Accelerator Driven Systems and Spent Nuclear Fuel

Rob Forrest
UC Davis HEP Seminar
May 29, 2012

CISAC
STANFORD


Country : Japan
Area : Fukushima Daiichi Nuclear Facility
Tsunami Damage
Acquisition Date : March 14, 2011
Sensor : Worldview-2
Resolution : 0.5 Meters
www.satimagingcorp.com
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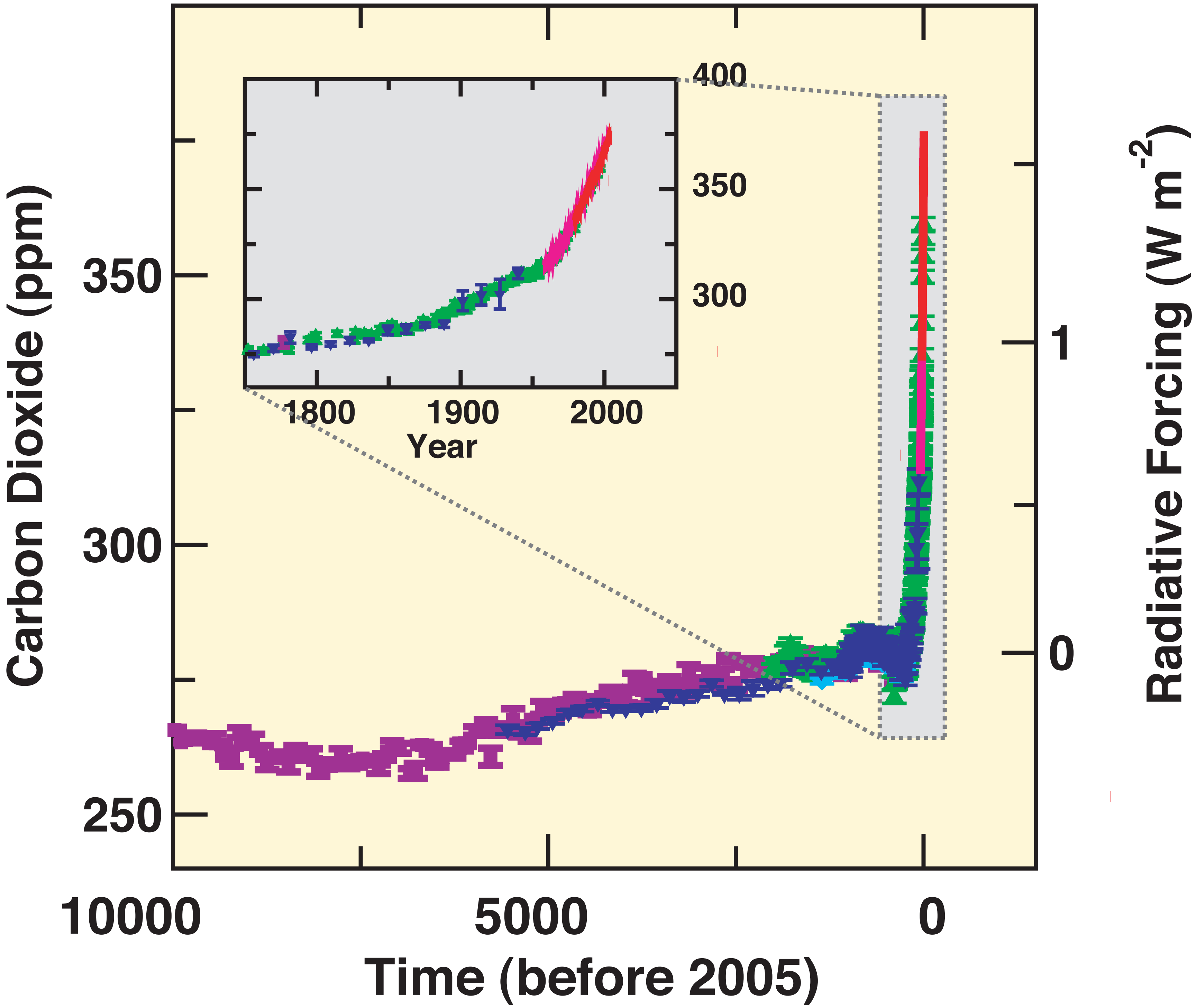
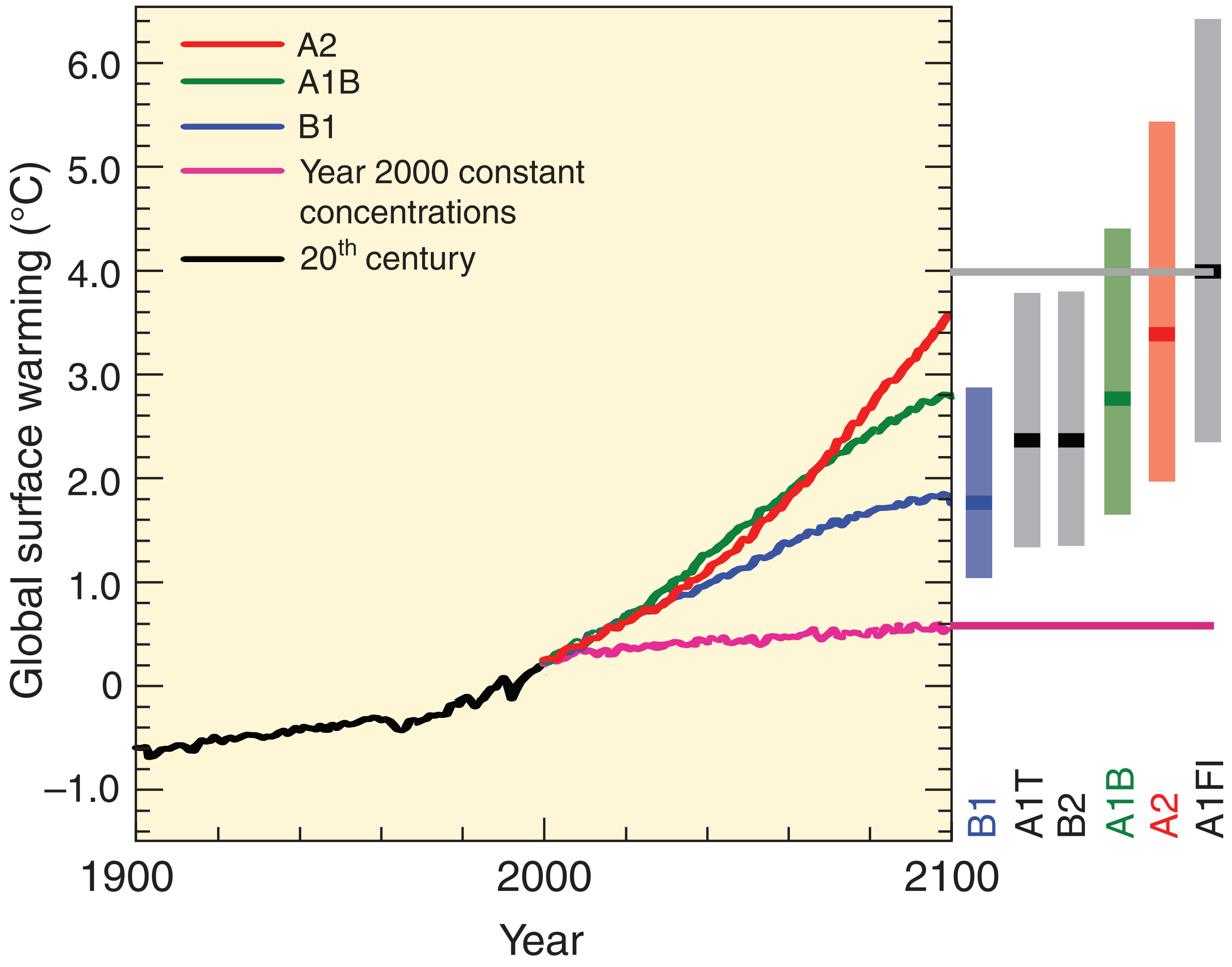
Outline

- Energy in the US
- Nuclear Power and its problems
- Spent Nuclear Fuel and Transmutation
- ADS, Examples


Carbon Dioxide (ppm)
350
300
250
10000
5000
0
Time (before 2005)
Radiative Forcing (W m^{-2})
1
0
400
350
300
1800
1900
2000
Year

Warming Situation

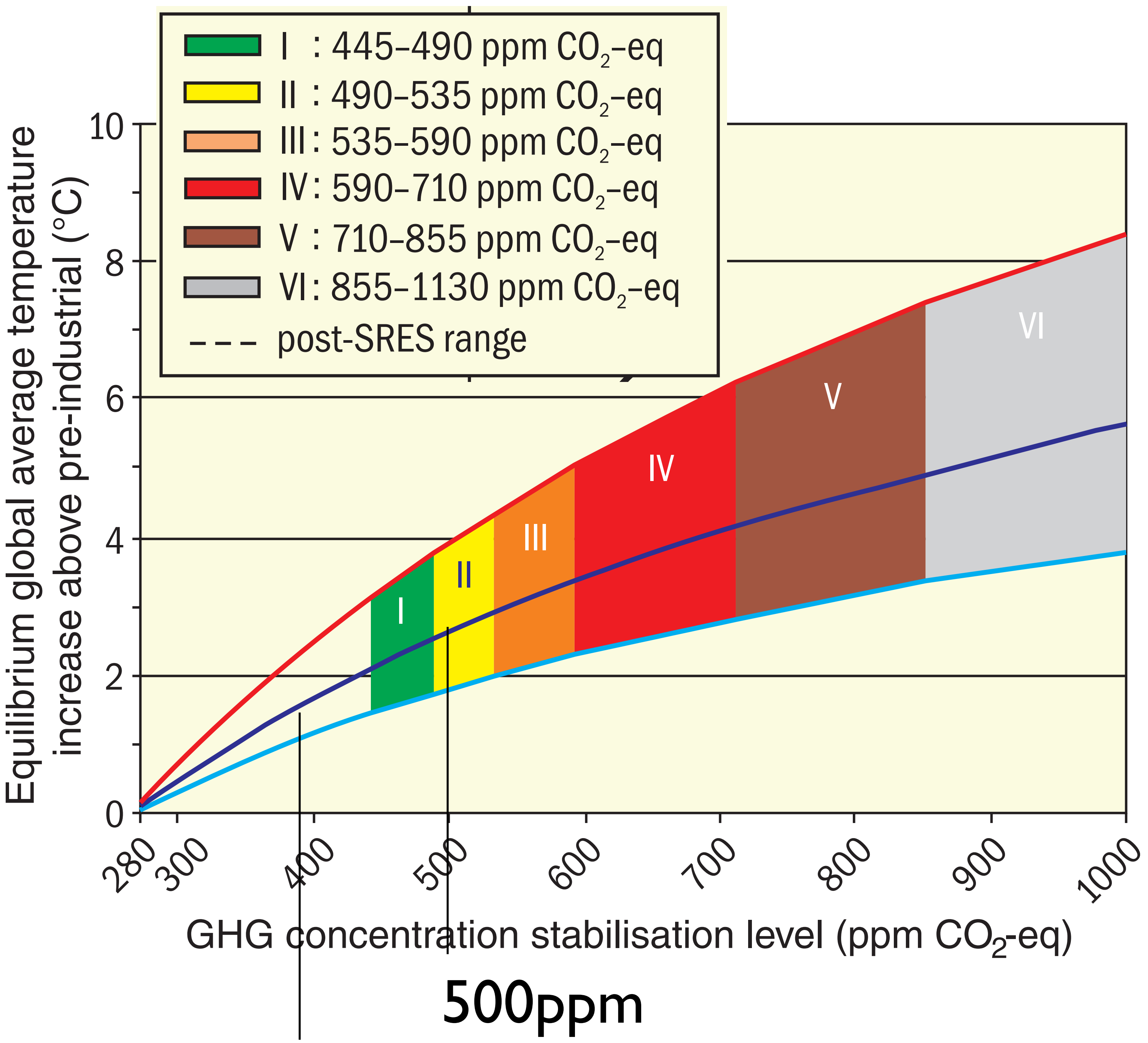


Growth as Usual

Year 2000 Levels

IPCC 07

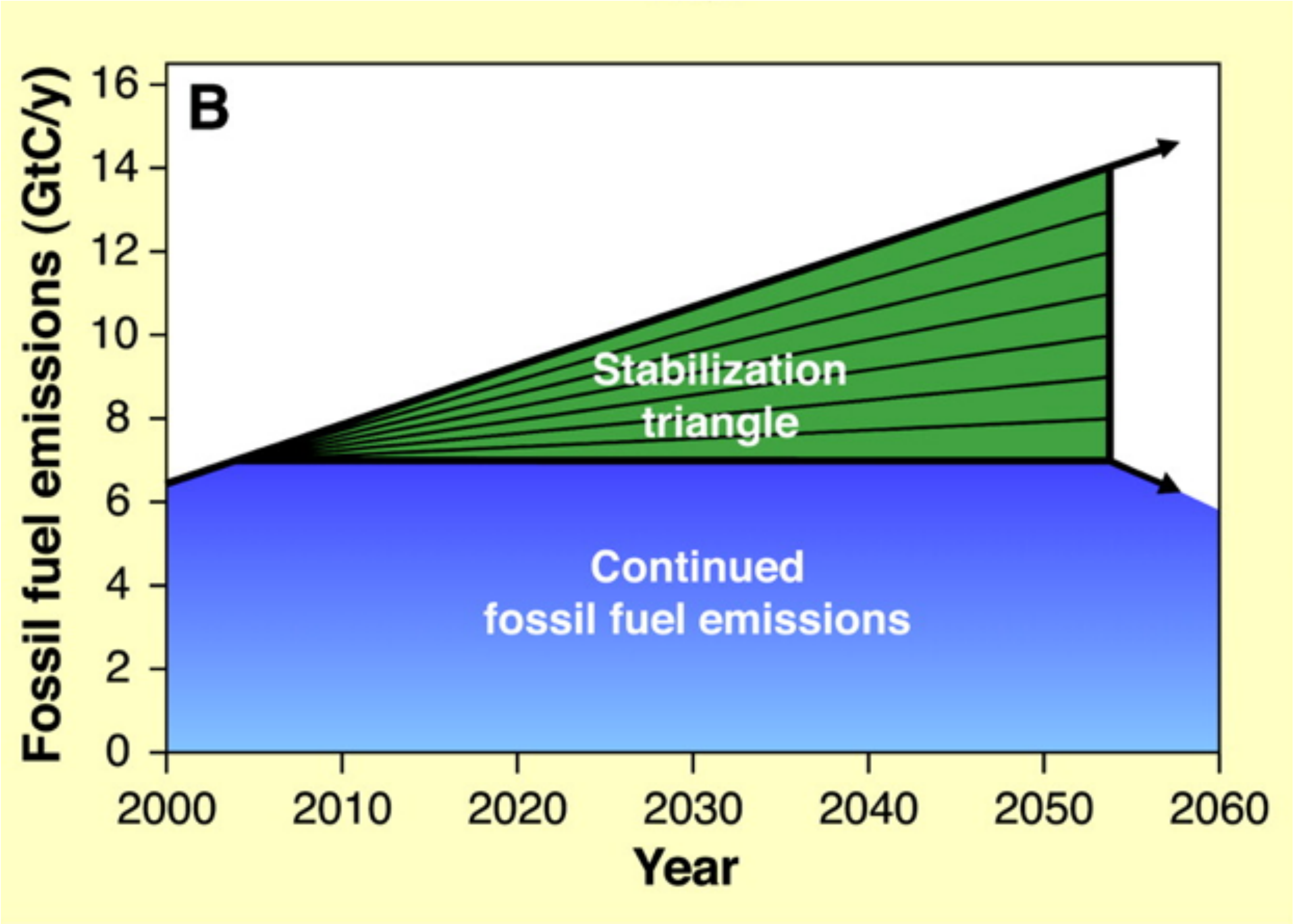
CO_2 stabilization levels



2012

IPCC 07

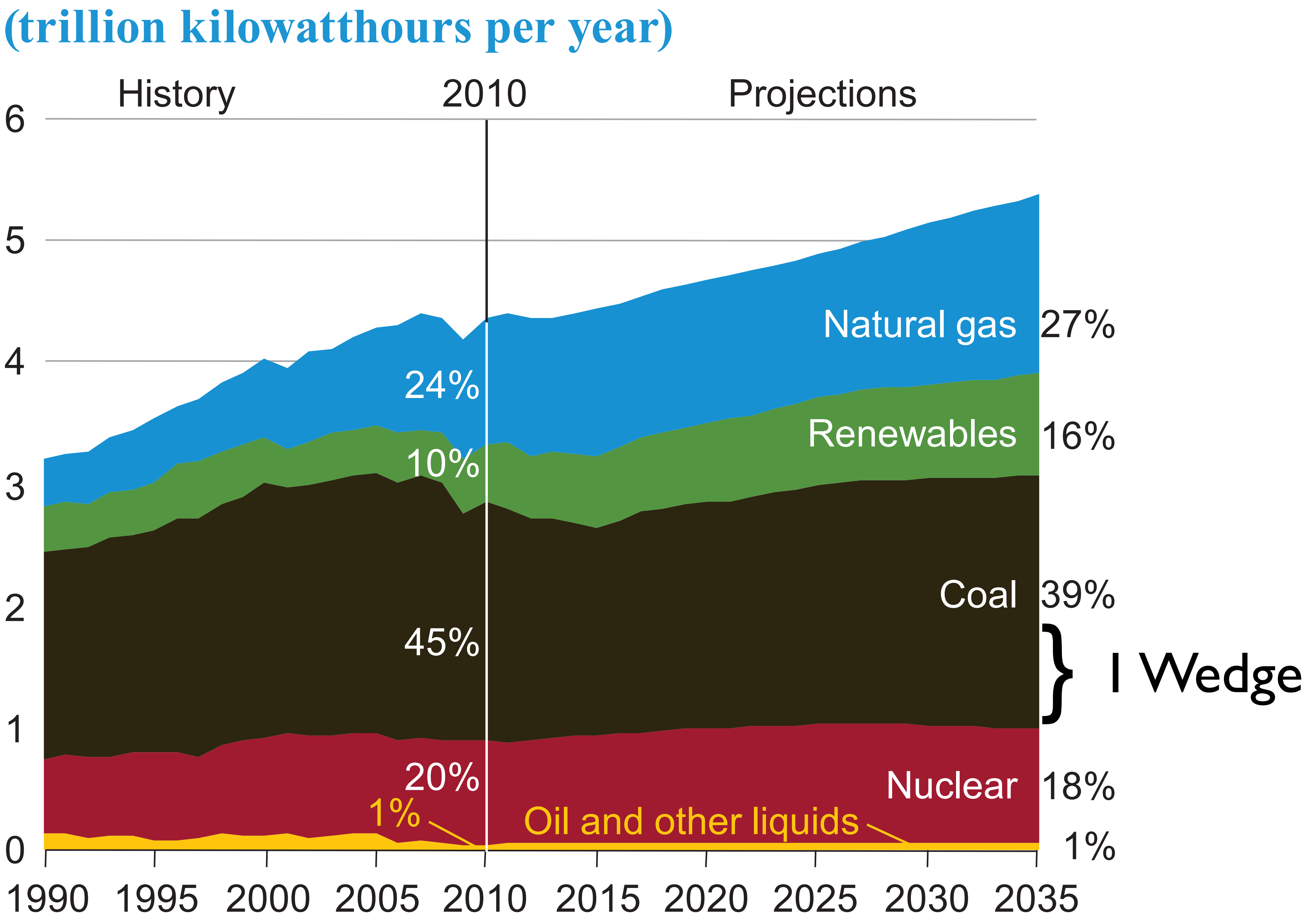
stabilization wedges



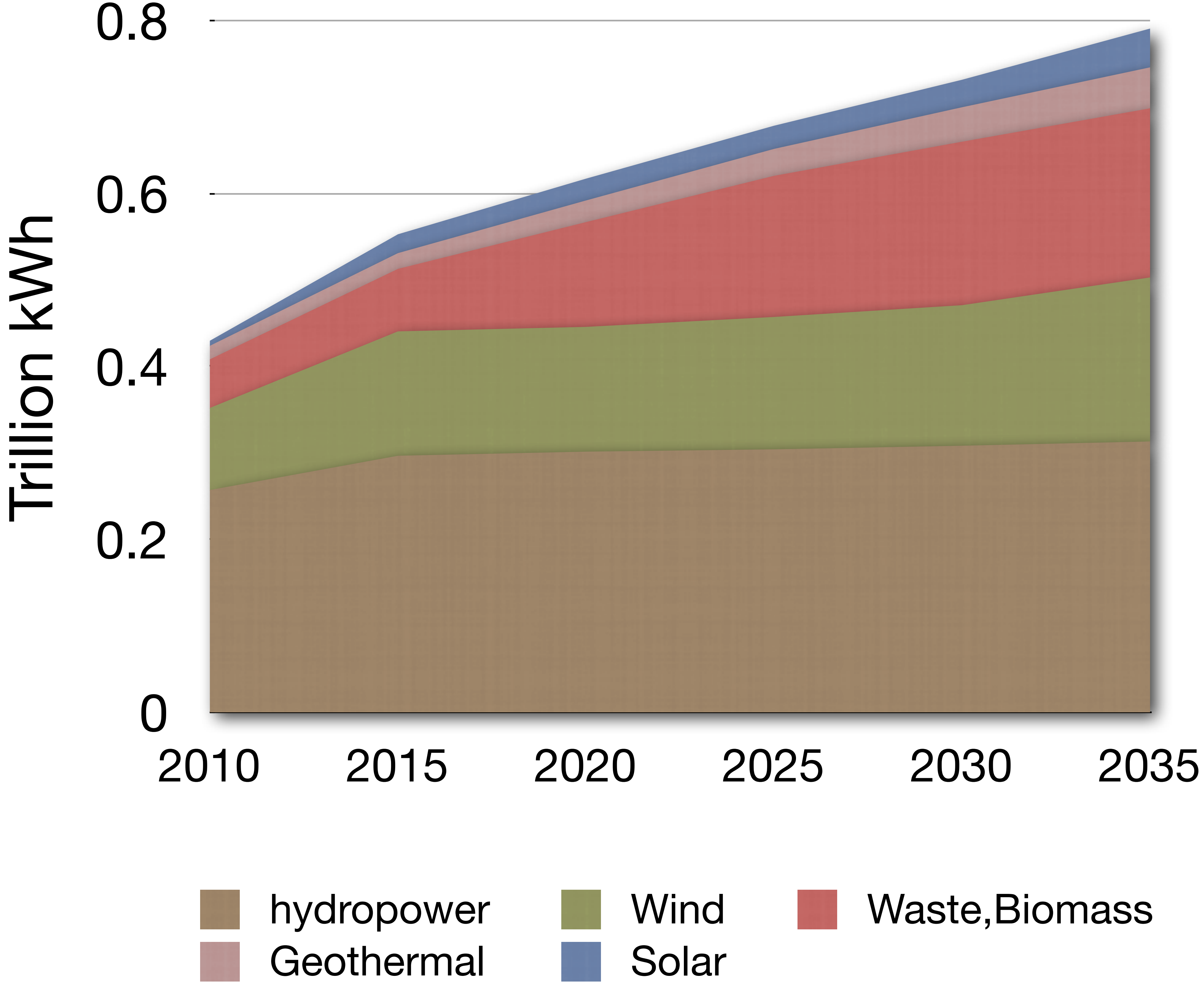
1 'wedge' = 1 Gton of Carbon

1 Wedge:
2 billion cars from 30 to 60 mpg
Replace 700 GW of coal by nuclear

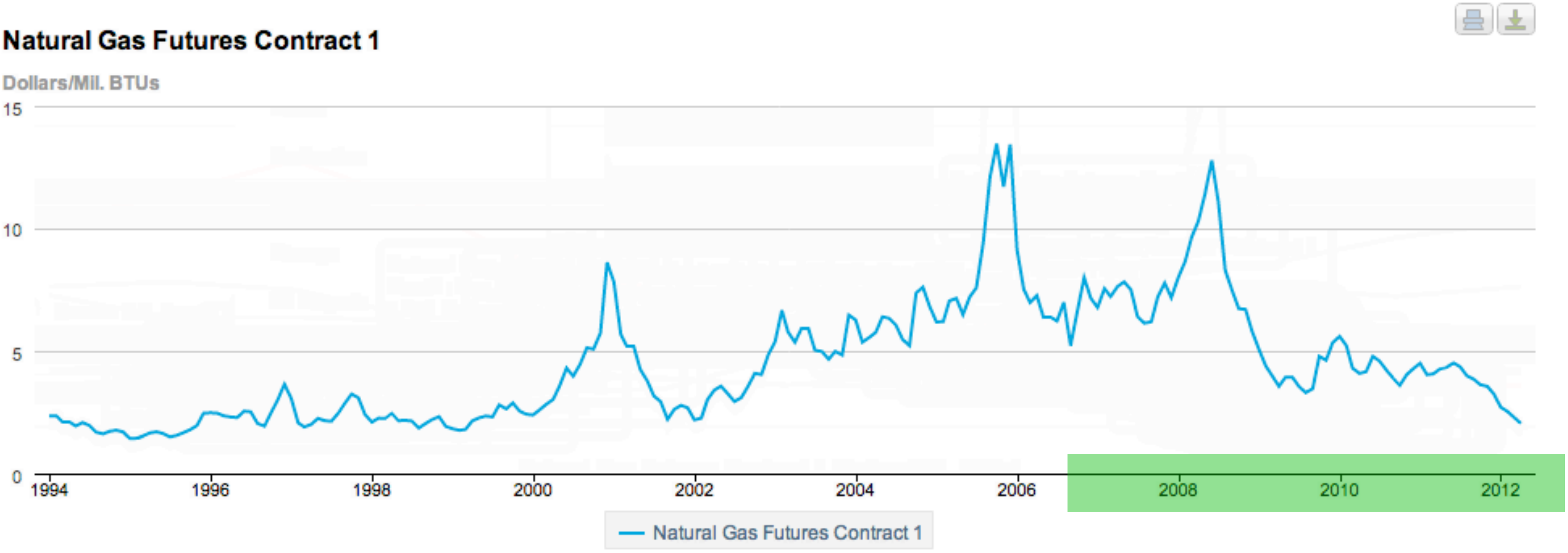
US Electricity Generation



US Renewables Projected (eia)

