Muons, Inc.
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Continuous Improvement in a Field Frozen by Regulation

Accelerator-Driven Molten Salt Subcritical System (non-reactor) to ease Regulatory Burdens and "Improve Constantly and Forever"

SUMMARY - Mu*STAR Nuclear Power Plants
Clean Nuclear Energy - Converting SNF to Energy

Flexible Regulatory Approach Possible -> Improve Continuously and Forever
- Subcritical - No Criticality Accidents
- Accidental Radioactive Releases Mitigated by Online Fission Product Removal
- Uranium and Plutonium consumed in reactor –> Cleaner Final Waste Disposal

Decouples nuclear energy from nuclear weapons
- No Uranium enrichment
- No dedicated reprocessing facility with plutonium stream
- No weapons proliferation risks –> bomb materials consumed in reactor

Inexpensive Nuclear Energy -> High burnup of Spent Nuclear Fuel (SNF)
- Online neutron poison removal improves efficiency

Consumes waste from other reactors – SNF becomes a valuable commodity

Thanks! Any Questions or Comments?

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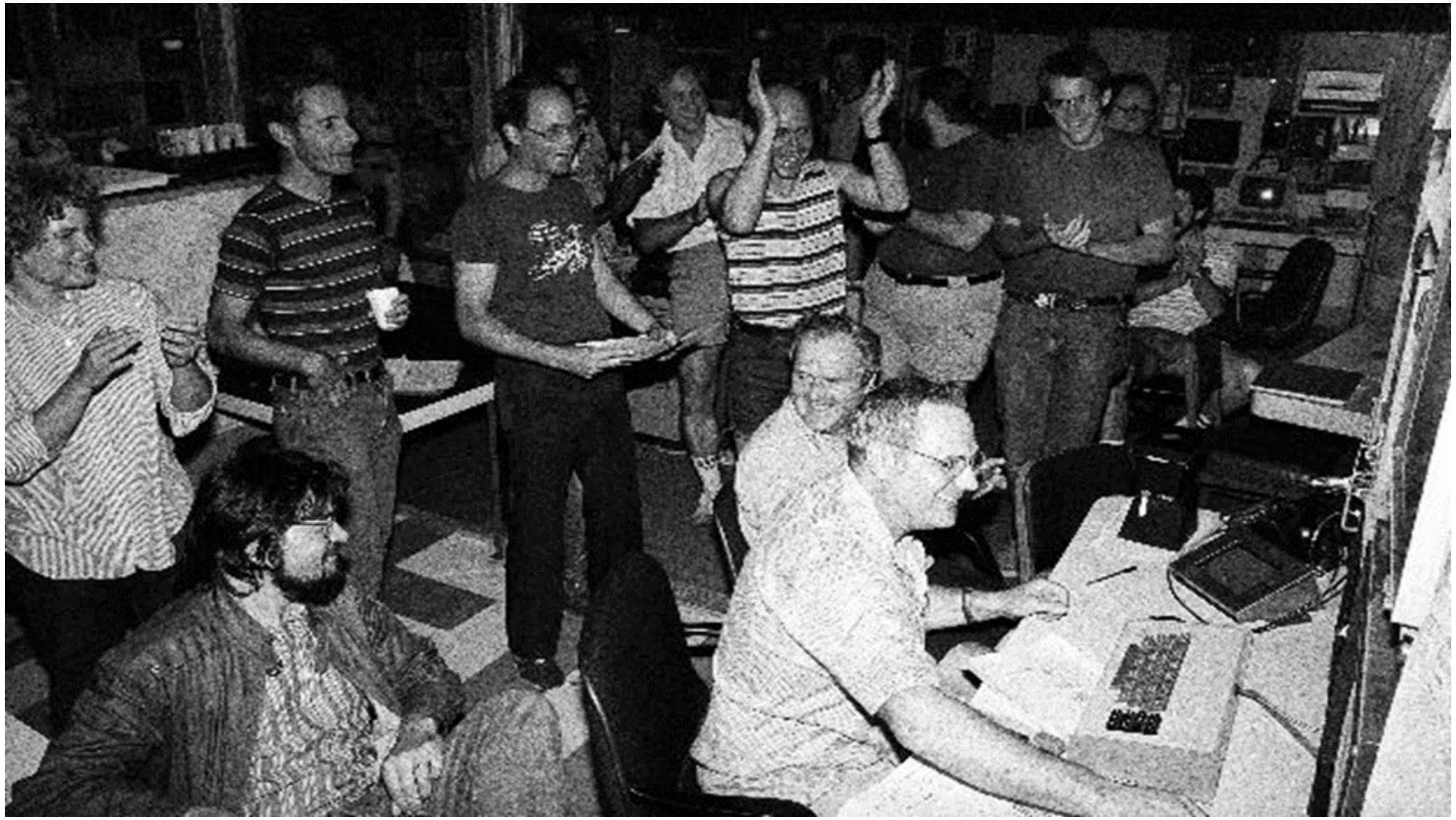


Muons, Inc. has over 20 years of R&D experience developing particle accelerators and related technology, having been awarded and delivered over 32M USD in private and government contracts in partnership with 11 National Labs and 9 Universities. Founded by scientists from National Labs.

Nuclear Now!

