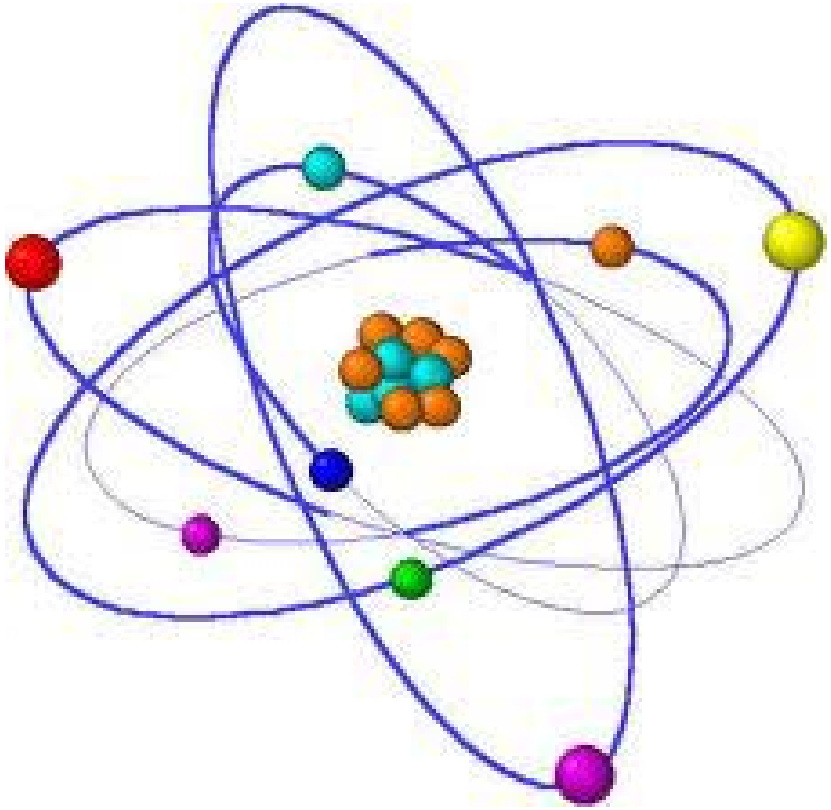
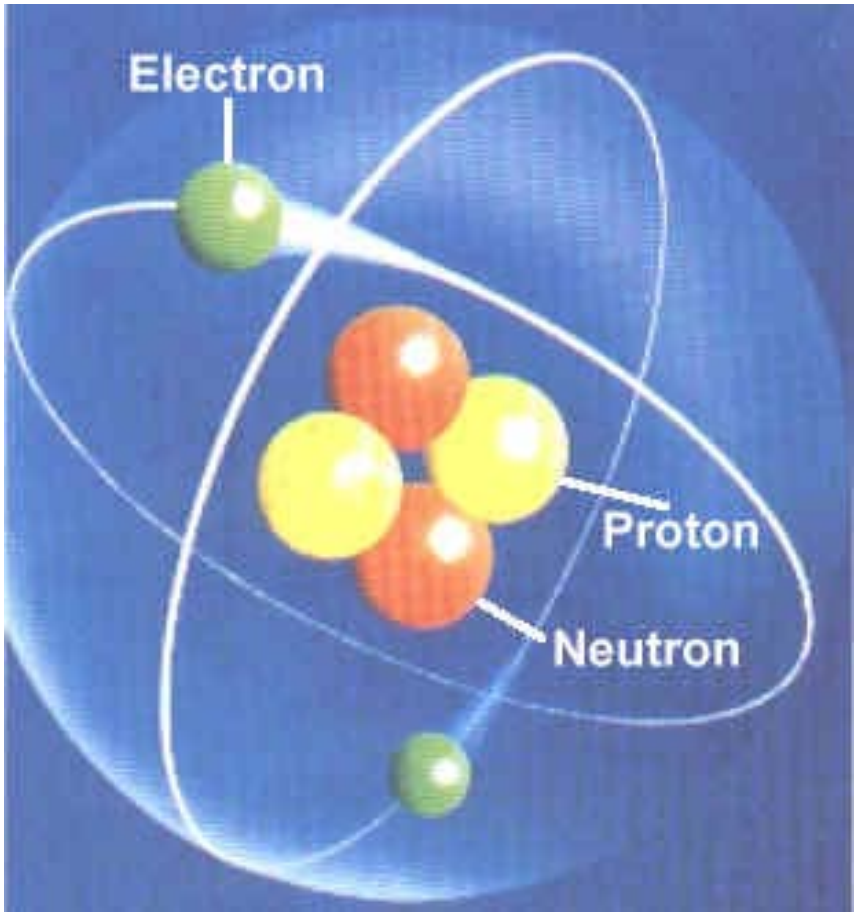
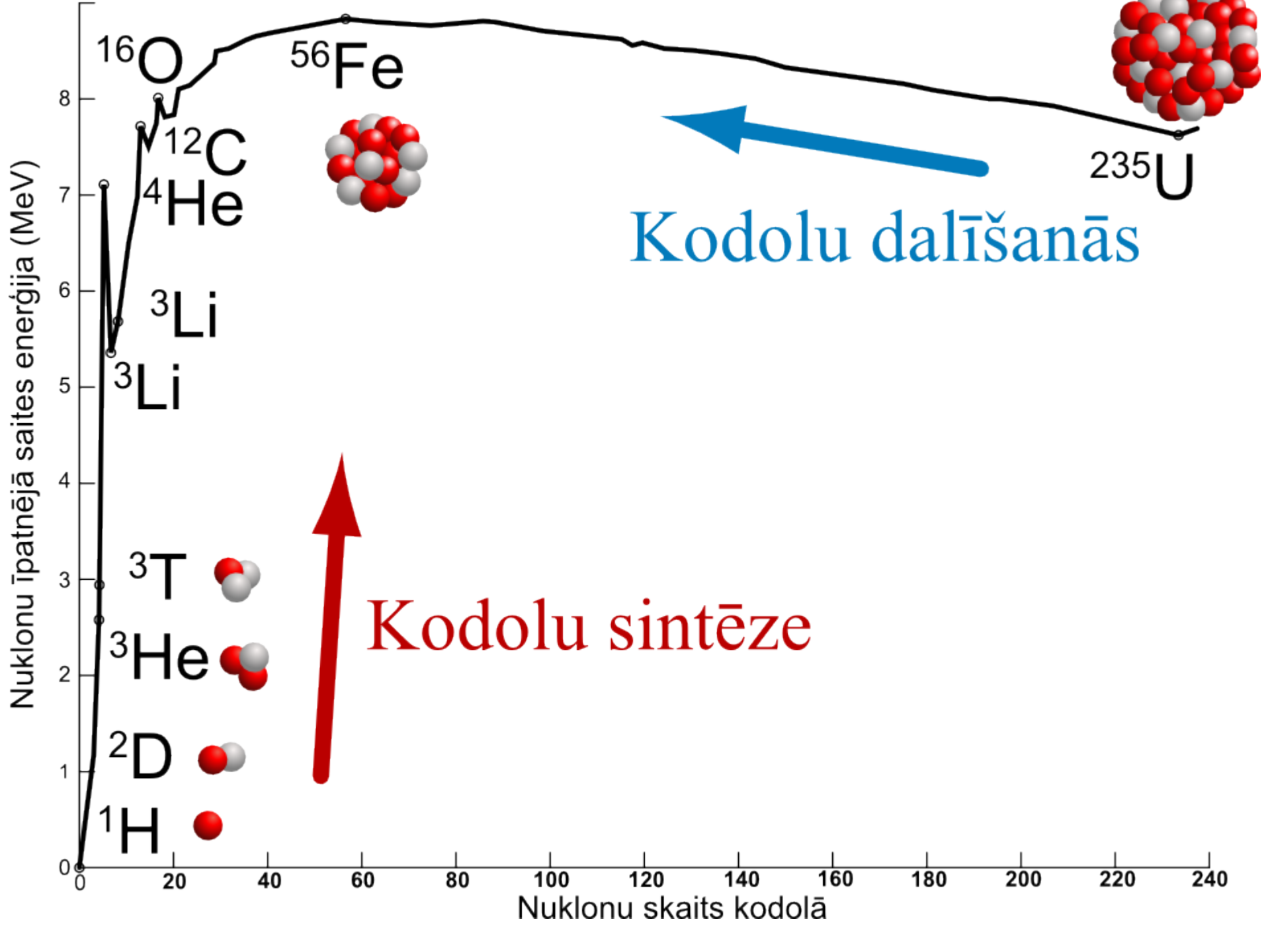
Kodolenerģētika