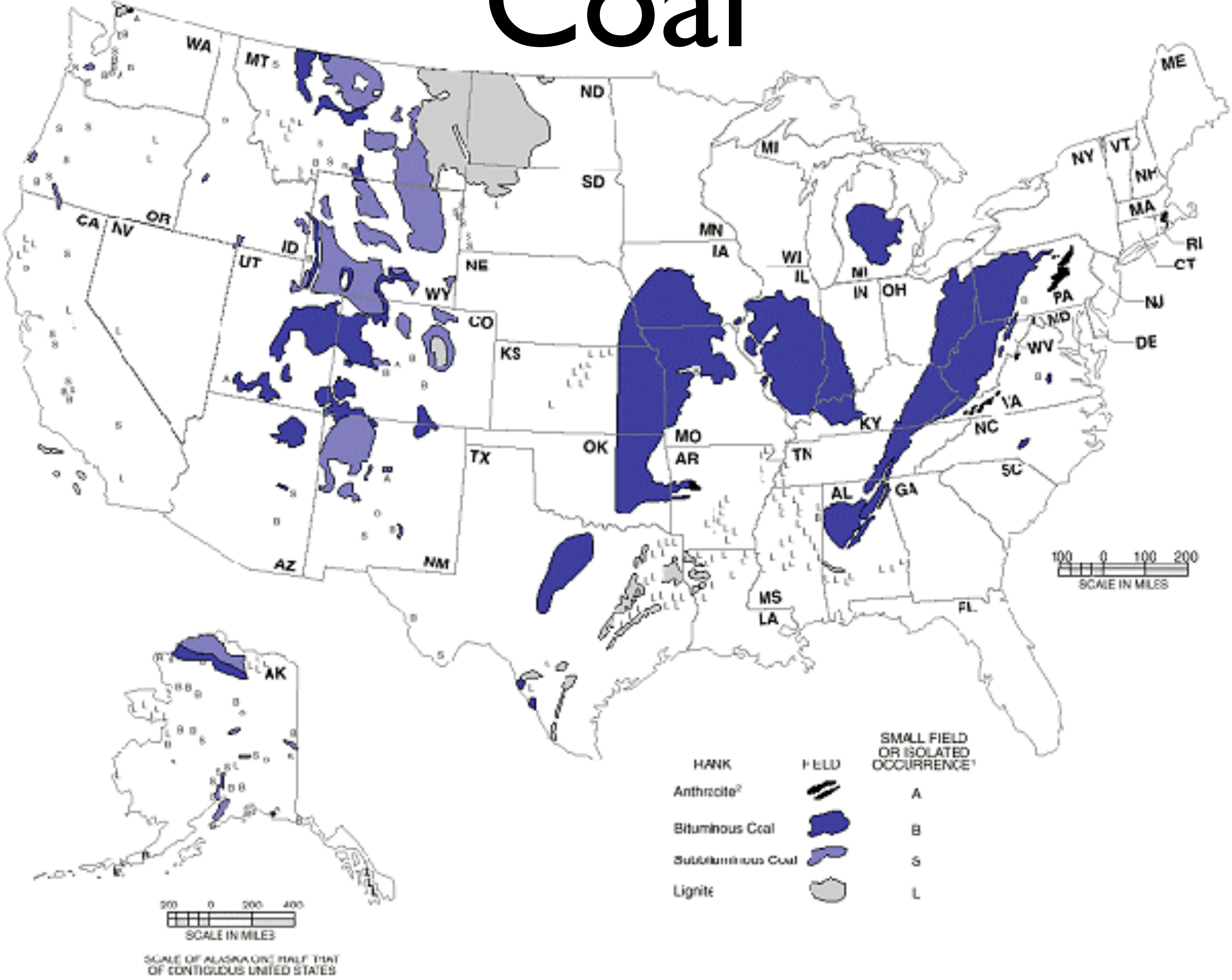


Natural Gas



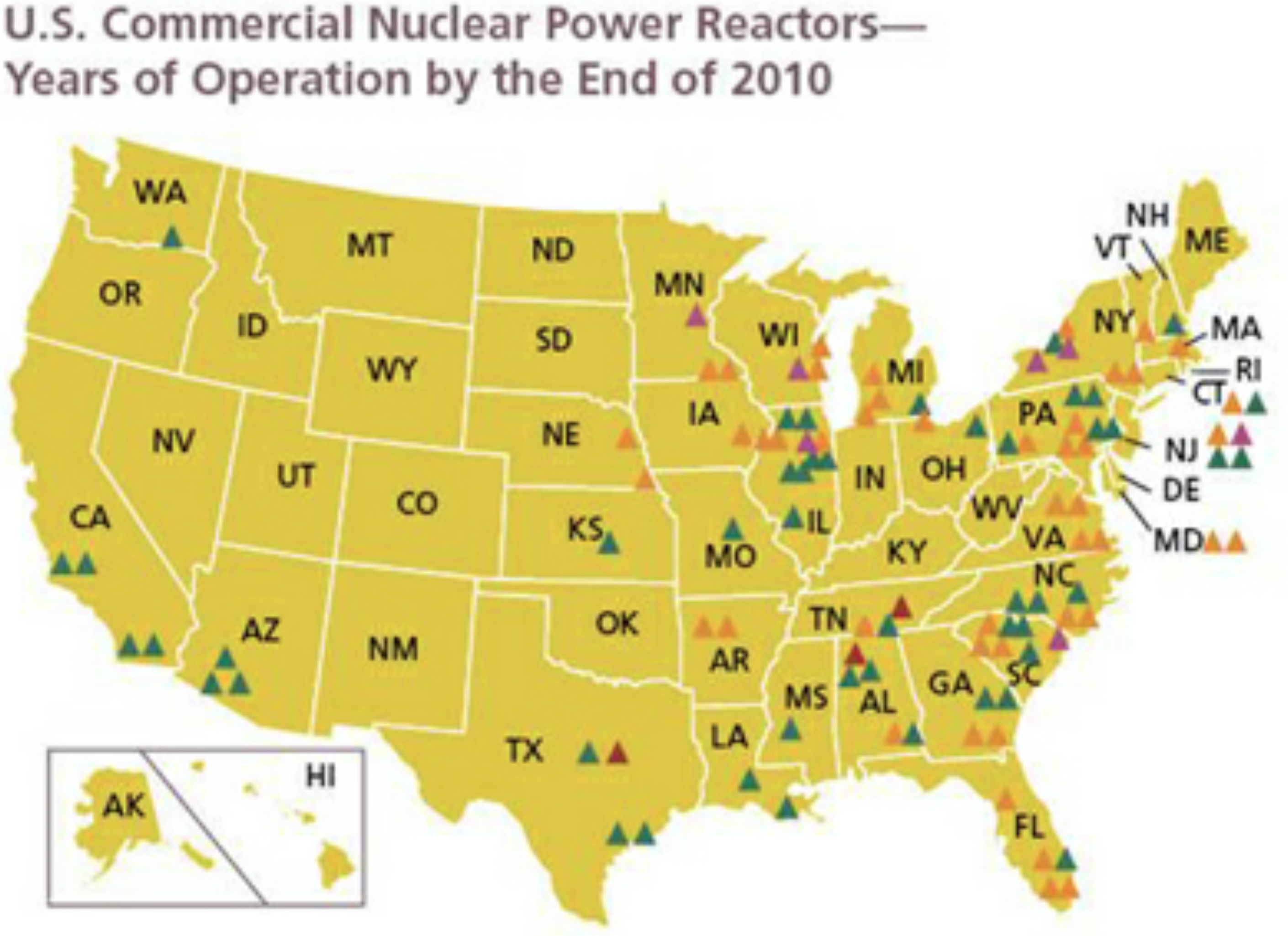
Fracking

Coal



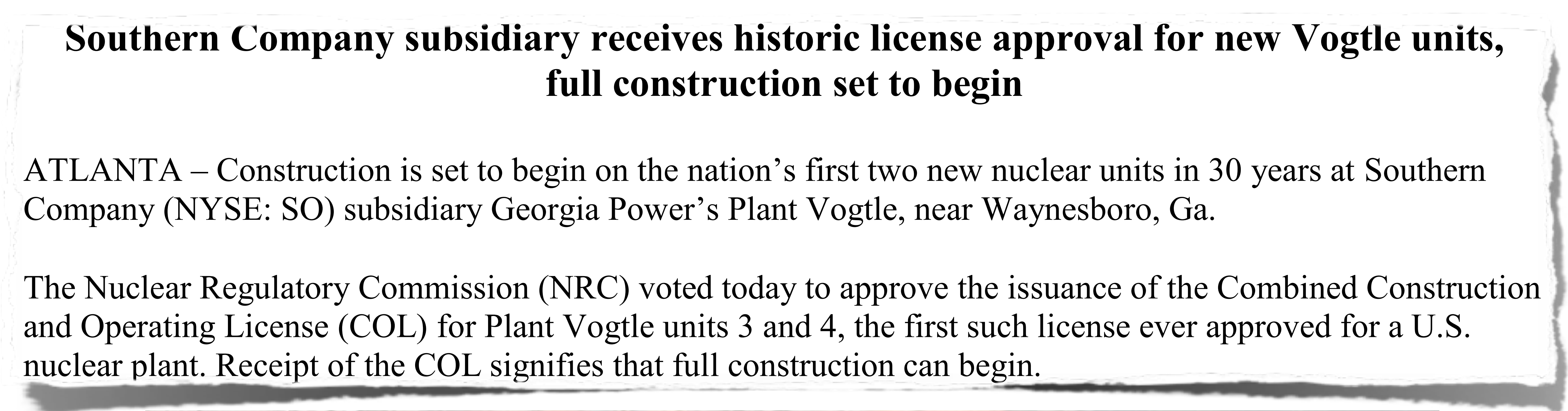
- 45% of all fuel sources for electricity
- 81% of CO_2 emissions

Nuclear



U.S. Commercial Nuclear Power Reactors—
Years of Operation by the End of 2010

- 20% of US electricity generation (104 reactors).
- ≈0 carbon, base load source.



Southern Company subsidiary receives historic license approval for new Vogtle units, full construction set to begin

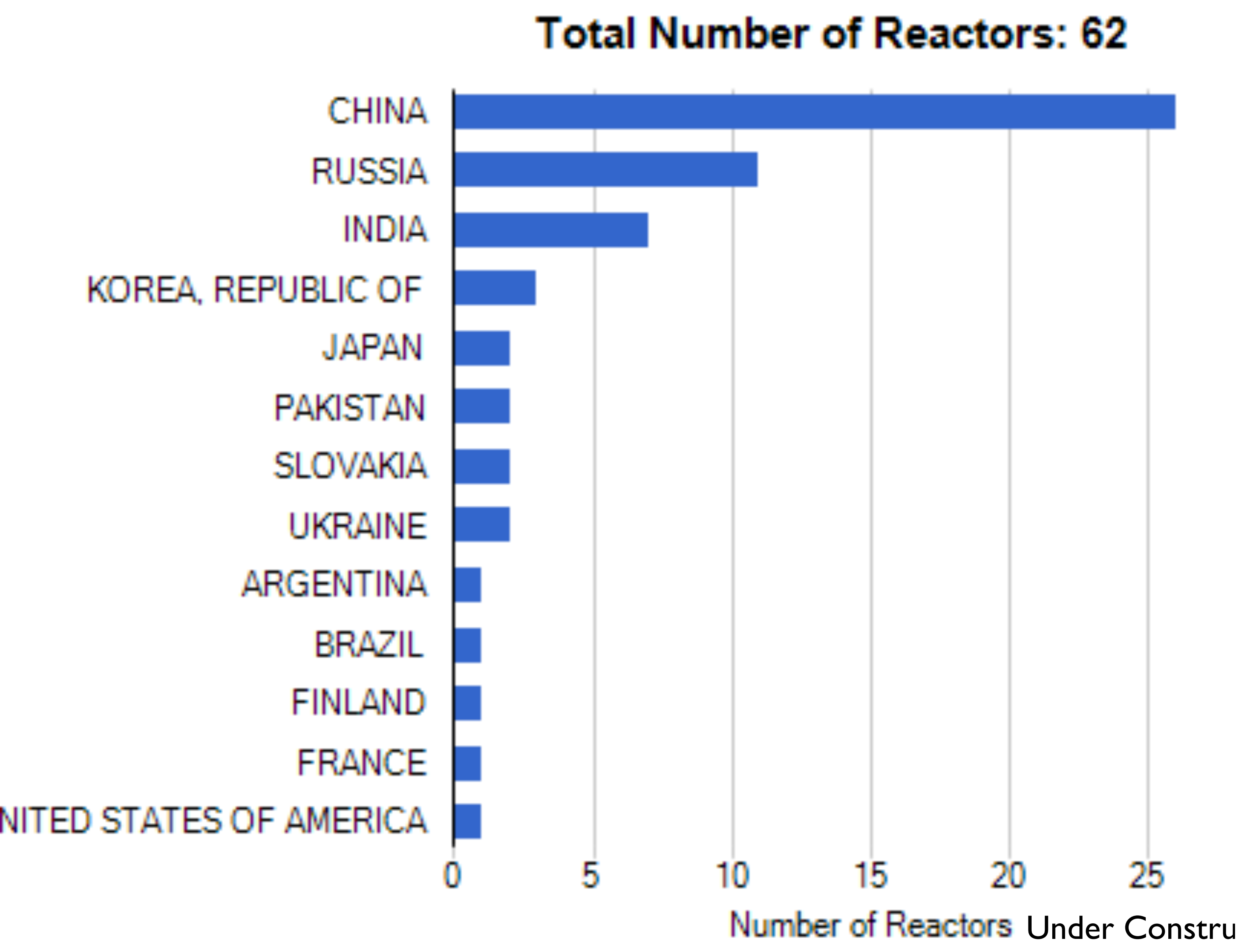
ATLANTA – Construction is set to begin on the nation’s first two new nuclear units in 30 years at Southern Company (NYSE: SO) subsidiary Georgia Power’s Plant Vogtle, near Waynesboro, Ga.

The Nuclear Regulatory Commission (NRC) voted today to approve the issuance of the Combined Construction and Operating License (COL) for Plant Vogtle units 3 and 4, the first such license ever approved for a U.S. nuclear plant. Receipt of the COL signifies that full construction can begin.

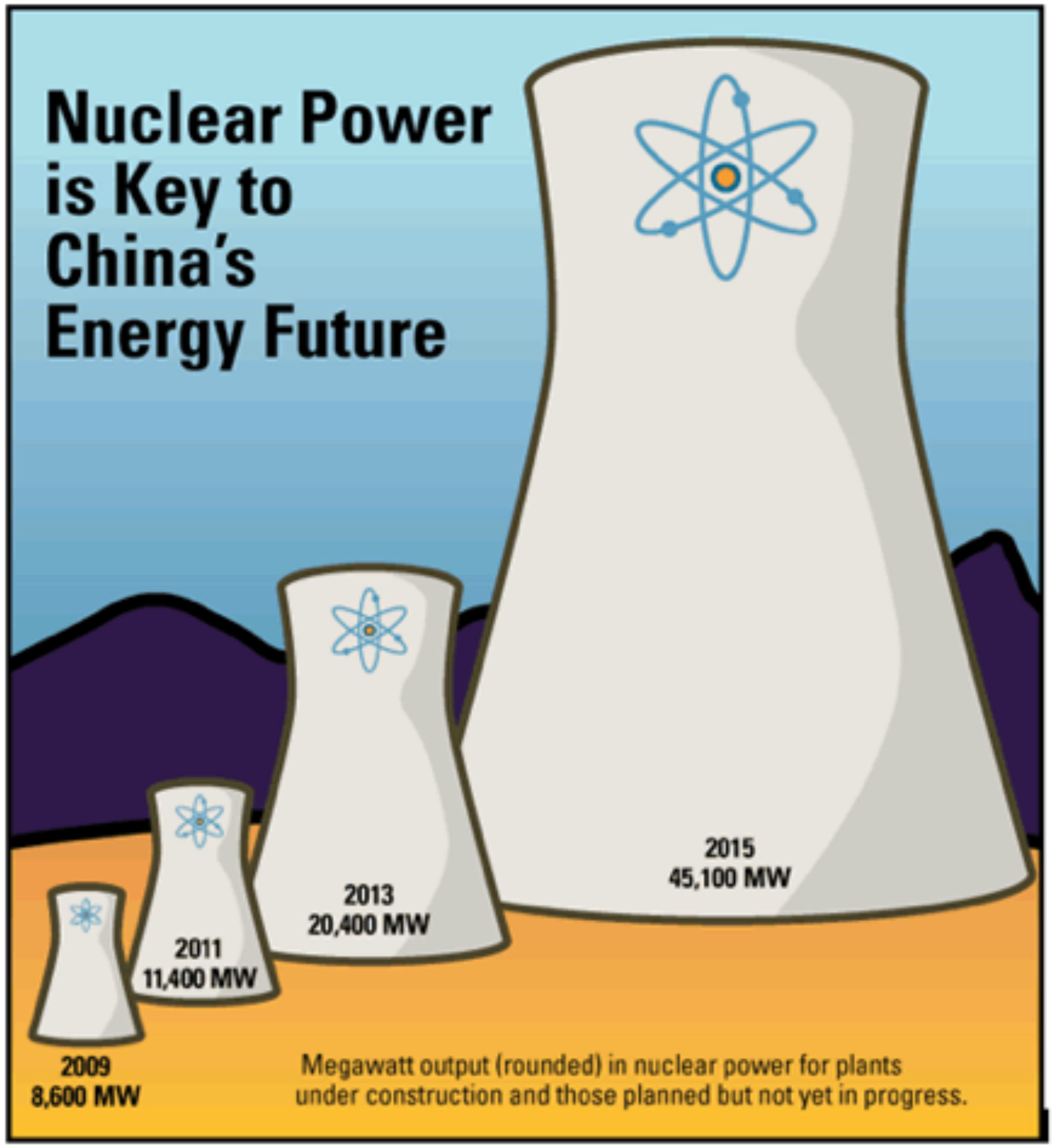
Perspectives

China has about 28 plants either permitted or under construction. ... This is the largest nuclear power production program of any country in the world, equaling the rapid expansion of nuclear in the U.S. just prior to Three Mile Island.

By 2015, China could be constructing more than 50 nuclear plants simultaneously.



Under Constru



Megawatt output (rounded) in nuclear power for plants under construction and those planned but not yet in progress.

Perspectives

May 30, 2011

Germany, in Reversal, Will Close Nuclear Plants by 2022

By JUDY DEMPSEY and JACK EWING

BERLIN — The German government on Monday announced plans to shut all of the nation's nuclear power plants within the next 11 years, a sharp reversal for Chancellor Angela Merkel after the Japanese disaster at Fukushima caused an electoral backlash by voters opposed to reliance on nuclear energy.

Last Reactor of 50 in Japan Is Shut Down

By MARTIN FACKLER

TOKYO — Japan's last operating reactor was taken offline Saturday, as public distrust created by last year's nuclear disaster forced the nation to at least temporarily do without atomic power for the first time in 42 years.

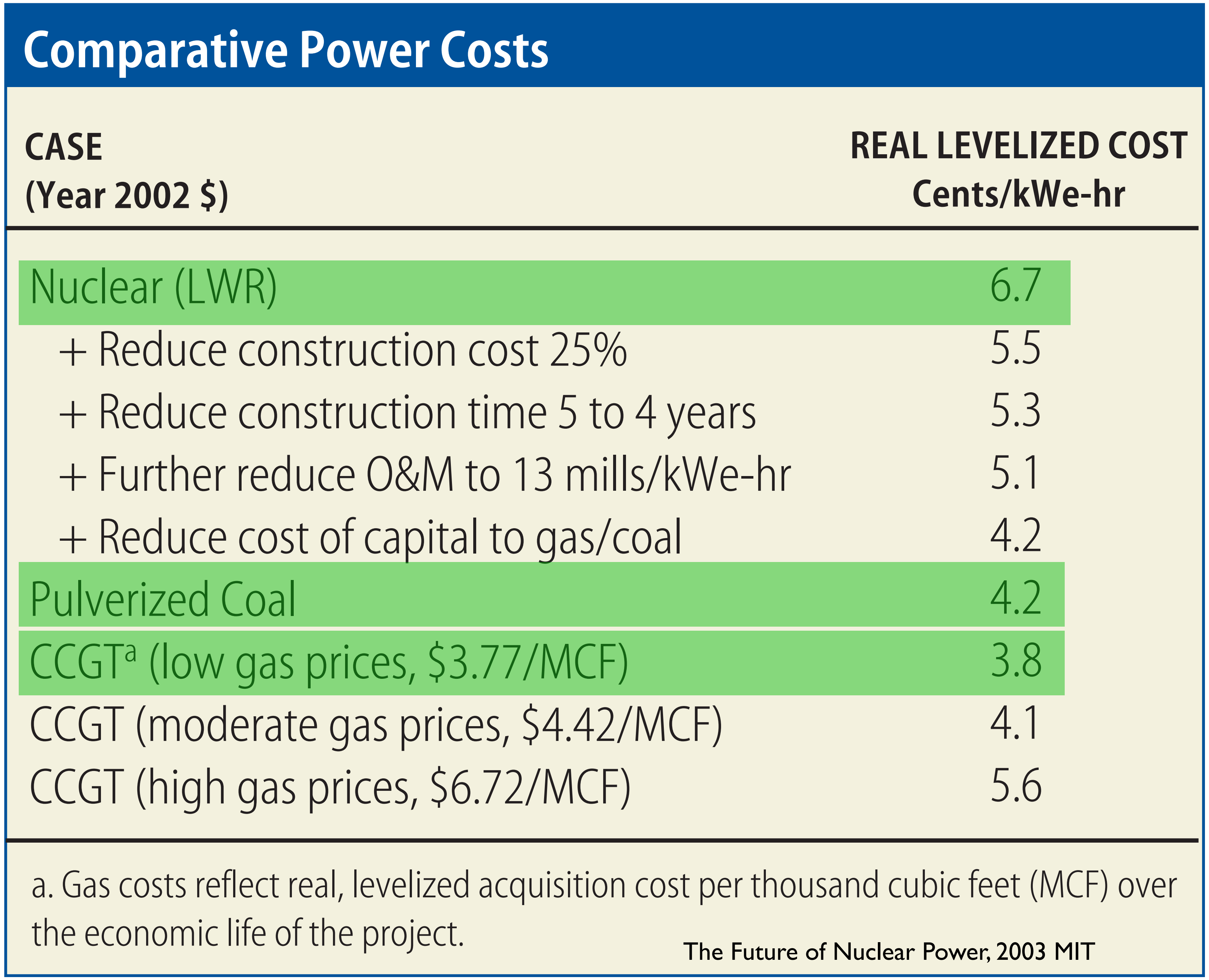
Problems

Cost

Safety

Spent Fuel

Problems



Comparative Power Costs

CASE (Year 2002 $)	REAL LEVELIZED COST Cents/kWe-hr
Nuclear (LWR)	6.7
+ Reduce construction cost 25%	5.5
+ Reduce construction time 5 to 4 years	5.3
+ Further reduce O&M to 13 mills/kWe-hr	5.1
+ Reduce cost of capital to gas/coal	4.2
Pulverized Coal	4.2
CCGT[a] (low gas prices, $3.77/MCF)	3.8
CCGT (moderate gas prices, $4.42/MCF)	4.1
CCGT (high gas prices, $6.72/MCF)	5.6

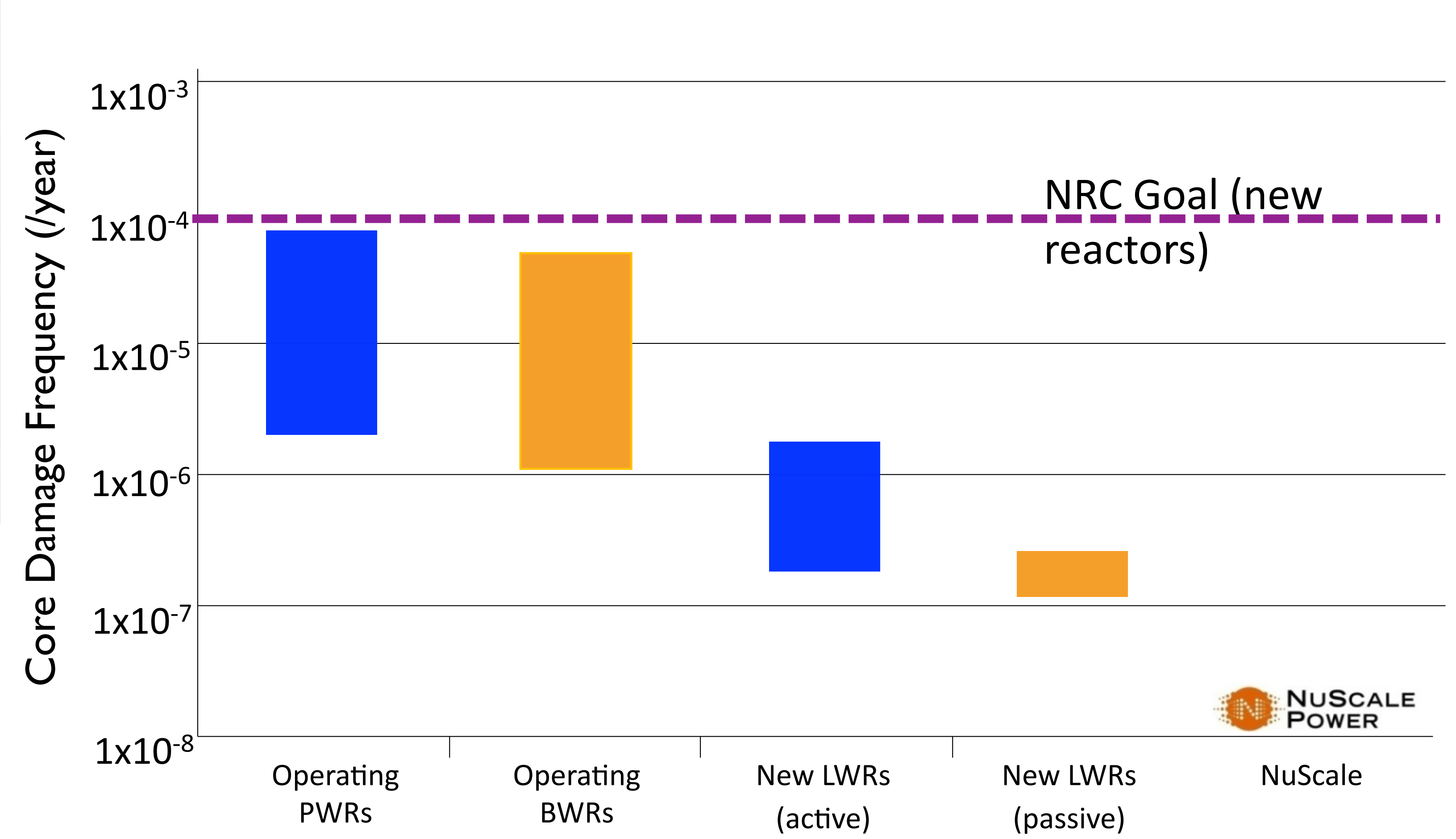
a. Gas costs reflect real, levelized acquisition cost per thousand cubic feet (MCF) over the economic life of the project.