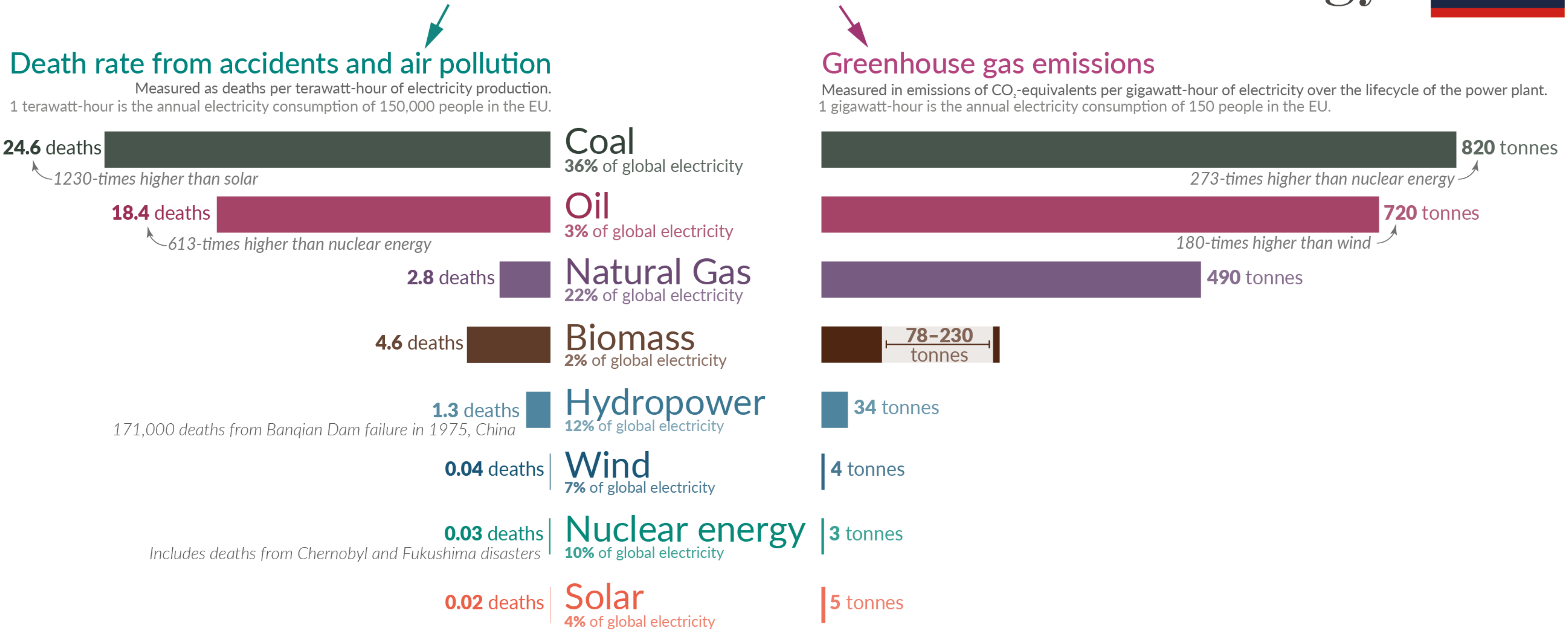
- No Greenhouse gas emission during operation
- Safest form of Electricity Generation
- Highest Energy Density / Low Footprint
- Lowest amount of waste

CHALLENGES:

- What to do with the SNF (Spent Nuclear Fuel)?
- Designs Frozen By Regulation = Innovation Gap!*
- Uranium Enrichment and Weapons Proliferation

What are the safest and cleanest sources of energy?