J. Bērziņš

12.04.2012



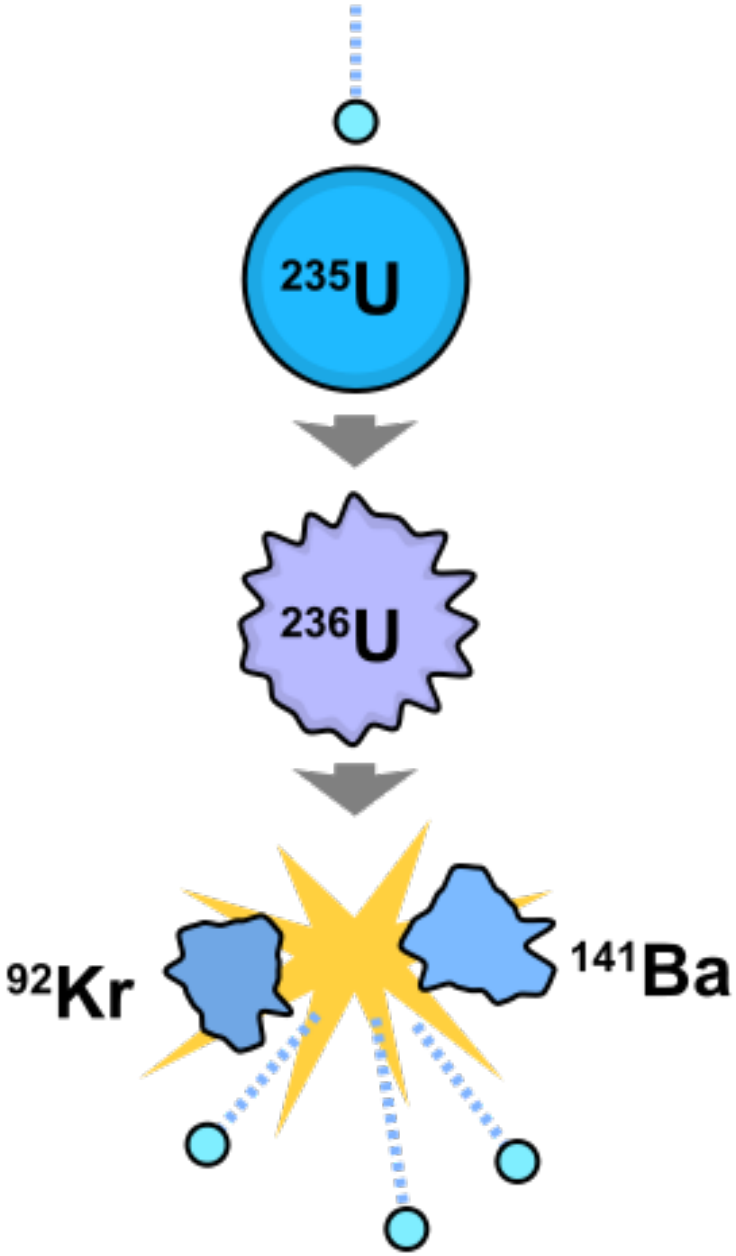

Electron
Proton
Neutron


^{16}O
^{56}Fe
^{12}C
^{4}He
^{3}Li
^{3}Li
^{235}U
Kodolu dalīšanās
^{3}T
^{3}He
^{2}D
^{1}H
Kodolu sintēze
Nuklonu īpatnējā saites enerģija (MeV)
Nuklonu skaits kodolā
0
1
2
3
4
5
6
7
8
0
20
40
60
80
100
120
140
160
180
200
220
240