The Future of Nuclear Power, 2003 MIT

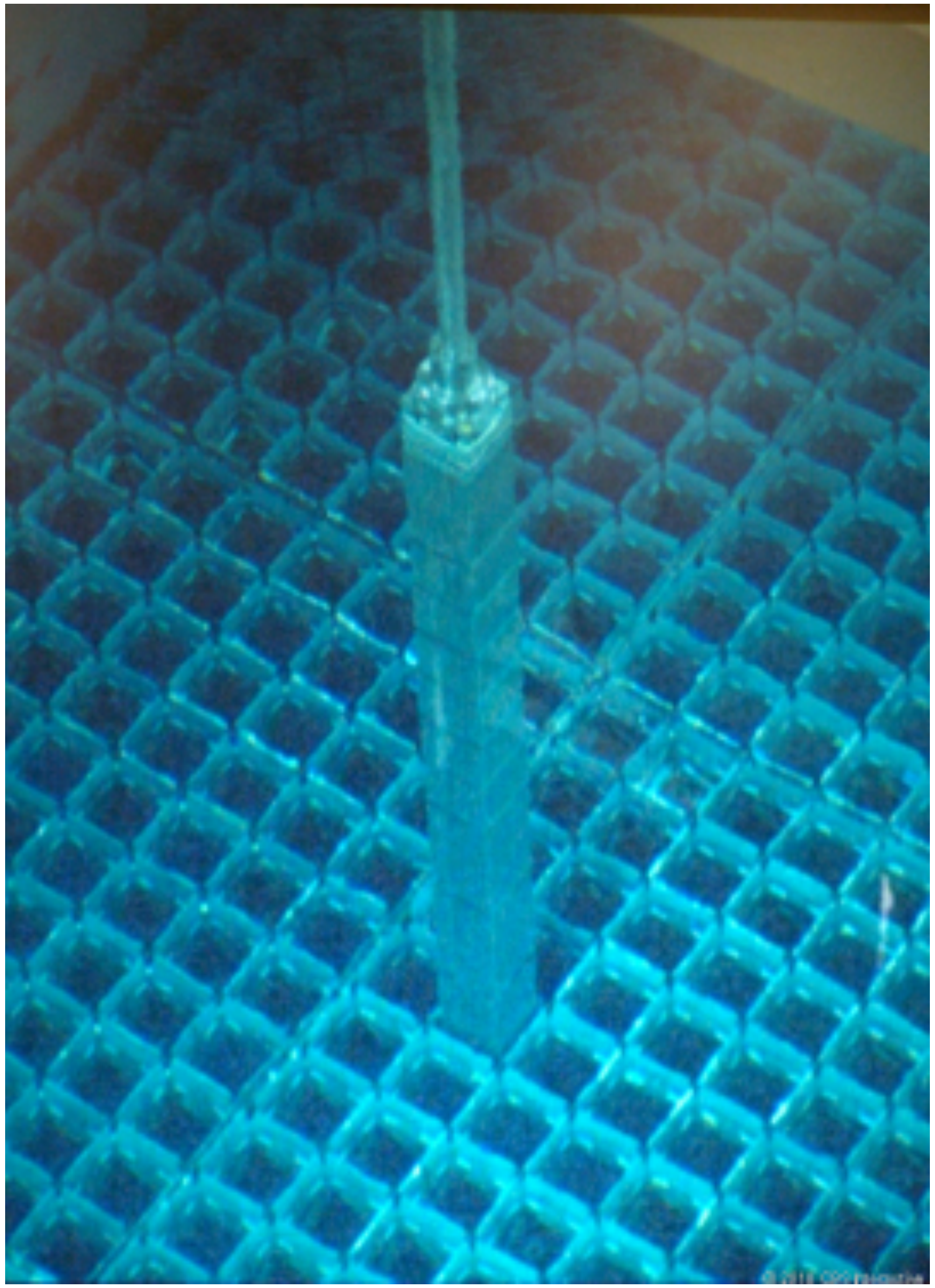
Cost

Problems

Safety

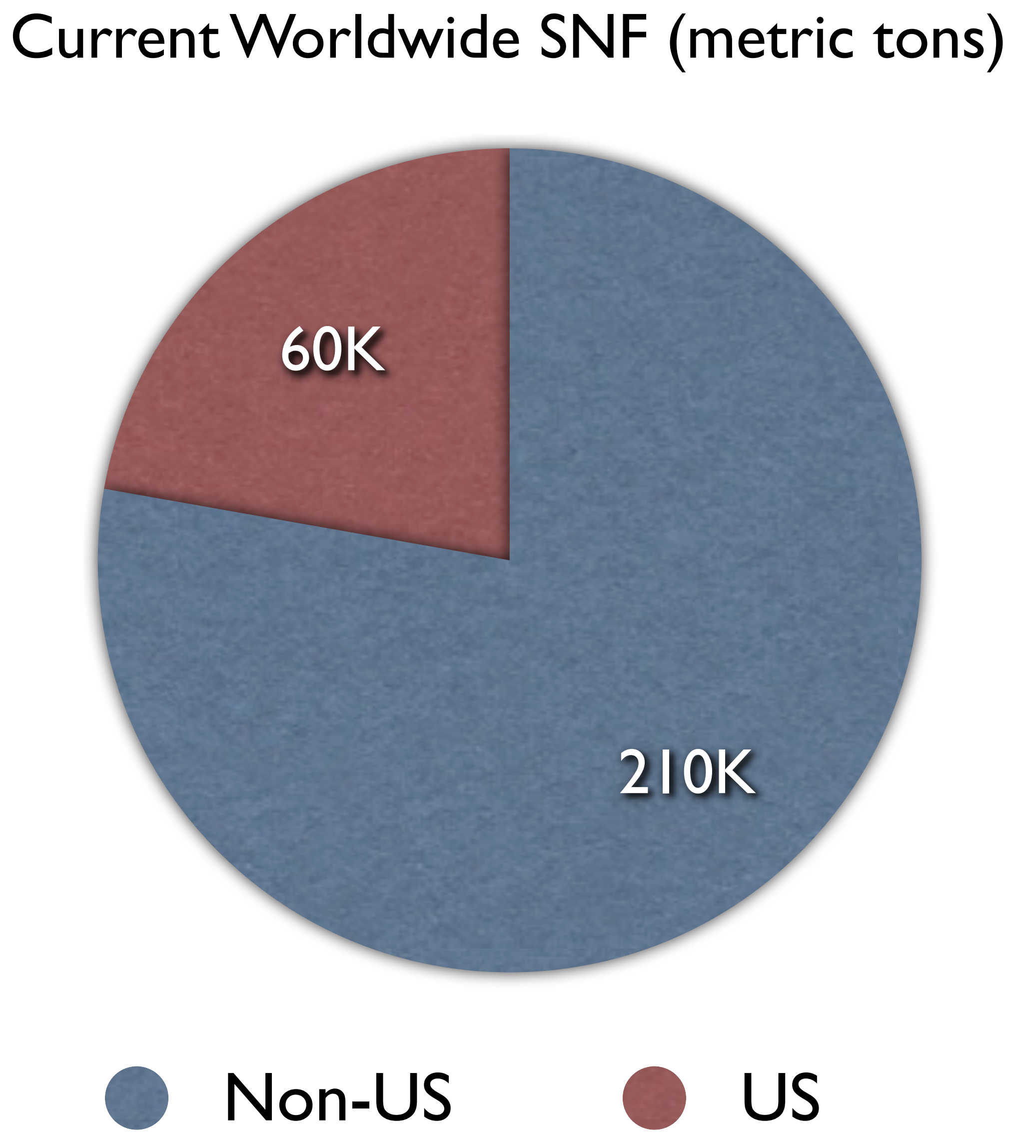


Problems



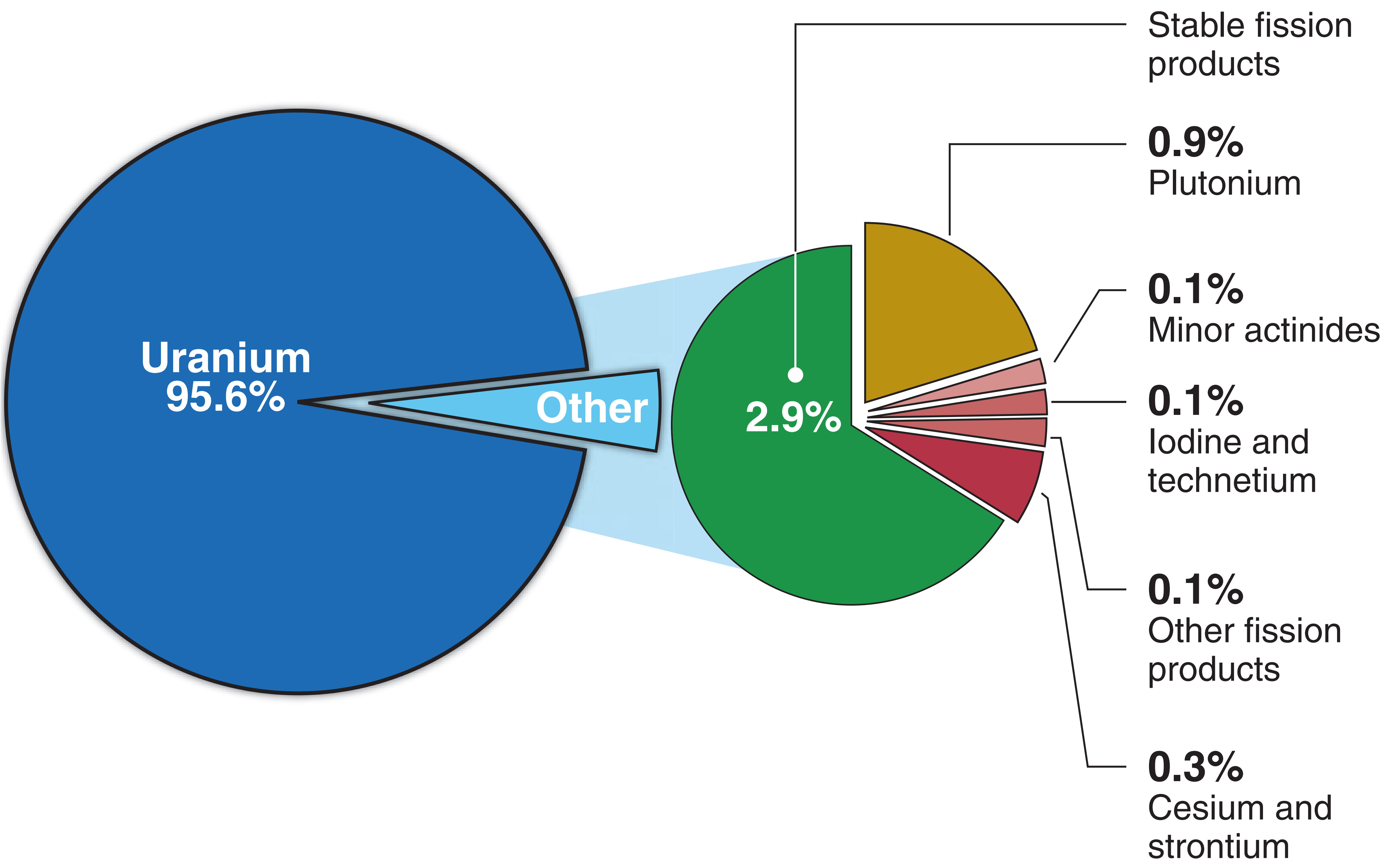
Spent Fuel

Love it or hate it, we have it



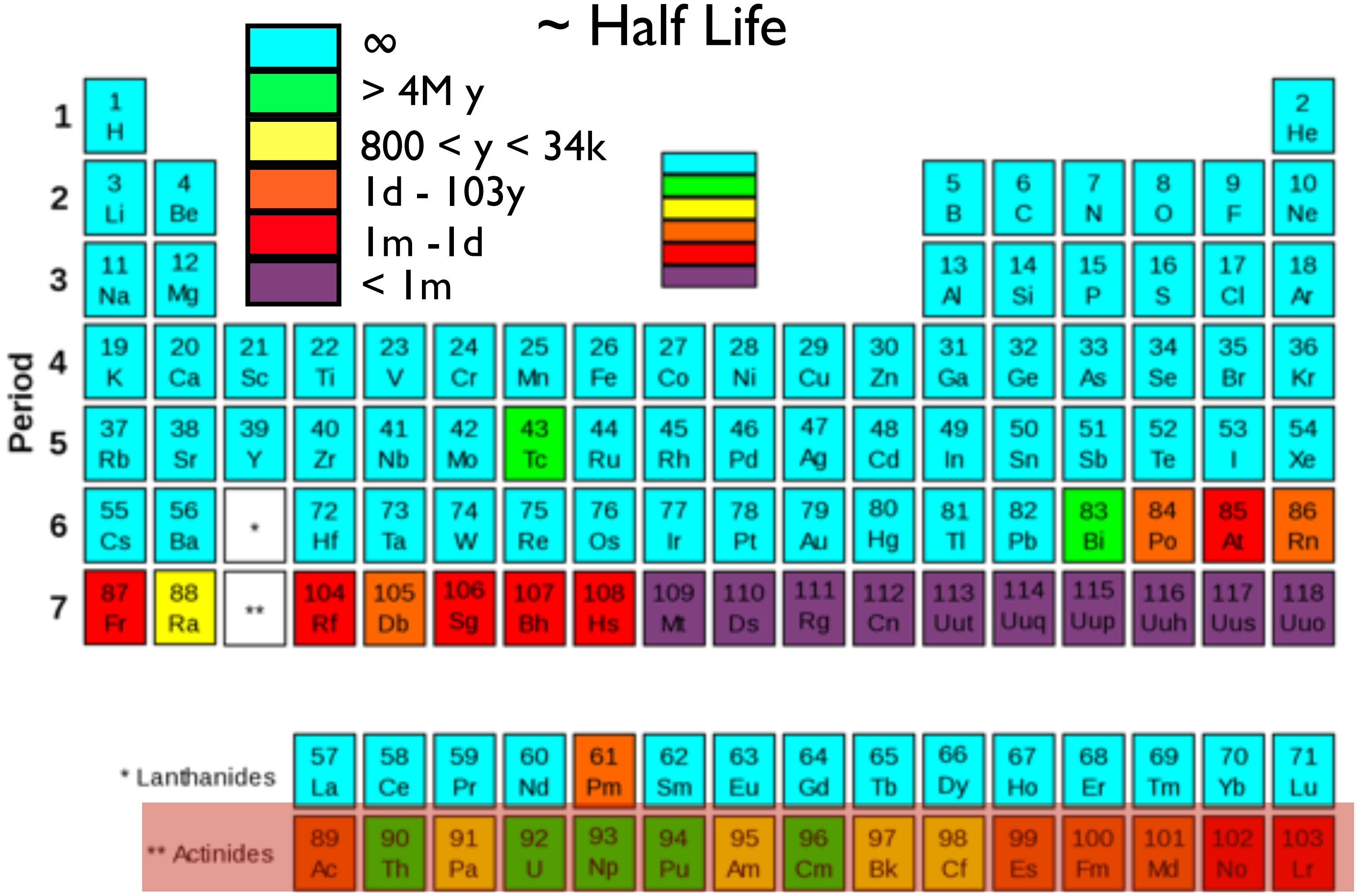
Annual Production:
12K Tons Worldwide
2k Tons US
27 Tons per reactor $\approx$ 25 m^3

SNF Composition



Source: GAO analysis of DOE data.

~ Half Life



Actinides 96.6%

(89<Z<103)

Major 96.5%: U, Pu

Minor 0.1%:

Neptunium (Np), Americium (Am), Curium (Cm)

Short Lived FPs 0.3%

Cesium (Cs), Strontium (Sr)

Long Lived FPs 0.2%

Iodine (I), Technetium (Te)...

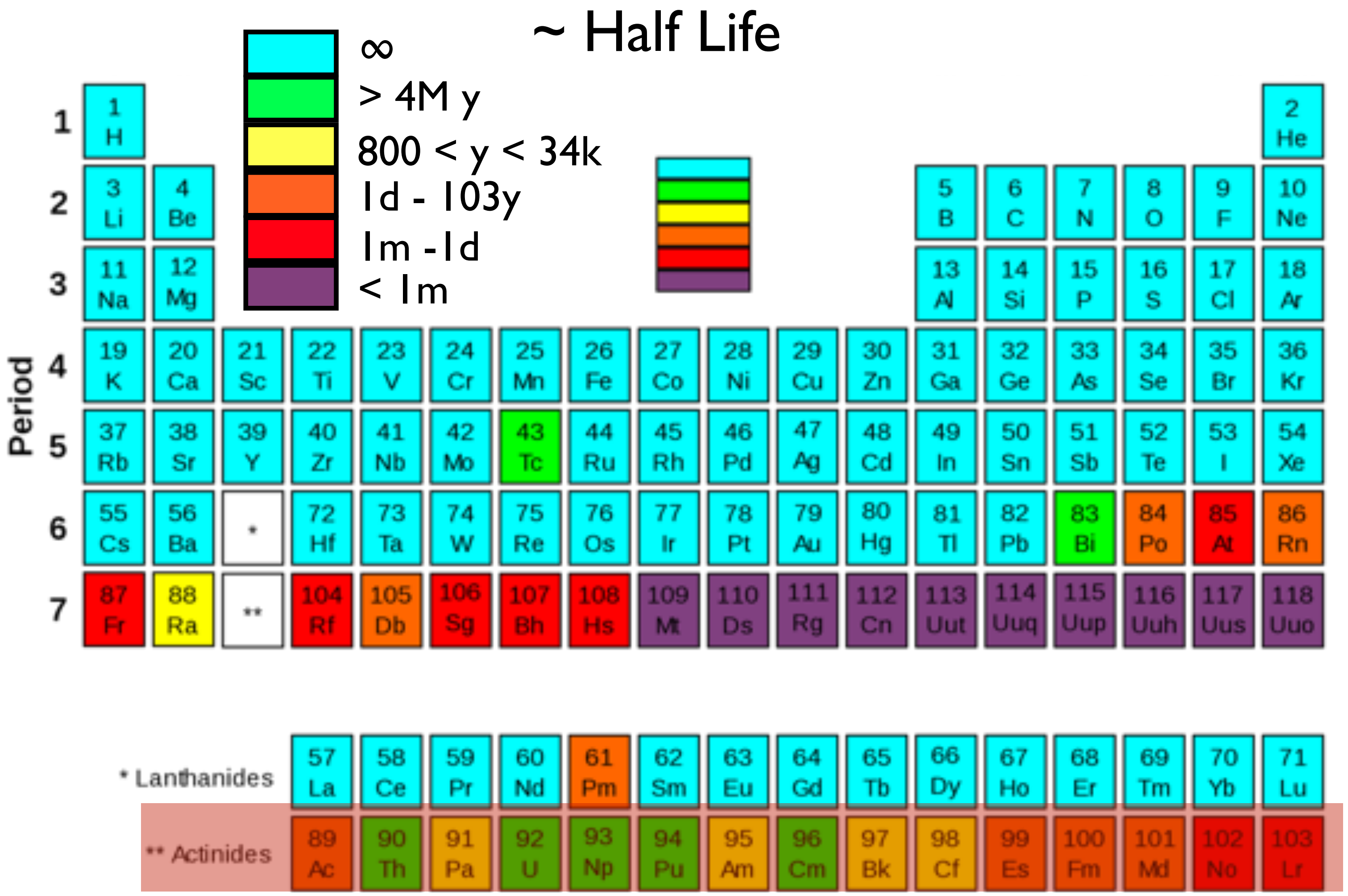
Major Actinides

Pu-241

Pu-240

Pu-239

Dominate Long-term radiotoxicity



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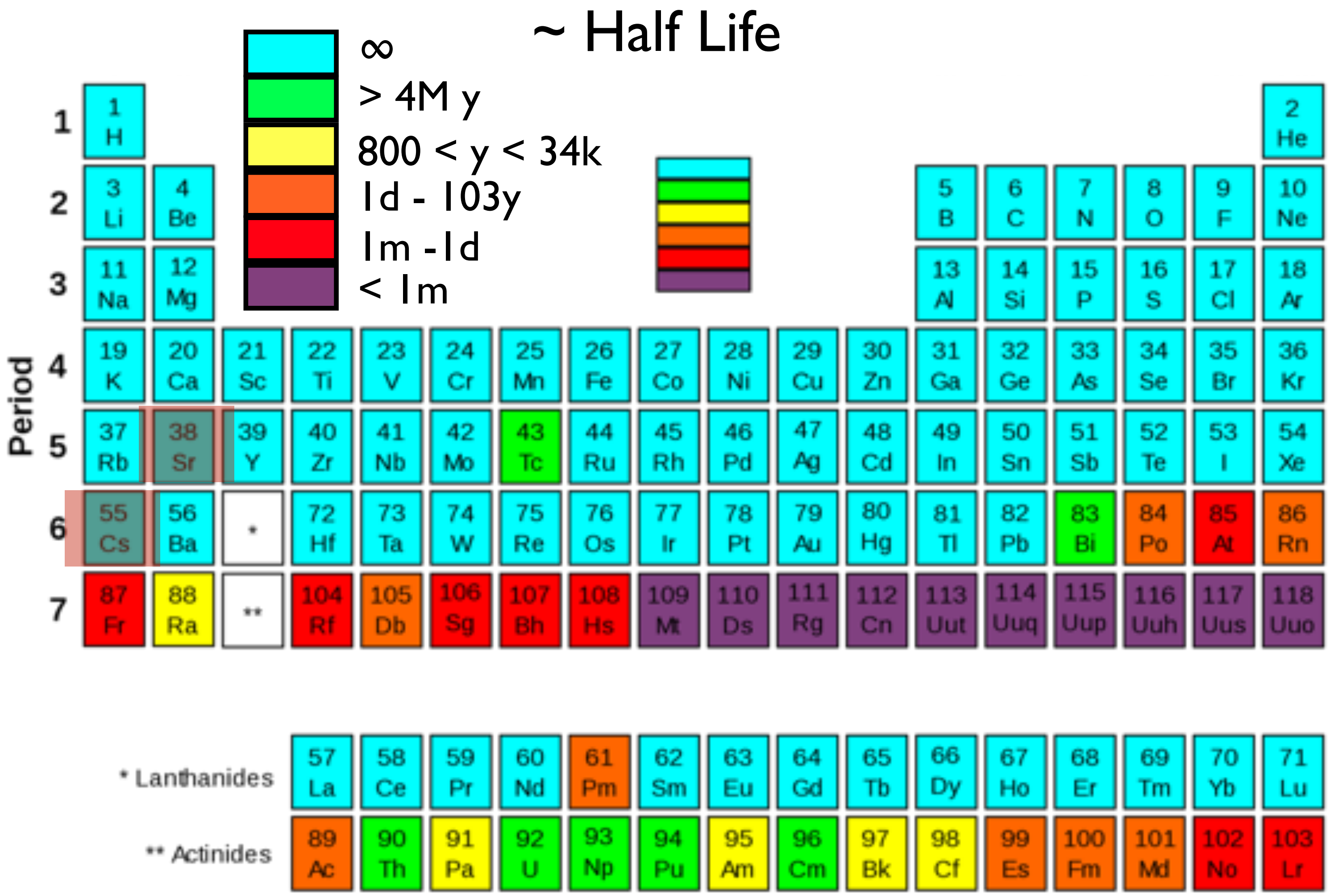
Minor Actinides (MA)

Shorter Term (~5000 year) concern



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Short Lived Fission Products

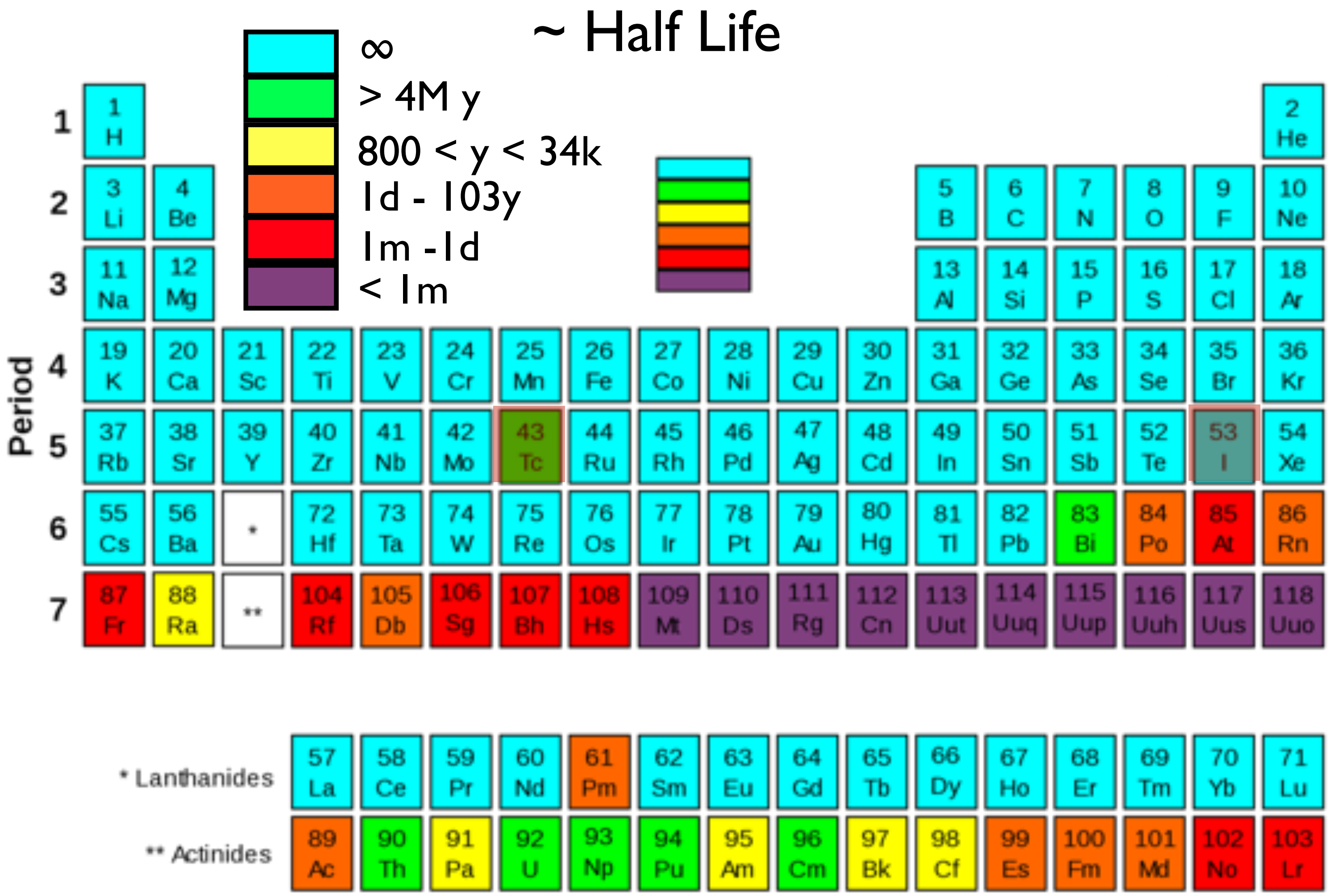
Heat Generators

Cs-137, Sr-90

Dominate heat output

for ~100 years

Health impacts



Actinides 96.6%
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Major 96.5%: U, Pu
Minor 0.1%:
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Short Lived FPs 0.3%
Cesium (Cs), Strontium (Sr)
Long Lived FPs 0.2%
Iodine (I), Technetium (Tc)...