Our World in Data

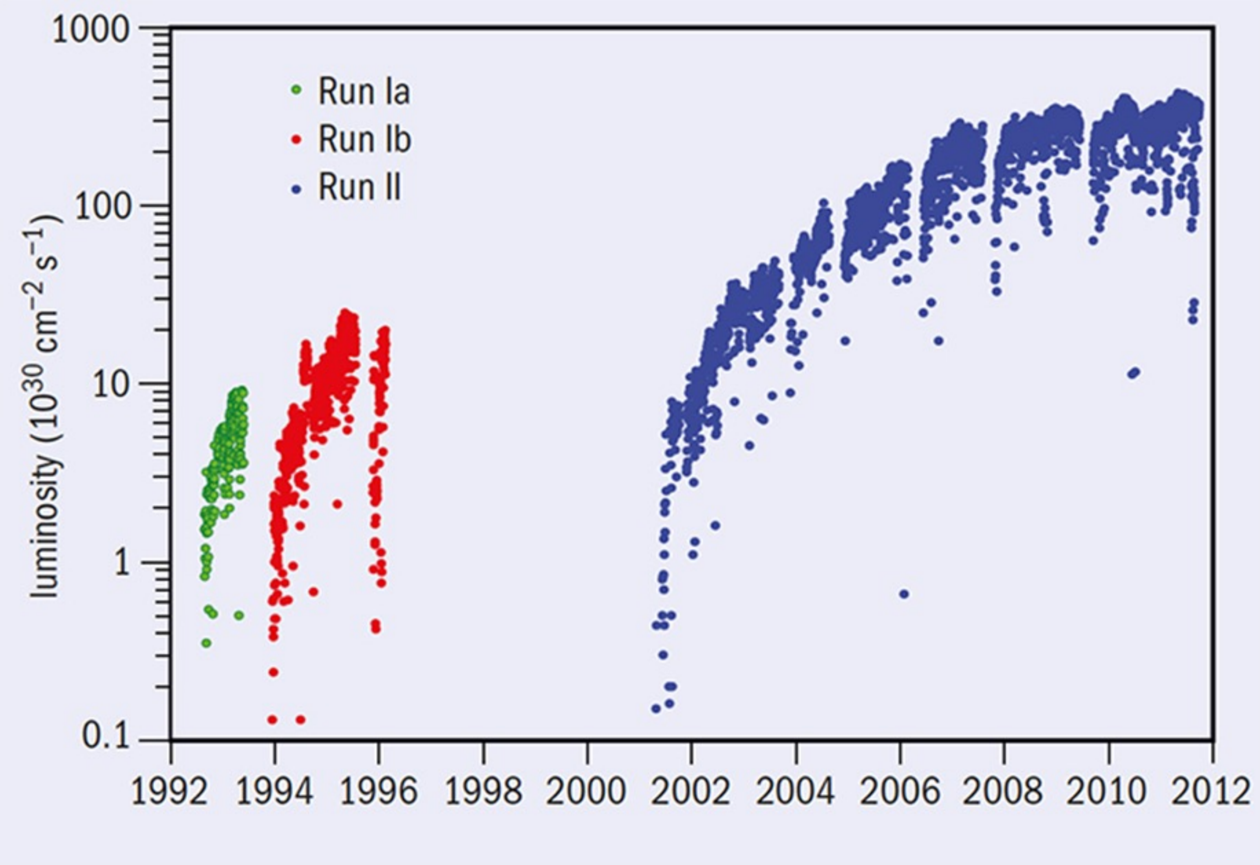


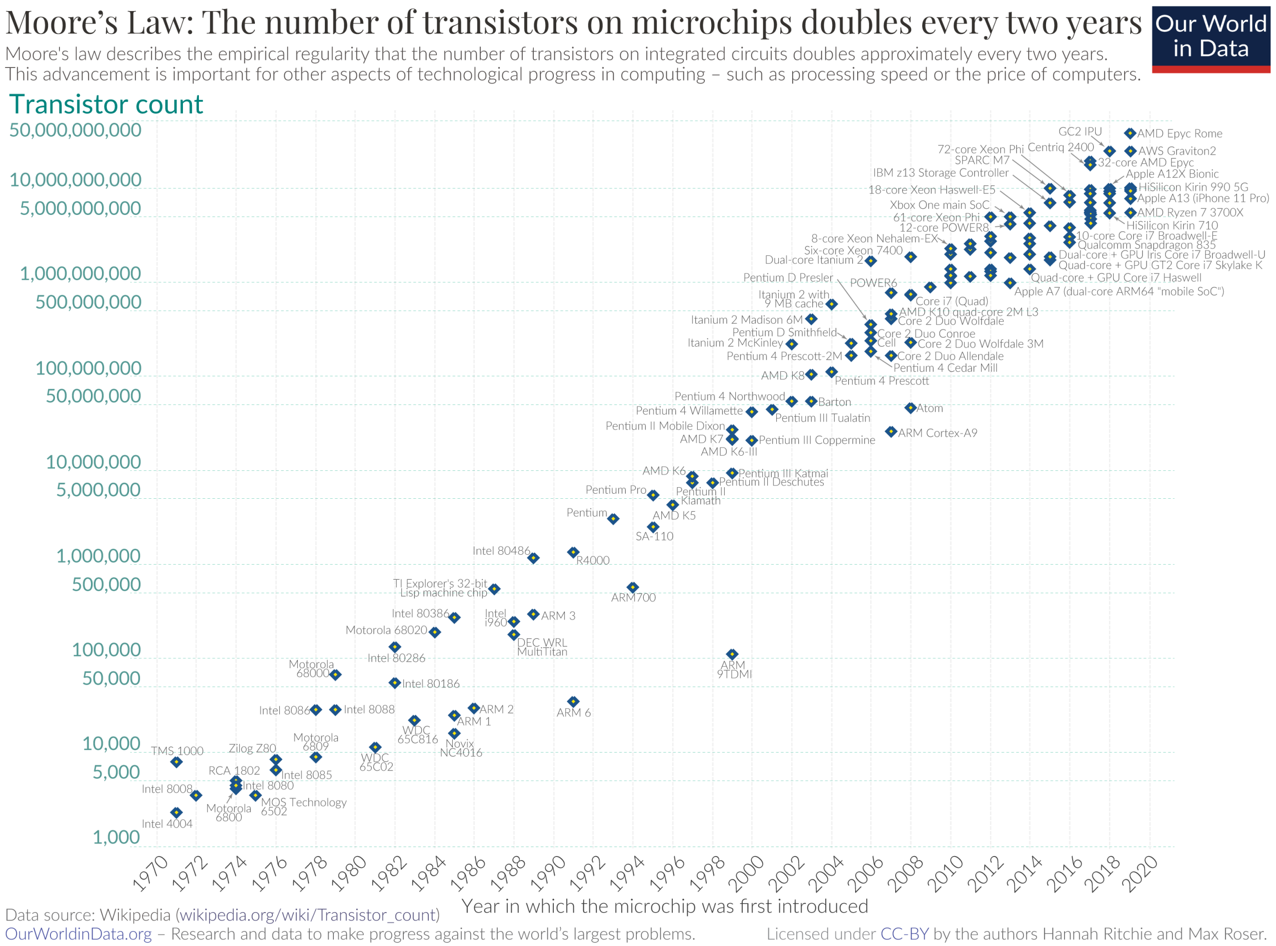
Death rates from fossil fuels and biomass are based on state-of-the art plants with pollution controls in Europe, and are based on older models of the impacts of air pollution on health. This means these death rates are likely to be very conservative. For further discussion, see our article: OurWorldinData.org/safest-sources-of-energy. Electricity shares are given for 2021.

