



Српска академија наука и уметности

**НАУЧНИ СКУП „УЛОГА НУКЛЕАРНЕ ЕНЕРГИЈЕ
У ЕНЕРГЕТСКОЈ ТРАНЗИЦИЈИ“**

Београд, 02.11.2020. године

**ТЕРМОЕЛЕКТРАНЕ НА НУКЛЕАРНА ГОРИВА
ЈУЧЕ, ДАНАС, СУТРА**

Миодраг Месаровић



TERMOELEKTRANA

**TOPLOTNA
ENERGIJA**



**MEHANIČKA
ENERGIJA**



**ELEKTRIČNA
ENERGIJA**

**SAGOREVANJE
GORIVA**

**NUKLEARNA
FISIJA/FUZIJA**

**SUNČEVO
ZRAČENJE**

**GEOTERMALNA
ENERGIJA**

RADNI MEDIJUM

TURBINA



НУКЛЕАРНА ТЕРМОЕЛЕКТРАНА

НУКЛЕАРНИ РЕАКТОР



The Carbon Intensity of Electricity Generation

All figures in g CO₂eq/kWh



Note: Data is the 50th percentile for each technology from a meta study of more than 50 papers

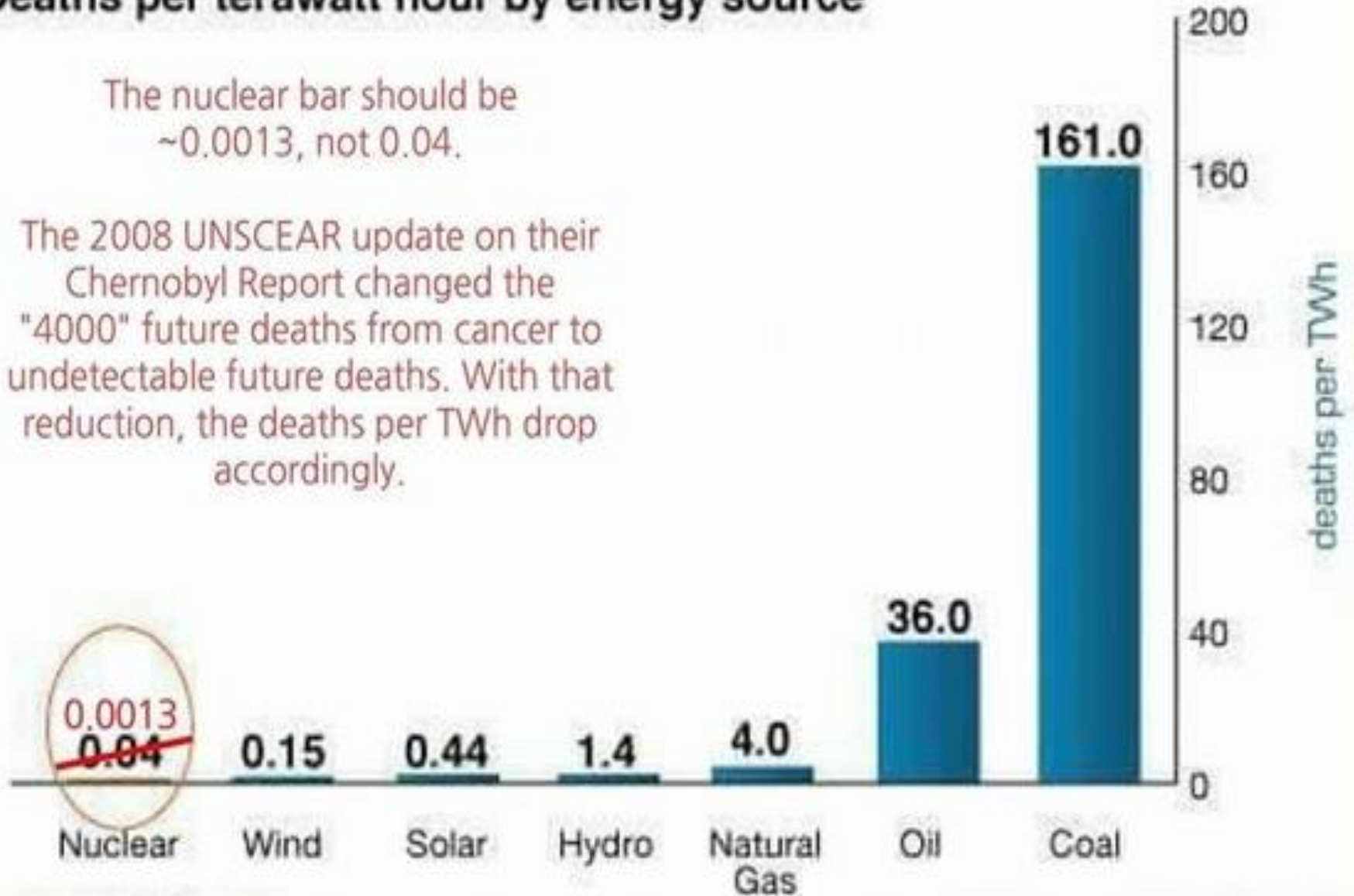
Source: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation

MORTALITET ZBOG UTICAJA IZVORA ENERGIJE

Deaths per terawatt hour by energy source

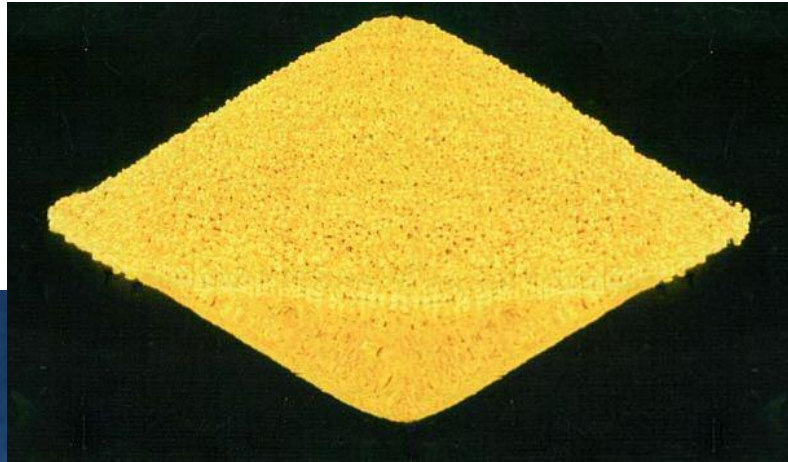
The nuclear bar should be
~0.0013, not 0.04.

The 2008 UNSCEAR update on their
Chernobyl Report changed the
"4000" future deaths from cancer to
undetectable future deaths. With that
reduction, the deaths per TWh drop
accordingly.