Long Lived Fission Products
Very long half life
Very low radiotoxicity
High mobility (Yucca)
(I-129, Tc-99, Cs-135)

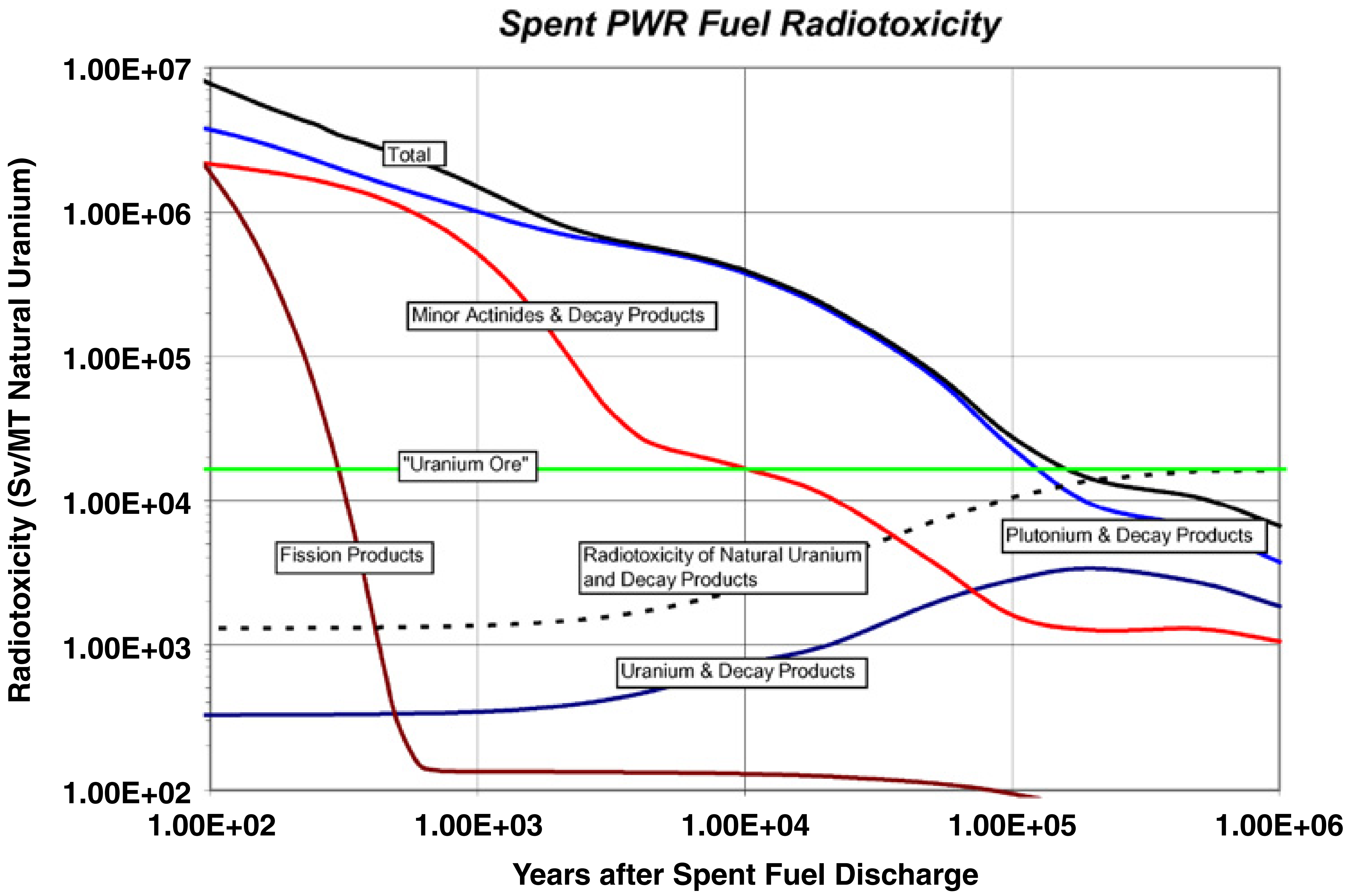
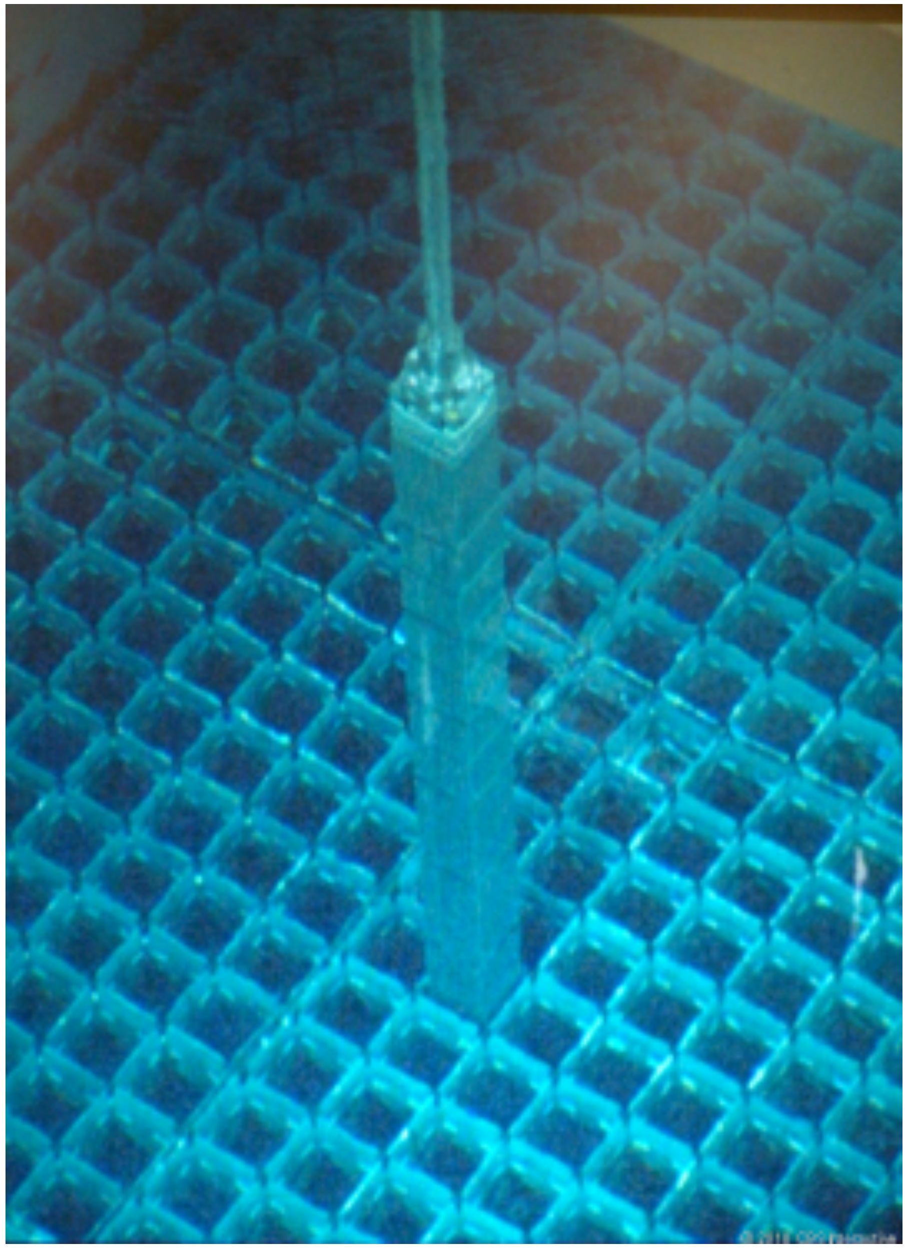


Fig. 2. Spent PWR fuel radiotoxicity and its components.

Radioactive waste partitioning and transmutation within advanced fuel cycles: Achievements and challenges
M. Salvatores [a,b,*], G. Palmiotti [b]

Current US Policy:

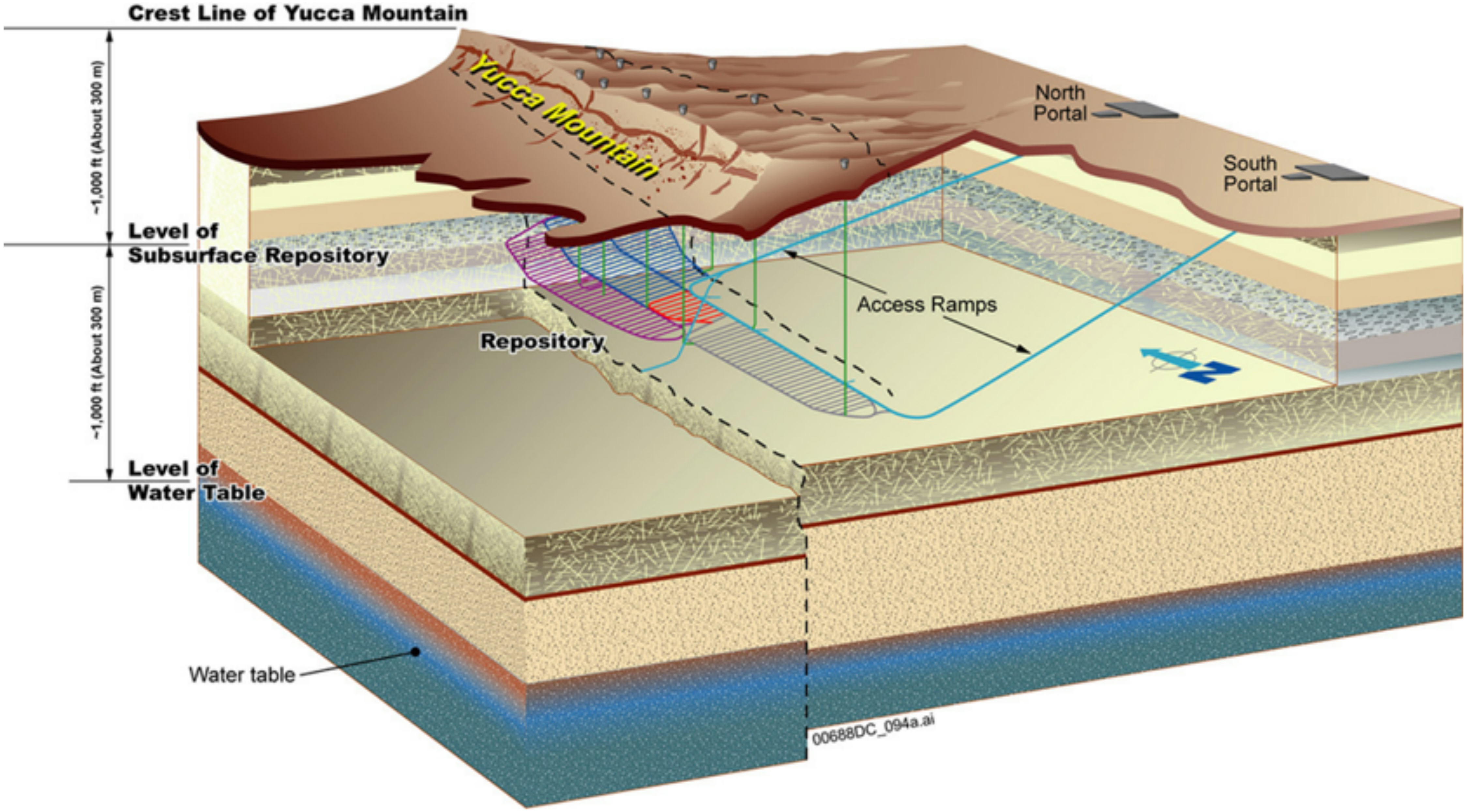


“The Department of Energy's failure to begin disposing of waste on January 31, 1998 has created a liability, based on the Standard Contracts signed by the Department and each utility operating a nuclear reactor. This liability is expected to exceed $20,000,000,000 by 2020, and accruing an additional $500,000,000 for each year after 2020 that the Department has not accepted spent nuclear fuel.

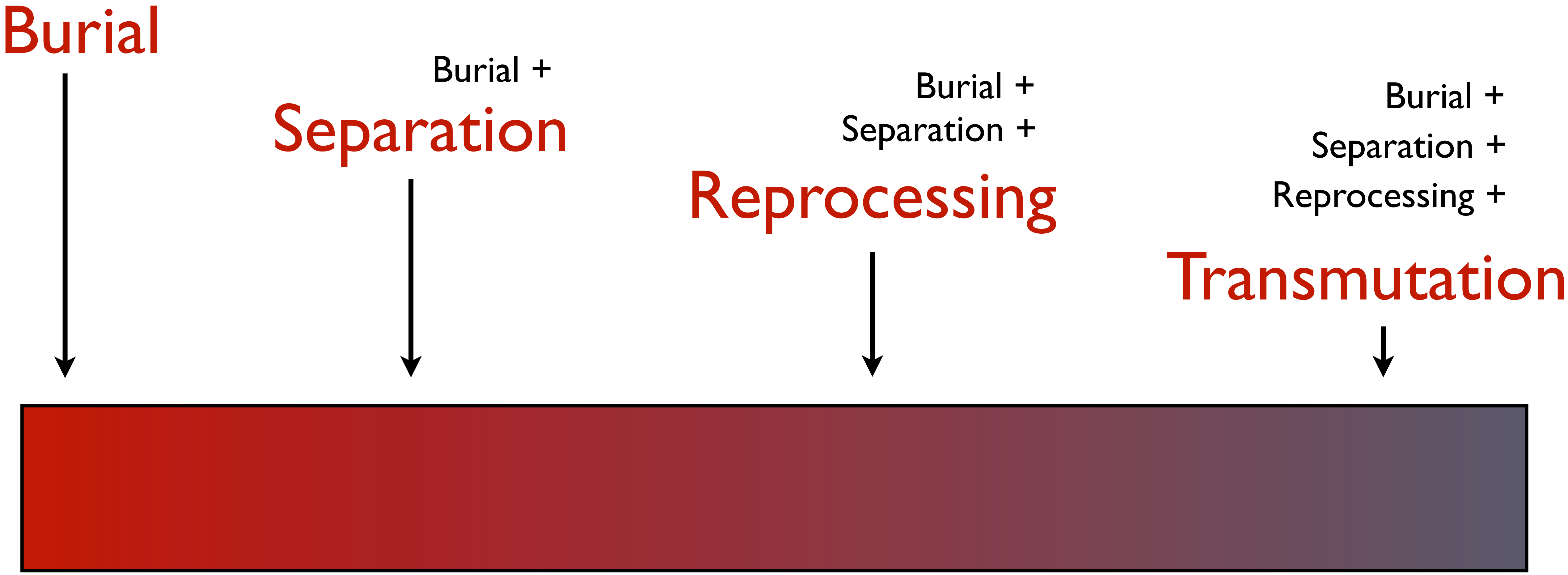
- SENATE ENERGY AND WATER DEVELOPMENT APPROPRIATIONS BILL - 2013

What will we do?

Bury It



How Much?
How Long?



Burial

Burial +
Separation

Burial +
Separation +
Reprocessing

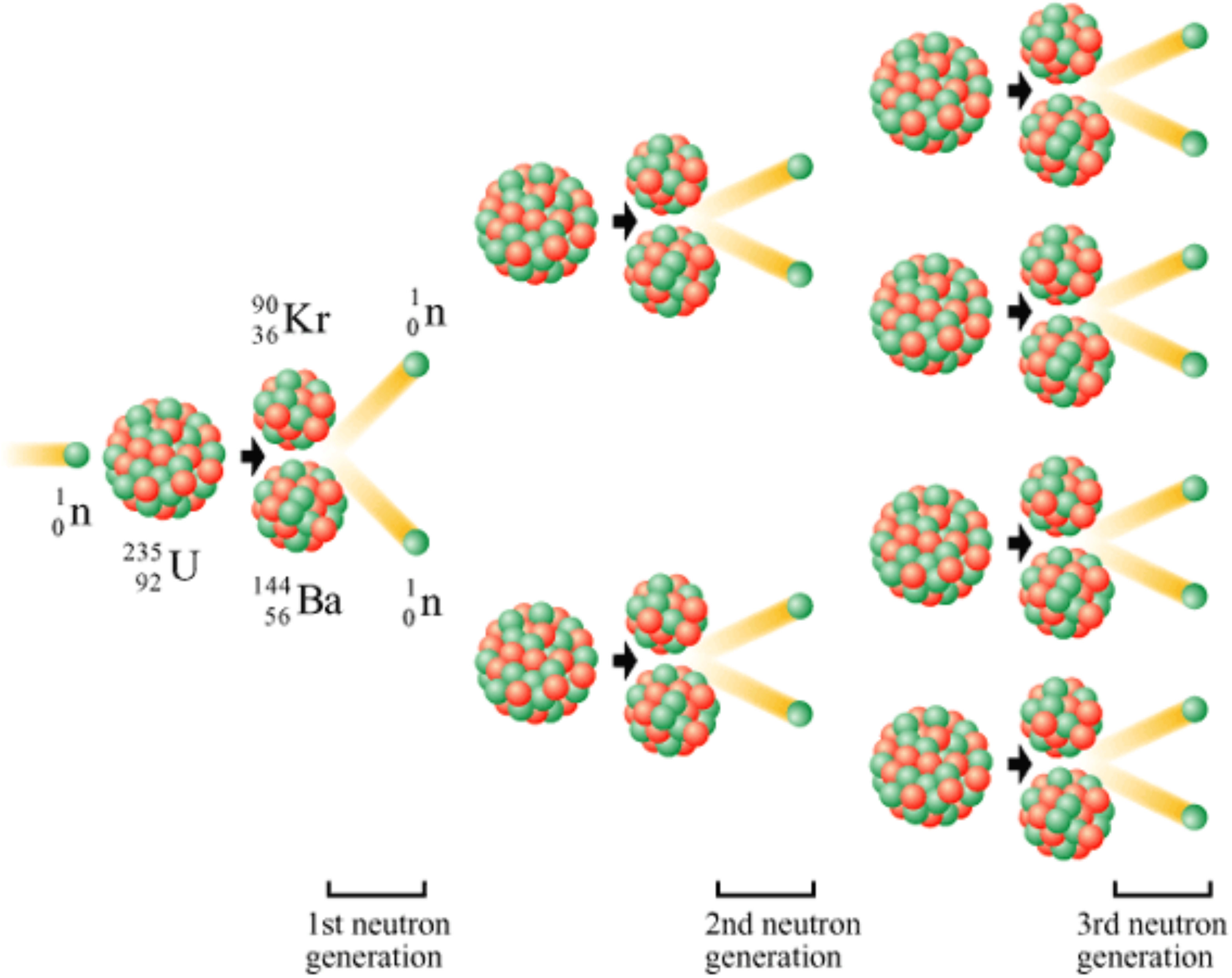
Burial +
Separation +
Reprocessing +
Transmutation

A lot
Long Time

How Much?
How Long?

A little
Short Time

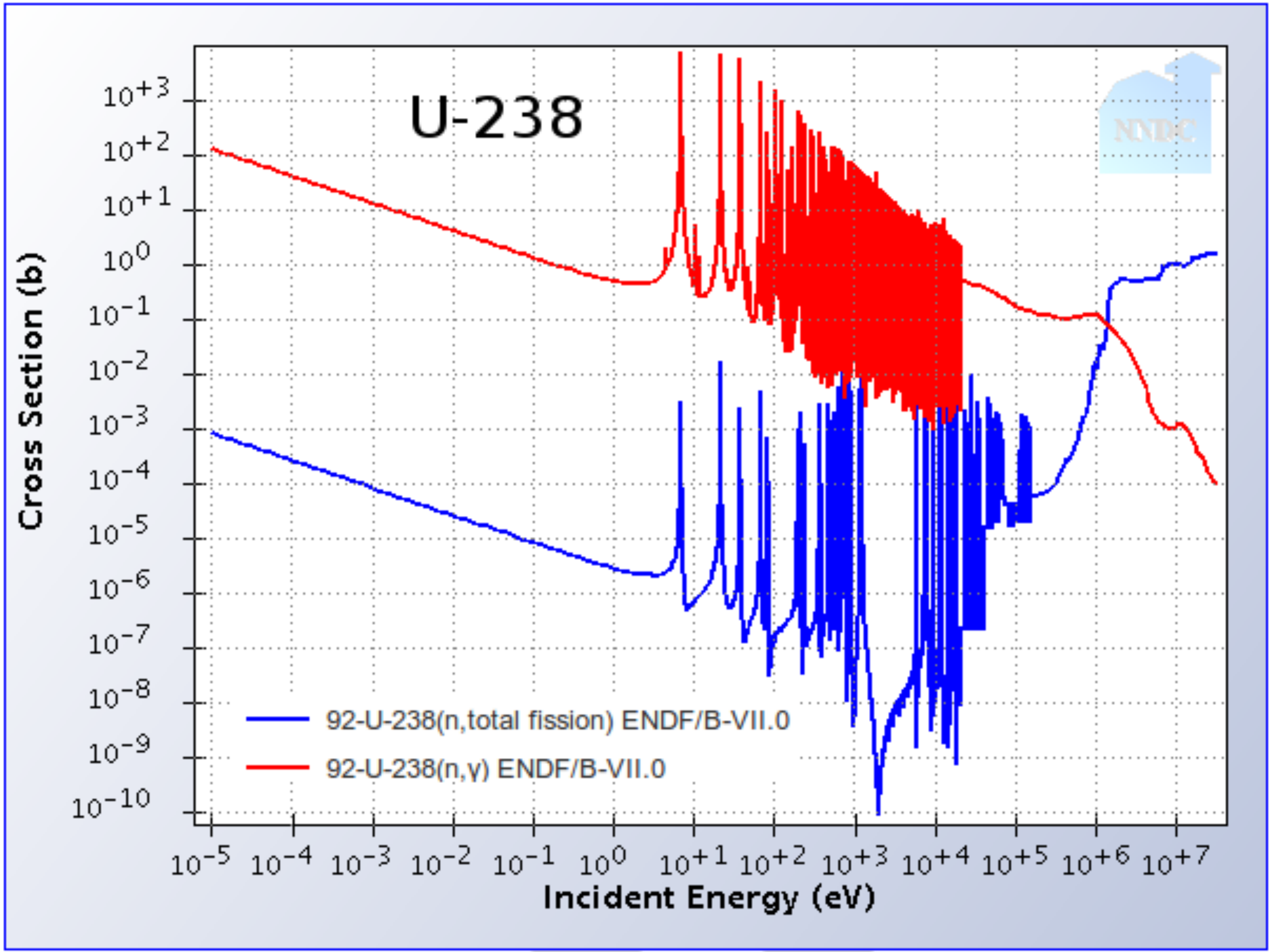
Transmutation, Fission



Keff = Ratio of neutrons between generations.

Keff = 1 Critical
< 1 Subcritical
> 1 Supercritical

Fast Neutrons

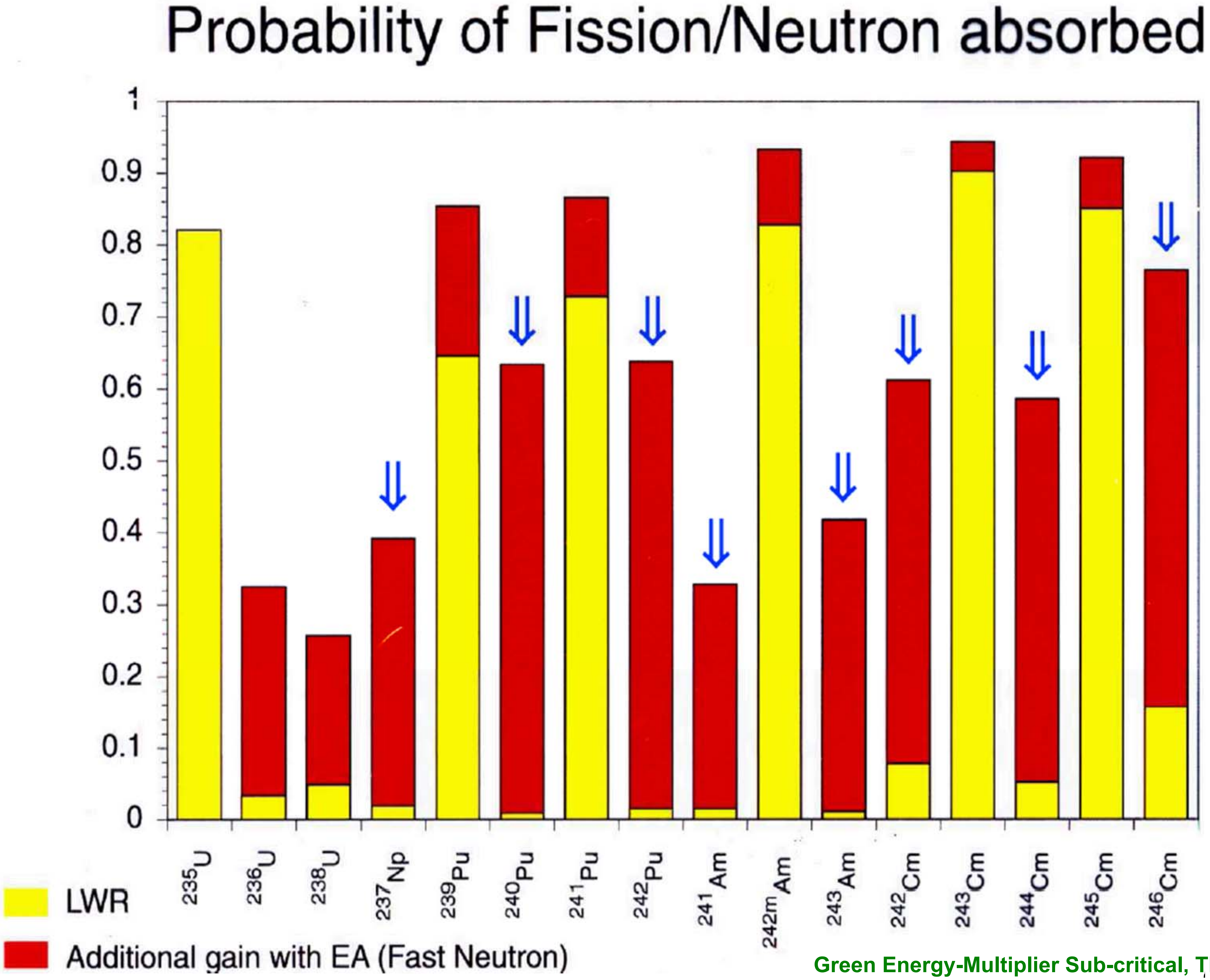


Fission σ

Capture σ

Whatisnuclear.com

Fast Neutrons



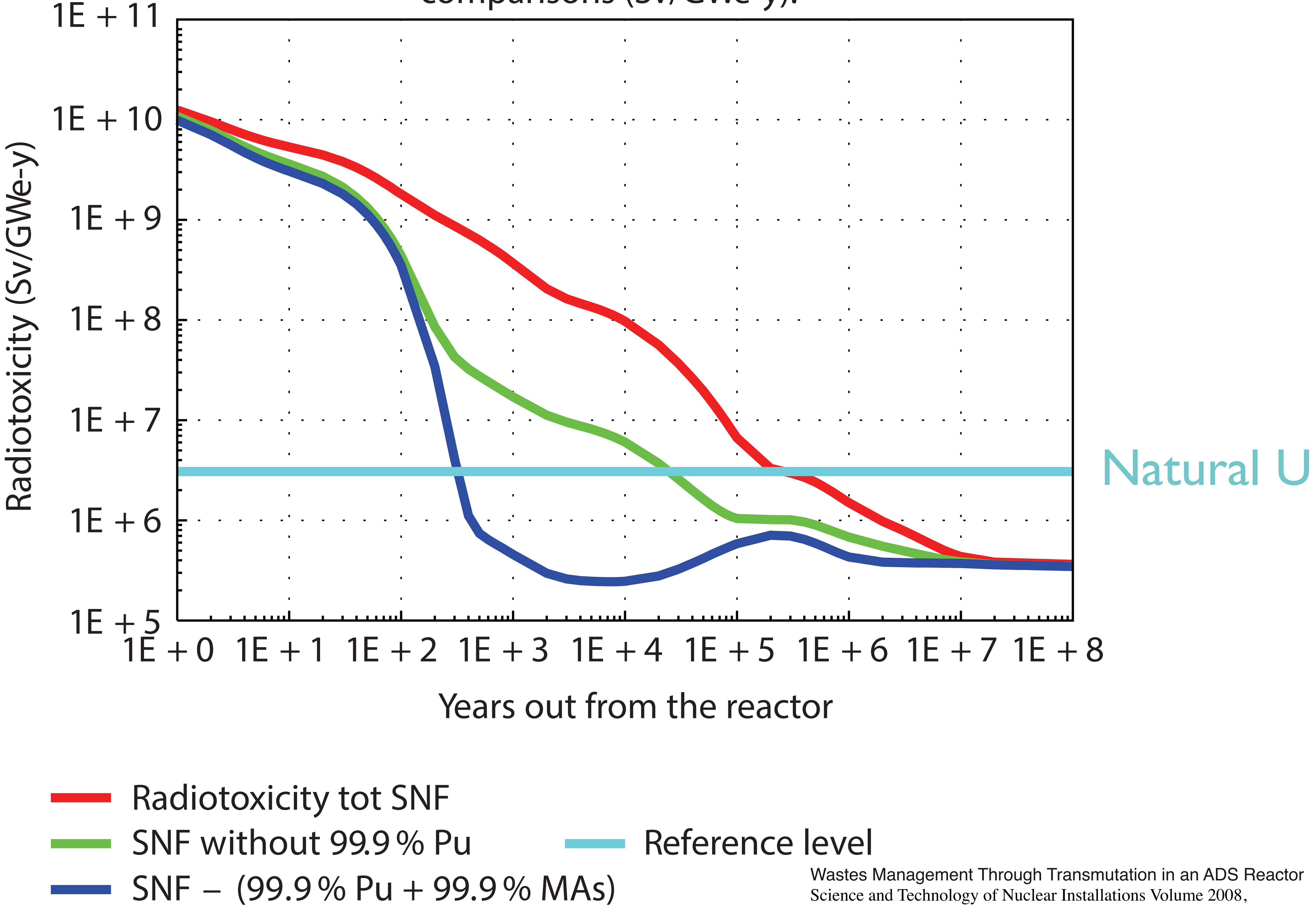
Probability of Fission/Neutron absorbed

Green Energy-Multiplier Sub-critical, Thermal-spectrum, Accelerator-driven, Recycling Reactor

R. Bruce Vogelaar

Transmuted MA

comparisons (Sv/GWe-y).