Data sources: Markandya & Wilkinson (2007); UNSCEAR (2008; 2018); Sovacool et al. (2016); IPCC AR5 (2014); Pehl et al. (2017); Ember Energy (2021).

OurWorldinData.org – Research and data to make progress against the world's largest problems.

TEVATRON performance over 20 years, including contributions by Bill Foster





<u>The results were amazing, but in successful companies, such stories are normal for those that can follow Demings' principle to "Improve Constantly and Forever…"</u>

Nuclear Improvements Frozen by Regulations

The Nuclear Energy Industry is hobbled by Regulatory Demands to prevent:

- **Criticality Accidents** (like Chernobyl)
- **Accidental Release of Radioactive Isotopes** (like Chernobyl, 3-Mile Island, Fukushima)

These challenges can be overcome with an ACCELEATOR-DRIVEN SUBCRITICAL DESIGN and MOLTEN SALT FUEL with continuous removal of volatile radioactive isotopes.

CFR10: a nuclear reactor is defined as "any apparatus or device in which a nuclear chain reaction can be sustained and controlled in a self-supporting or neutron multiplying medium, and which is designed or used to produce heat, power, or any other form of radiation."

CFR10 Part 50, Appendix A: nuclear power plants must limit the release of radioactive materials into the environment following an accident. The limit for the release of iodine-131 is 5 curies per day. The limit f the release of cesium-137 is 15 curies per day.

Nuclear Improvements Frozen by Regulations

- Decades required to certify reactor designs and components.
- Defense-in-depth approach.
- Regulatory process time consuming and expensive (~$1B for Nuscale).
- Designs cast in concrete.
- Operation limited to same procedures for the following 6-8 decades.

Mu*STAR Nuclear Power Plants

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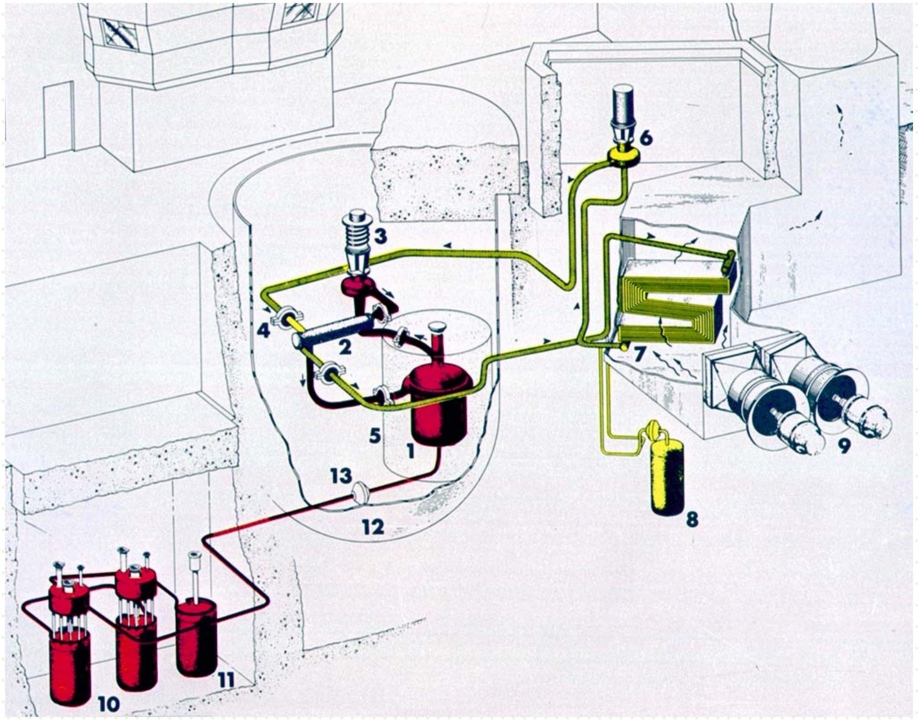
Overcoming challenges using proven US National Lab Innovations

Our Solution to overcoming the two constraints come from one new and one old development at Oak Ridge National Laboratory. The Superconducting Linac of the Spallation Neutron Source (SNS) which has the power to drive multiple subcritical Small Modular Reactors (operated from 2010 to now)