OD RUDE URANA DO GORIVA

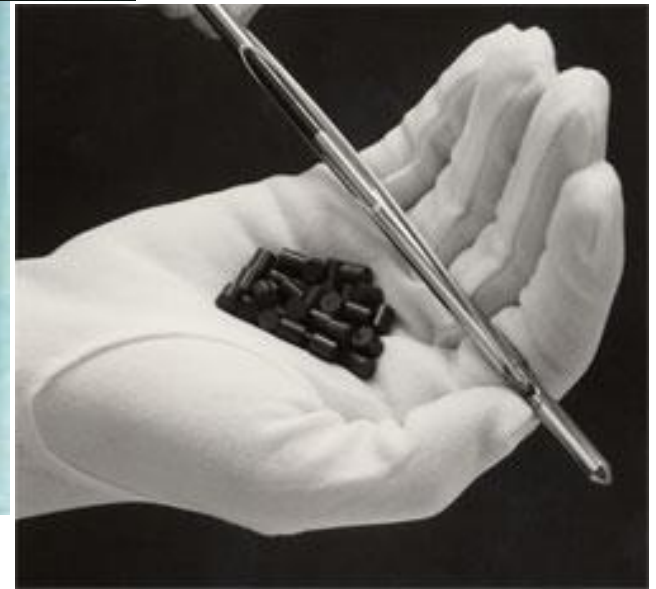
RUDA



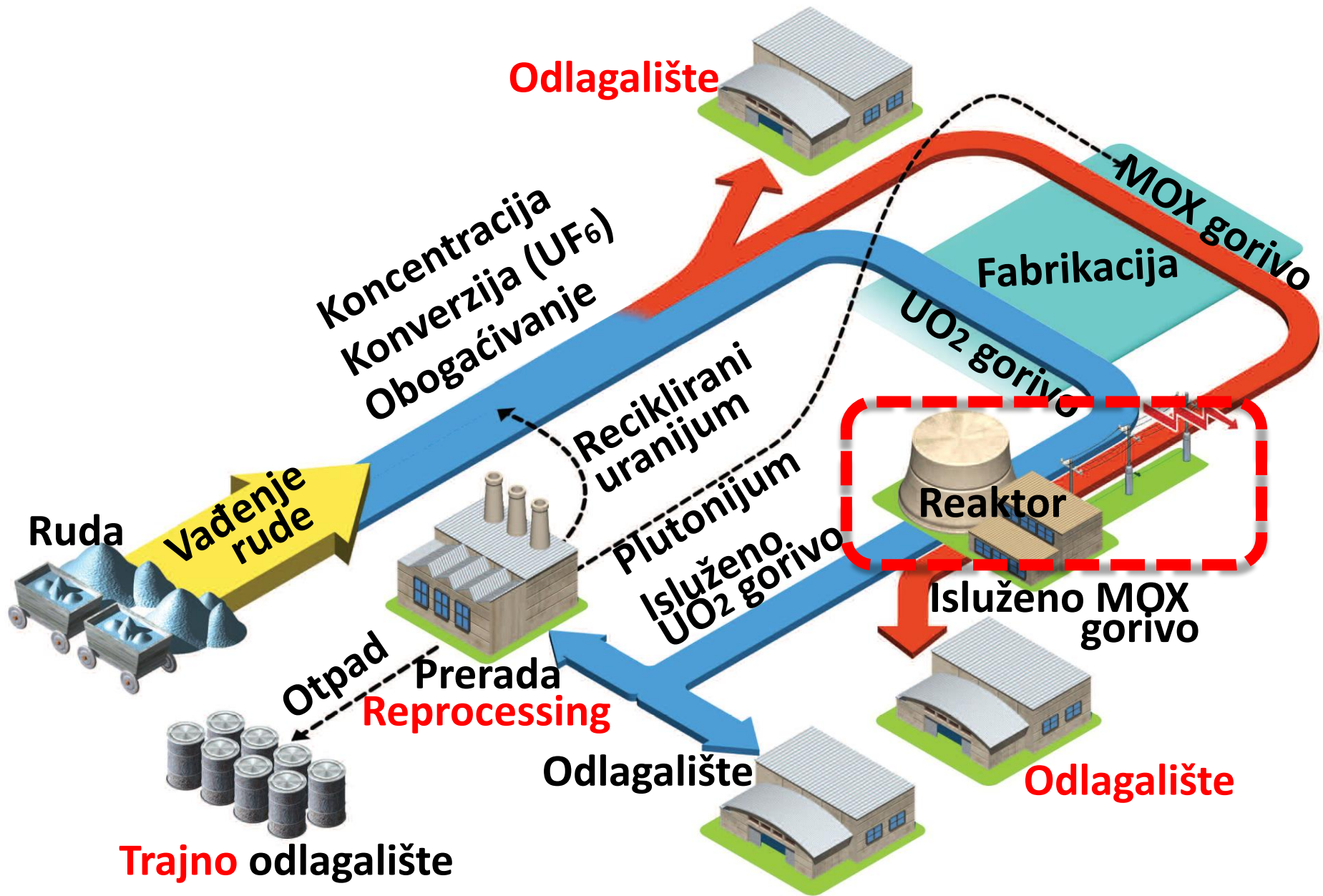
GORIVO



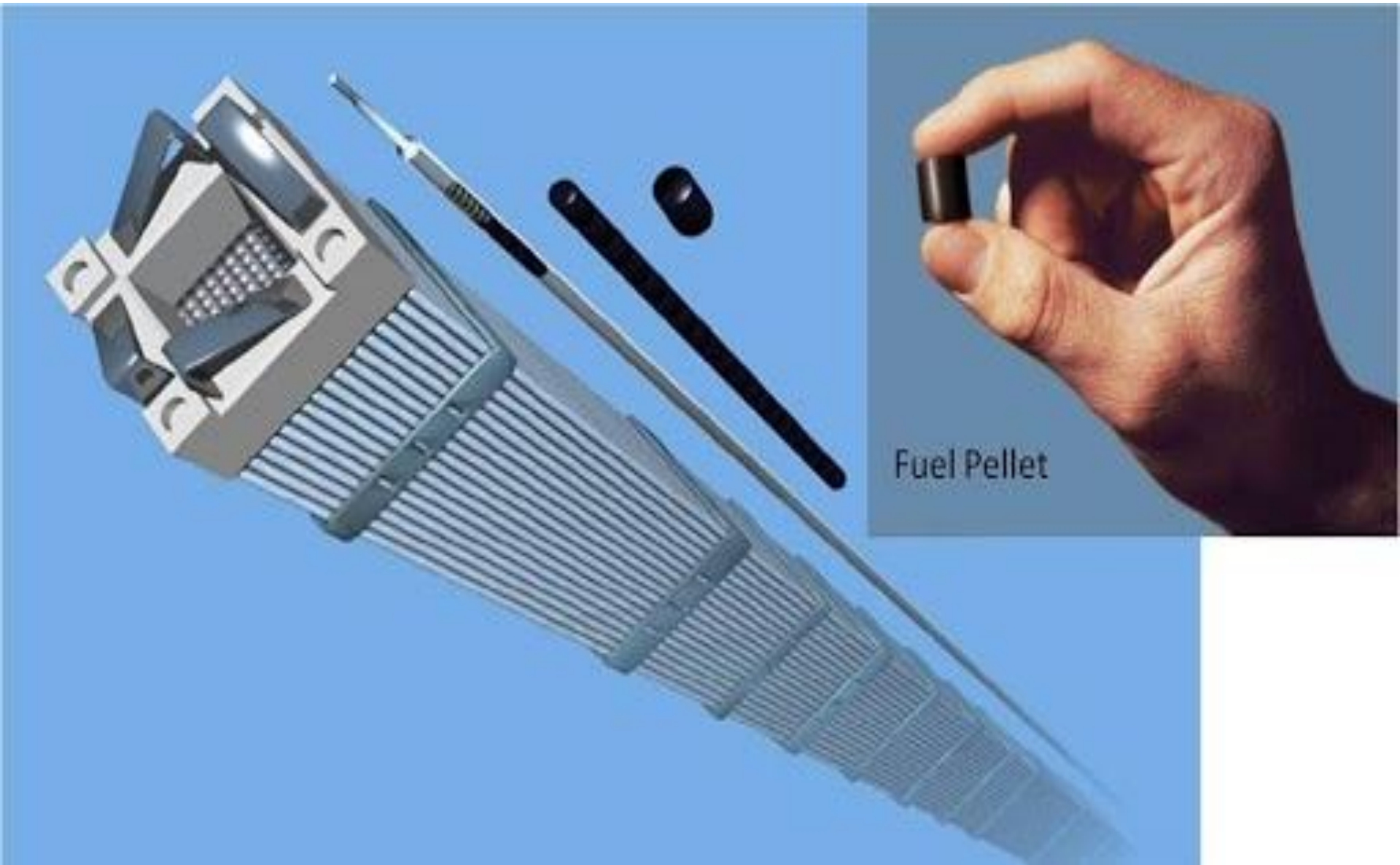
UF₆



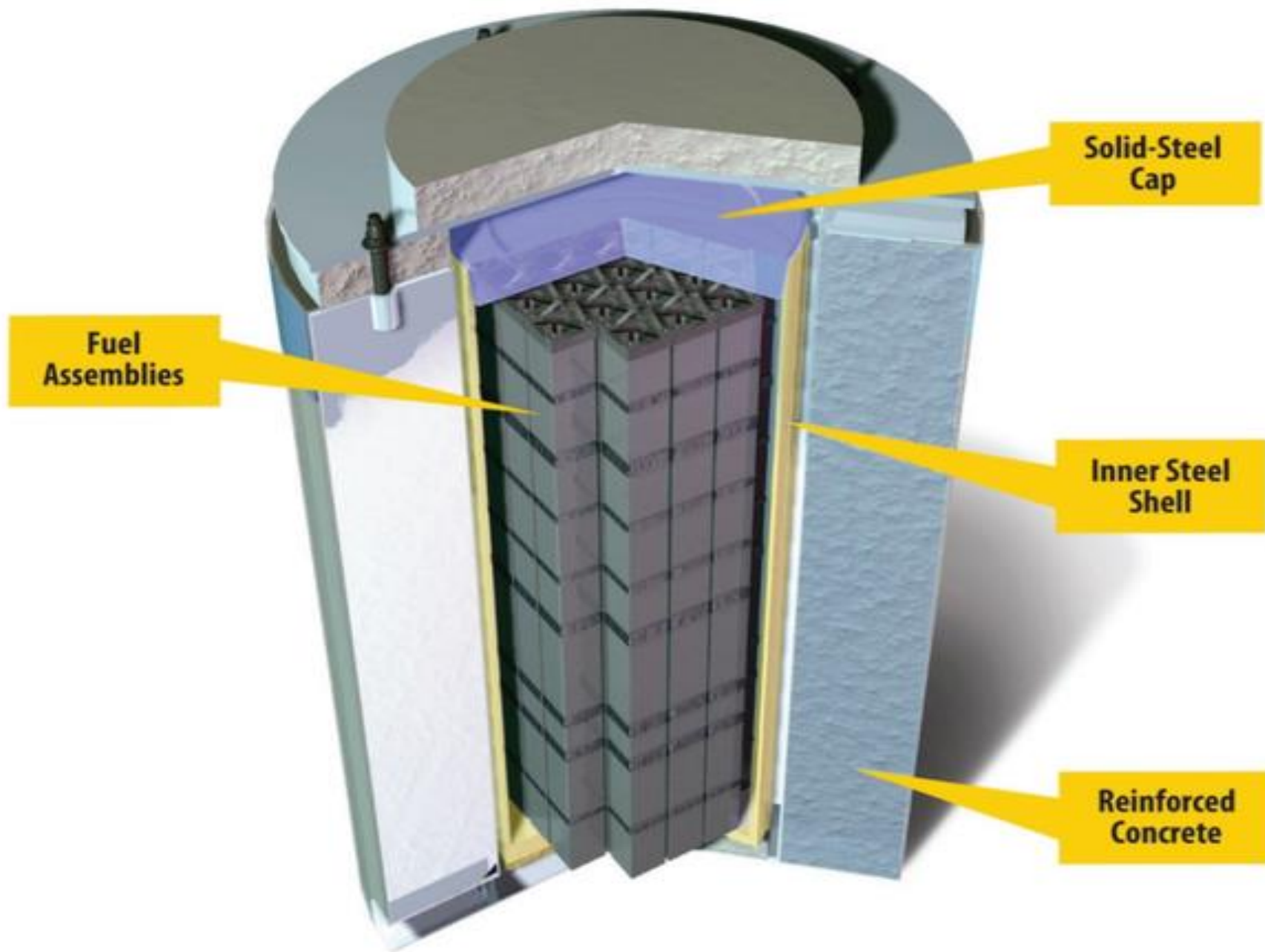
TIPIČAN NUKLEARNI GORIVNI CIKLUS



ГОРИВНИ ЕЛЕМЕНТ (СНОП)



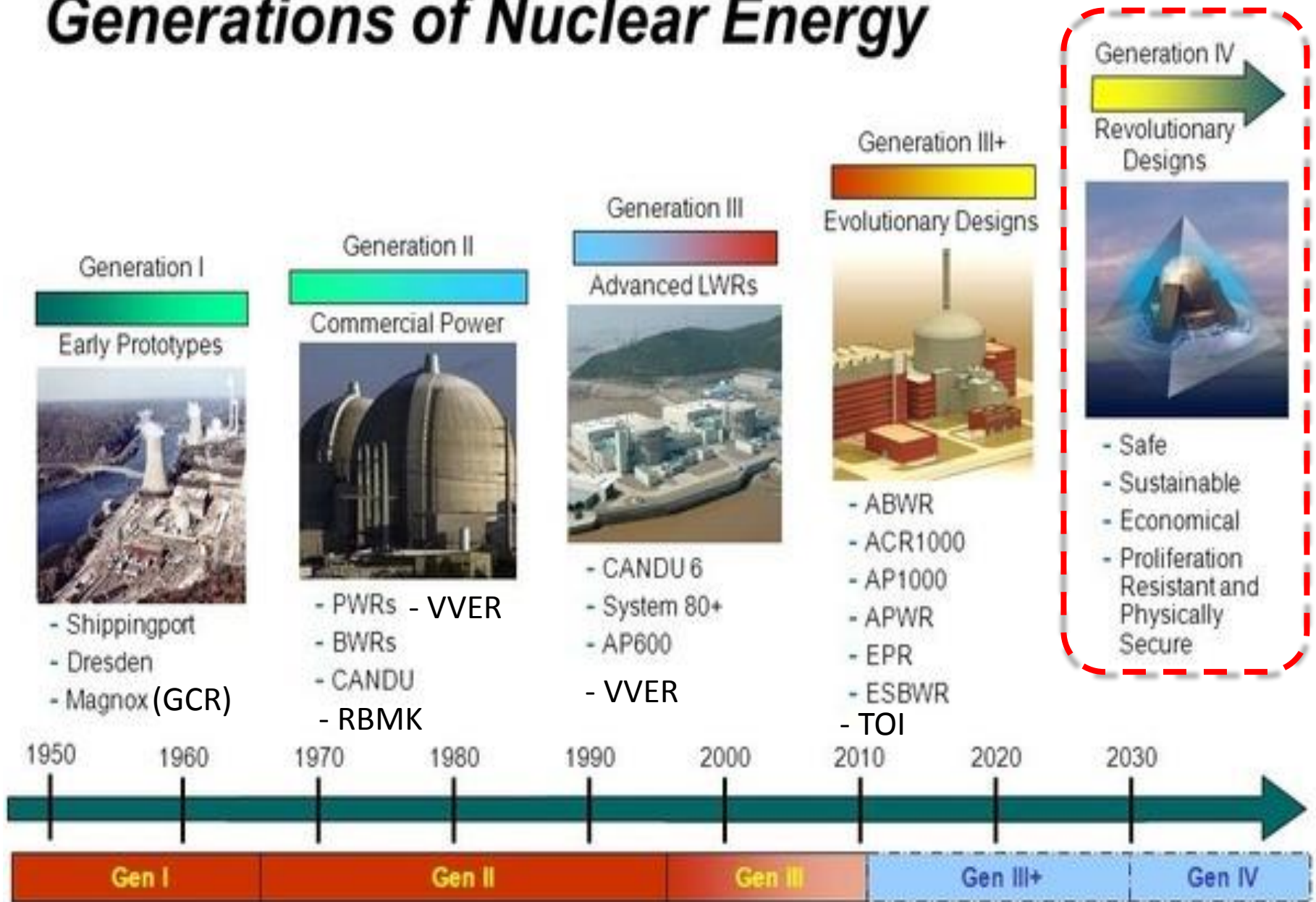
PRIPREMA ZA SUVO ODLAGALIŠTE



SUVO ODLAGALIŠTE ISLUŽENOG GORIVA



Generations of Nuclear Energy





PRVA NA MREŽI (1954.)

Обнинская АЭС

([Obninsk Atomic Energy Station](#)).