Urāna-235 kodola dalīšanās

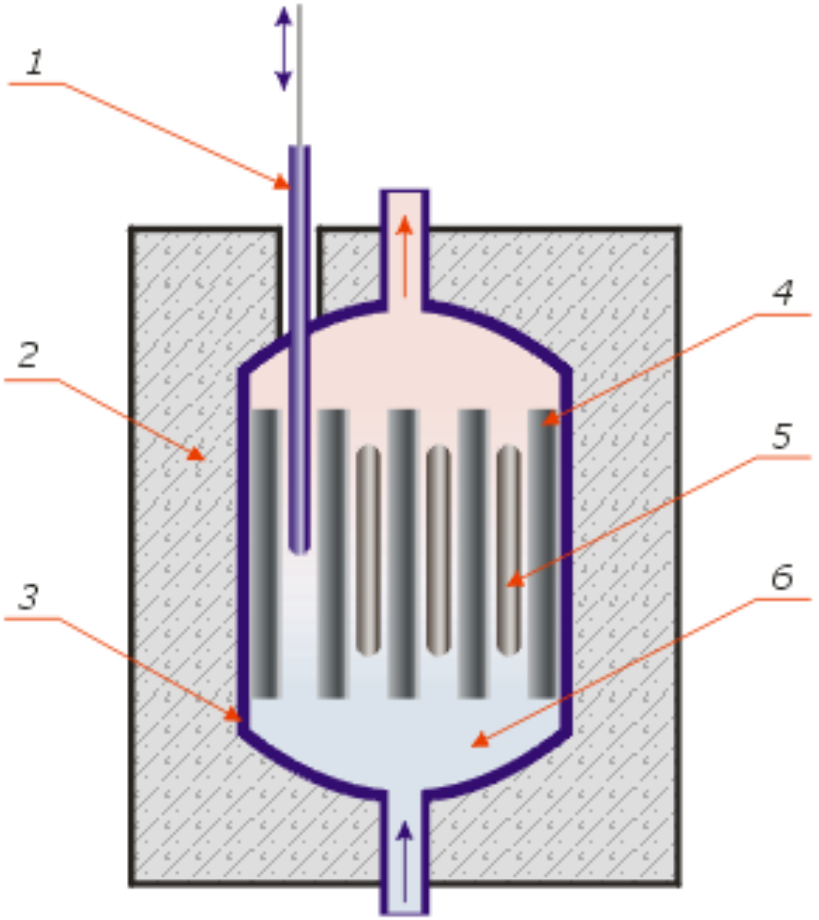
Otto Hahn

Enrico Fermi

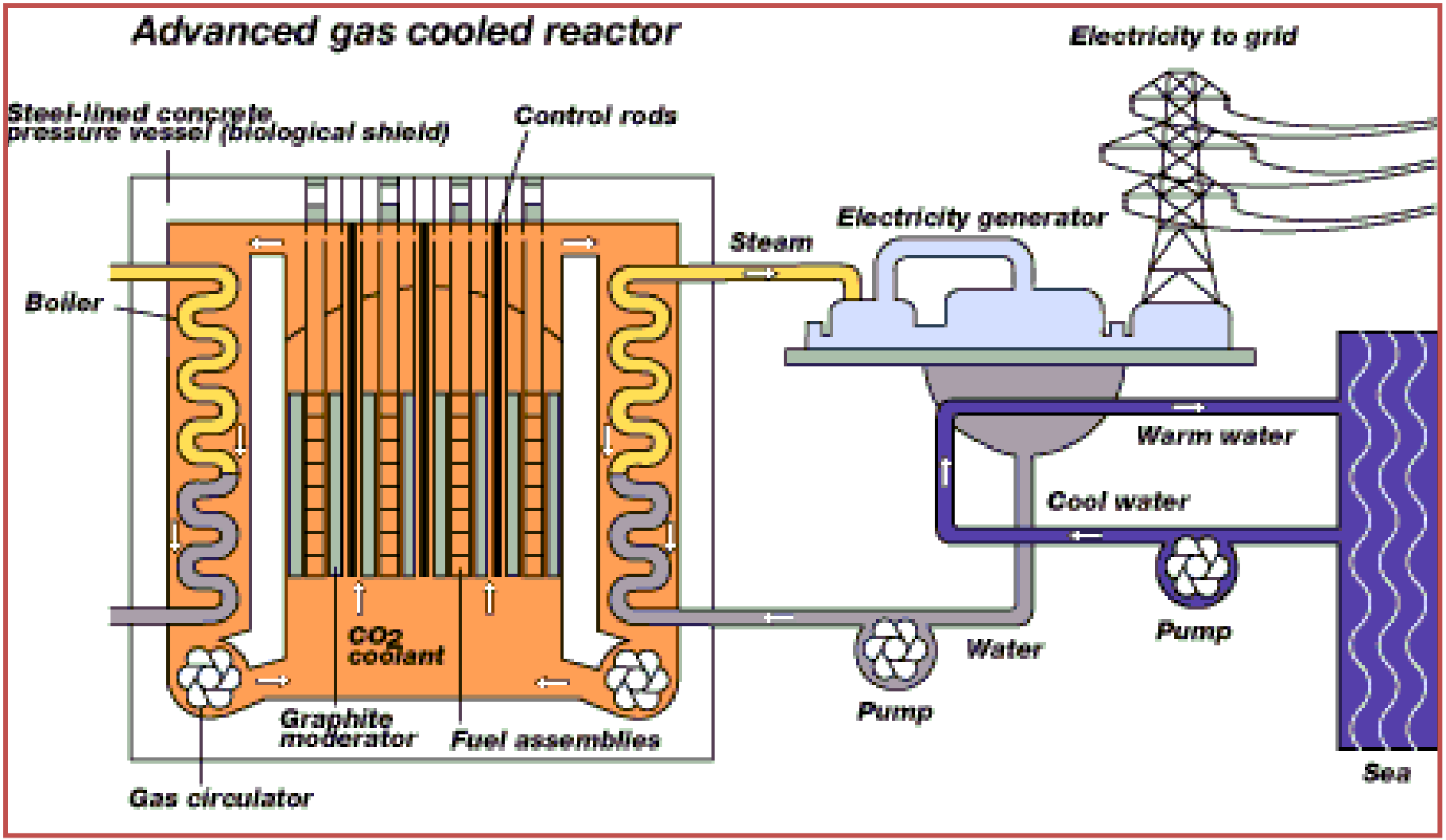


Lēno neitronu heterogēnā kodolreaktora shematisks attēls

1 — vadības stienis;
2 — bioloģiskā aizsardzība;
3 — siltumaizsardzība;
4 — neitronu palēninātājs;
5 — kodoldegviela;
6 — siltumnesējs.