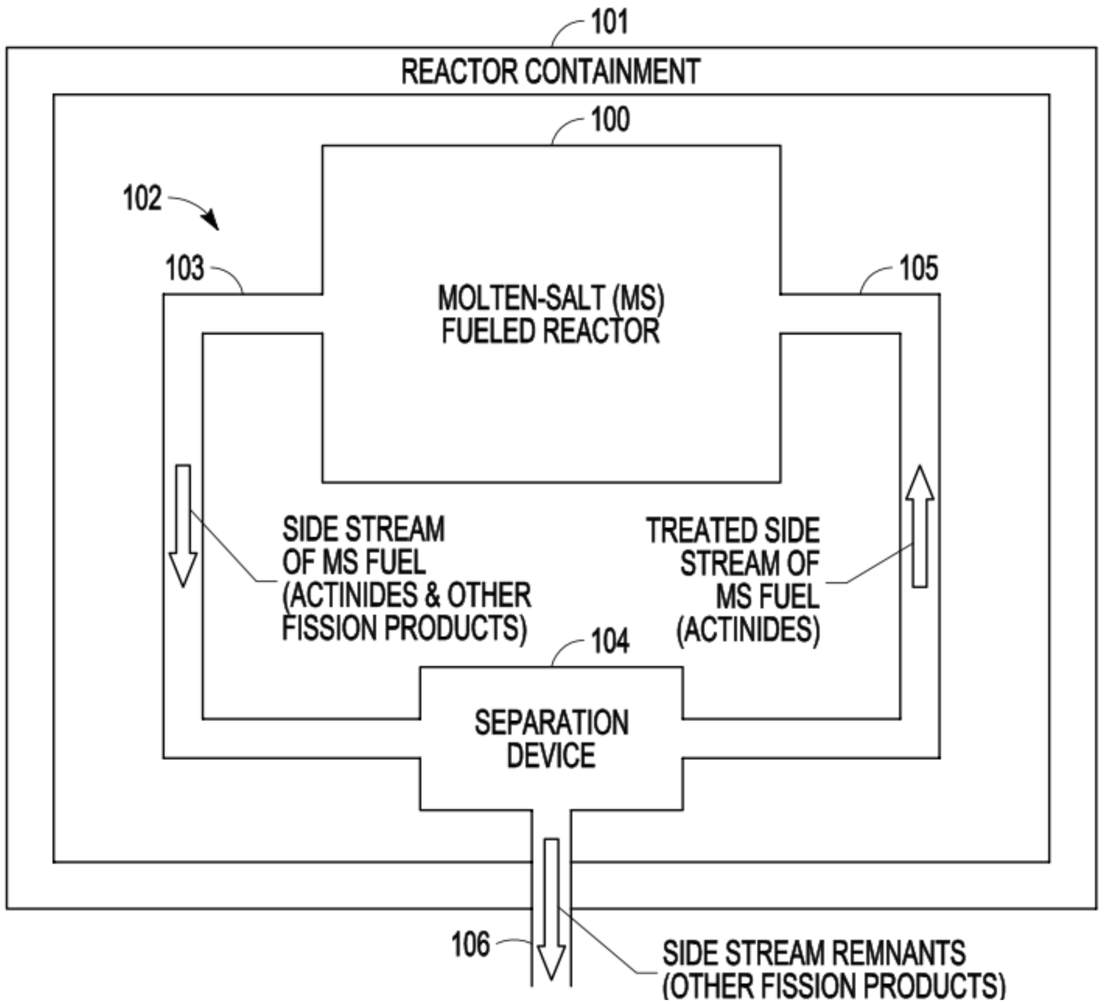
ORNL SNS (2010-...)