Атом Мирный 1

(Peaceful Atom 1) reactor

30 MWt

6(5) MWe

Tip RBMK



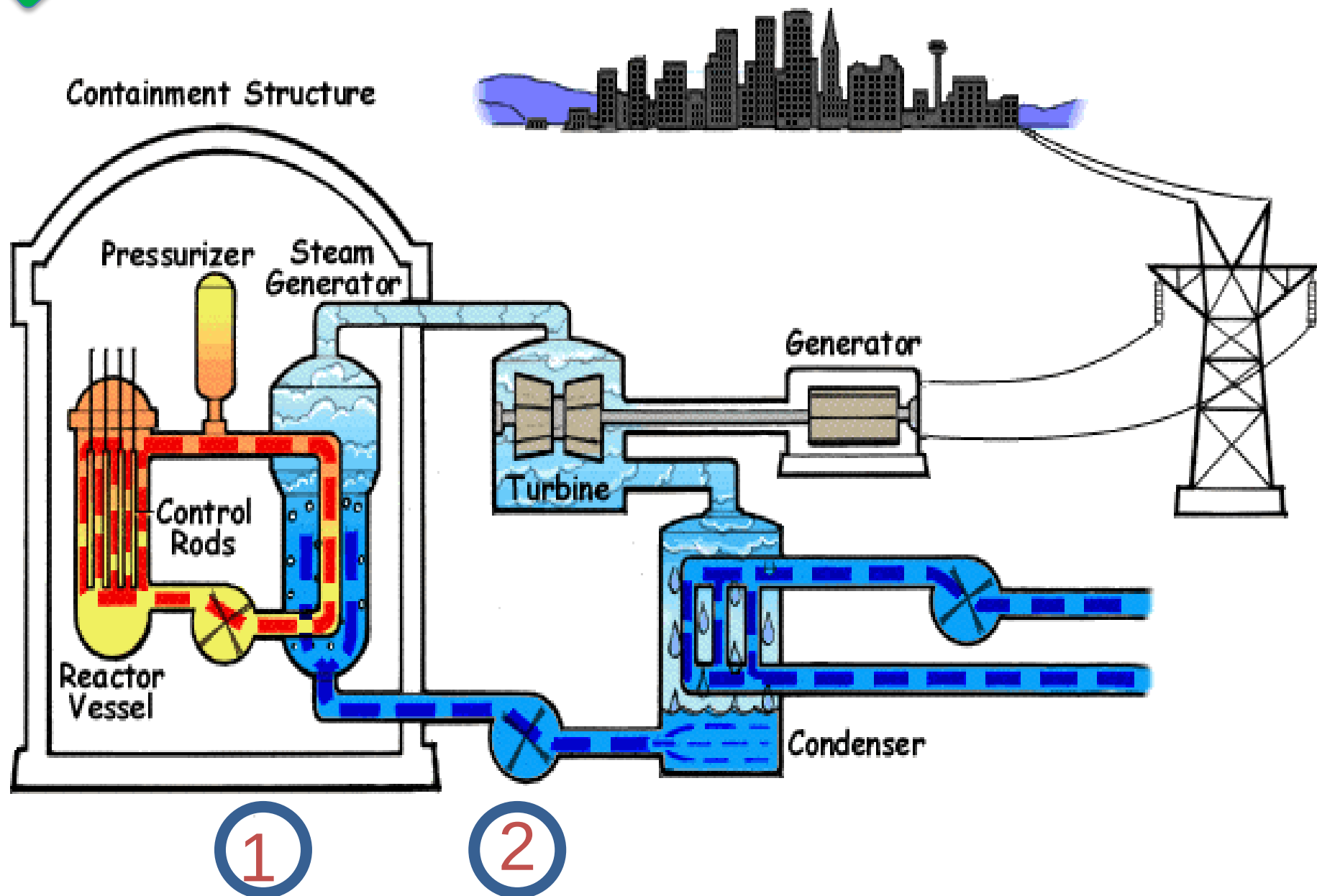
PRVA N.E. 'VELIKE' SNAGE (1956.)

GCR

60 MW_e

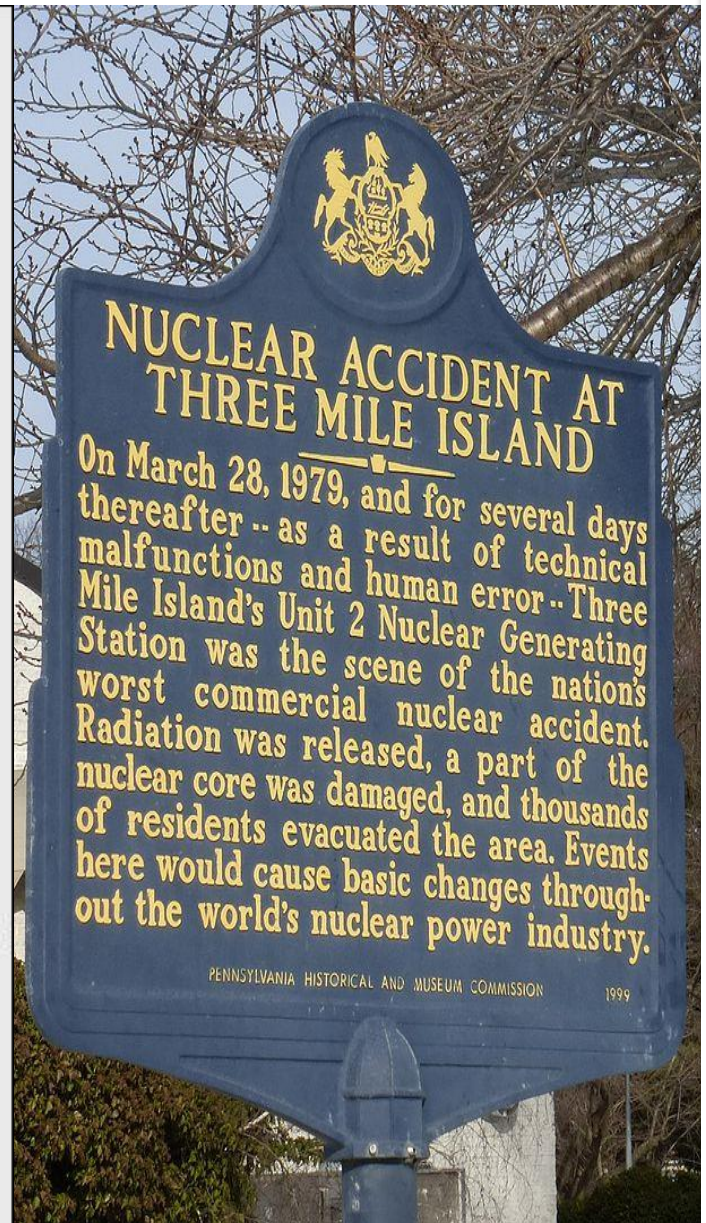
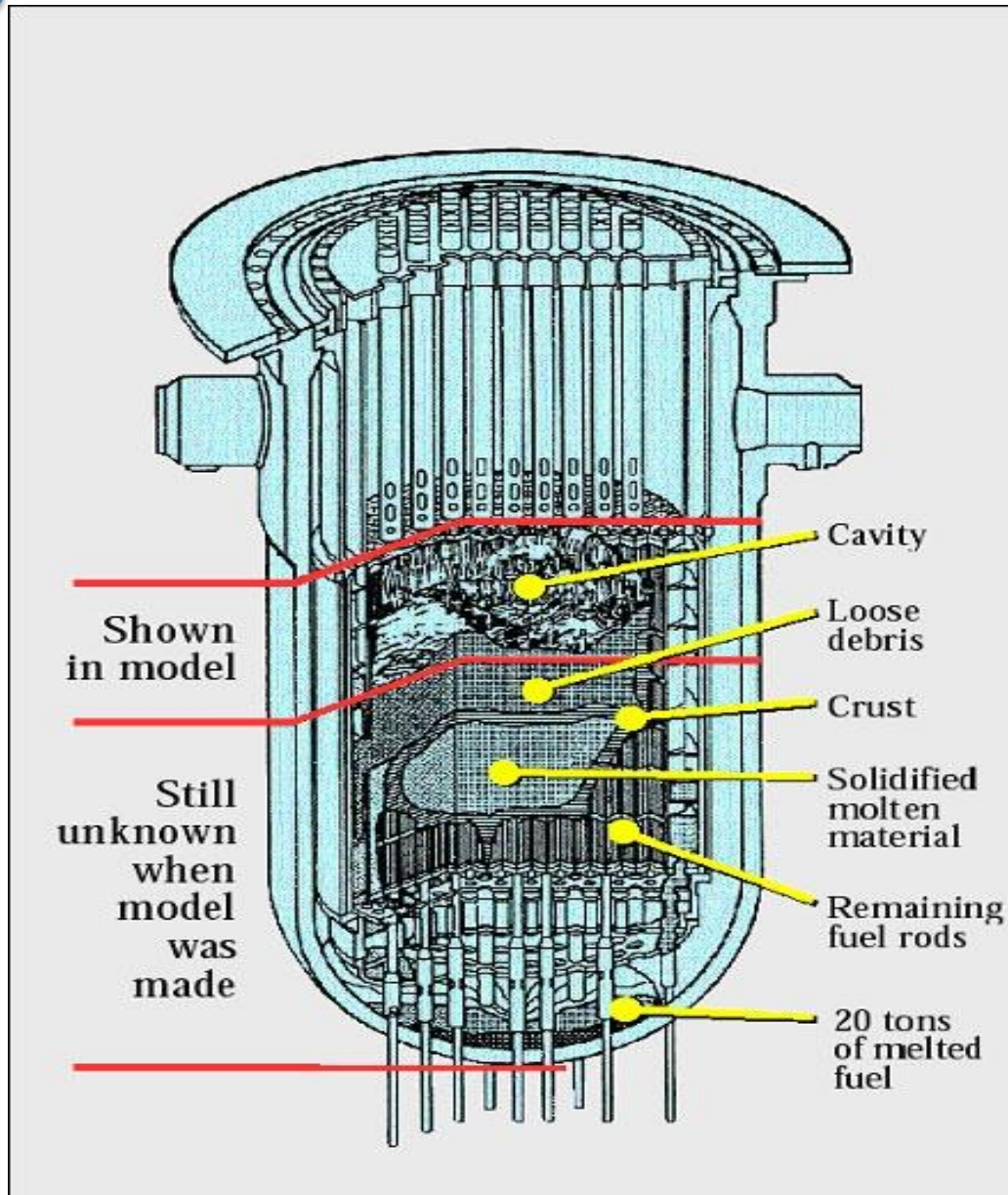


NUKLEARNA ELEKTRANA – 'PWR'