Atomelektrostacija



The 50s : Nuclear Electricity

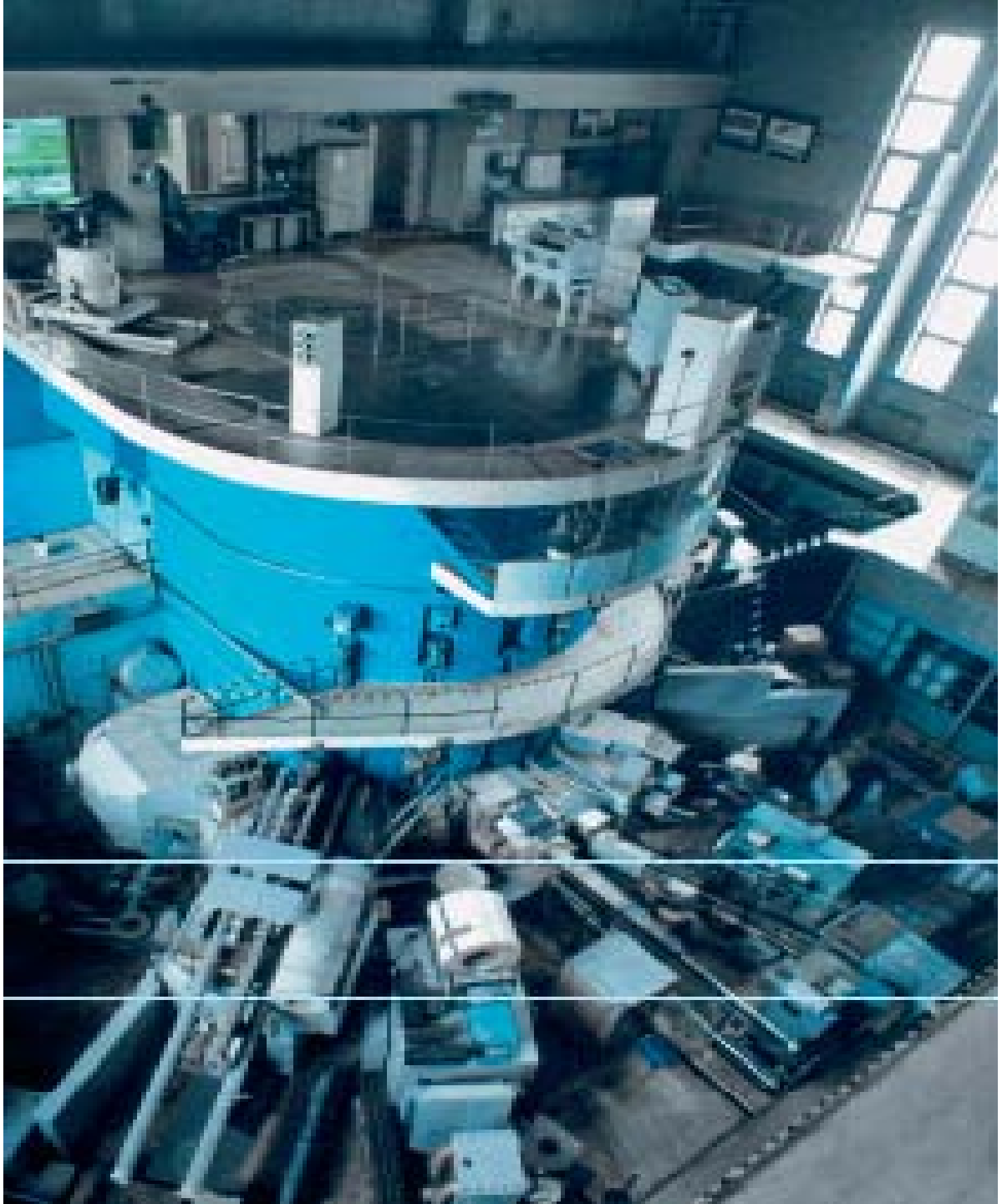
1951 : EBR (Idaho)1 lits
4 200 W Bulbs

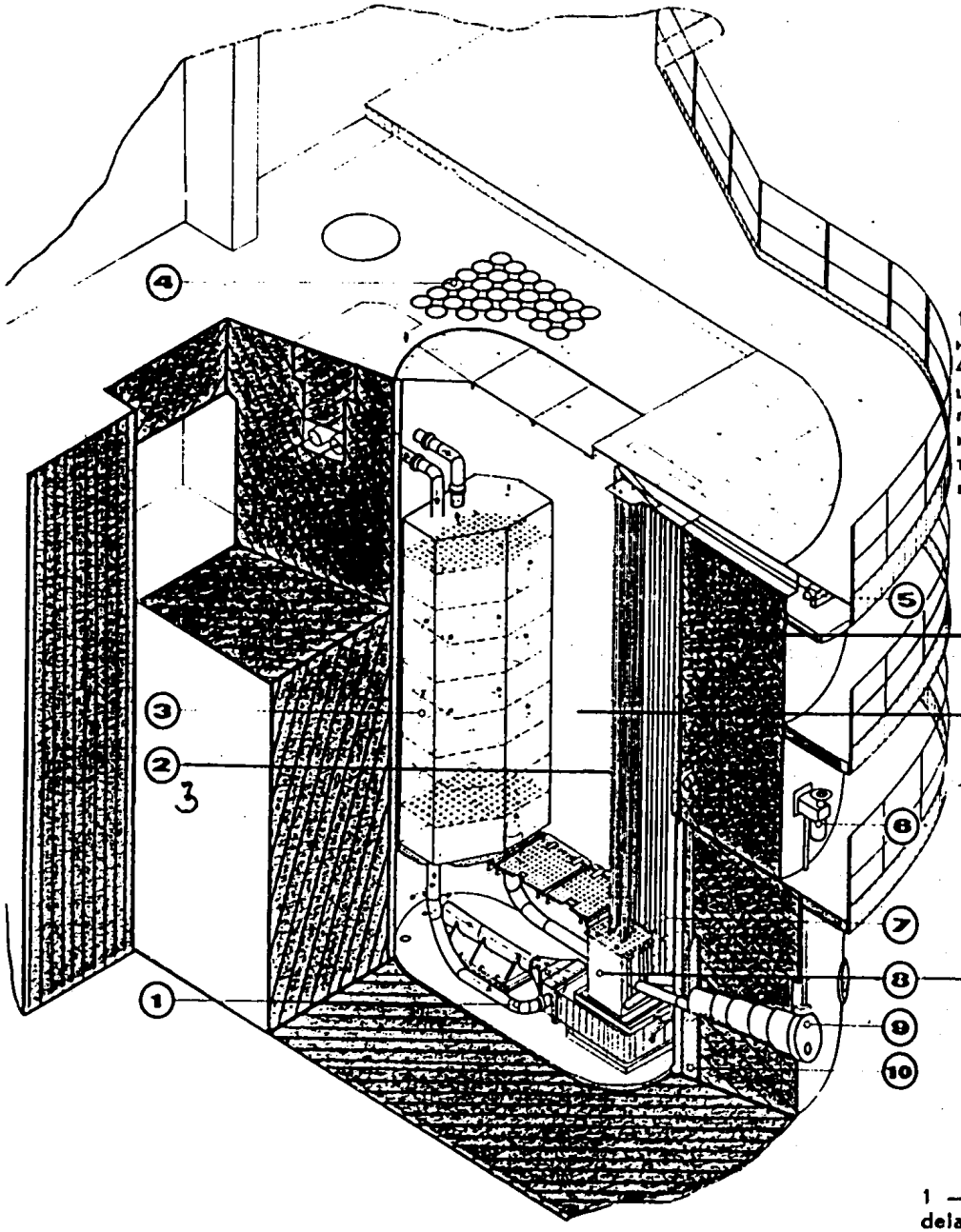
1954 : Obninsk, 5 MWe

1956 : Inauguration of Calder Hall by Elisabeth II

Kernkraftwerk Philippsburg

Olkiluoto atomelektrostacija





Reaktora uzbūve

1 — dzesēšanas cauruļvads; 2 — vadības kanāli; 3 — siltumnesēja aiztures tilpne; 4 — radioaktīvo paraugu glabātava; 5 — vadības stieņu piedziņas servomotori; 6 — aizvara piedziņa; 7 — vertikālais eksperimentālais kanāls; 8 — aktīvā zona; 9 — horizontālais eksperimentālais kanāls; 10 — siltumekrāns

Конструкция реактора

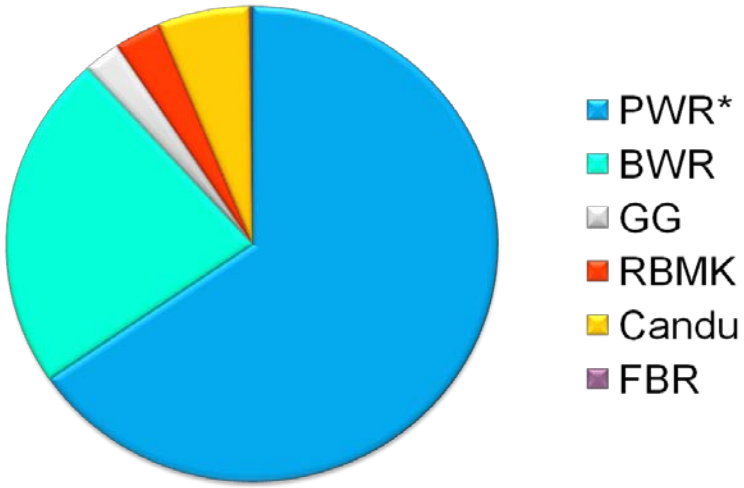
1 — трубопровод охлаждения; 2 — каналы управления; 3 — задерживающая емкость теплоносителя; 4 — сухие сборки для хранения радиоактивных образцов; 5 — сервоприводы стержней регулирования; 6 — привод шибера; 7 — вертикальный экспериментальный канал (ВЭК); 8 — активная зона; 9 — горизонтальный экспериментальный канал (ГЭК); 10 — тепловой экран