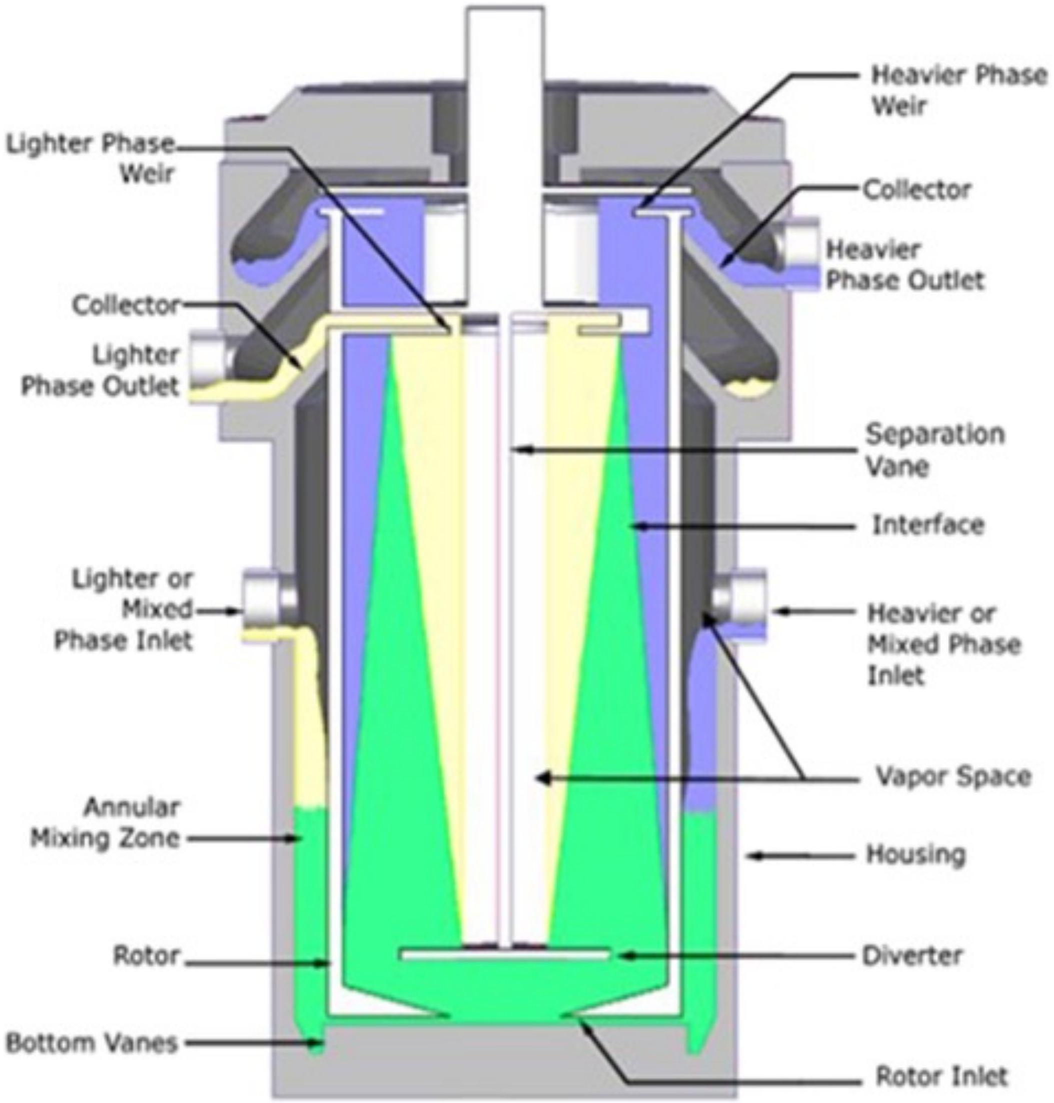


ORNL MSRE (1965-1970) Diagram

The Molten Salt Reactor Experiment (MSRE) (operated from 1965 to 1970) which demonstrated how we can continuously remove fission products from an operating reactor.