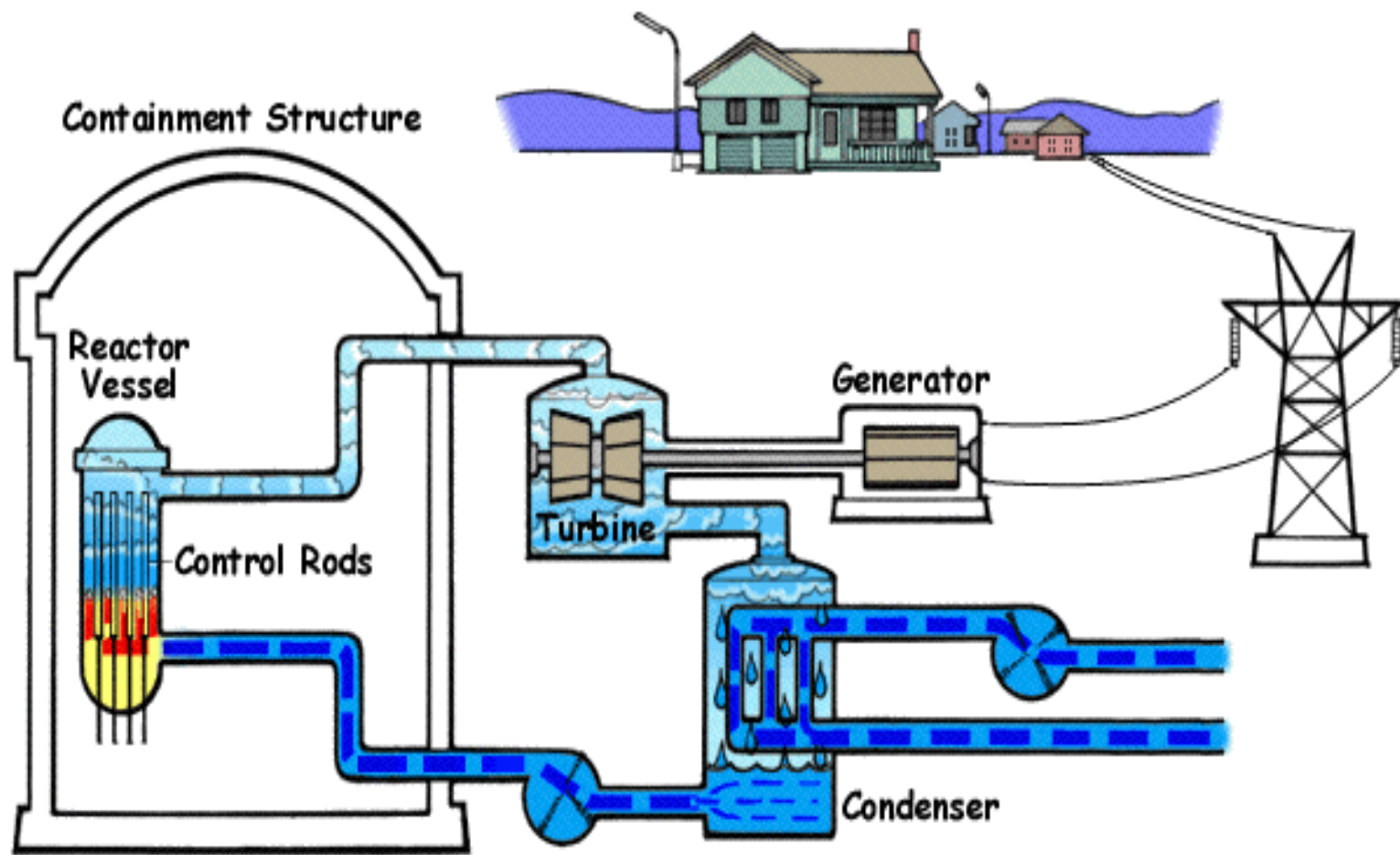


TMI 2, REAKTOR 'PWR' TIPA

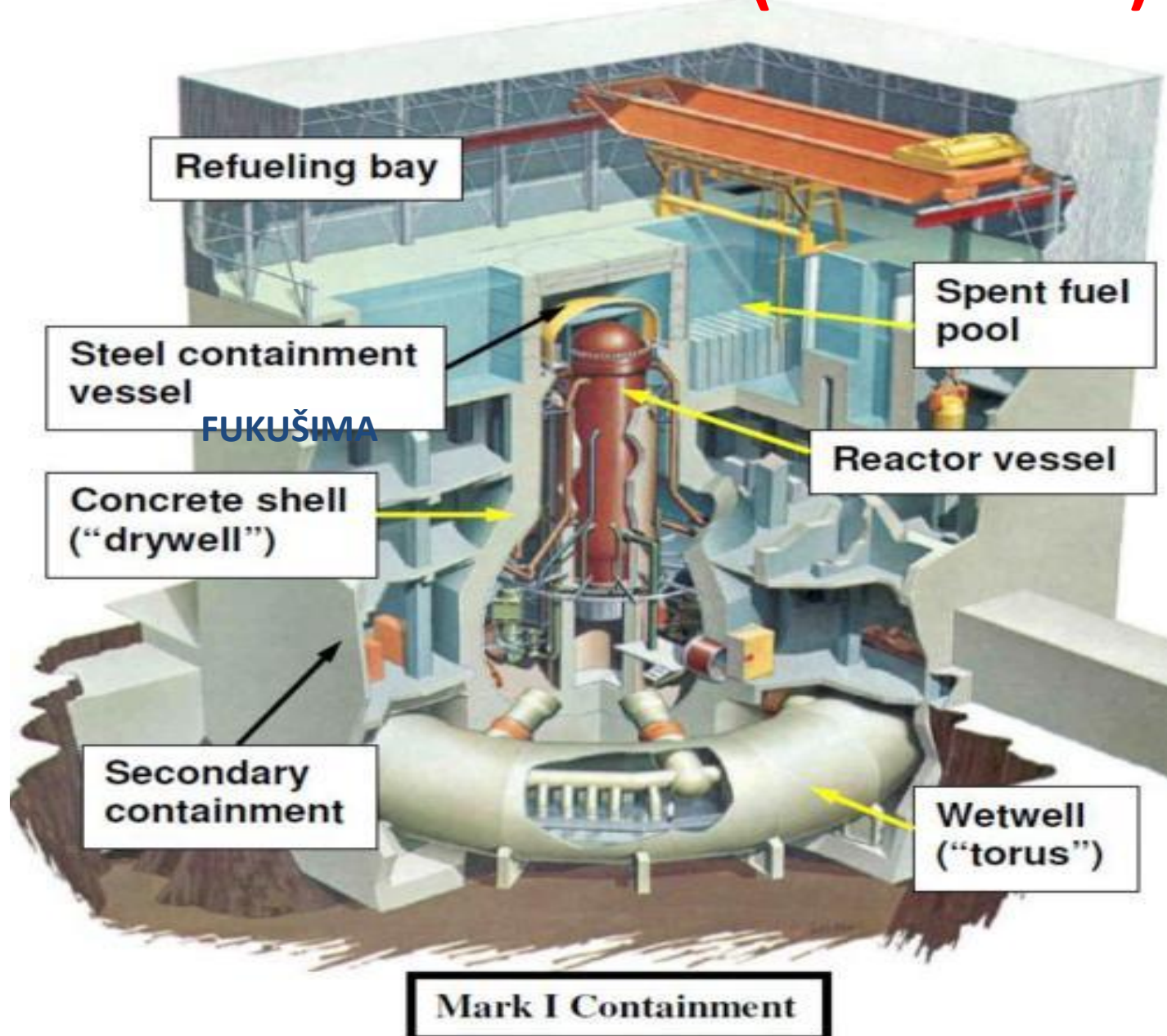
II



NUKLEARNA ELEKTRANA – 'BWR'



REAKTOR 'BWR' TIPA (FUKUŠIMA)

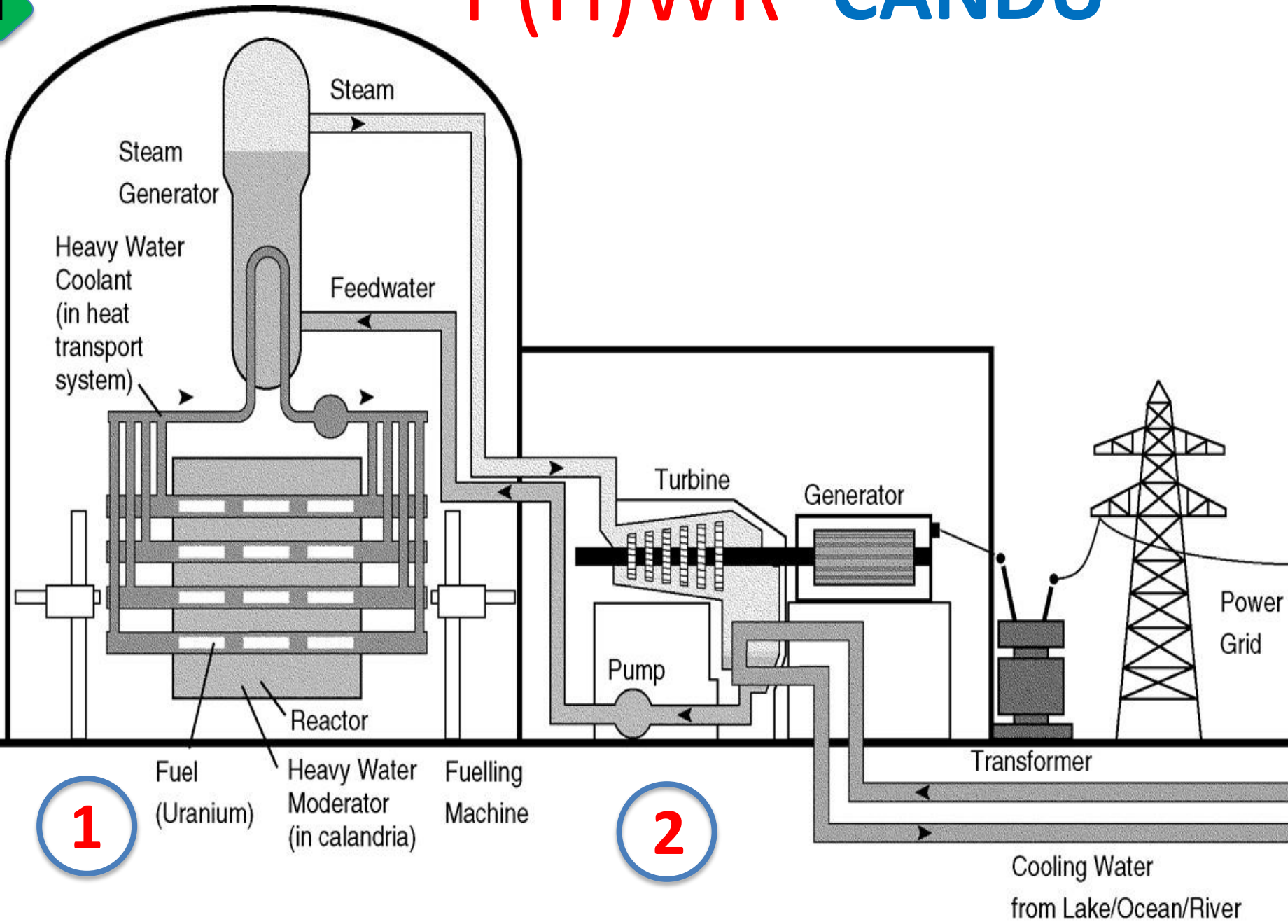


EKSPLOZIJA VODONIKA

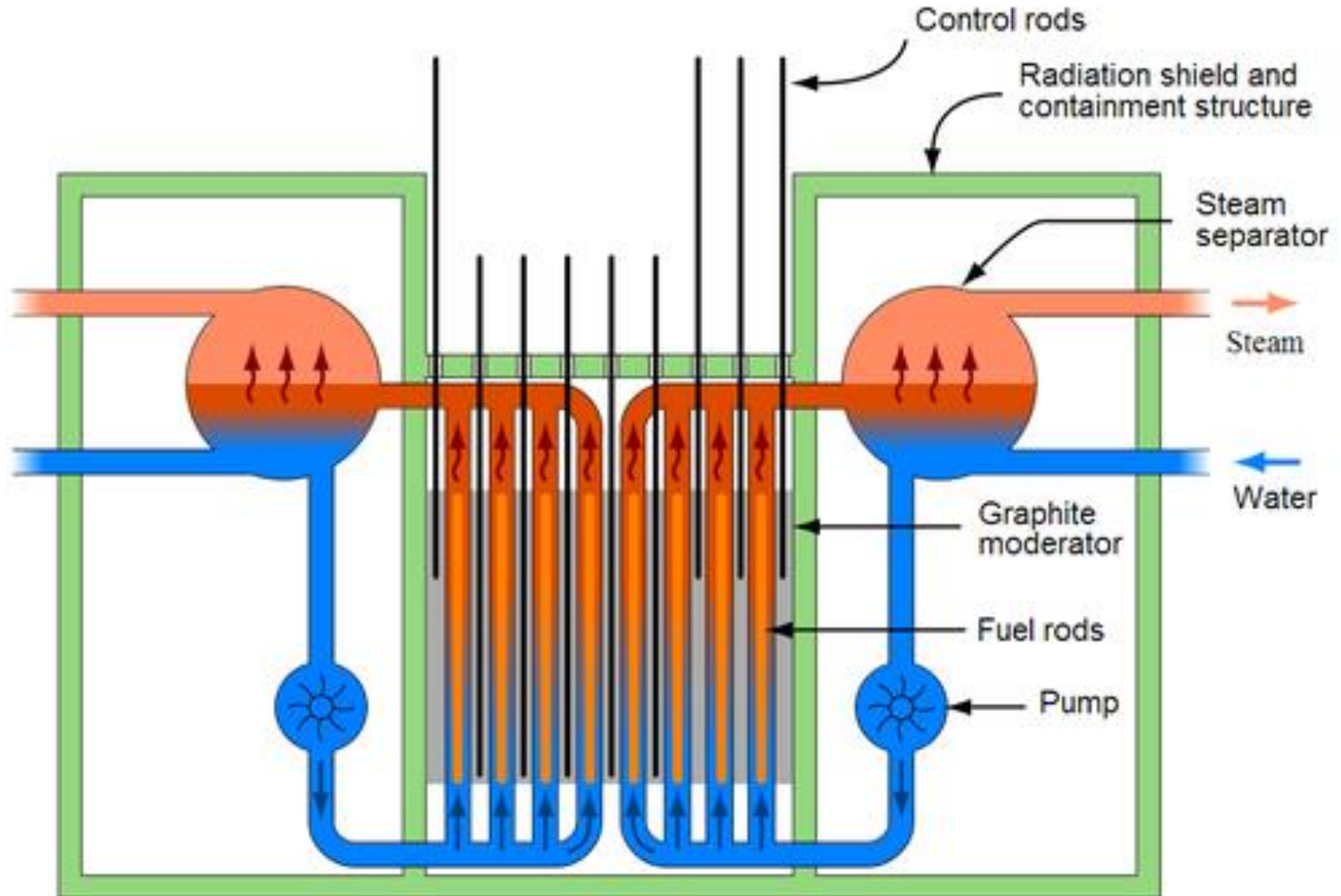


P(H)WR CANDU

II



REAKTOR 'RBMK' TIPA (ČERNOBILJ)