Wastes Management Through Transmutation in an ADS Reactor
Science and Technology of Nuclear Installations Volume 2008,

Fast Neutrons

2 Options

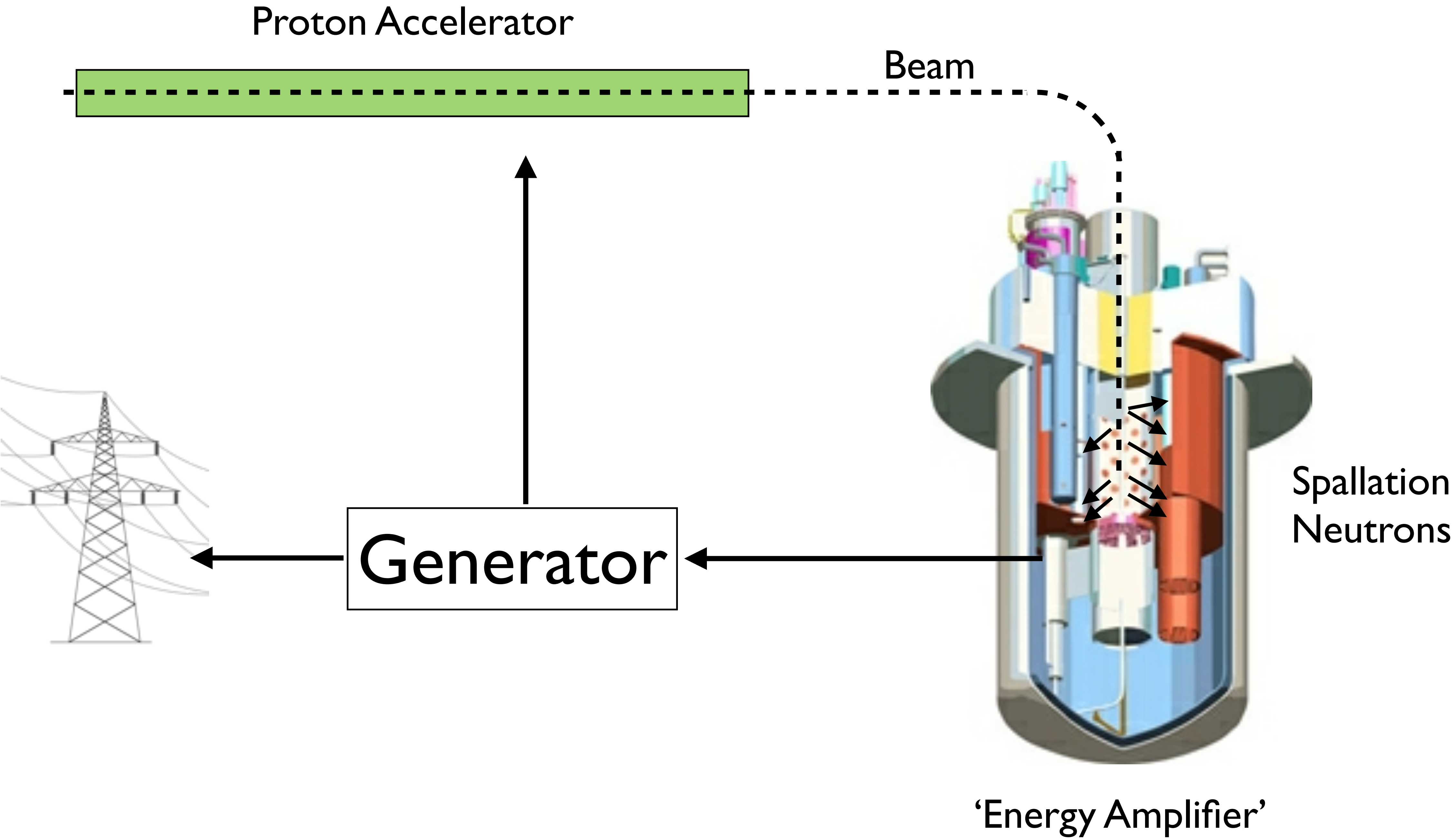
Fast Reactors:

Yet to catch on-
Uneconomic
Technical Hurdles

Accelerators:

Buy fast neutrons
from particle
physicists

Accelerator Driven System



Proton Accelerator

Beam

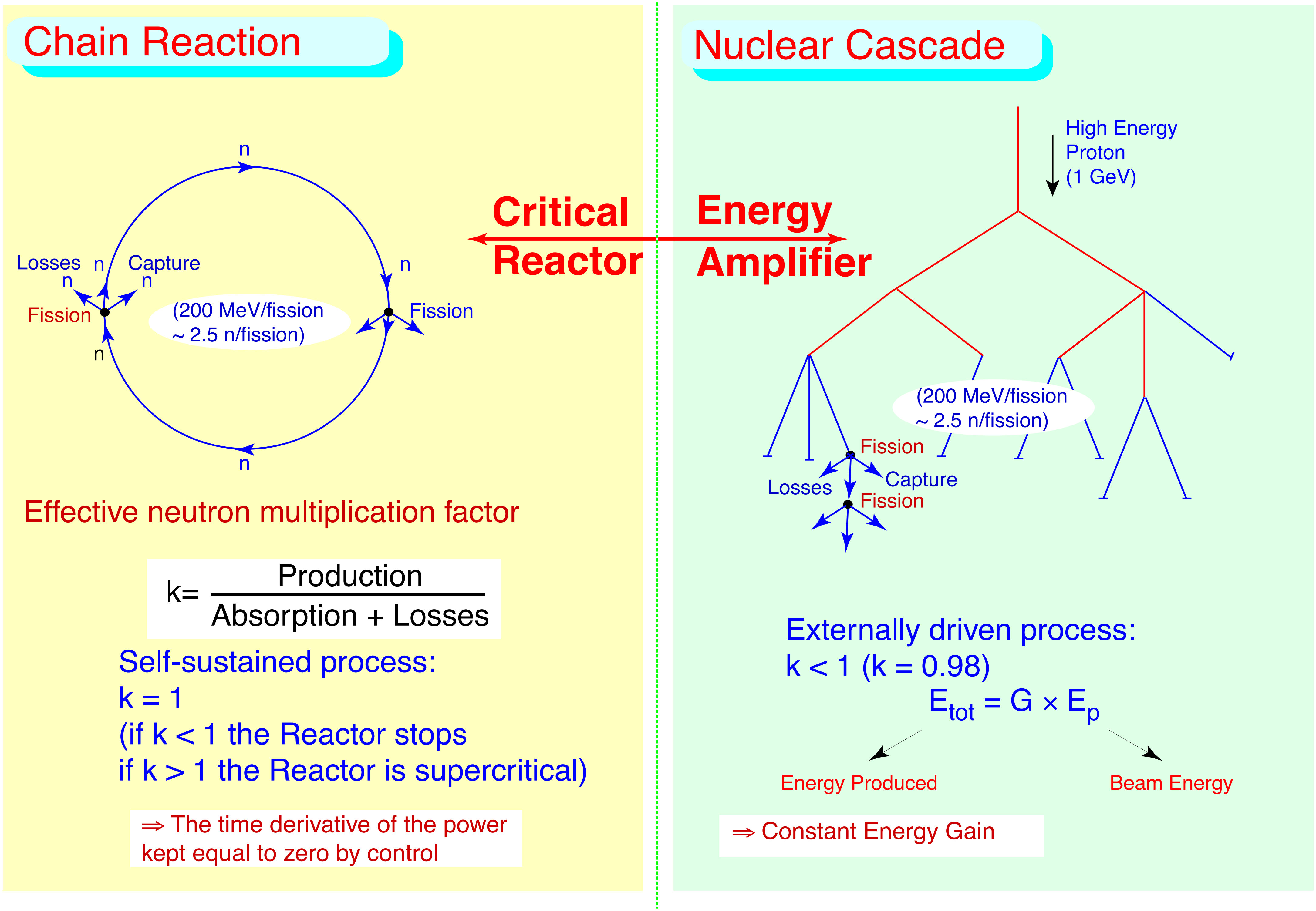
Generator

Spallation Neutrons

‘Energy Amplifier’

Subcritical core (Keff < 1)
Passively Safe

LWR vs. ADS



Chain Reaction

Nuclear Cascade

Critical Reactor ← → **Energy Amplifier**

Effective neutron multiplication factor

$$k = \frac{\text{Production}}{\text{Absorption + Losses}}$$

Self-sustained process:
$k = 1$
(if $k < 1$ the Reactor stops
if $k > 1$ the Reactor is supercritical)

⇒ The time derivative of the power kept equal to zero by control

Externally driven process:
$k < 1$ ($k = 0.98$)

$$E_{tot} = G \times E_p$$

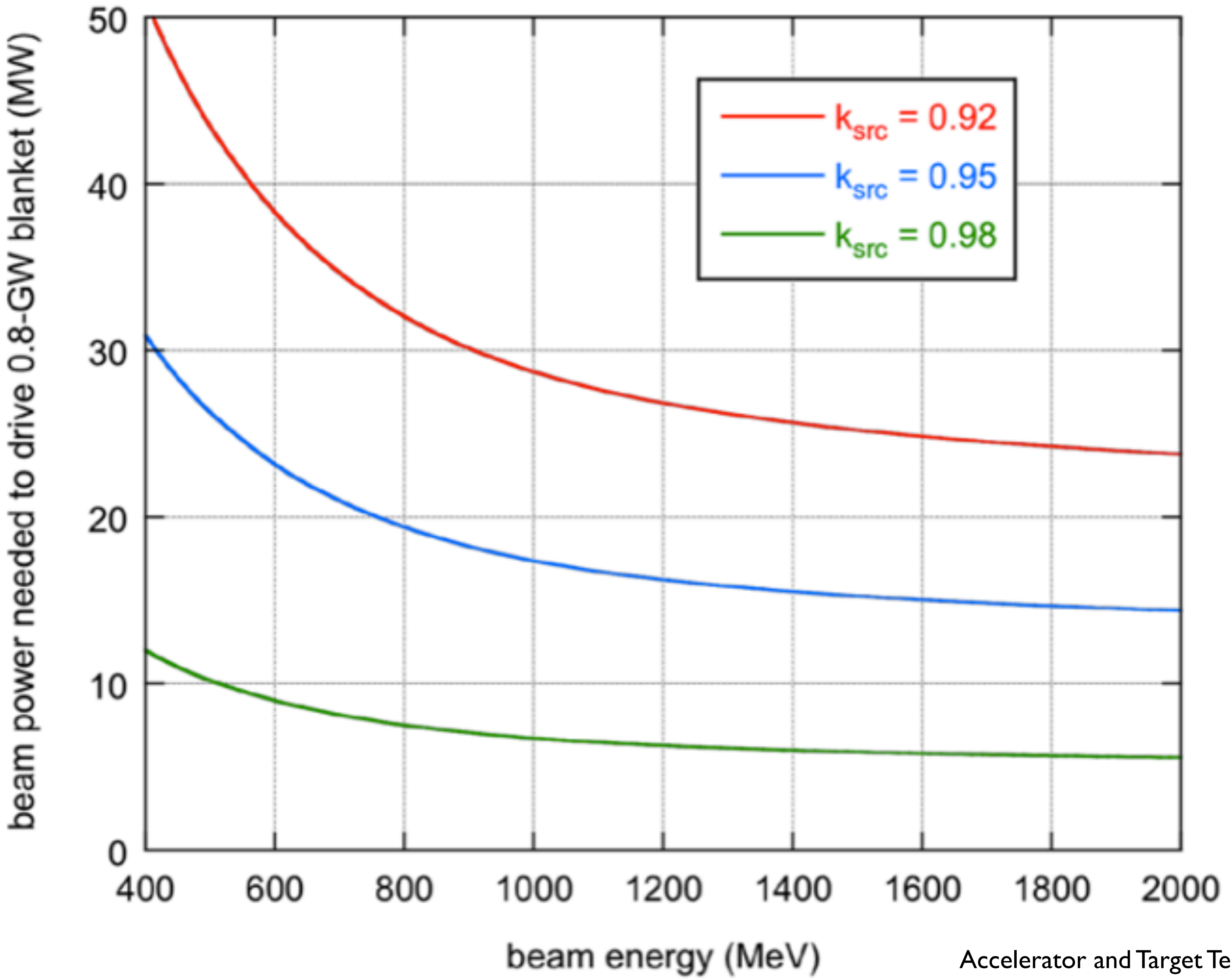
Energy Produced

Beam Energy

⇒ Constant Energy Gain

Figure 11: Illustration of the nuclear cascade that drives an ADS as opposed to the self sustained chain reaction driving a critical fission reactor.

Keff



Accelerator and Target Technology for Accelerator Driven Transmutation and Energy Production

Keff is:
A design parameter (core composition/geometry)
A safety margin

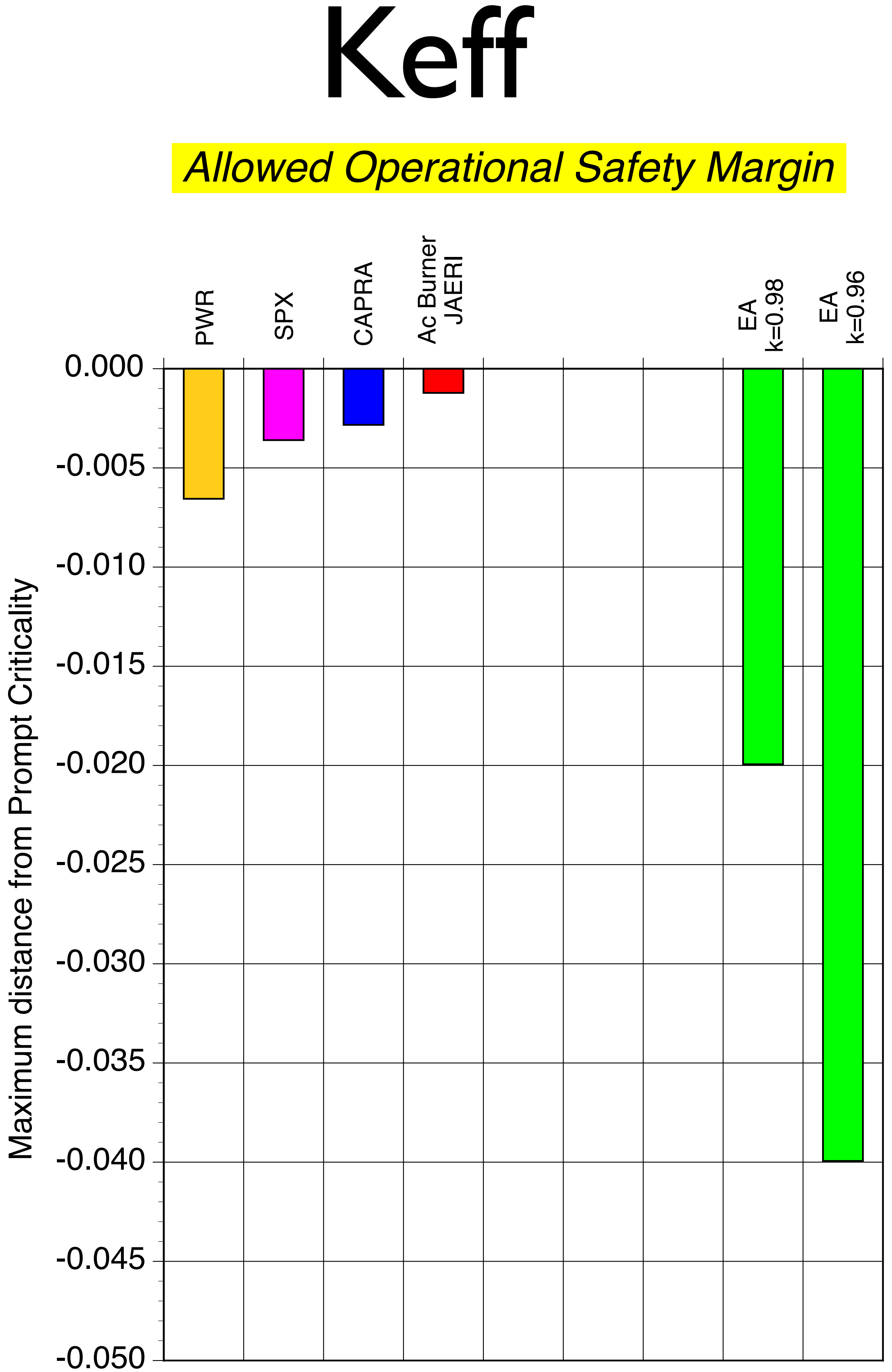
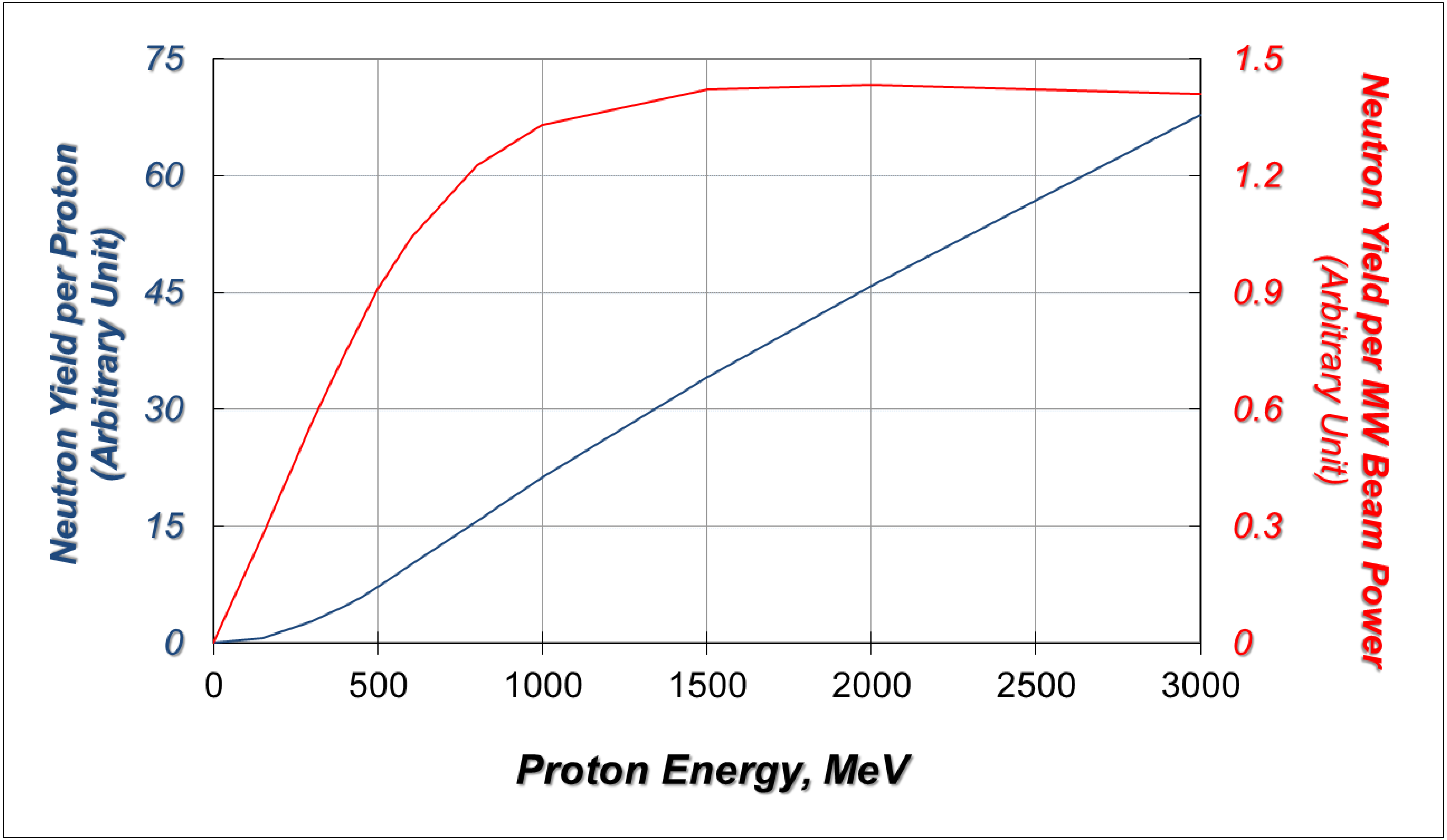
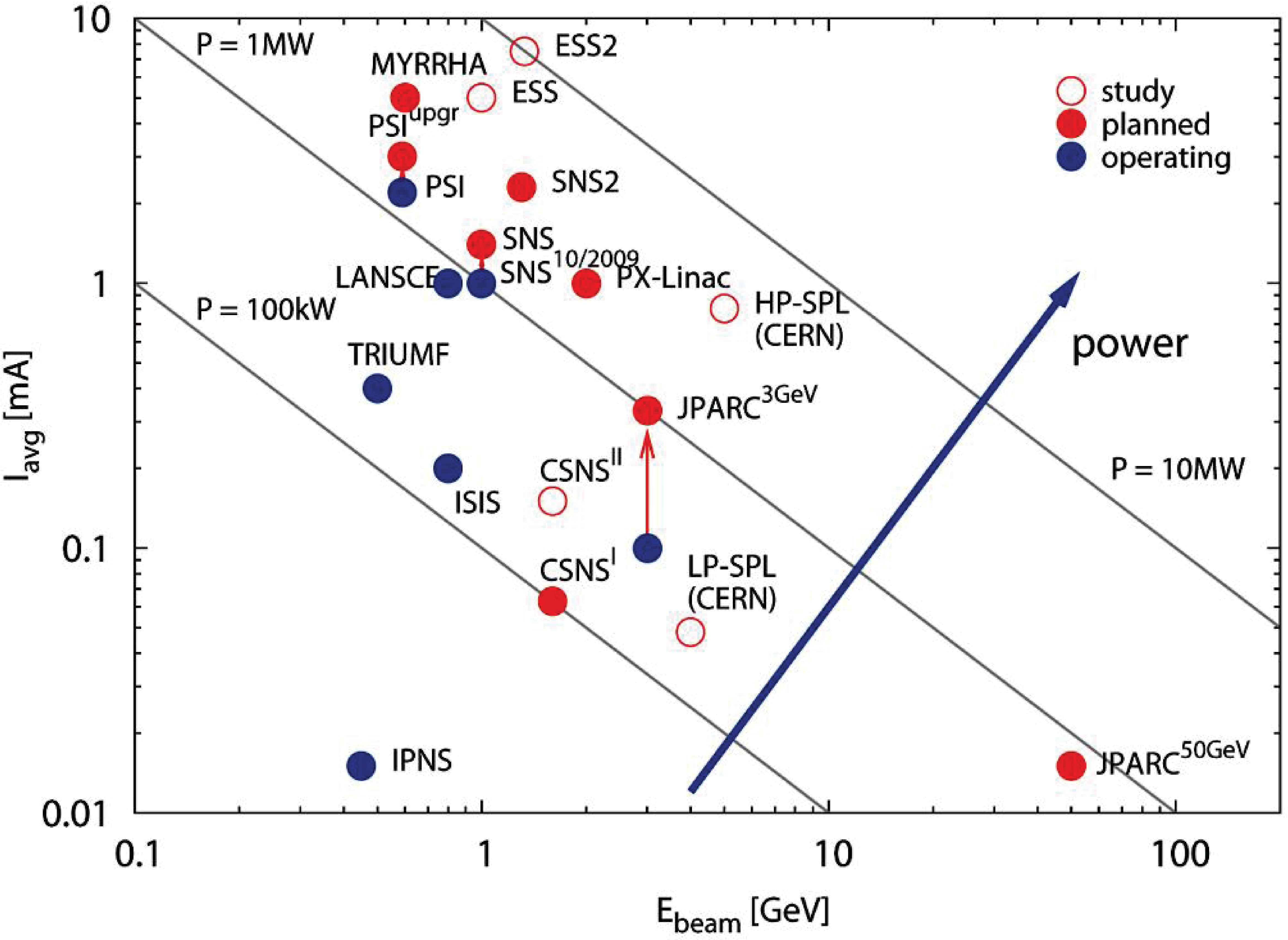


Figure 28: Comparison of the maximum allowable safety margins for minor actinide burning in critical reactors and in ADS.

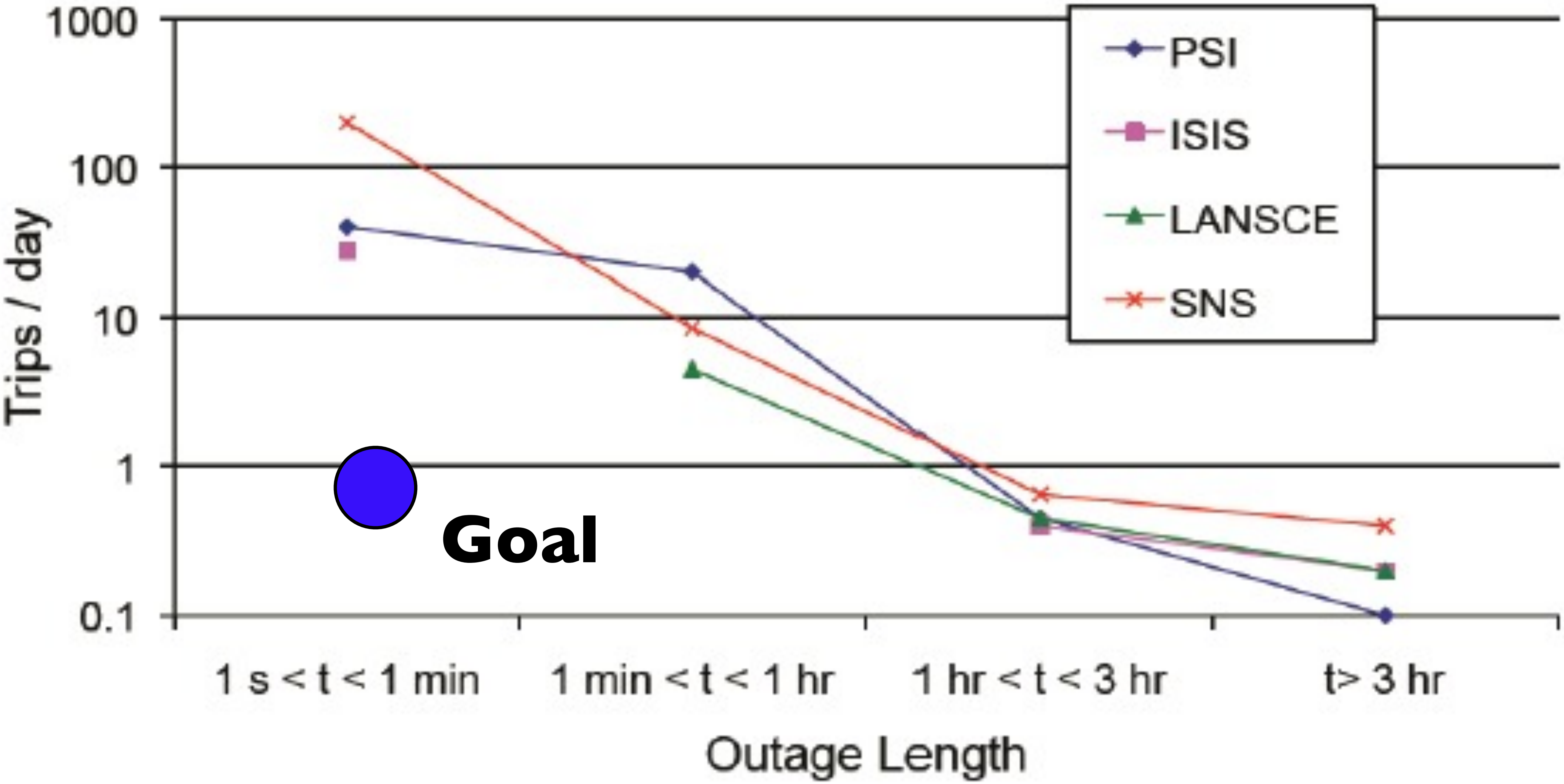
ADS Design


75
60
45
30
15
0
Neutron Yield per Proton
(Arbitrary Unit)
1.5
1.2
0.9
0.6
0.3
0
Neutron Yield per MW Beam Power
(Arbitrary Unit)
0
500
1000
1500
2000
2500
3000
Proton Energy, MeV

Accelerators



Reliability Problem

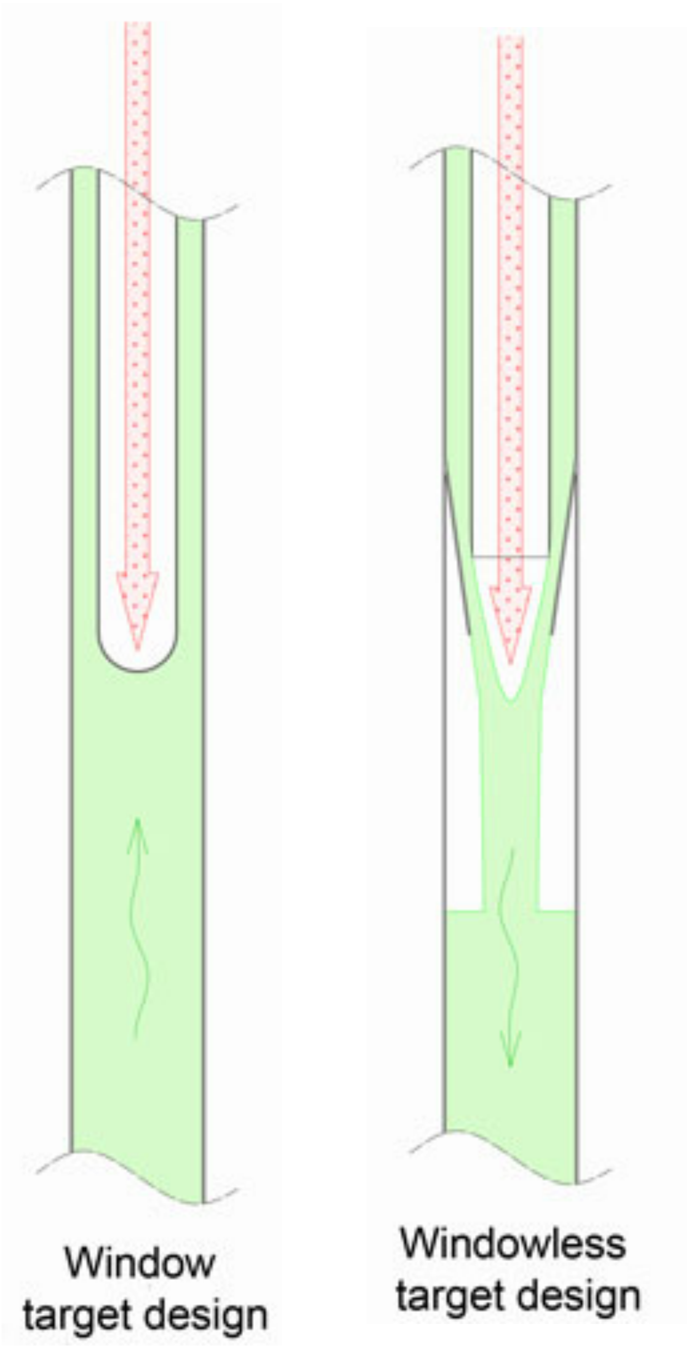


Goal

Window / Spallation Target

- Target: Solid or Liquid
- Beam-Core: window or windowless

Issue List:
-Cooing
-Lifetime
-Replaceability
-Radiochemical issues



From MYRRHA

Many Successful Target Experiments
Ex: Megapie - 1 MW LBE target

December 21

2006

At 8:00 in the morning, after 4 months of operation, the beam on the MEGAPIE target has been stopped according to plan. The target has performed almost perfectly over the period and is still in good shape. We have accumulated about 2.8 Ah of charge.
The experiment therefore can be considered as full success.