Improvement for Removing Neutron Poisons / PUREX inspired



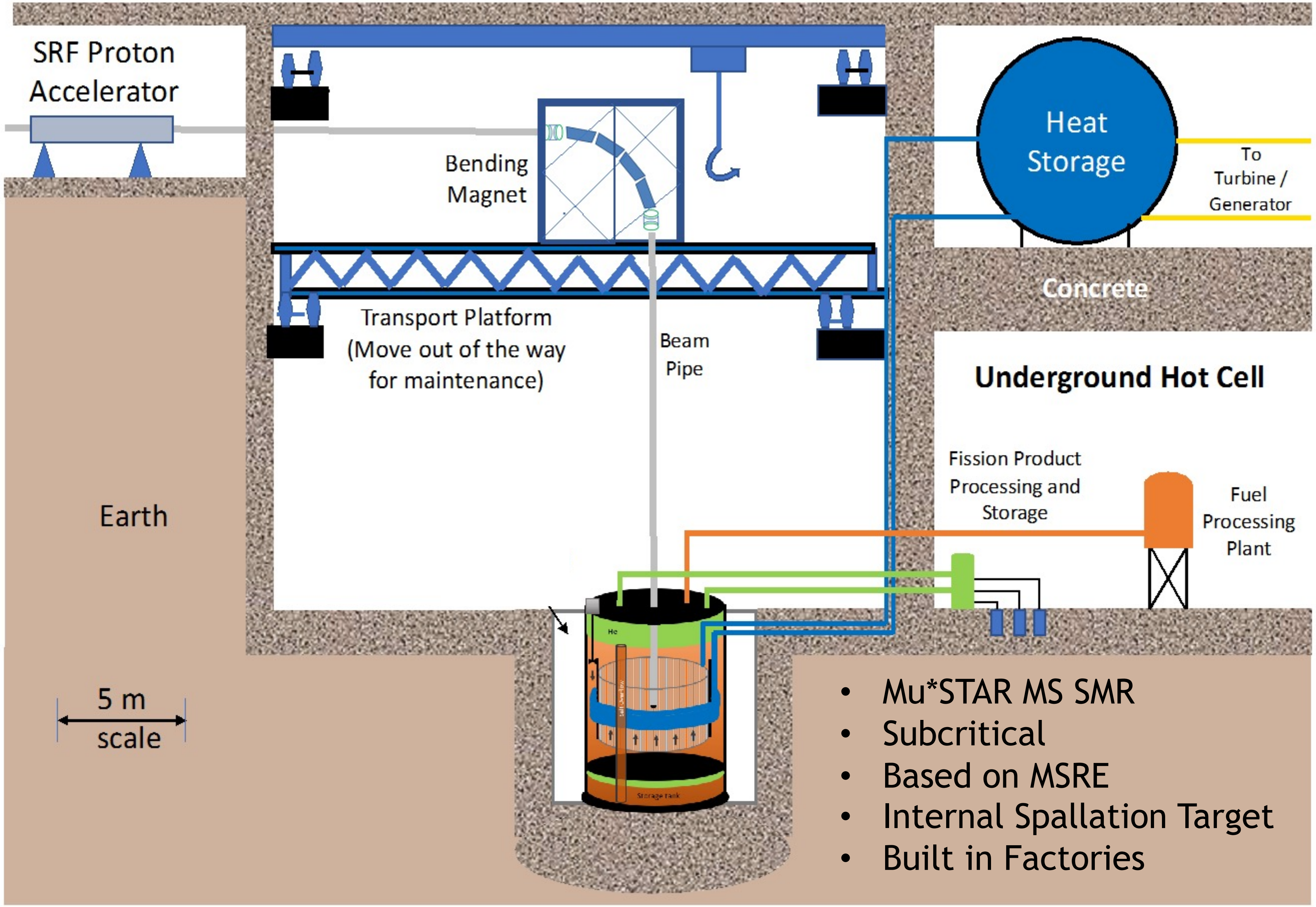


Business Drivers

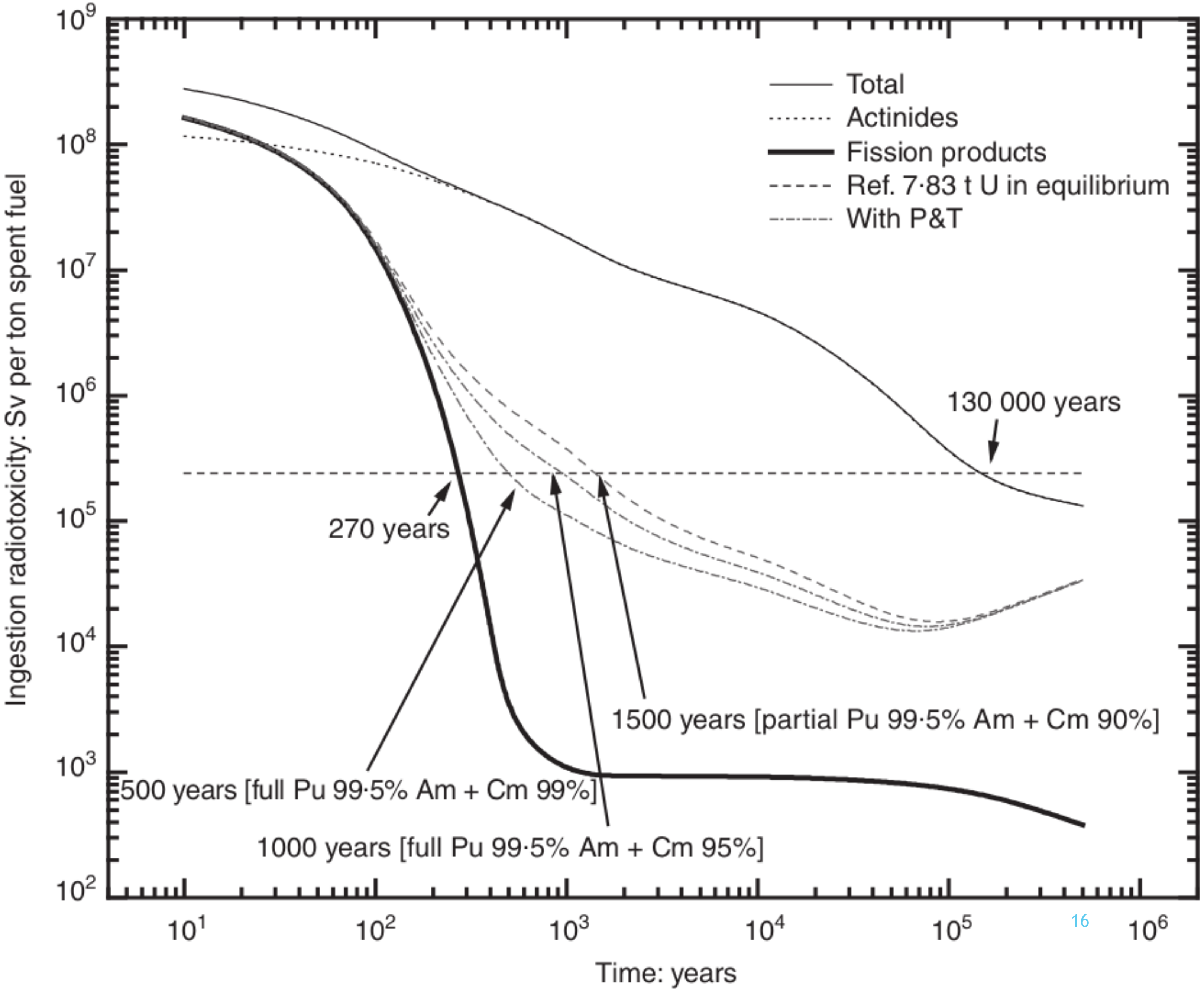
Profitably Solving Legacy LWR SNF Waste Challenge

0.002x	**Radiotoxic lifetime**	Reduction in radiotoxic lifetime of nuclear waste from 130,000 years to 270 years. Reduces need for geological disposal
$3 TUSD	**Waste to Asset**	The current unwanted 80kT of nuclear waste in the US alone can be used to produce carbon-free electrical energy worth Trillions of dollars.
$12.70	**Carbon Credits**	From voluntary and legislated carbon credits for Carbon free generated Energy. $/ton of CO2