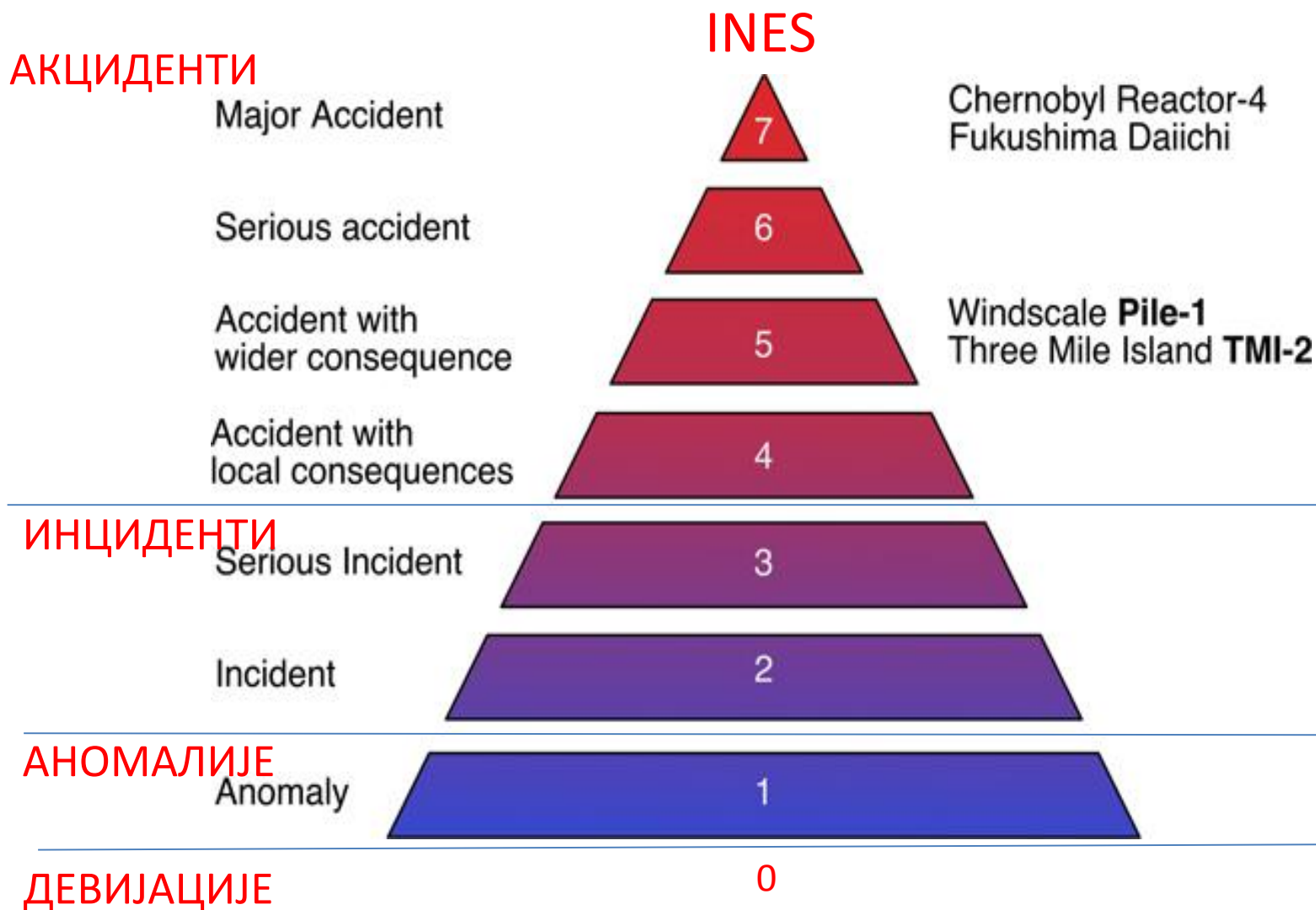




„SARKOFAG“ ZA OPOMENU



КЛАСИФИКАЦИЈА ДОГАЂАЈА ОД ИНТЕРЕСА ЗА СИГУРНОСТ



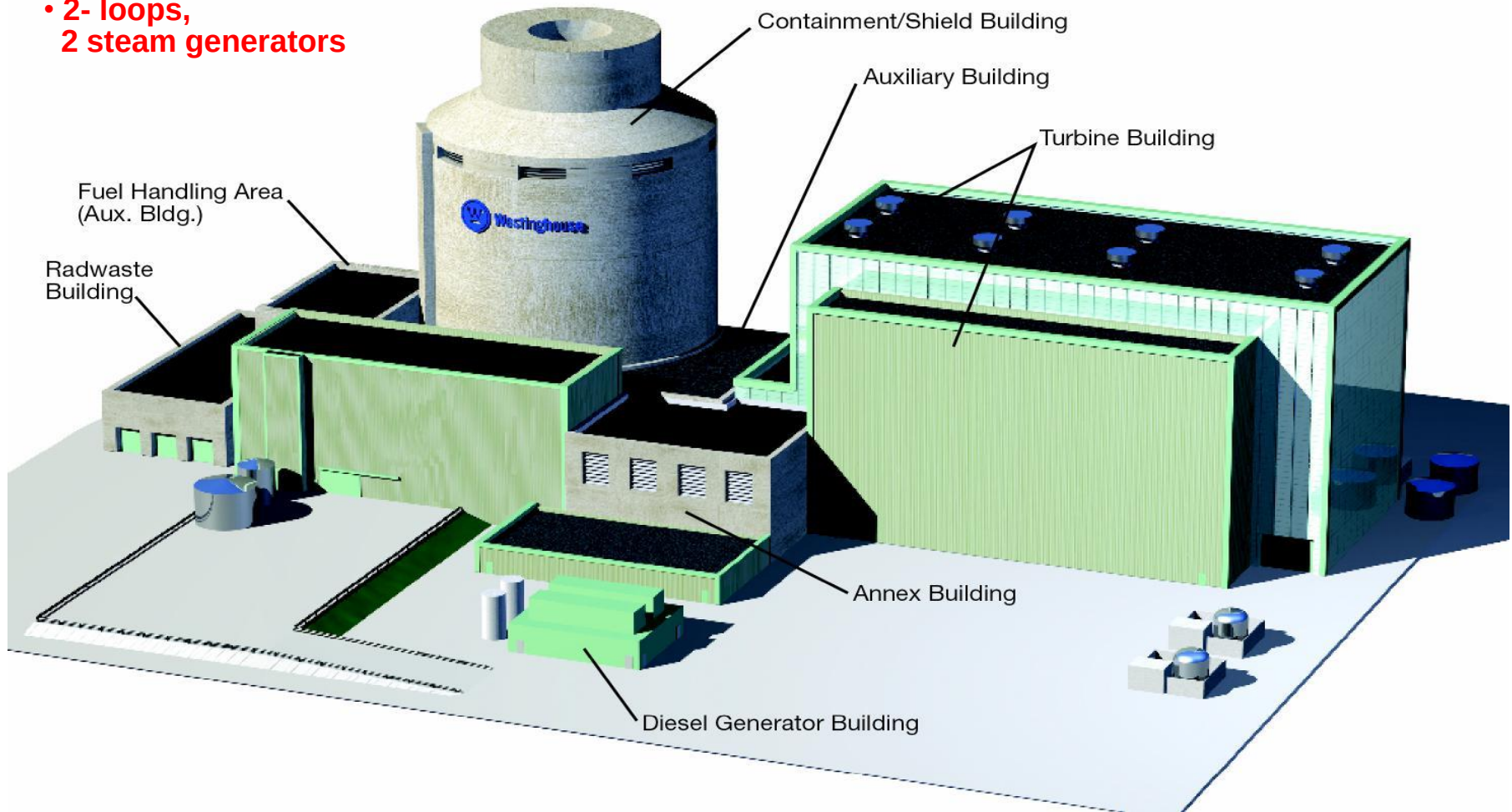
'AP1000' – A Passive Safety Reactor

A compact station

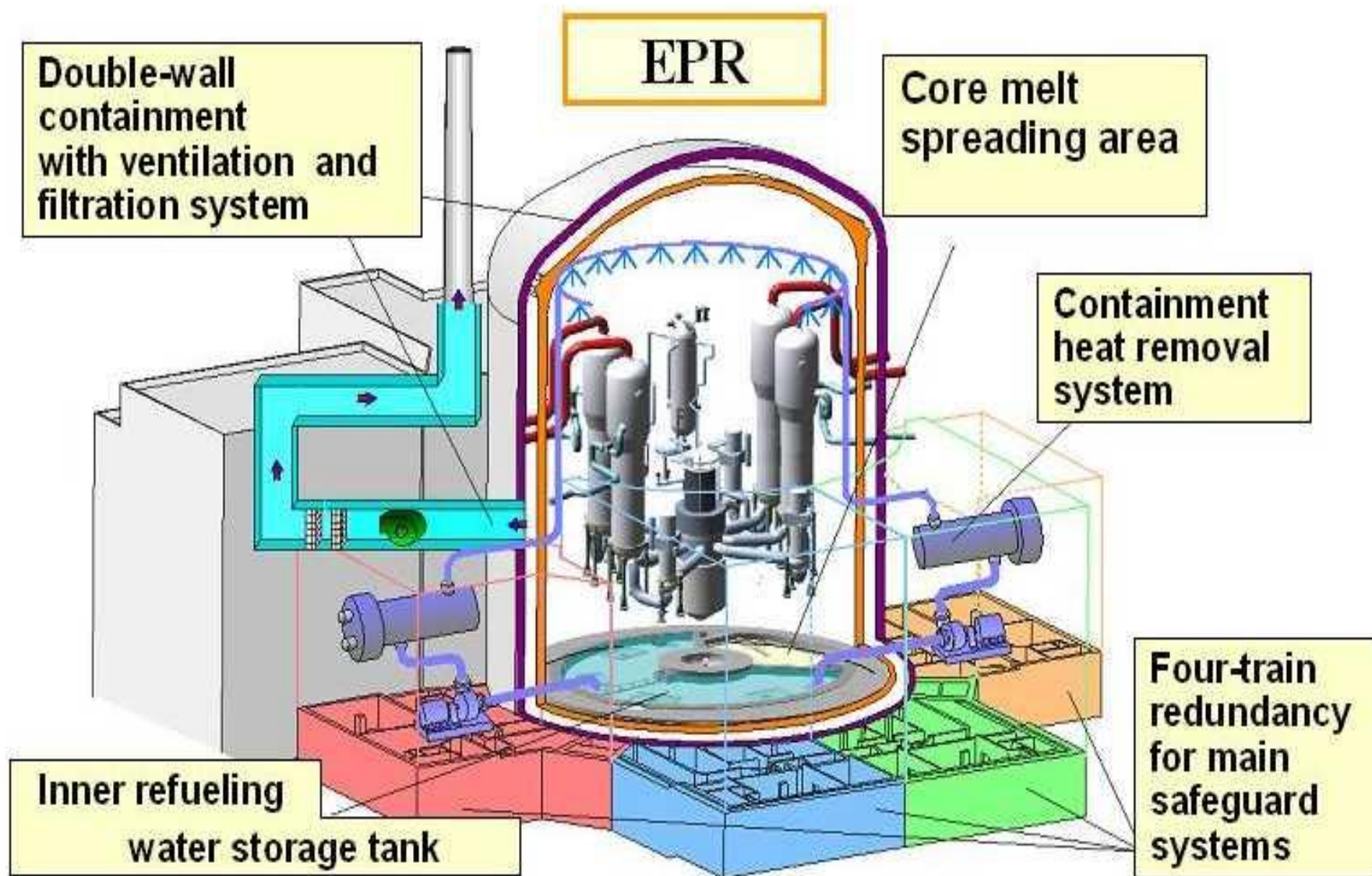
• 3415 MWt (1117 MWe)