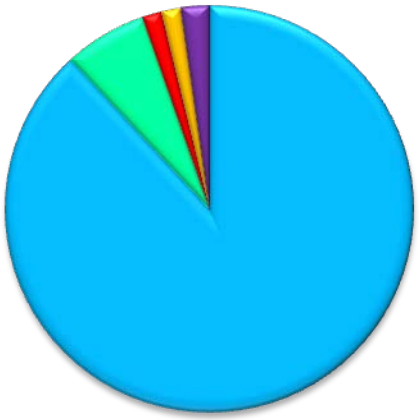
Design

1 — cooling pipeline; 2 — control channels; 3 — coolant delay tank; 4 — dry assemblies for radioactive sample storage; 5 — servodrives of control rods; 6 — gate drives; 7 — vertical experimental channel (VEC); 8 — reactor core; 9 — horizontal experimental channel (HEC); 10 — heat shield

O. Dumbrājs, LZA, 2011. gada 9. februāris.

GWe Installed in the World, July 2010





Operating : **438** Units, 372 GWe

Under Construction:**61** Units, 59 GWe
53 PWR+VVR

PWR : pressure water reactor (ūdens-ūdens spiediena kodolreaktors) II paaudze
BWR: boiling water reactor (vāroša ūdens kodolreaktors) II paaudze
GG:
RBMK: (lieljaudas kanāļu reaktors) I paaudze
Candu: Canada deuterium uranium (smagā ūdens reaktors) II paudze
FBR: fast breeder reactor (ātro neitronu brīdera reaktors)
VVR: Russian PWRs

Kodolenerģija 2009-10

Country	*GWe*	TWh	Units	%Elec
USA	*101*	797	104	20
France	*63*	392	58	75
Japan	*47*	263	54	29
Russia	*23*	153	32	18
S Korea	*18*	141	20	35
Germany	*20*	128	17	26
Canada	*13*	85	18	15
Ukraine	*13*	78	15	49
China	*9*	66	11	2
Spain	*7*	50	8	18
Sweden	*9*	50	10	35
WORLD	*374*	2 558	438	14

Isotope	Radiation	Half-life	GI absorption
Strontium-90/yttrium-90	β	28 years	30%
Caesium-137	β,γ	30 years	100%
Promethium-147	β	2.6 years	0.01%
Cerium-144	β,γ	285 days	0.01%
Ruthenium-106/rhodium-106	β,γ	1.0 years	0.03%
Zirconium-95	β,γ	65 days	0.01%
Strontium-89	β	51 days	30%
Ruthenium-103	β,γ	39.7 days	0.03%
Niobium-95	β,γ	35 days	0.01%
Cerium-141	β,γ	33 days	0.01%
Barium-140/lanthanum-140	β,γ	12.8 days	5%
Iodine-131	β,γ	8.05 days	100%
Tritium	β	13 years	100%

Spent Fuel Management

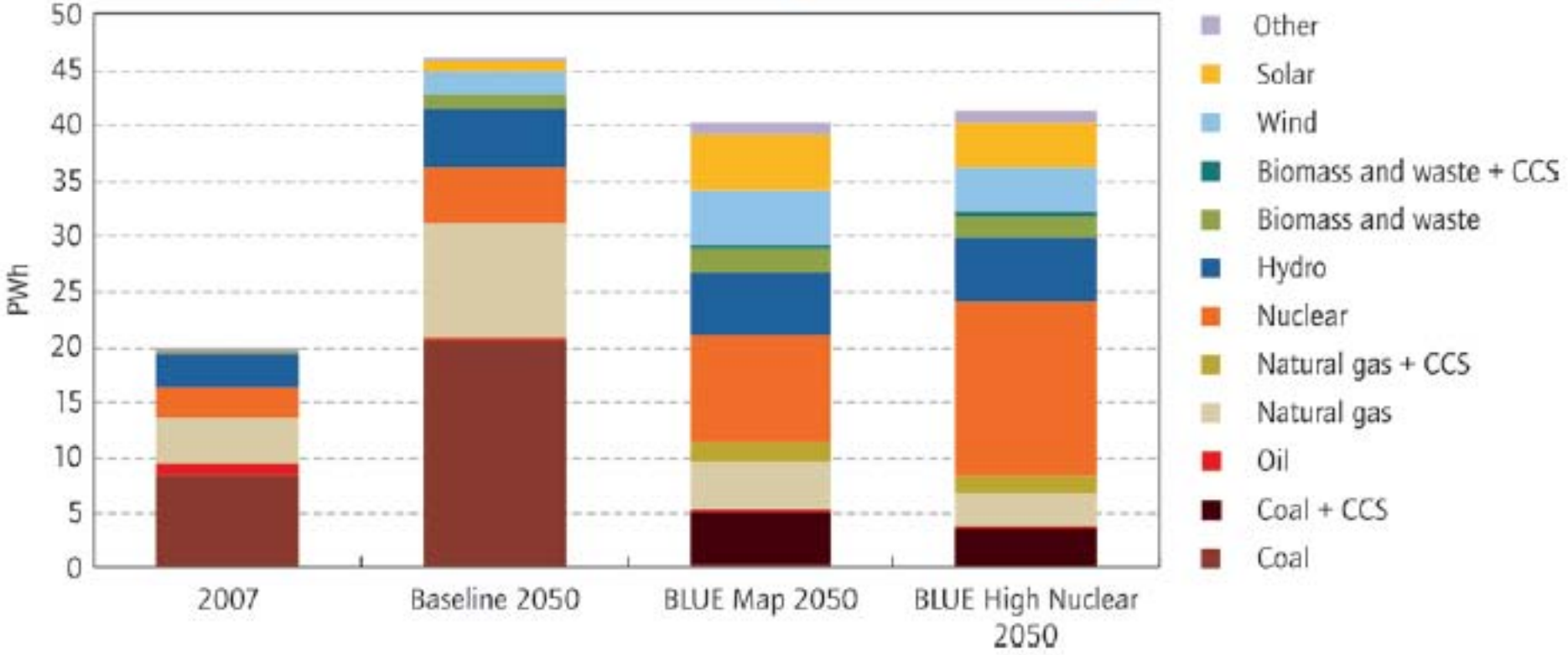
Spent fuel.