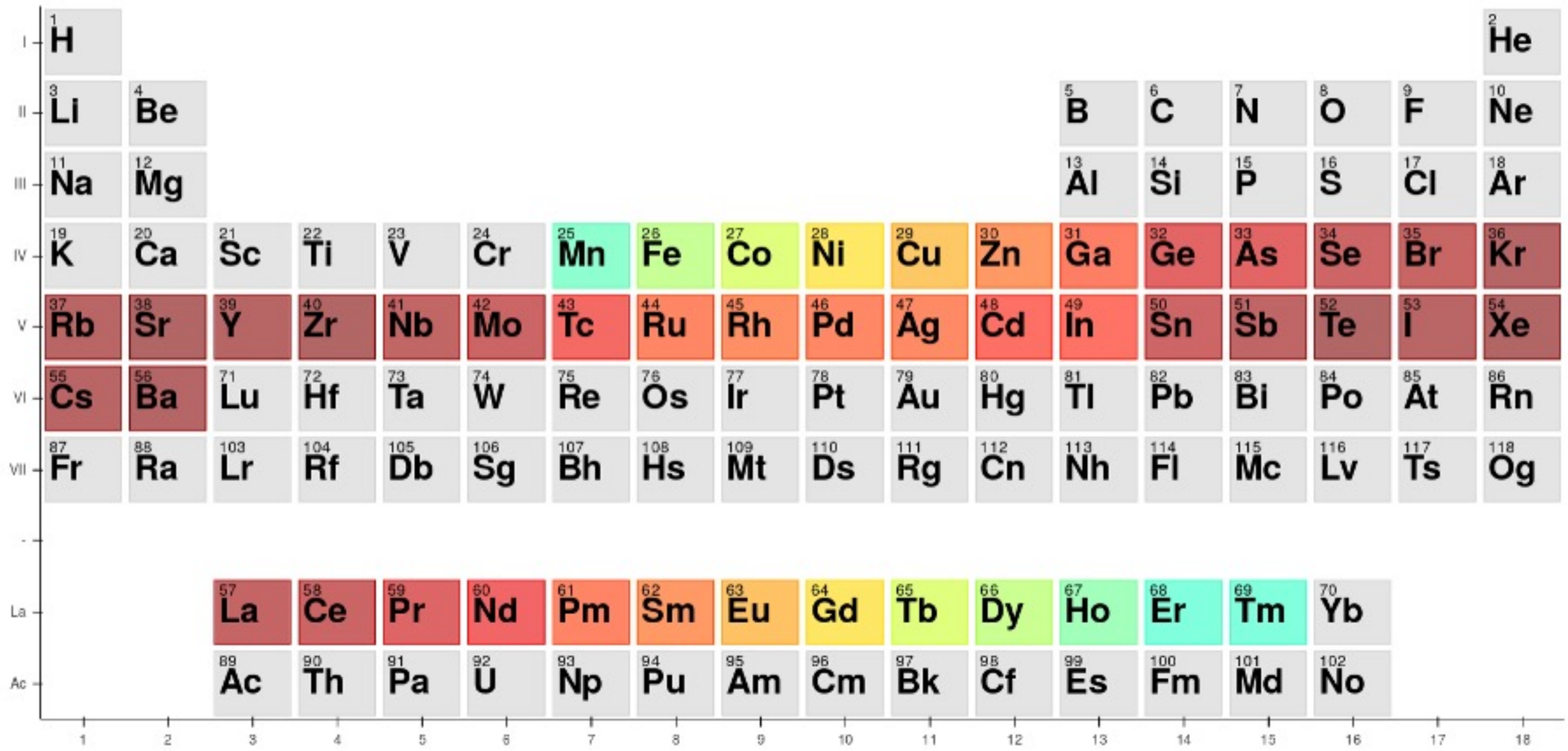
Underground Build:
- MS fuel prep
- FP Removal
- FP Storage
- MS Heat Storage
  - Decay Heat
  - Downtimes
- SRF Linac
- Mu*STAR SMR



- Mu*STAR MS SMR
- Subcritical
- Based on MSRE
- Internal Spallation Target
- Built in Factories



Ingestion radiotoxicity: Sv per ton spent fuel
Time: years
Total
Actinides
Fission products
Ref. 7·83 t U in equilibrium
With P&T
130 000 years
270 years
1500 years [partial Pu 99·5% Am + Cm 90%]
500 years [full Pu 99·5% Am + Cm 99%]
1000 years [full Pu 99·5% Am + Cm 95%]



I
II
III
IV
V
VI
VII
La
Ac
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
37 Rb
38 Sr
39 Y
40 Zr
41 Nb
42 Mo
43 Tc
44 Ru
45 Rh
46 Pd
47 Ag
48 Cd
49 In
50 Sn
51 Sb
52 Te
53 I
54 Xe
55 Cs
56 Ba
71 Lu
72 Hf
73 Ta
74 W
75 Re
76 Os
77 Ir
78 Pt
79 Au
80 Hg
81 Tl
82 Pb
83 Bi
84 Po
85 At
86 Rn
87 Fr
88 Ra
103 Lr
104 Rf
105 Db
106 Sg
107 Bh
108 Hs
109 Mt
110 Ds
111 Rg
112 Cn
113 Nh
114 Fl
115 Mc
116 Lv
117 Ts
118 Og
57 La
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
89 Ac
90 Th
91 Pa
92 U
93 Np
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Highest Energy Density

Medium	Energy Density MJ/m³	Electrical Energy Density kWh/m³	Conv. Effic.	Comments
Natural uranium (Fast)	150,000,000,000	12,500,000,000	30%	Fast reactors
Natural uranium LWR	950,000,000	80,000,000	30%	Thermal
Black coal	24,000	2,300	35%	-
Brown coal	15,000	1,000	25%	-
Dry wood	10,000	970	35%	Biomass
Natural gas	38	5	45%	CCGT

Energy density is expressed in megajoules (MJ) per cubic meter (m^3). There is always some loss in converting the stored energy to electrical energy, so the table shows the typical conversion efficiency and the electrical energy recovered per cubic metre of fuel.