$\eta = 32,3\%$

• 2- loops,
2 steam generators



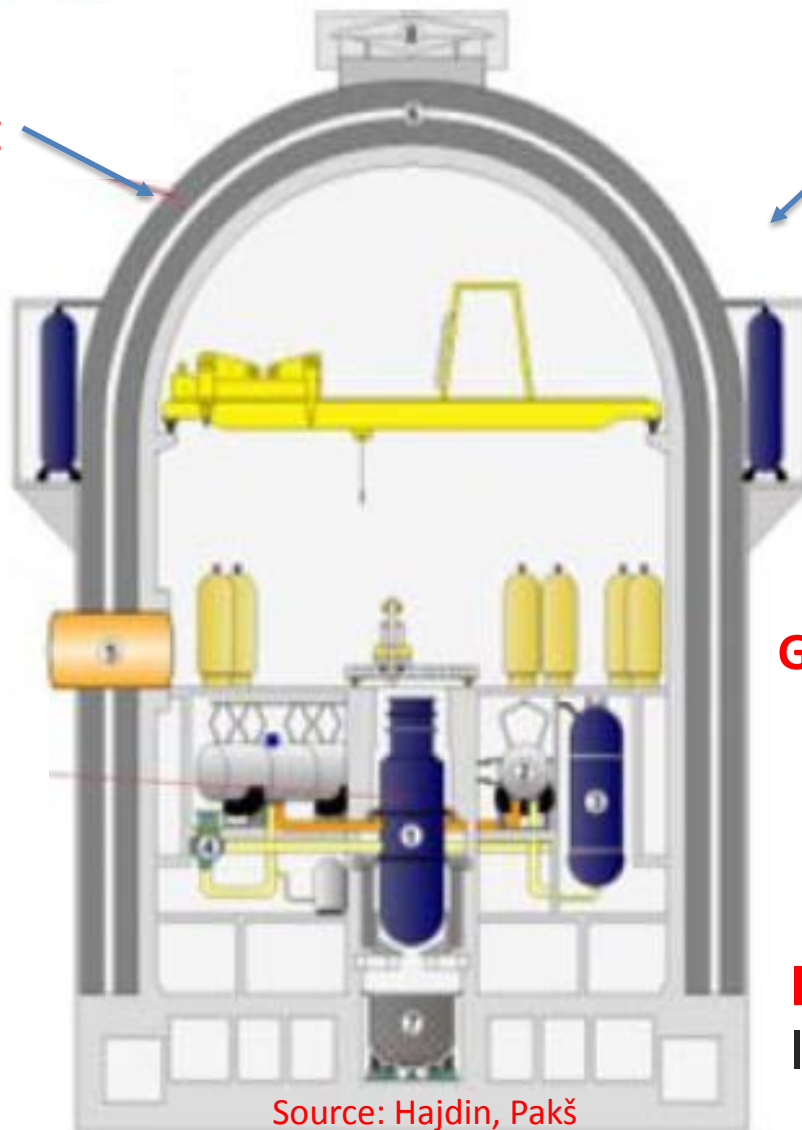
Generacija III: 'EPR 1600'



REAKTOR 'VVER-1200'

Dvostruki
kontejnment

Pasivni
sigurnosni
sistemi



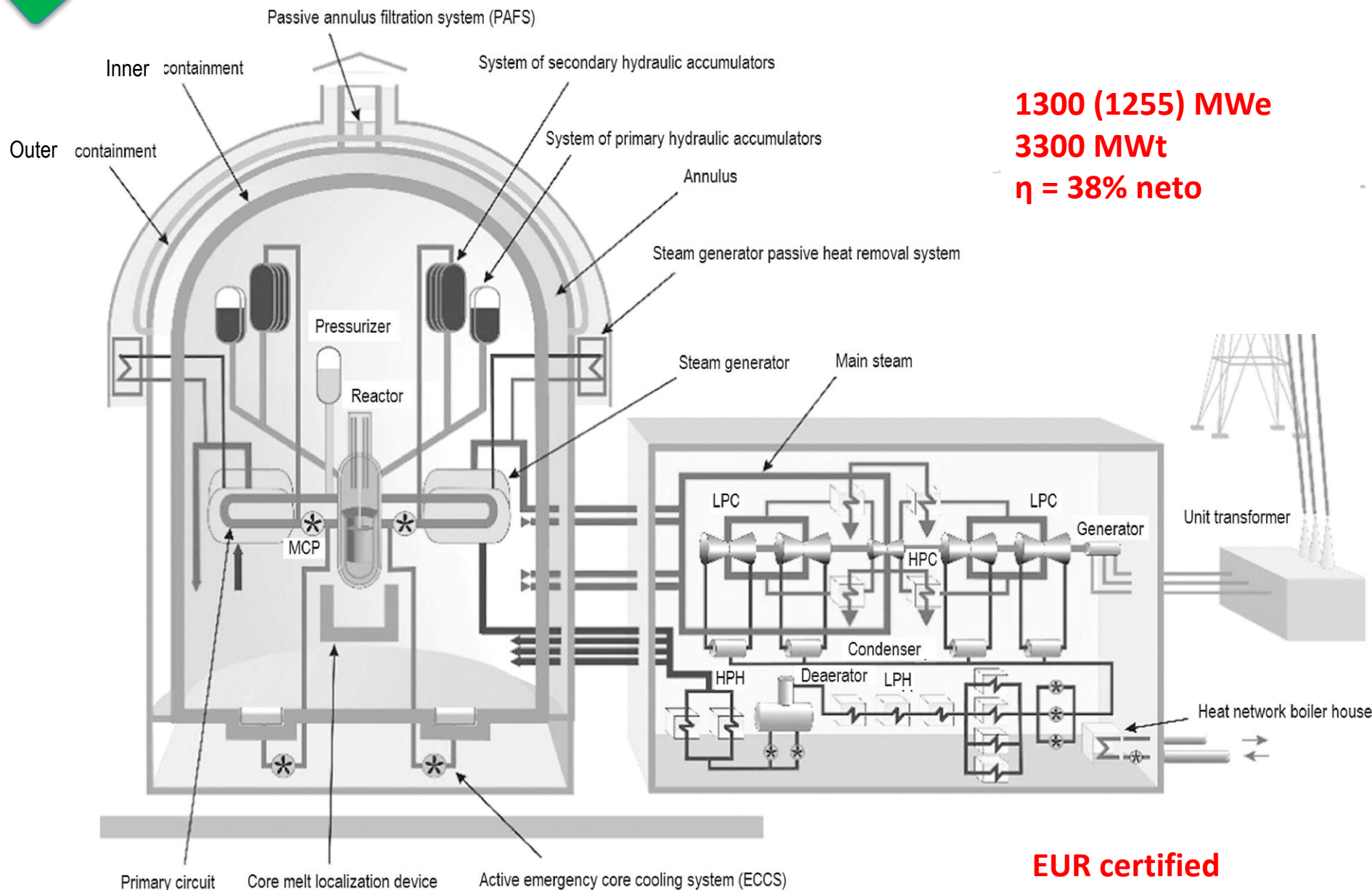
VVER-210	Gen. II
VVER-365	Gen. II
VVER-440	Gen. II
VVER-1000	Gen. II
VVER-1200	Gen. III
VVER-TOI	Gen. III+

Gen.	MWe	$\eta_b, \%$
II	210	27,63
II	365	27,55
II	440	32,00
II	1000	33,33
III	1200	37,36
III+	1300	39,39

Source: Hajdin, Pakš

Generacija III+: VVER TOI

III+



1300 (1255) MWe

3300 MWt

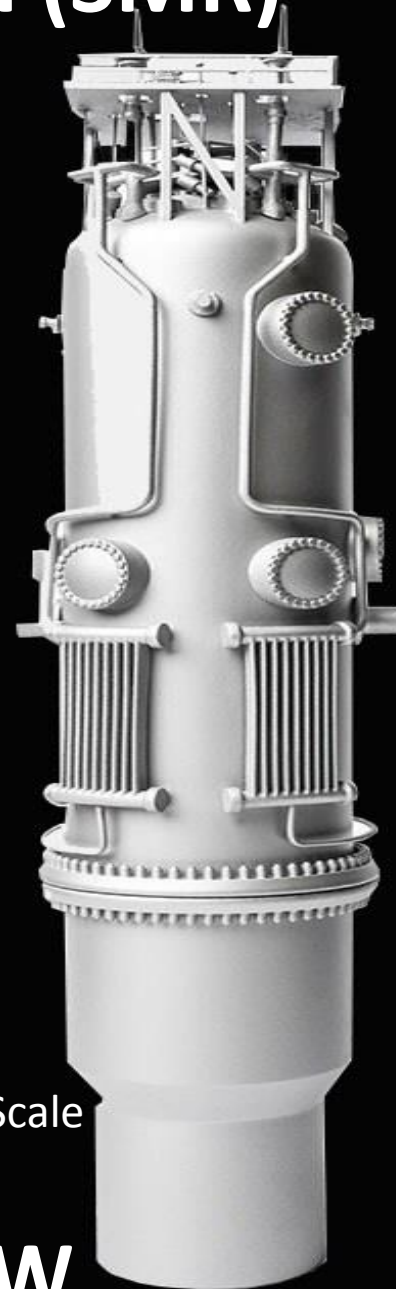
$\eta = 38\%$ neto

EUR certified

МАЛИ МОДУЛАРНИ РЕАКТОРИ (SMR)



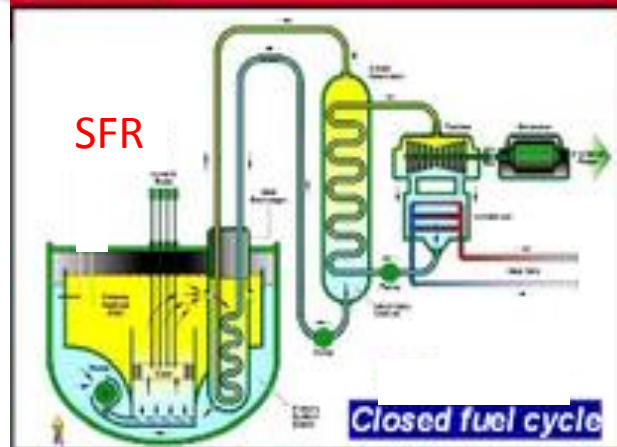
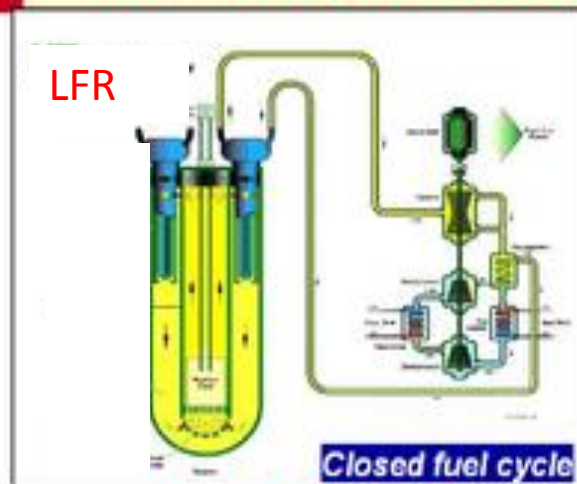
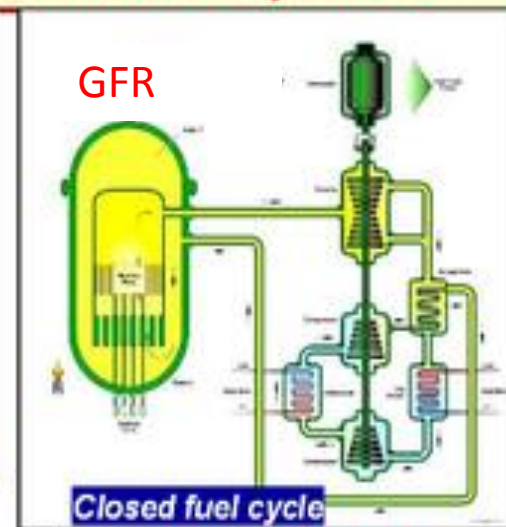
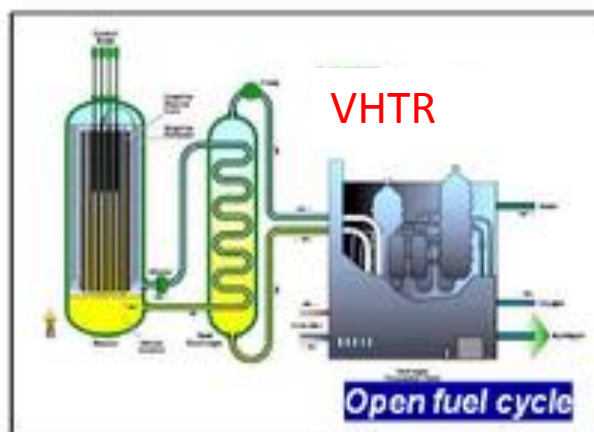
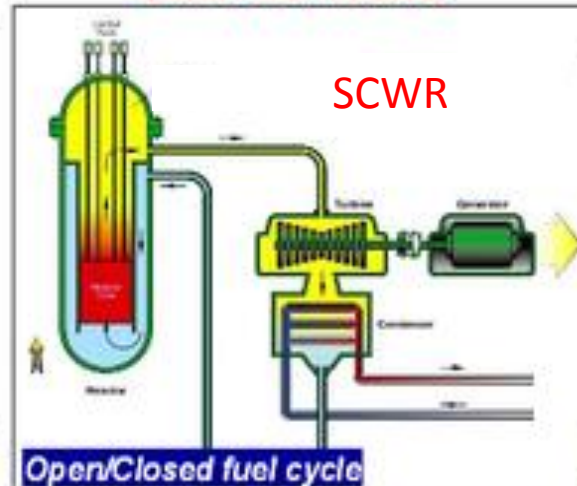
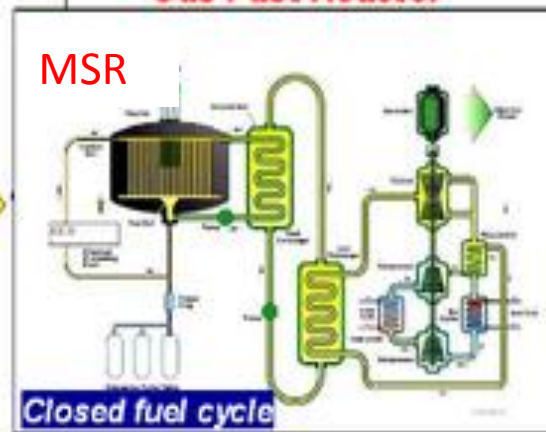
NuScale