Reversible direct disposal

Storage, then decision

Reprocessing & Recycle + HLW reversible disposal

Figure 6. Global electricity production by source in 2007, and in 2050 in ETP 2010 Baseline, BLUE Map and BLUE High Nuclear scenarios



Source: IEA, 2010.

Note: CCS is carbon capture and storage. "Other" includes geothermal, tidal and wave power.

KEY POINT: In the BLUE Map scenario, nuclear power is the largest single source of electricity in 2050.

Pasaulē 18% 2000.g. 14% 2009.g. no AES

Jaunu AES konstrukcija pieaugusi no 25 līdz > 60

Pašlaik EU 27 valstīs 28% elektrība no AES

Plāns 2050 30% no AES

CO_2 samazināšana

Ja katru gadu pieprasījums aug par 1%

Tuvāko 40 gadu laikā vajag 4-5 jaunās paaudzes reaktorus gadā

2008.g.beigās pasaulē 438 reaktori ar kopējo jaudu 373 GWe

Projekti 2000 – 2050

31 valsts

3 reaktori ar ātriem neitroniem **SFR LFR GFR**

1 reaktors ar siltuma neitroniem **VHTR**

2 reaktori ar ātriem un siltuma neitroniem **SCVR MSR**

10^9 USD katrai sistēmai līdz 2020. gadam

Towards sustainable nuclear energy

Current and future Light Water Reactors

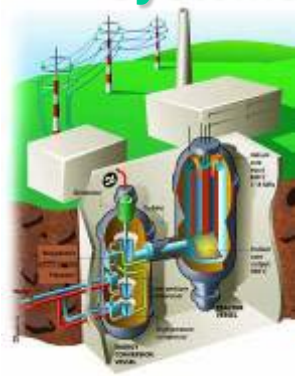
Fast neutron reactors with closed fuel cycle