Accelerator and Target Technology for Accelerator Driven Transmutation and Energy Production

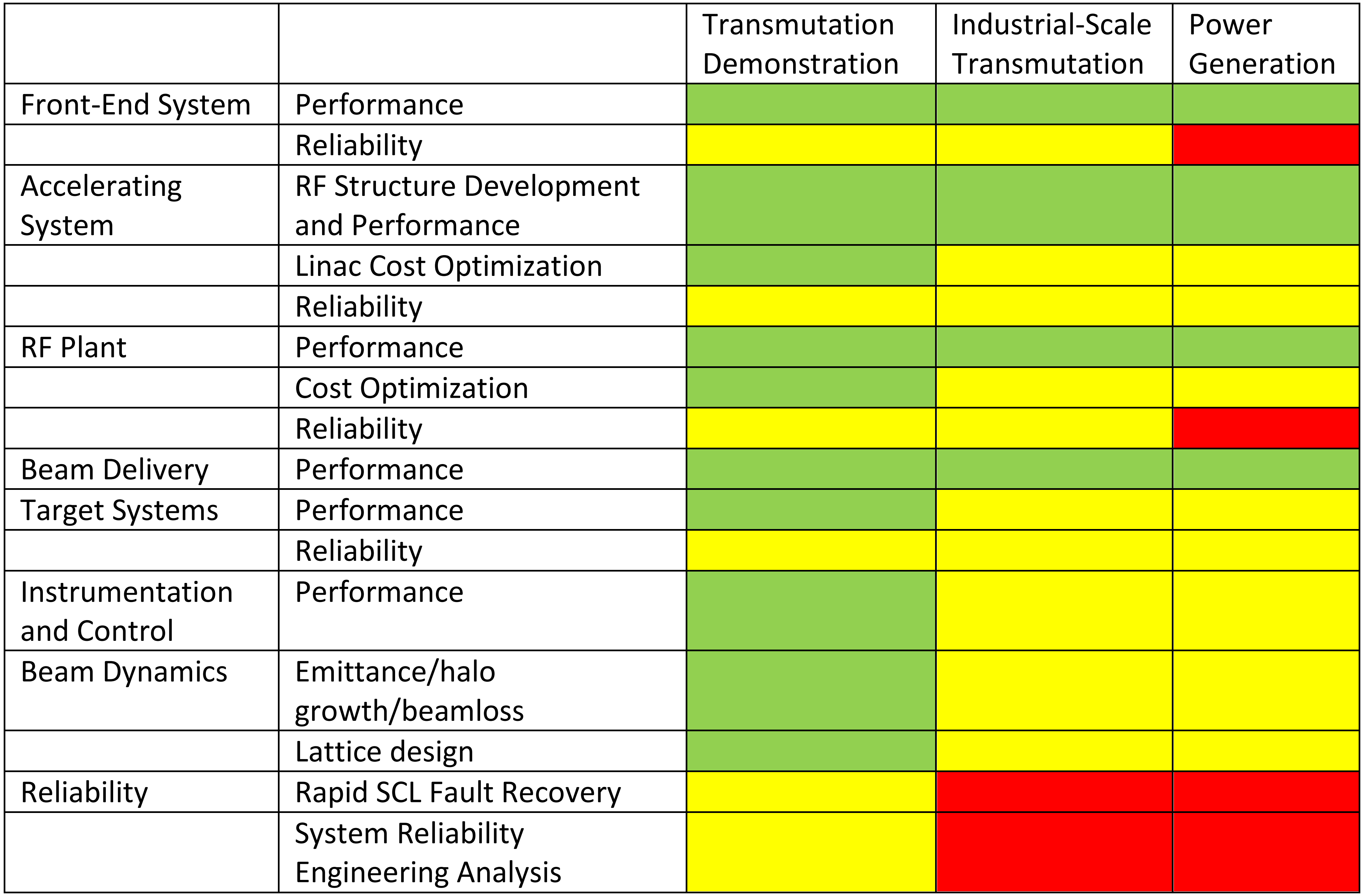
H. Aït Abderrahim[h], J. Galambos[d], Y. Gohar[a], S. Henderson[c*], G. Lawrence[e], T. McManamy[d], A. C. Mueller[g], S. Nagaitsev[c], J. Nolen[a], E. Pitcher[e*], R. Rimmer[f], R. Sheffield[e], M. Todosow[b]

🟩 Ready

🟨 ‘demonstration or further analysis is required’

🟥 ‘more development is required’

Table 3: ADS technology readiness assessment. The color-coding is explained in the text.



		Transmutation Demonstration	Industrial-Scale Transmutation	Power Generation
Front-End System	Performance	🟩	🟩	🟩
	Reliability	🟨	🟨	🟥
Accelerating System	RF Structure Development and Performance	🟩	🟩	🟩
	Linac Cost Optimization	🟩	🟨	🟨
	Reliability	🟨	🟨	🟨
RF Plant	Performance	🟩	🟩	🟩
	Cost Optimization	🟩	🟨	🟨
	Reliability	🟨	🟨	🟥
Beam Delivery	Performance	🟩	🟩	🟩
Target Systems	Performance	🟩	🟨	🟨
	Reliability	🟨	🟨	🟨
Instrumentation and Control	Performance	🟩	🟨	🟨
Beam Dynamics	Emittance/halo growth/beamloss	🟩	🟨	🟨
	Lattice design	🟩	🟨	🟨
Reliability	Rapid SCL Fault Recovery	🟨	🟥	🟥
	System Reliability Engineering Analysis	🟨	🟥	🟥

Fuel Design

- Solid v. Liquid Fuel
- MA Fuels, Liquid Fuels are exotic
- Optimization for stability (%Pu) vs. efficiency (%MA)

Solid Fuels:
-Fission product poisoning
-Thermal shock on cladding
-Non-uniform burnup:

Liquid Fuels:
-Little experience
-Years (decades?) to validate novel fuel.

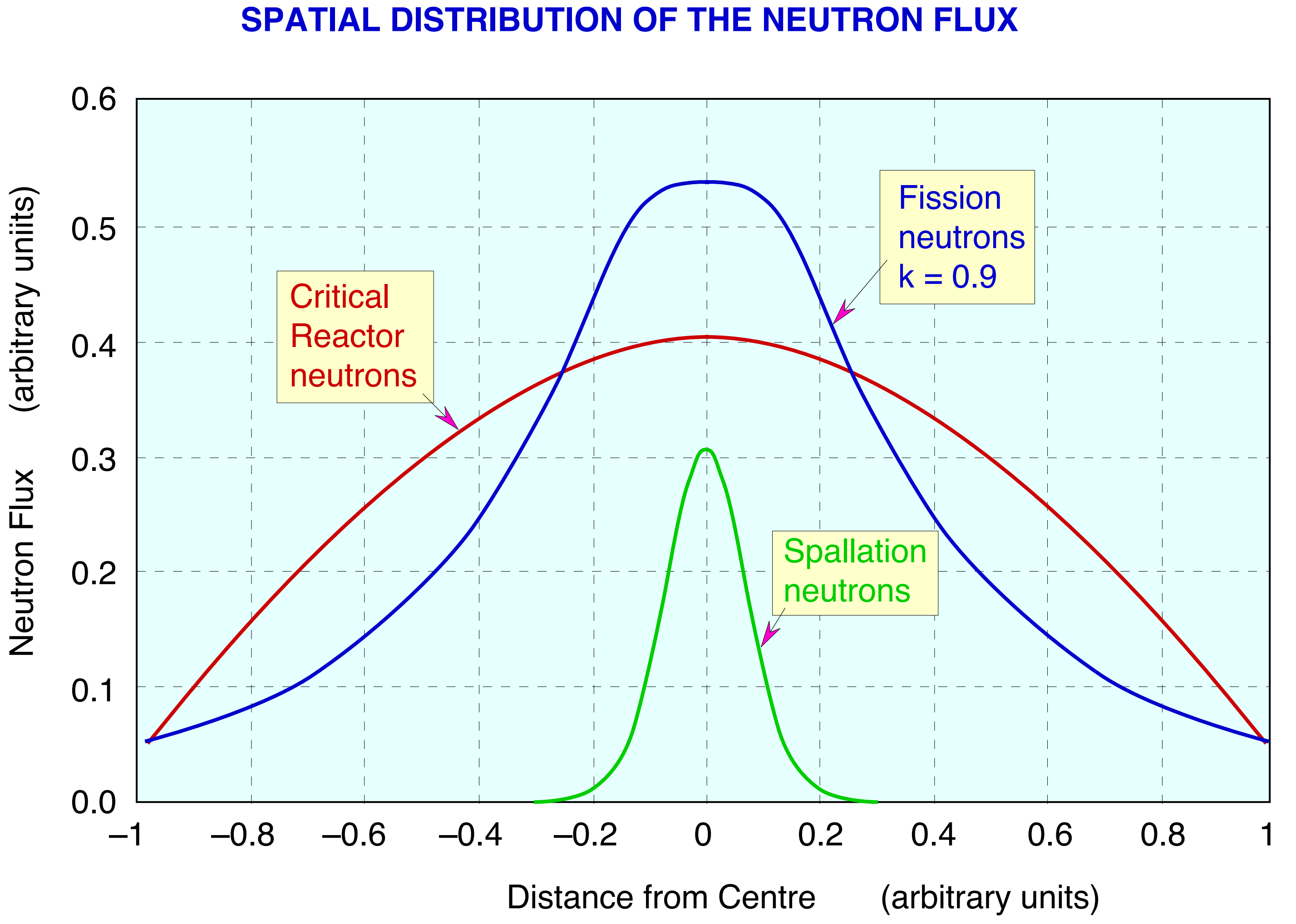
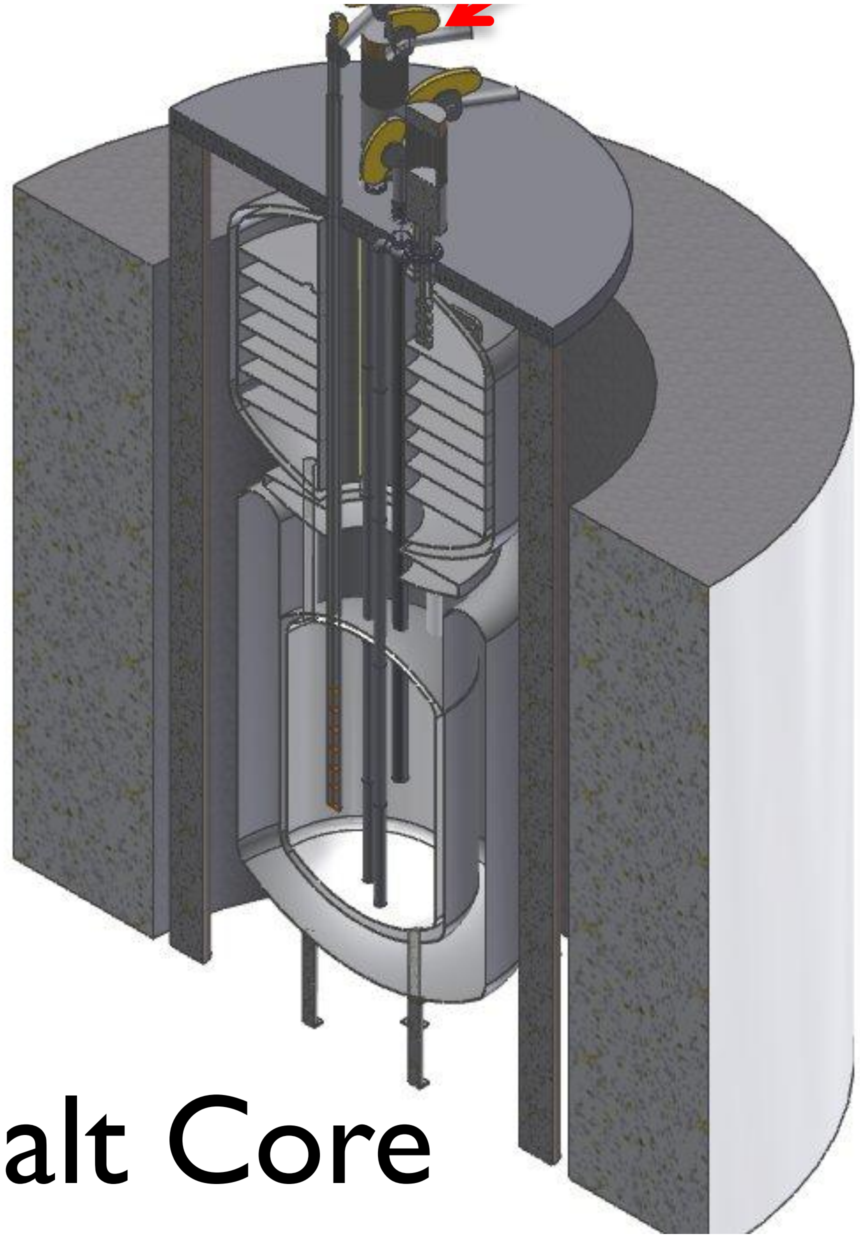


Figure 14: Spatial distribution of the neutron flux depending on the value of *k*.

Core Design

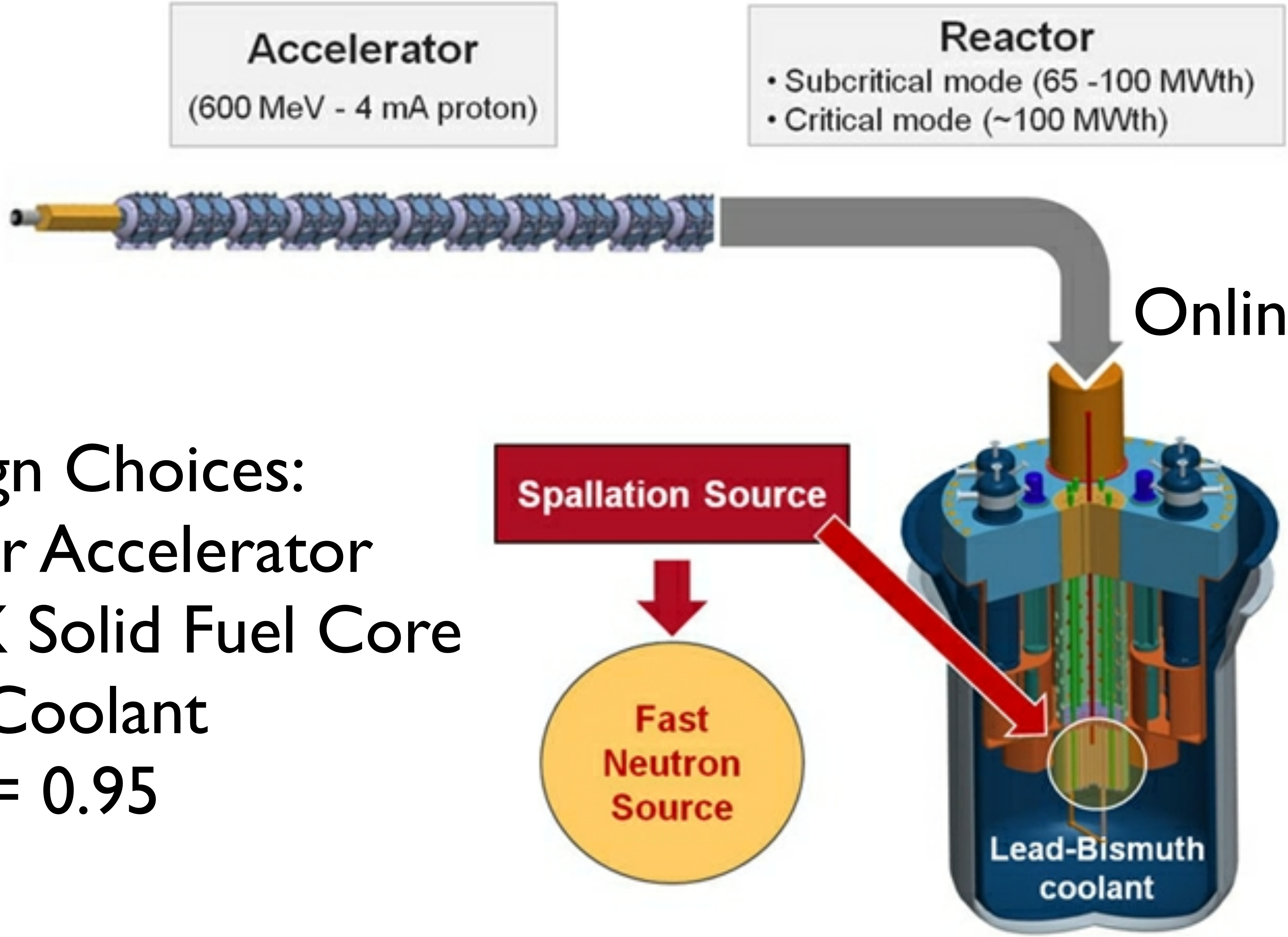
- Choice of coolant (low σ, high heat capacity)
- Metal or Salt Coolant
- Geometry
- Safety Issues



Salt Core

MYRRHA: Multi-purpose hybrid research reactor for high-tech applications

STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE



Accelerator

(600 MeV - 4 mA proton)

Reactor

- Subcritical mode (65 -100 MWth)
- Critical mode (~100 MWth)

Online: 2024

Design Choices:
Linear Accelerator
MOX Solid Fuel Core
LBE Coolant
Keff = 0.95

Accelerator

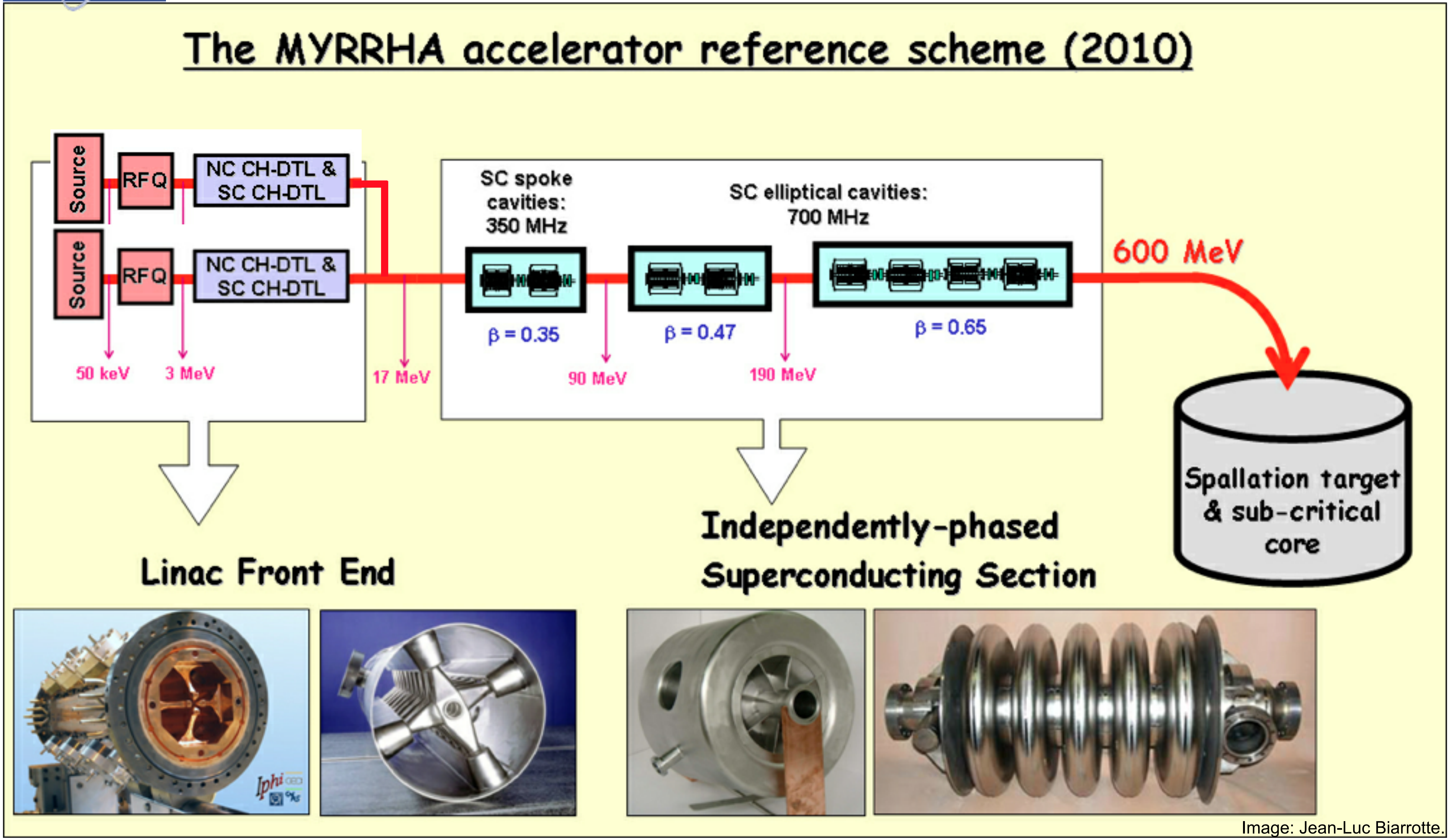
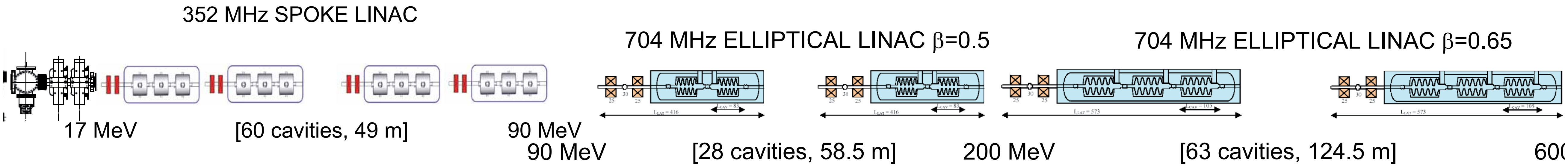


Image: Jean-Luc Biarrotte.