NuScale

'Akademik Lomonosov' SMR 2x35 MW

GIF Selection of six Nuclear Systems

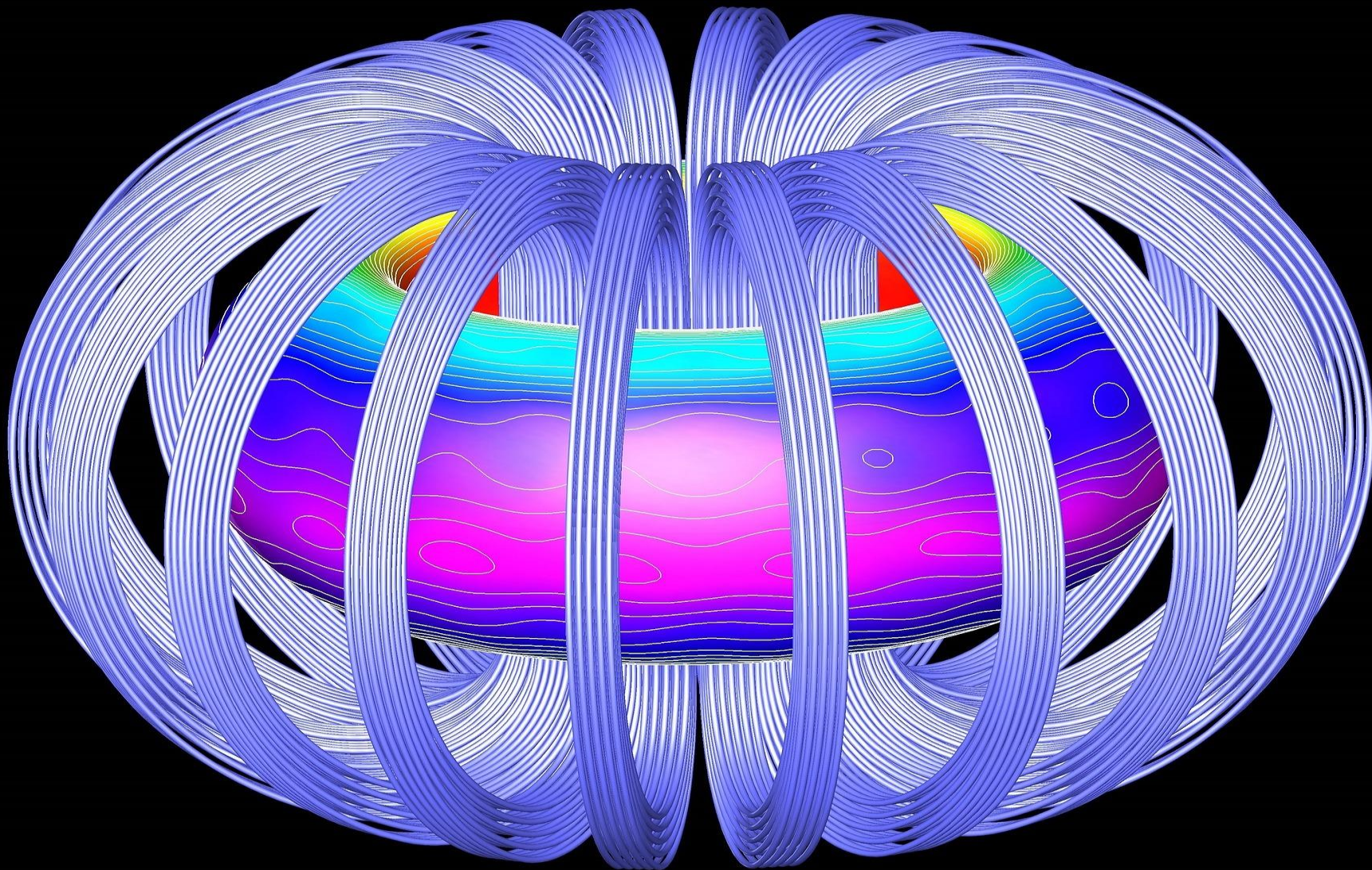
**Sodium Fast Reactor****Lead Fast Reactor****Gas Fast Reactor****Very High Temperature Reactor****Super Critical Water Reactor****Molten Salt Reactor**

Recognition of the major potential of fast neutron systems with closed fuel cycle for breeding (fissile re-generation) and waste minimization (*minor actinide burning*)

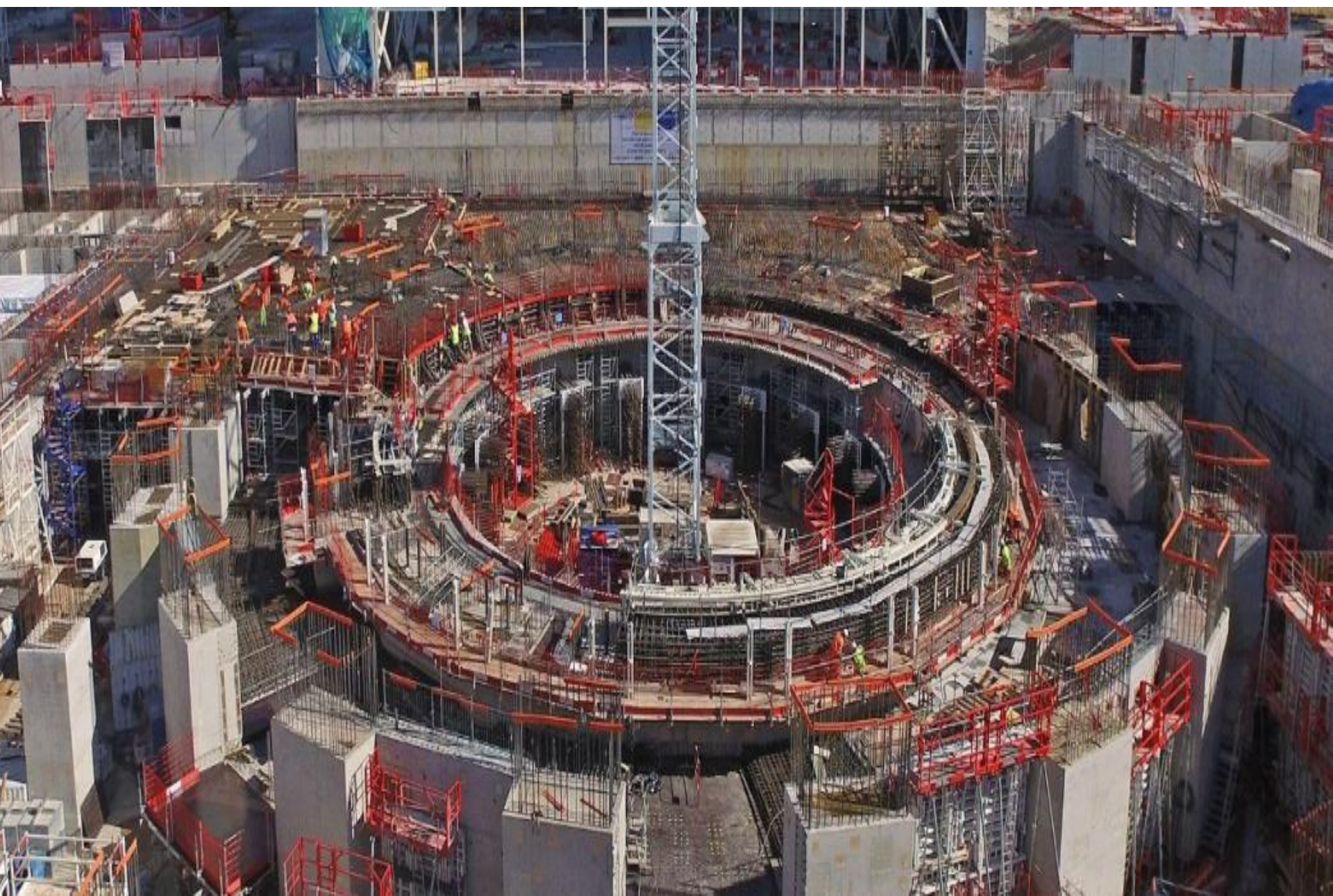
Tip reaktora	Spektar neutrona	Hladilac	Temperatura, °C	Pritisak	Gorivni ciklus	Snaga, MWe	Namena reaktora
Gasom hlađeni brzi - GFR	Brzi	Helijum	850	Visok	Zatvoren	288	Električna energija i vodonik
Visoko temperaturni - VHTR	Termalni	Helijum	1000	Visok	Otvoren	250	Električna energija i vodonik
Vodom pod superkritičnim parametrima hlađen - SCWR	Termalni ili brzi	Voda	510-550	Vrlo visok	Otvoren - termalni Zatvoren - brzi	1500	Električna energija
Natrijumom hlađeni brzi - SCR	Brzi	Natrijum	550	Nizak	Zatvoren	150-500	Električna energija
Olovom hlađeni brzi - LCR	Brzi	Olovo - Bizmut	550-800	Nizak	Zatvoren	50-150 300-400 1200	Električna energija i vodonik
Rastopljenim solima hlađen - MSR	Epitermalni	Fluoridi	700-800	Nizak	Zatvoren	1000	Električna energija i vodonik



