would offer a very large margin for not to reach prompt-criticality in any event.

The main drawback of this proposal is that a sizeable fraction of the energy generated in the cycle (about 1/3, maybe a little more) would not be converted to electricity

A fraction of the generated electricity, between 5 and 10 %, would have to be recirculated to feed the accelerator activating the neutron source

The overall result would be very positive, because more than 50 % of the natural resources could be exploited with such a cycle, using very safe reactors

An element for NUCLEAR FISSION SUSTAINABILITY