First accelerator built for reliability

Accelerator

High β Cavities



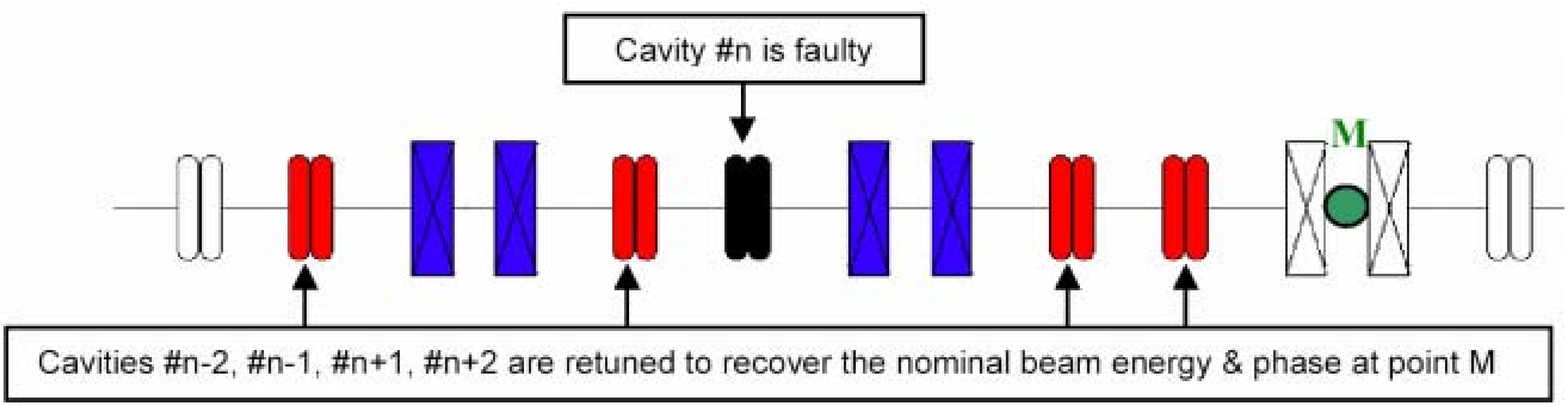
352 MHz SPOKE LINAC

704 MHz ELLIPTICAL LINAC β=0.5

704 MHz ELLIPTICAL LINAC β=0.65

17 MeV [60 cavities, 49 m] 90 MeV

90 MeV [28 cavities, 58.5 m] 200 MeV [63 cavities, 124.5 m] 60



Cavity #n is faulty

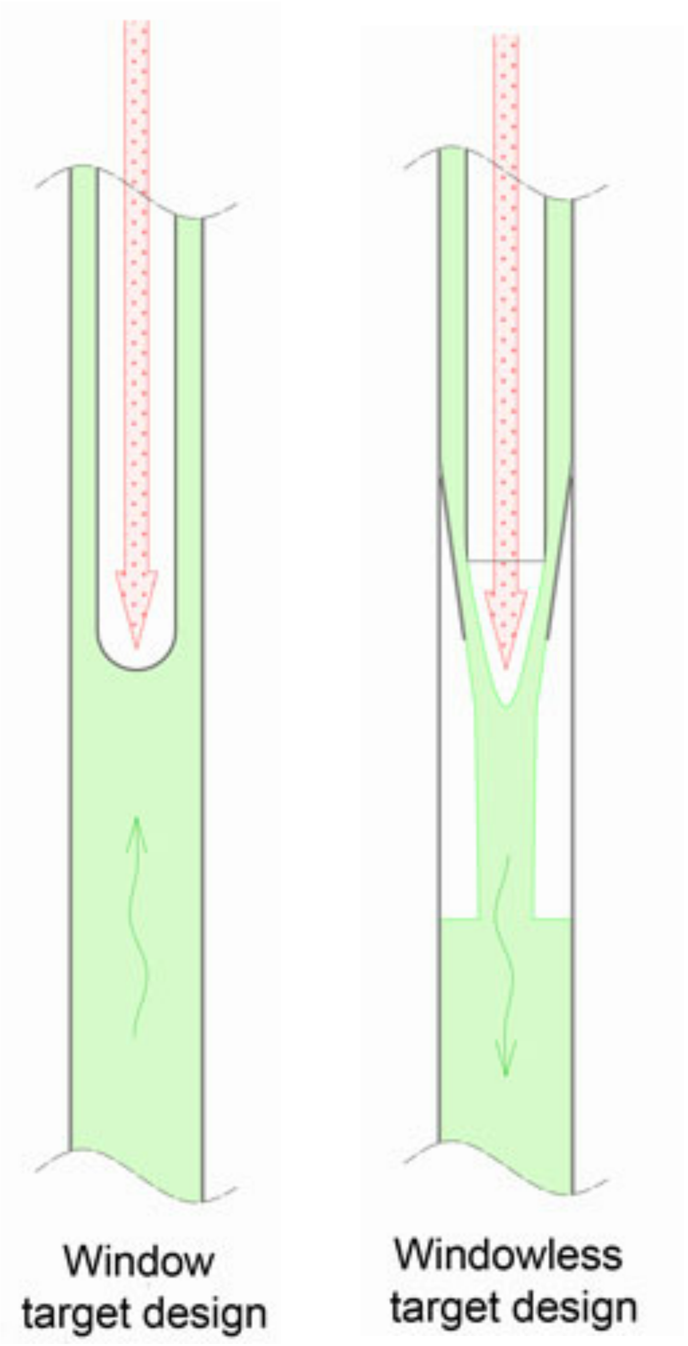
Cavities #n-2, #n-1, #n+1, #n+2 are retuned to recover the nominal beam energy & phase at point M

Fault Tolerance “Local Compensation”

BEAM DYNAMICS STUDIES FOR THE FAULT TOLERANCE ASSESSMENT OF THE PDS-XADS LINAC DESIGN
Proceedings of EPAC 2004,

Spallation Target

Undecided



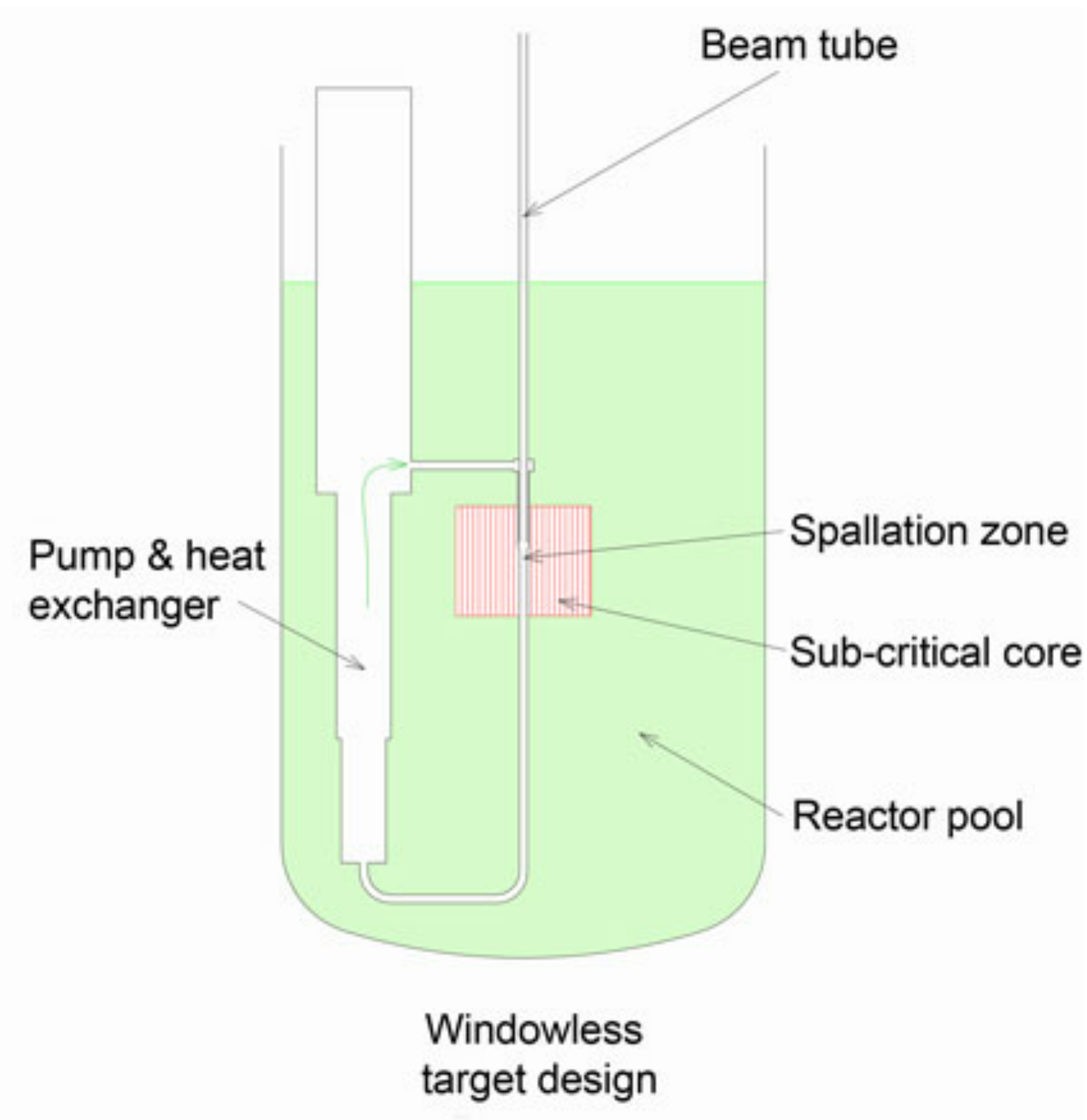
The core coolant, LBE, is the target.

Target Must:

-Sit in the core - radiation rich environment

-Absorb ~65% of the beam power as heat

-Maintain cooling and a reasonable lifetime

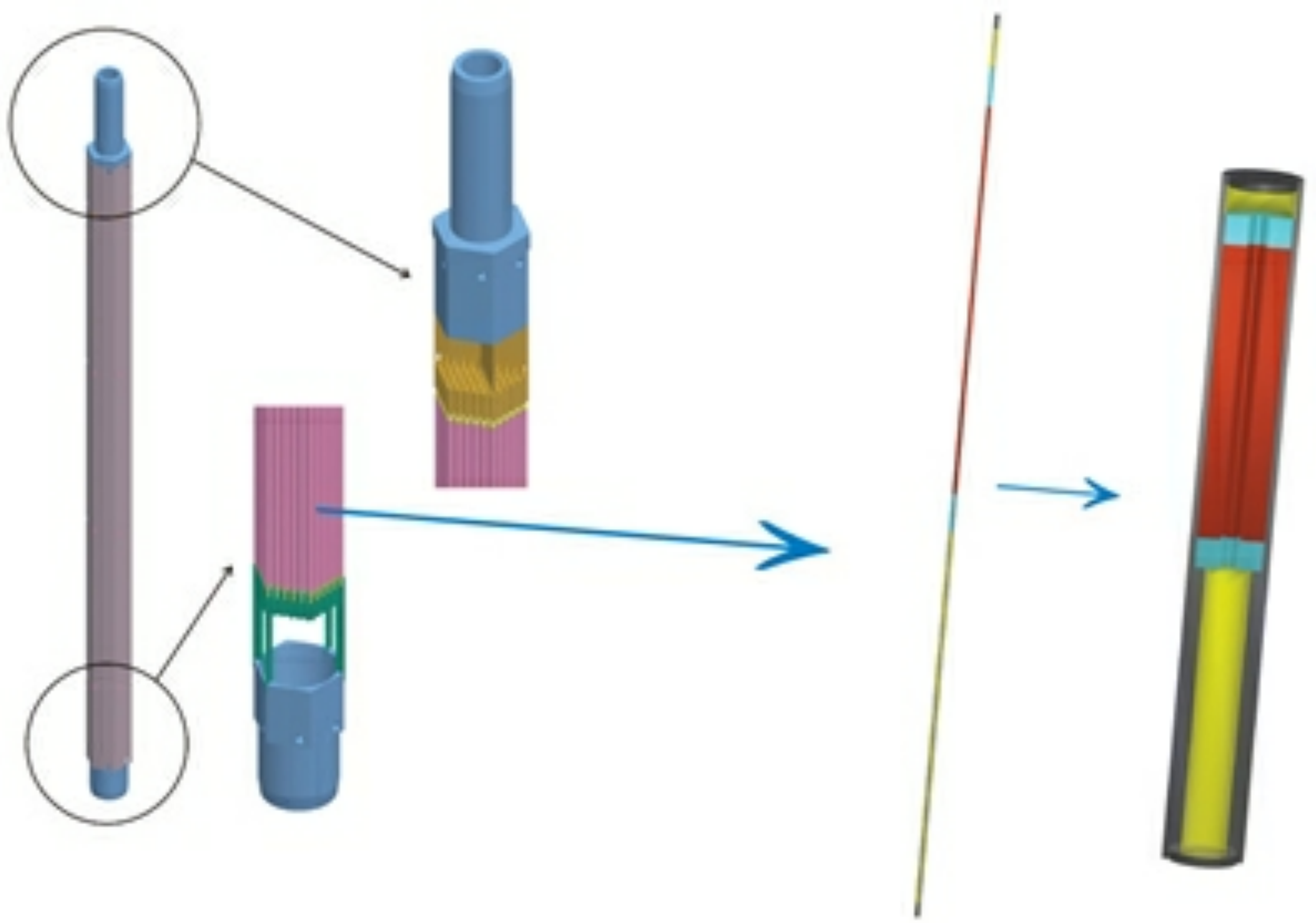


From MYRRHA

Fuel

MOX (Mixed Oxide) Pu (35%) & U

“The design and licensing of new fuels does not comply with MYRRHA's time frame.”



Fuel assembly layout

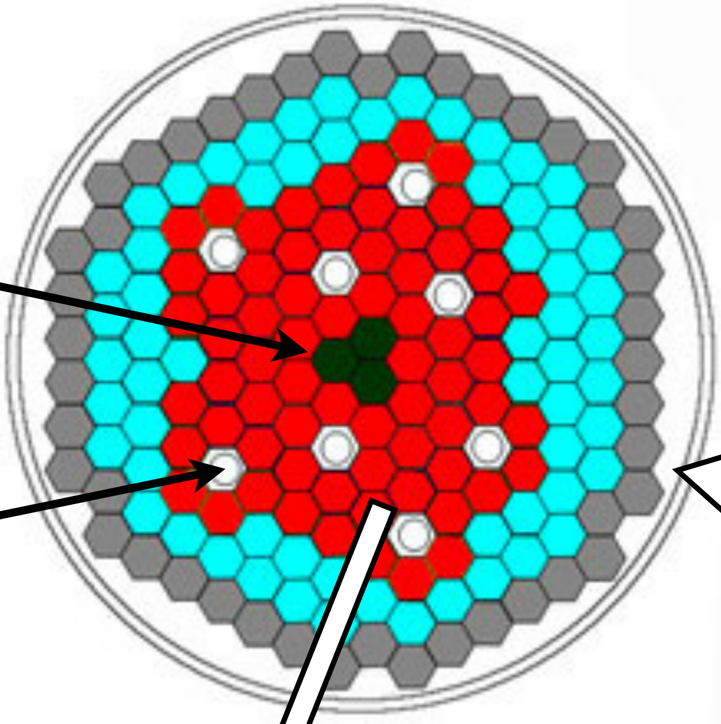
Fuel pin design

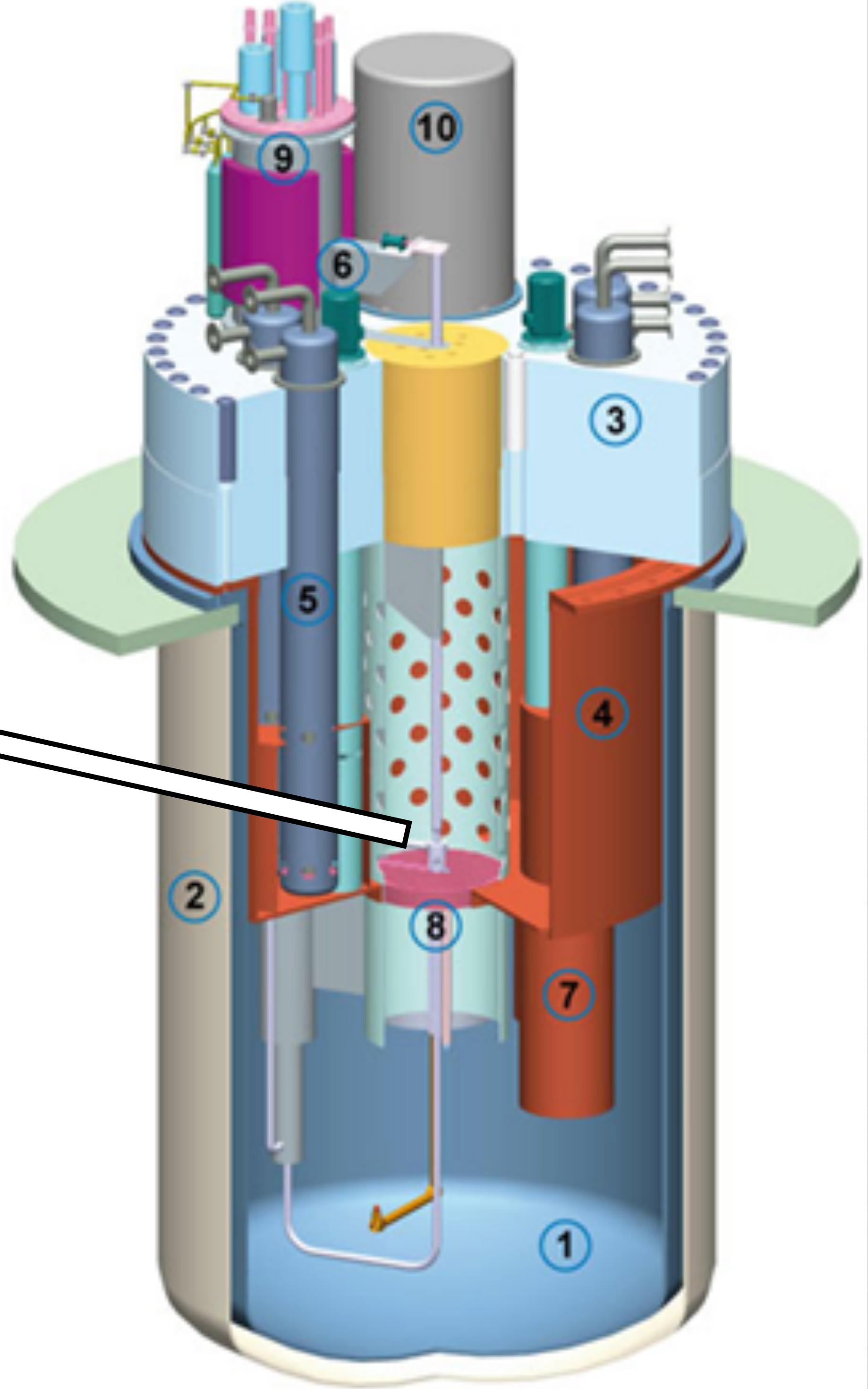
-MOX is understood

Core

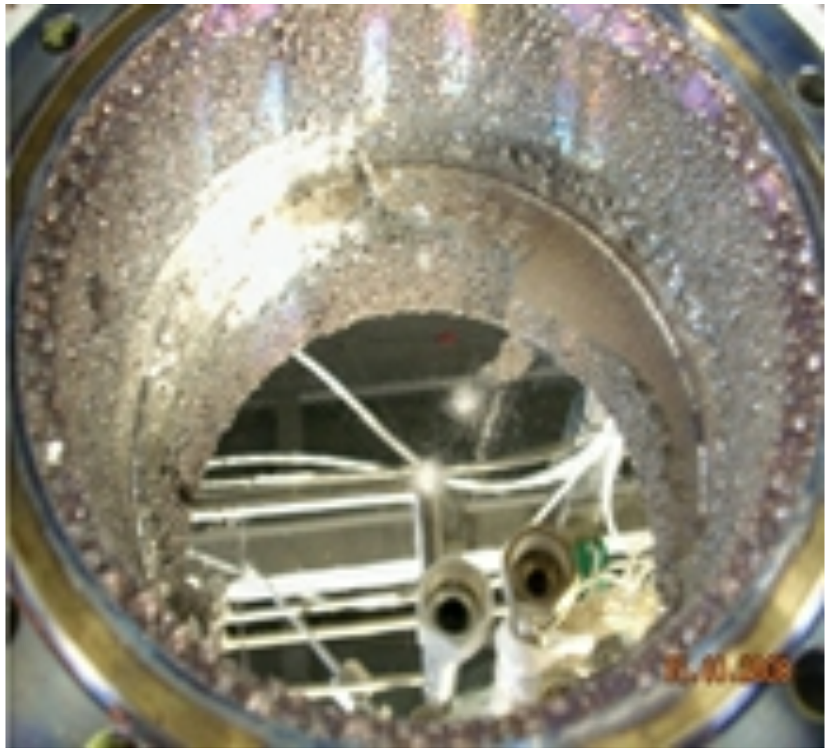
Spallation Target

Void Slots for Experiments





90 Day reshuffling Scheme:
1. Keff = 0.955
2. 90 Days, Keff drops to 0.94
3. turn off, reshuffle fuel rods
4. Turn on



Coolant

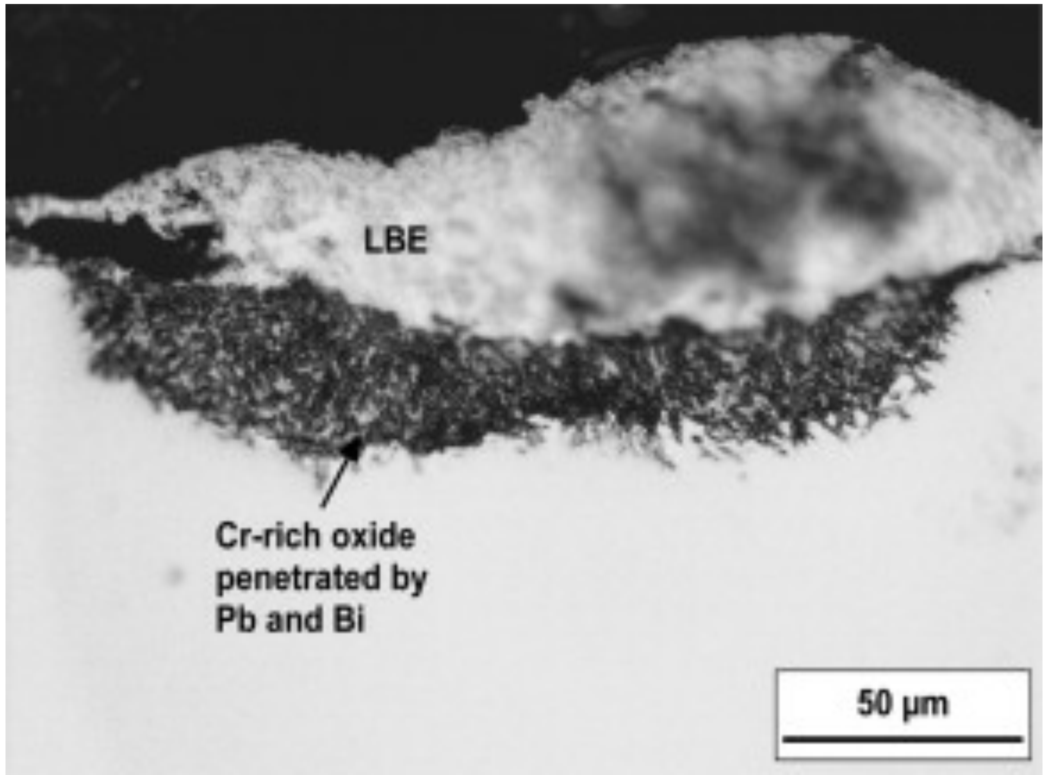
Lead Bismuth Coolant

Disadvantages:

reactive to metals
not understood over long time frames
Needs extensive study

Advantages:

Low melting point, high boiling point (no need to pressurize)
self shielding
good spallation source
does not react with water or air
transparent to neutron radiation opaque to gamma radiation.



Oxidation behaviour of P122 and a 9Cr–2W ODS steel at 550 °C in oxygen-containing flowing lead–bismuth eutectic

R&D Program

- Identification of key material issues
  - Collaboration with designers, fuel, safety and coolant chemistry groups
  - Assistance in design
    - Material choice justification
    - Various scenarios related to material failure
    - Preliminary assessment of material damage mechanisms
- Assessment of material properties
  - Development of testing procedures (FP7 MATTER)
  - Identified material issues and our related R&D program
    - Liquid Metal Corrosion (LMC)
    - Liquid Metal Embrittlement (LME)
    - Irradiation effects
- Development of testing infrastructure

Effects of Corrosion on Reactor Operation

- Material loss (dissolution, erosion) → compromise of component integrity
- Change in thermal conductivity (oxidation) → change of heat transfer characteristics
- Plugging due to deposition of corrosion products → flow obstruction

Principal directions of corrosion program

- Prediction of max corrosion depth (deterministic↔empiric approach)
  - Boundary operating conditions and a little bit beyond
    - For oxidation ([O]↑, T↑, v↑)
    - For dissolution ([O]↓, T↑, v↑)
- Investigation of oxide layer properties
  - Maximum and average thicknesses
  - Thermal conductivity
- Assessment of corrosion products release to the coolant and oxygen consumption

Pool type experiments

Heat exchangers

Lead-Bismuth Eutectic (LBE) pumps

LIDAR: LIght Detection And Ranging

Ultrasound imaging

Robotics

● ● ●

Material issues for design and licensing of MYRRHA ADS system
S. Gavrilov, R. Fernandez, M. Schyns, H. Aït Abderrahim

SCK•CEN

Criticisms

- Accelerator unproven (reliability)
- Throughput very low
- Fuel Rod reshuffling, MA buildup
- Unstable power output
- Lead underdeveloped

GUINEVERE: a new world premiere at the Belgian Nuclear Research Centre

2012-01-11

The Belgian Nuclear Research Centre (SCK•CEN) in Mol, **successfully coupled a reactor to a particle accelerator. For the first time in the history of nuclear science,** a demonstration model of a reactor, with a lead core and a particle accelerator, is in operation. The installation is subcritical because the reactor stops when the accelerator is turned off. This world premiere is part of the GUINEVERE project, initiated in collaboration with the French Centre National de la Recherche Scientifique (CNRS), the Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA), a dozen other European laboratories and the European Commission.

Guinevere is a demonstration model of an accelerator driven system or ADS. The accelerator was built by the CNRS. The CEA assisted in developing the concept and provided the fuel for the reactor. The inauguration of GUINEVERE took place in March 2010 at SCK•CEN in Mol. During the first year the accelerator, as well as the ventilation and monitoring of the installation, were tested exhaustively. In February 2011, the reactor was started in the classic critical mode and was subjected to a long series of tests.

Today, SCK•CEN and its research partners are pleased to announce that the accelerator and the reactor have been successfully connected, making the system now subcritical.

GUINEVERE, designed to support the MYRRHA project, is a test installation with a limited power. It is very important for the fine-tuning of the operation and control of future subcritical reactors, such as MYRRHA. This type of reactor is very safe because the reactor section of an ADS system depends for its operation on a particle accelerator: when it is turned off, the reactor will stop immediately.

Unlike conventional reactors systems, GUINEVERE and MYRRHA produce fast neutrons that can be used for the transmutation of high level radioactive waste. Transmutation is the fission of long-lived radioactive waste into products that are much less radio-toxic. This research complements the decision in favor of the geological disposal of this type of waste.

The successful launch of GUINEVERE is another important step towards the realization of MYRRHA, SCK•CEN's multipurpose research facility, which will be operational in 2023.