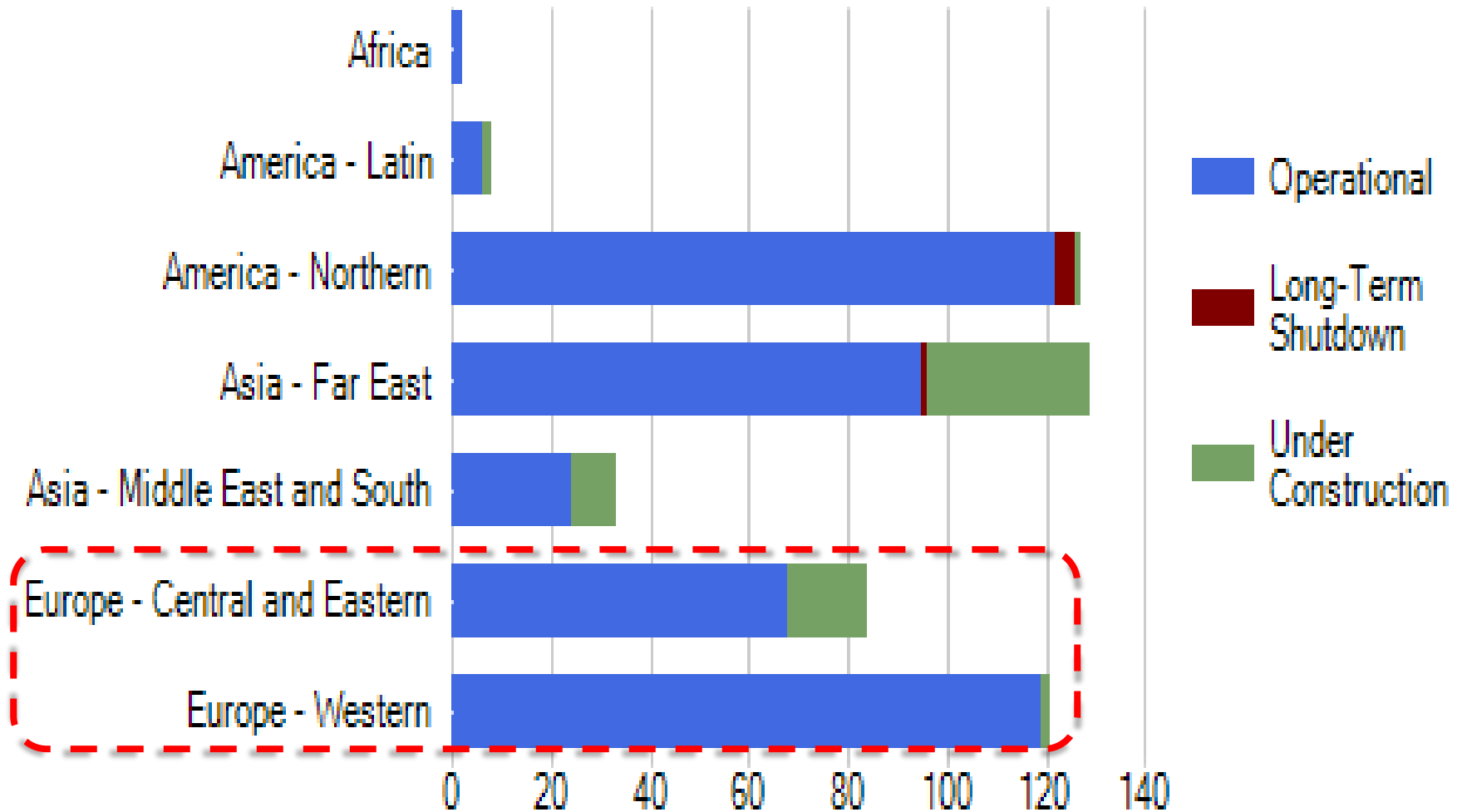
ФУЗИОНА ПЛАЗМА У МАГНЕТНОМ ПОЉУ



ITER construction site in Cadarache, France



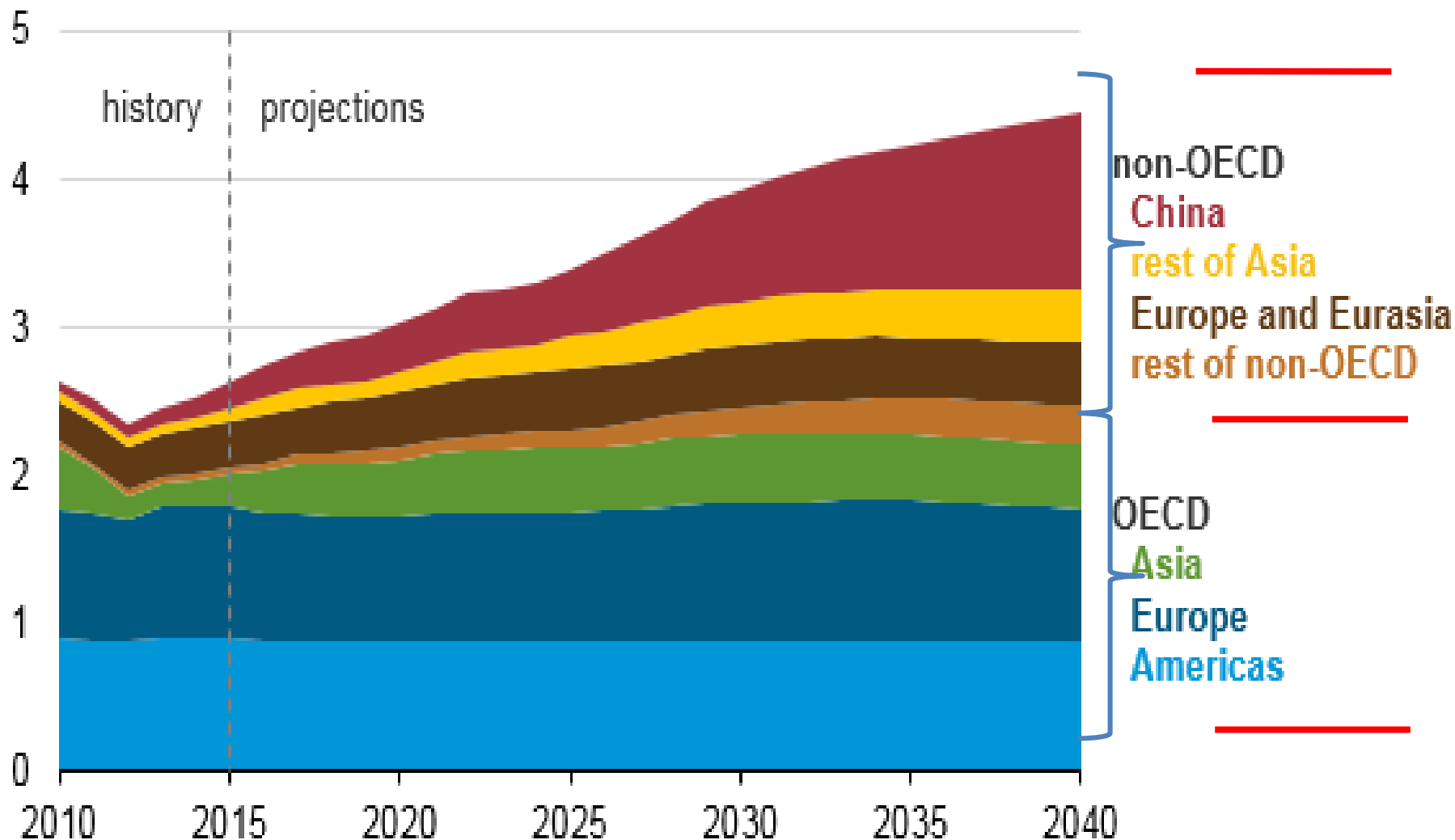
BROJ N.E. PO REGIONIMA



PROJECTED NUCLEAR GROWTH



Thousand TWh

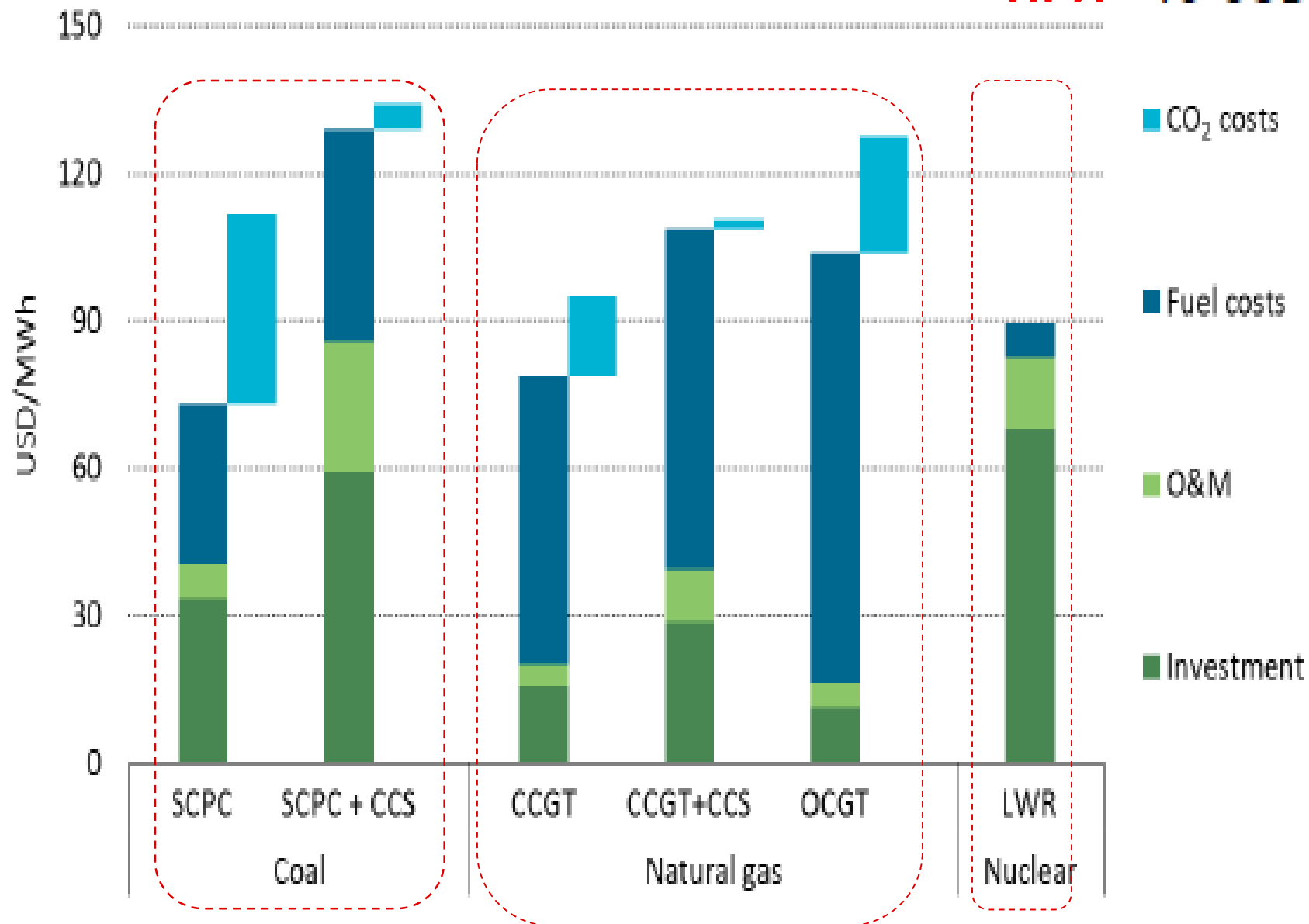


NOVE NUKLEARNE ELEKTRENE U OKRUŽENJU

Nuklearna elektrana	Snaga, MW	Tip reaktora	Investicija Milijarde \$	Jedinična \$/kW	Priključak na mrežu	Napomena
Akkuyu 1-4 Turska	4x1.200	PWR VVER-1200	22,0	4.580	2023.	Planirano još 2 bloka
Flamanville 3 Francuska	1x1.600	PWR EPR 1600	12,4	7.750	202?.	Kašnjenje Skok cene
Belarus 1&2 Belorusija	2x1.200	PWR VVER-1200	11,0	4.580	202?.	Planirano još 2 bloka
Olkiluoto 3 Finska	1x1.600	PWR EPR 1600	9,5	5.940	2022	Toplota za zagrevanje
Černavoda 3&4 Rumunija	2x700	PHWR Candu 6	8,8	6.290	202?.	Radni vek 30+25 god
Mohovce 3&4 Slovačka	2x440	PWR V-213 440	5,8	6.590	202?.	Usavršen VVER 440
Pakš II (5&6) Mađarska	2x1,200	PWR VVER-1200	12.5	5.200	2030.	Kašnjenje Brisela

ТРОШКОВИ ПРОИЗВОДЊЕ ЕНЕРГИЈЕ У *EU*, 2020

ПРИ *46 USD/t CO₂*



ХВАЛА НА ВАШОЈ ПАЖЊИ!