Other applications of nuclear energy

Current Reactors

Advanced Reactors

Future Systems



1970 1990 2010 2030 2050 2070 2090

Generation II

31% of EU's electricity

Generation III

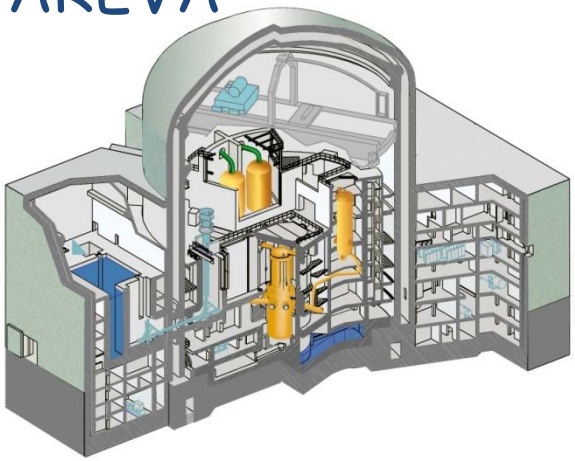
New builds in Finland and France…

Generation IV

Start of industrial deployment in 2040-2050

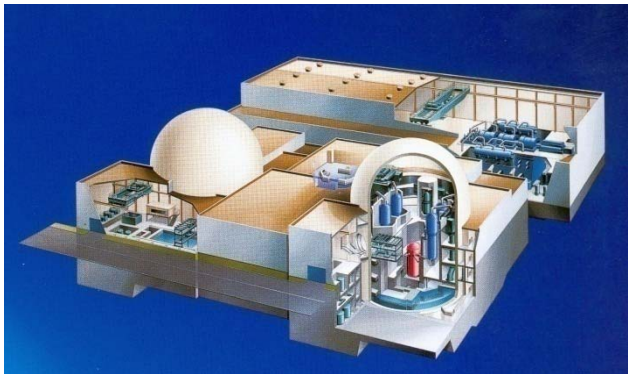
Generation III PWRs

EPR
AREVA

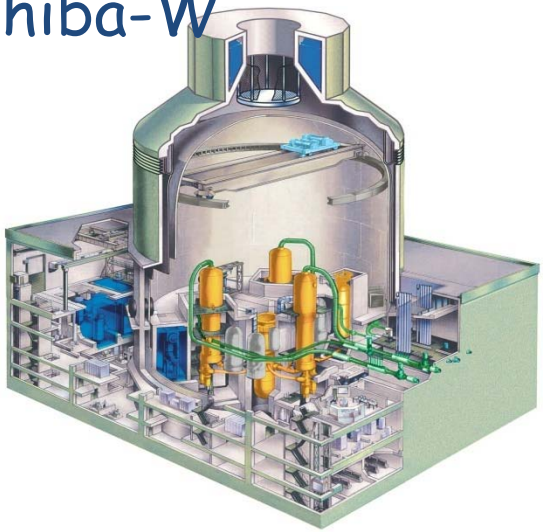


APR 1400 S Korea

APWR MHI

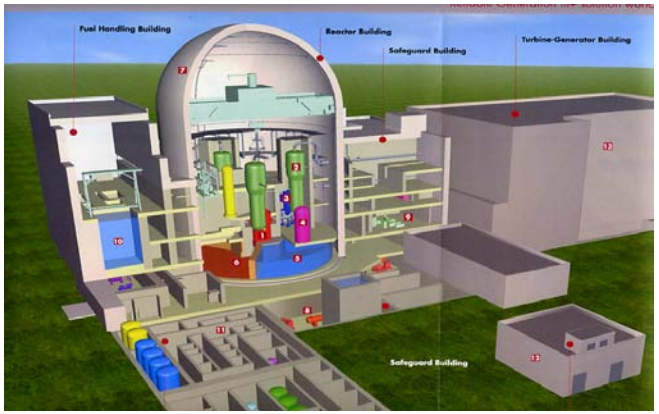


AP 1000
Toshiba-W



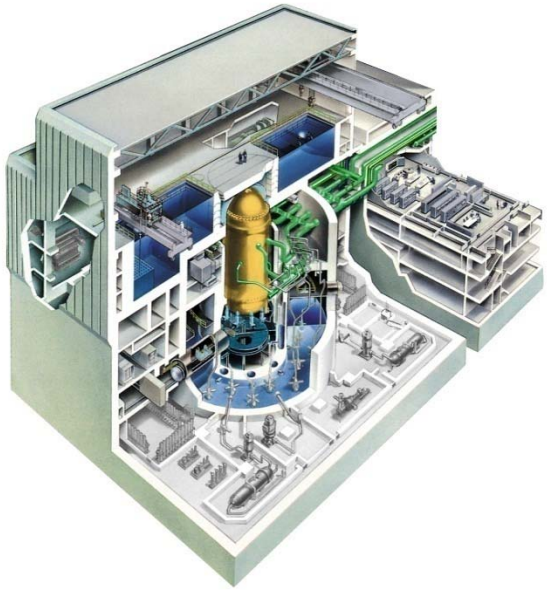
AES 92
Russia

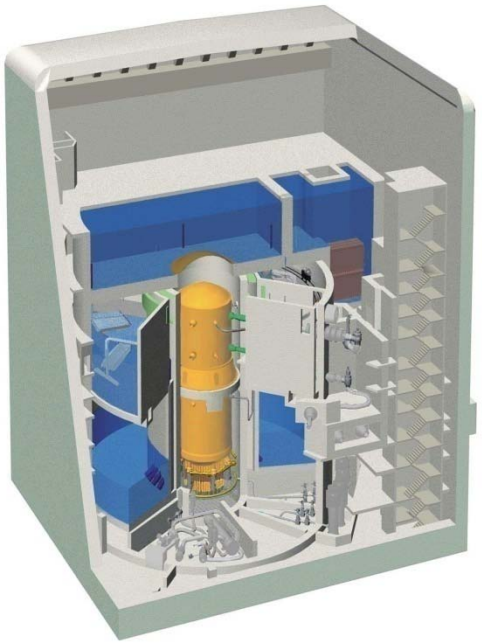
ATMEA Areva-Mitsubishi



Generation III BWRs

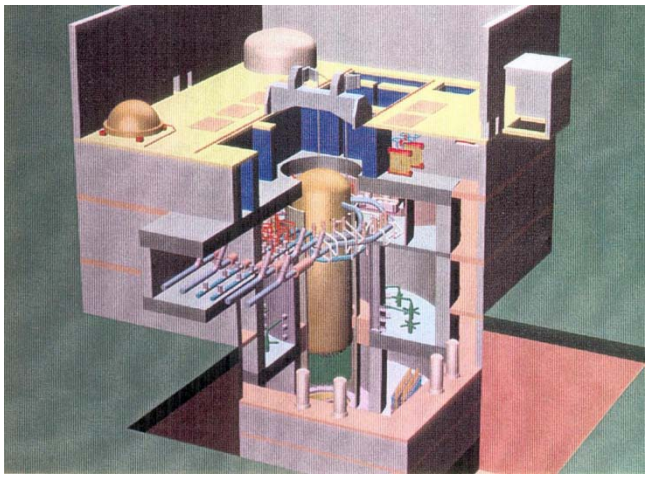
ABWR GE-Hitachi

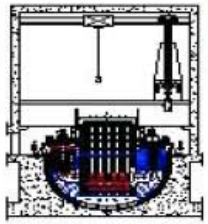




KERENA AREVA

ESBWR GE





2008

2012

2020

SFR

Reference technology

SFR Prototype
(250-600MWe)

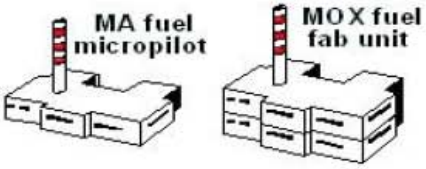
LFR

LFR Demo
50 -100MWth

Alternative technology

GFR

GFR Demo
50 -100MWth



Supporting infrastructures, research facilities
Irradiation facilities
and fuel manufacturing facilities

Sodium fast reactor (SFR) Japan, USA, France, Euratom, Korea, China, Russia as observer

Zona 550^0

600-1500 MW, 300-1500MW, 50-150MW

Efektivitāte 42%

Pu (14% loop, 25% pool)

Demo ~2020 Astrid France

Lead fast reactor (LFR) Euratom, Japan, USA+Russia as observers

Zona 380^0 ELSY 570^0 SSTAR

$(Pu,U)O_{2-x}$ 19%

Efektvitāte 42%

ELSY 600MW SSTAR 20MW transportable

Demo ~2025

Gas fast reactor (GFR He gas) France, Euratom, Japan, Switzerland
Zona 850^0
Efktivitāte 45%
Pu 12%
1000 MW
Demo ~2025 ALLEGRO demo 7MW

Very high temperature reactor (VRHT He gas) USA, Japan, France, Korea, Canada, Switzerland, China, Euratom, South Africa exp,2010
Elektrība un siltums
Siltuma neitronu spektrs
^{235}U, ^{233}U noTh, Pu 19%
Zona 1000^0
Efektivitāte ~50%
400-600MW
H ražošana ~200t/dienā
Demo ~2020 NGNP USA, HTR-PM China, GTHTR-300c Japan, NHI PBMR South Africa

Supercritical water reactor (SCWR) Euratom, Canada, Japan, Korea as observer

Pašlaik attīstās no GEN II un GEN III LWR EU un CANDU Kanāda

Siltuma neitroni

UO_2 CANDU ^{232}Th

Zona 625^0

Efektivitāte ~45%

1700MW

Demo 2025

Molten salt reactor (MSR) Euratom, France, USA & Russia as observers

Zona 800^0

Efektivitāte 45%

Ātrie neitroni bez C MGFR EU, MS-HTR USA augsta temperatūra

^{233}U no bagātināta ^{232}Th

1000MW

Demo 2030

Paldies par uzmanību