ADS Issues

- Separations
- Not just R&D - RDDD (research, development, demonstration, deployment)
- Gulf between feasibility and reality
- Cost/Benefit

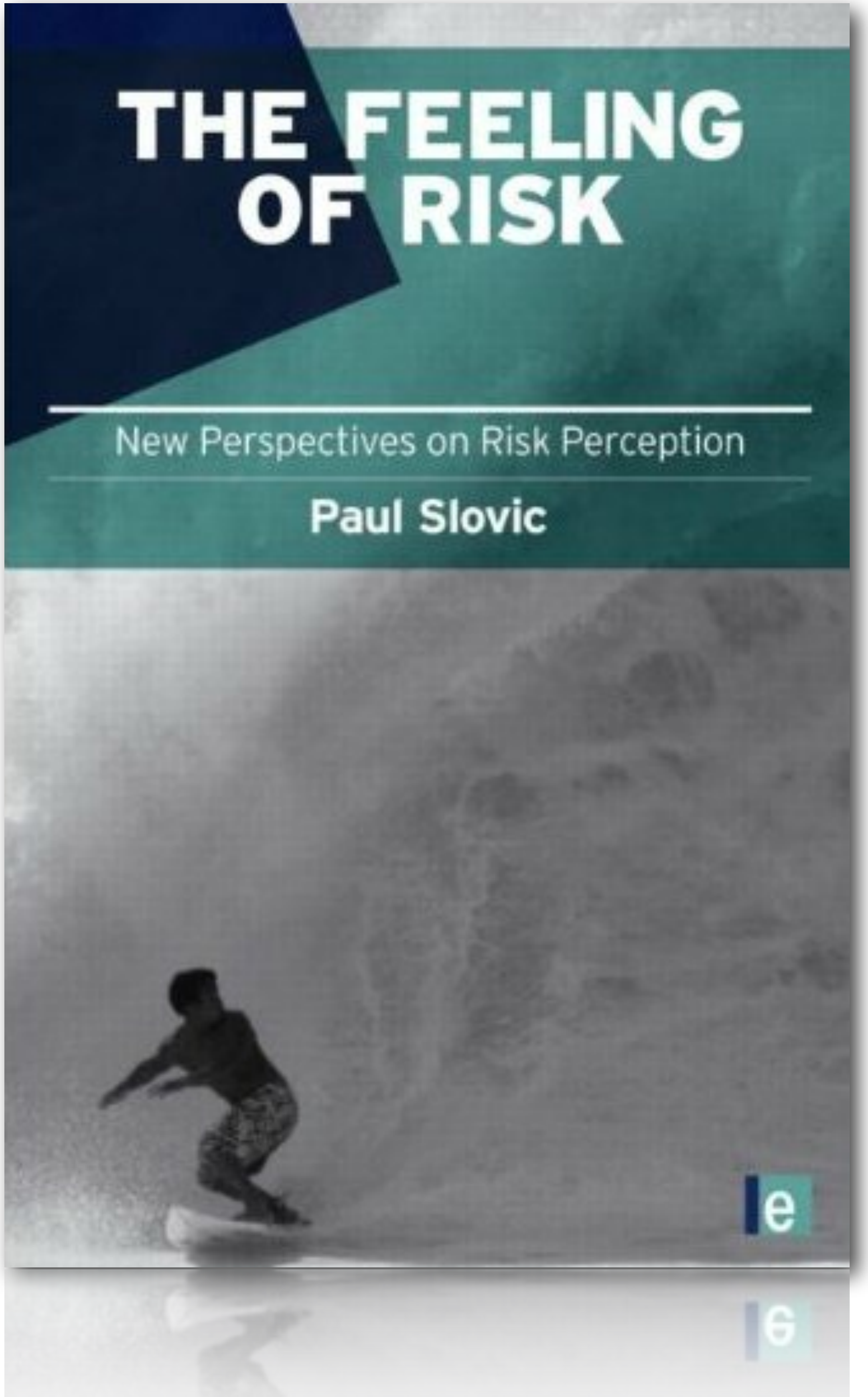
Policy Questions

Nuclear Fuel Recycling: More Trouble Than It's Worth [Preview]

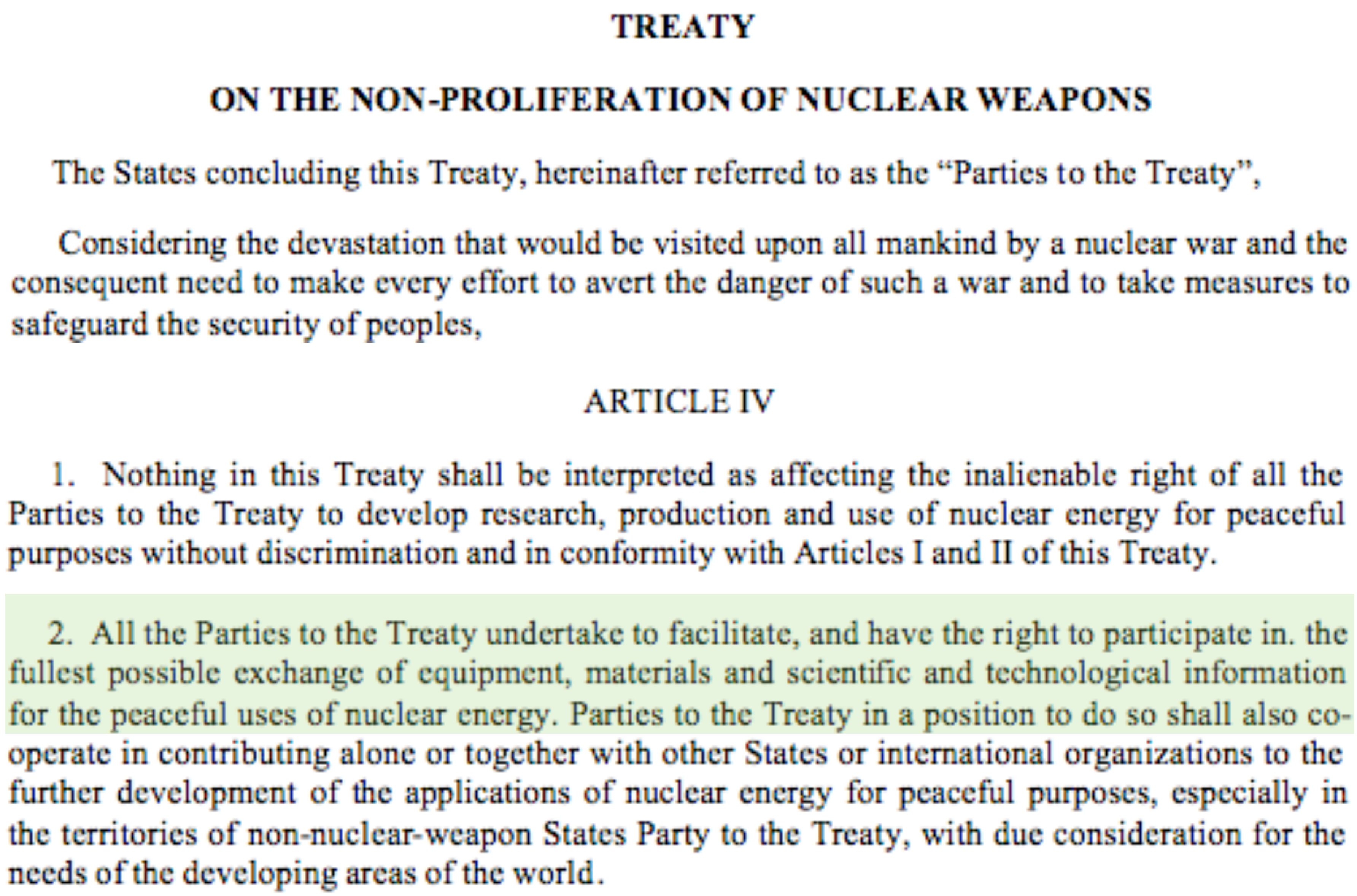
Plans are afoot to reuse spent reactor fuel in the U.S. But the advantages of the scheme pale in comparison with its dangers

By Frank N. von Hippel | April 28, 2008 | 💬 28

Policy Questions



Policy Questions



TREATY

ON THE NON-PROLIFERATION OF NUCLEAR WEAPONS

The States concluding this Treaty, hereinafter referred to as the "Parties to the Treaty",

Considering the devastation that would be visited upon all mankind by a nuclear war and the consequent need to make every effort to avert the danger of such a war and to take measures to safeguard the security of peoples,

ARTICLE IV

1. Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this Treaty.

2. All the Parties to the Treaty undertake to facilitate, and have the right to participate in. the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy. Parties to the Treaty in a position to do so shall also co-operate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.

U.S. set against recognizing Iranian right to enrich

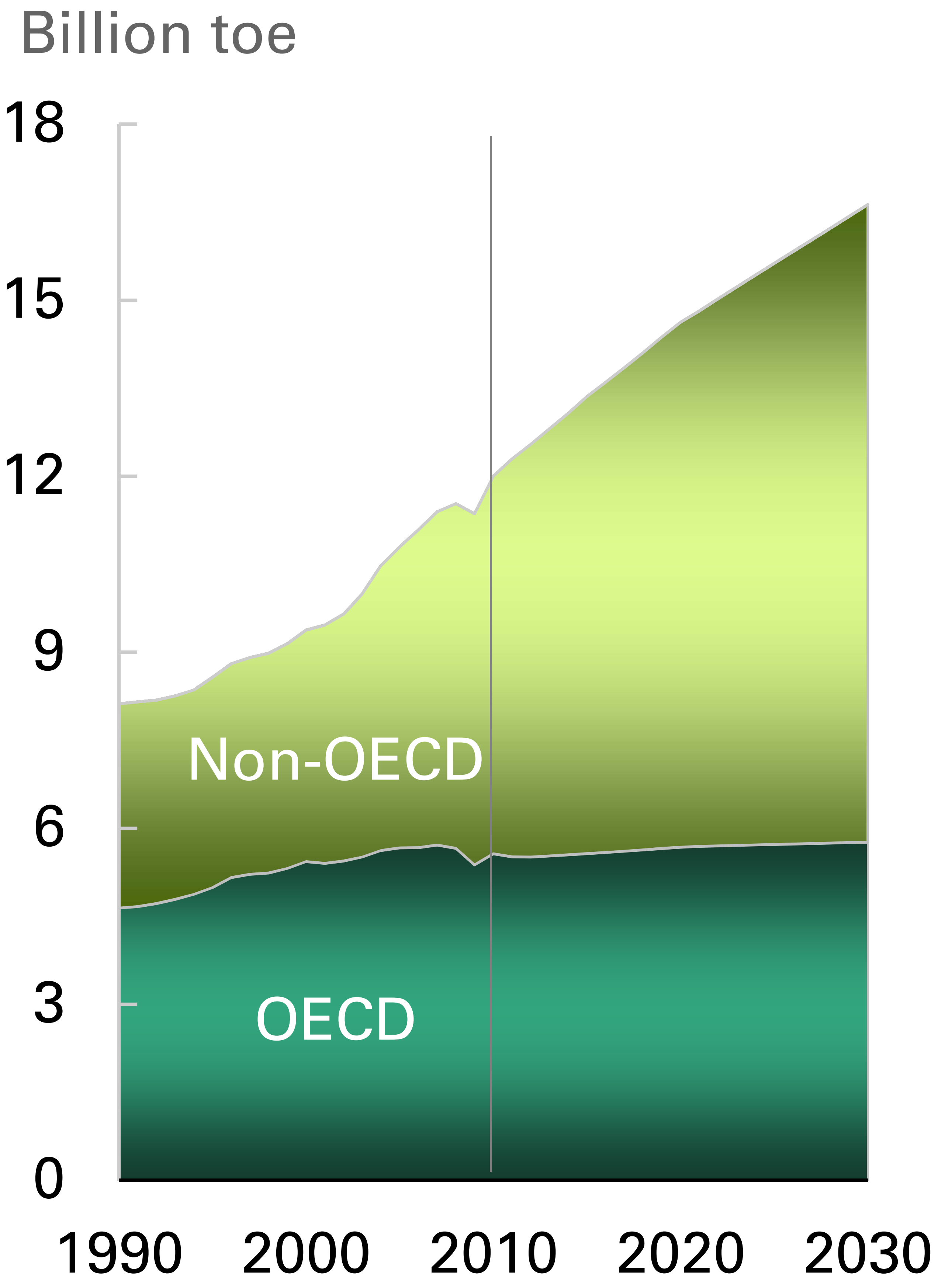
Thu, May 24 2012

By Andrew Quinn

BAGHDAD (Reuters) - Iran's insistence that world powers acknowledge what it sees as its right to enrich uranium emerged as a significant difference in international talks on its nuclear energy programme this week, a senior U.S. administration official said.

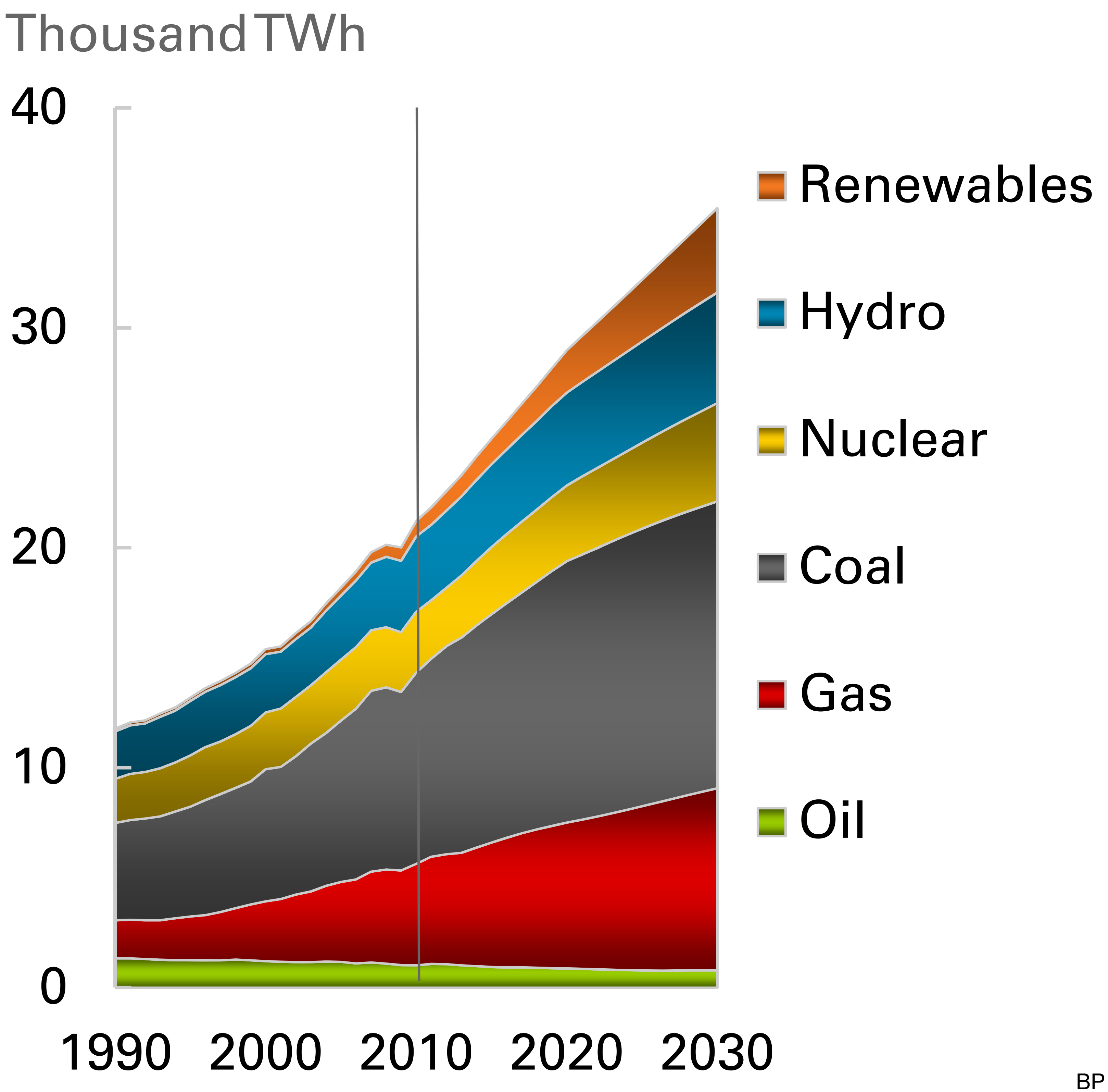
Thank You

Backup



Billion toe
18
15
12
9
6
3
0
Non-OECD
OECD
1990
2000
2010
2020
2030

Worldwide Electricity Generation

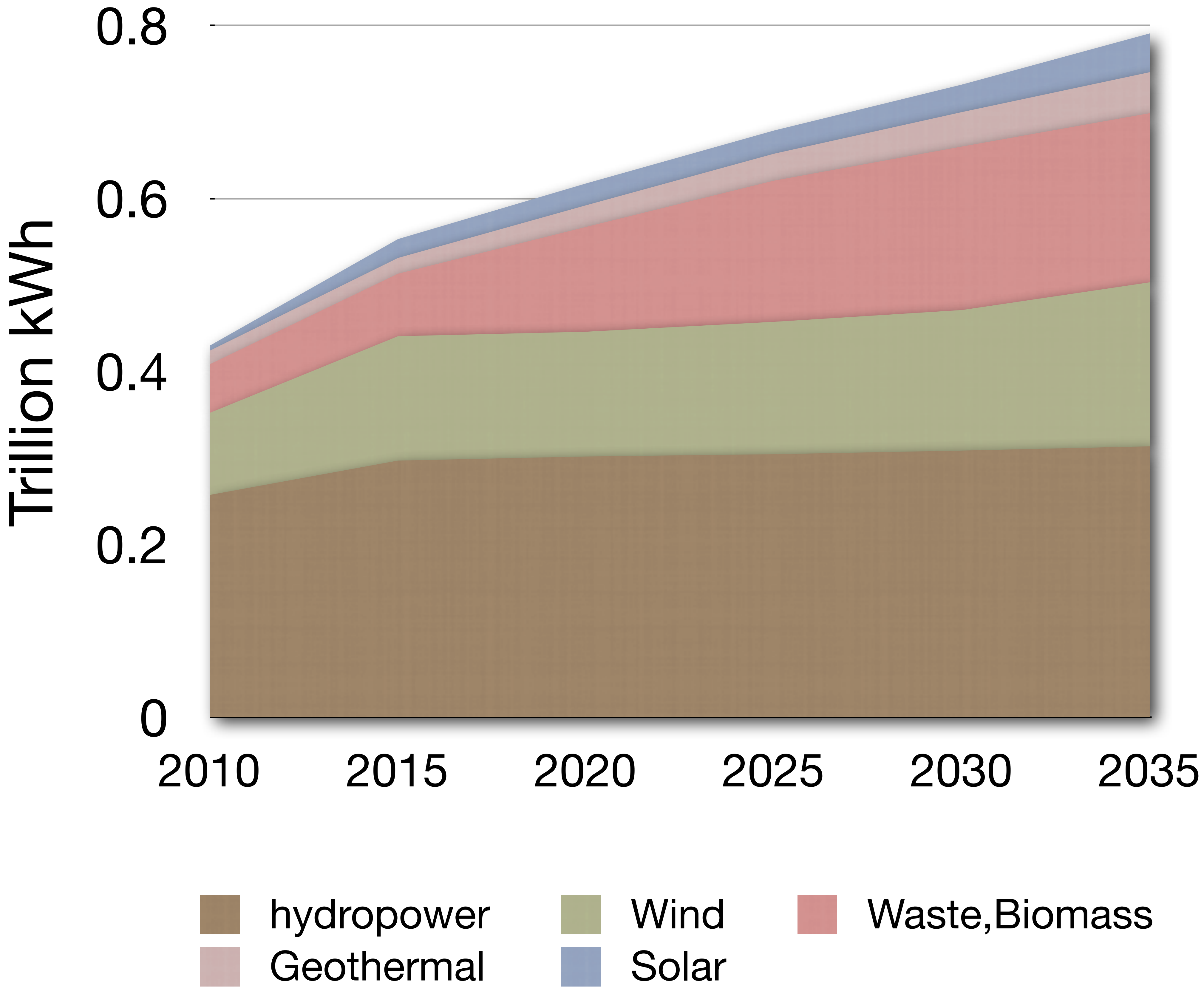


BP Energy Outlook 2030

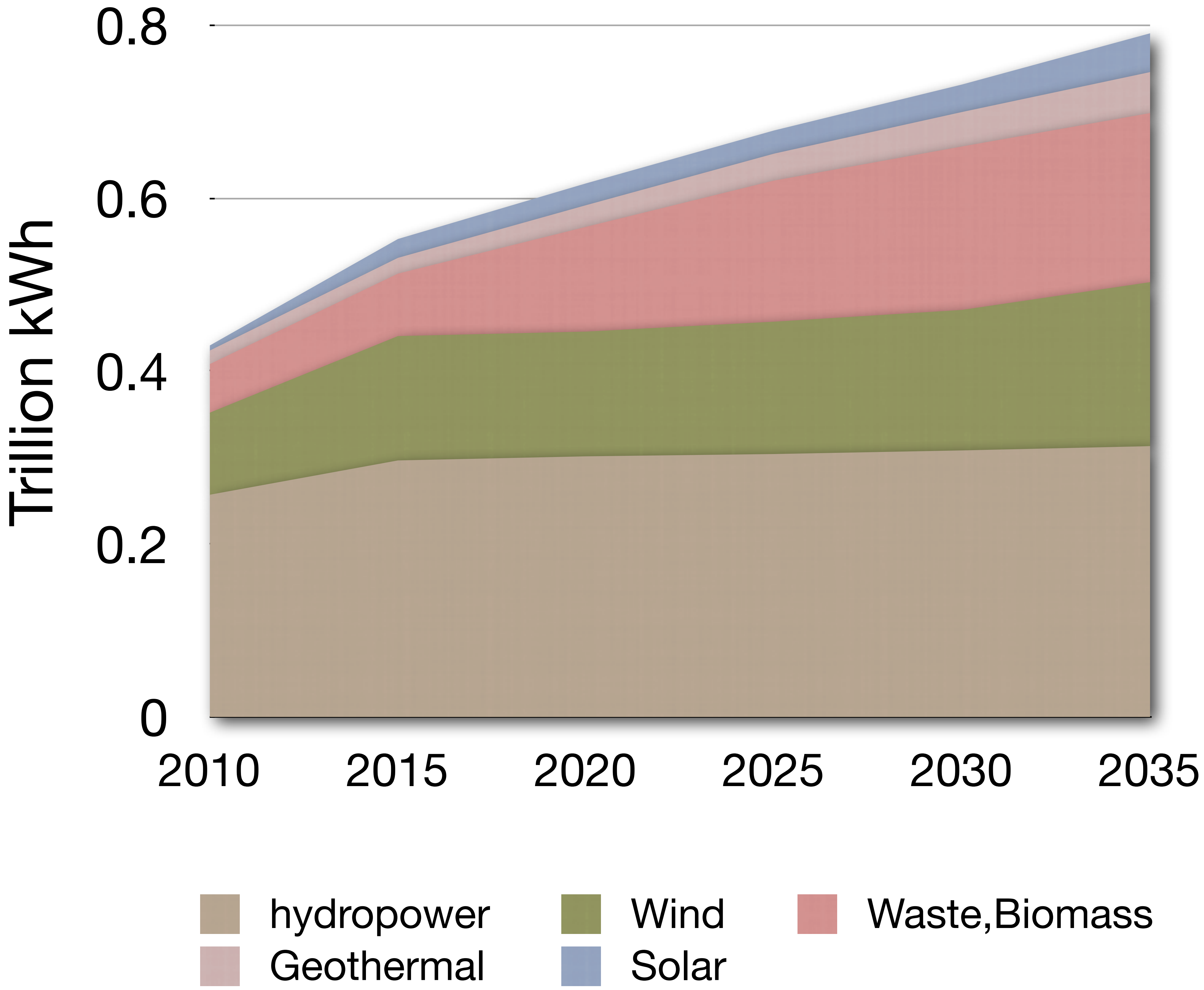
By Carbon

By Deaths

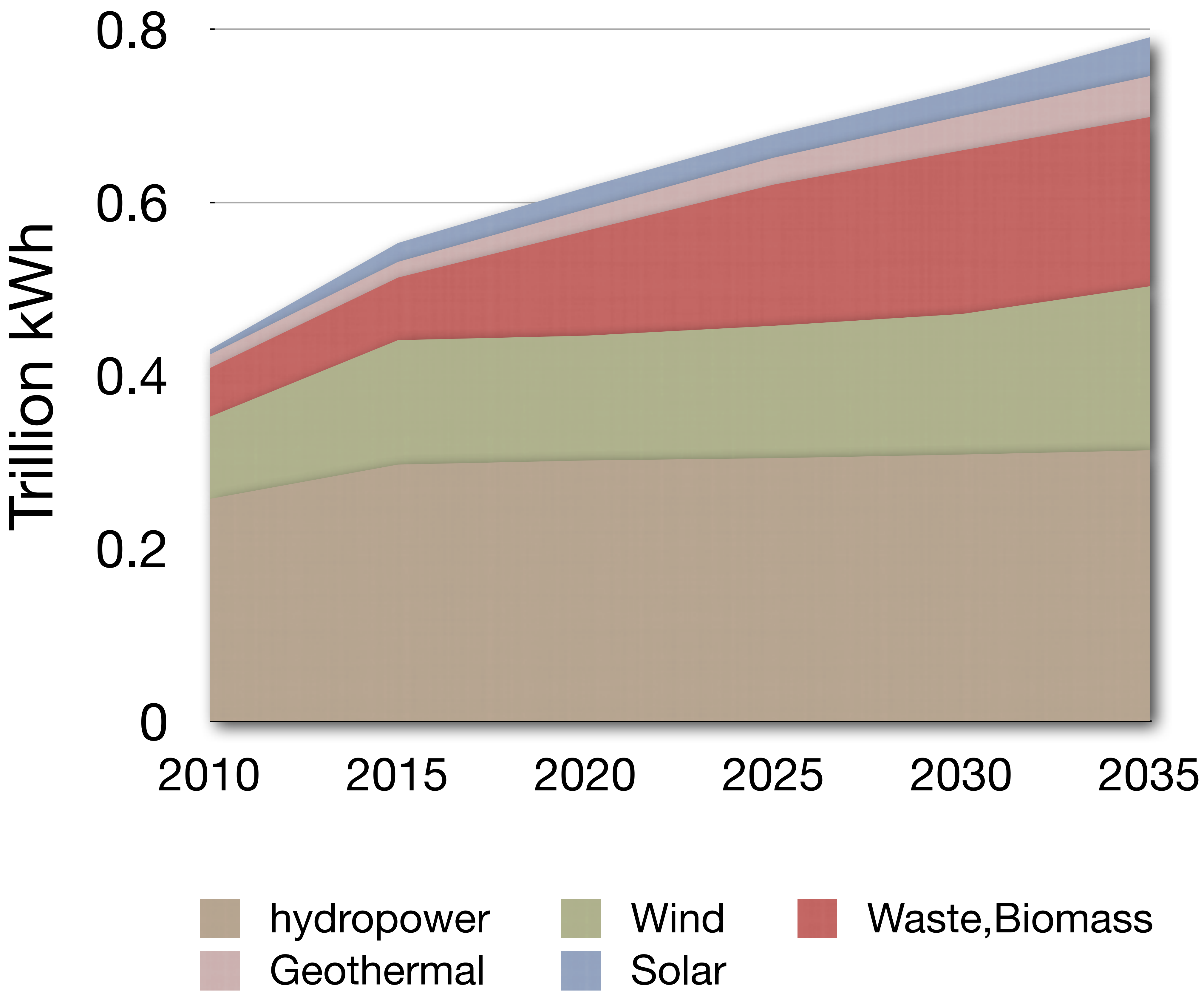
US Renewables Projected (eia)



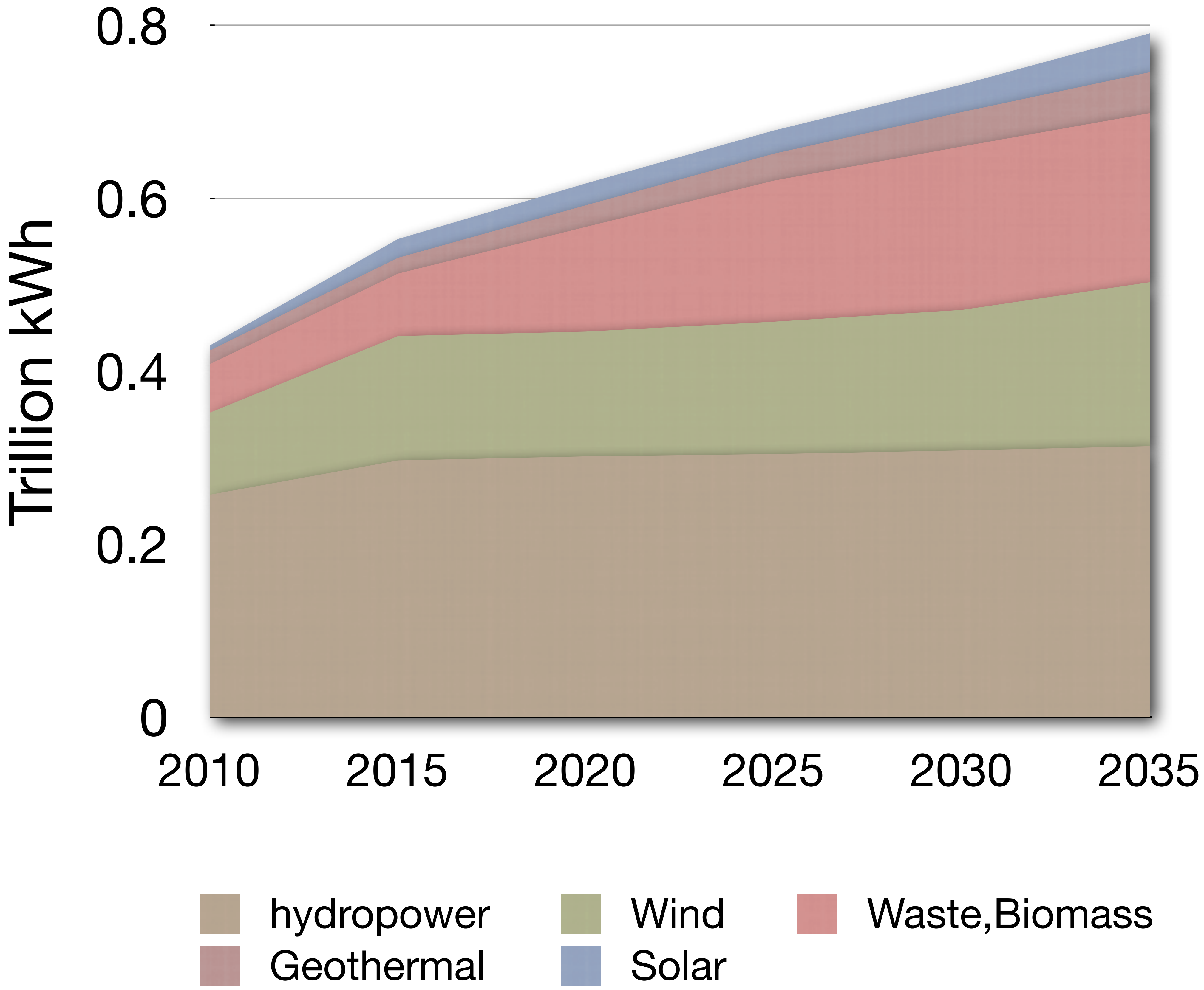
US Renewables Projected (eia)



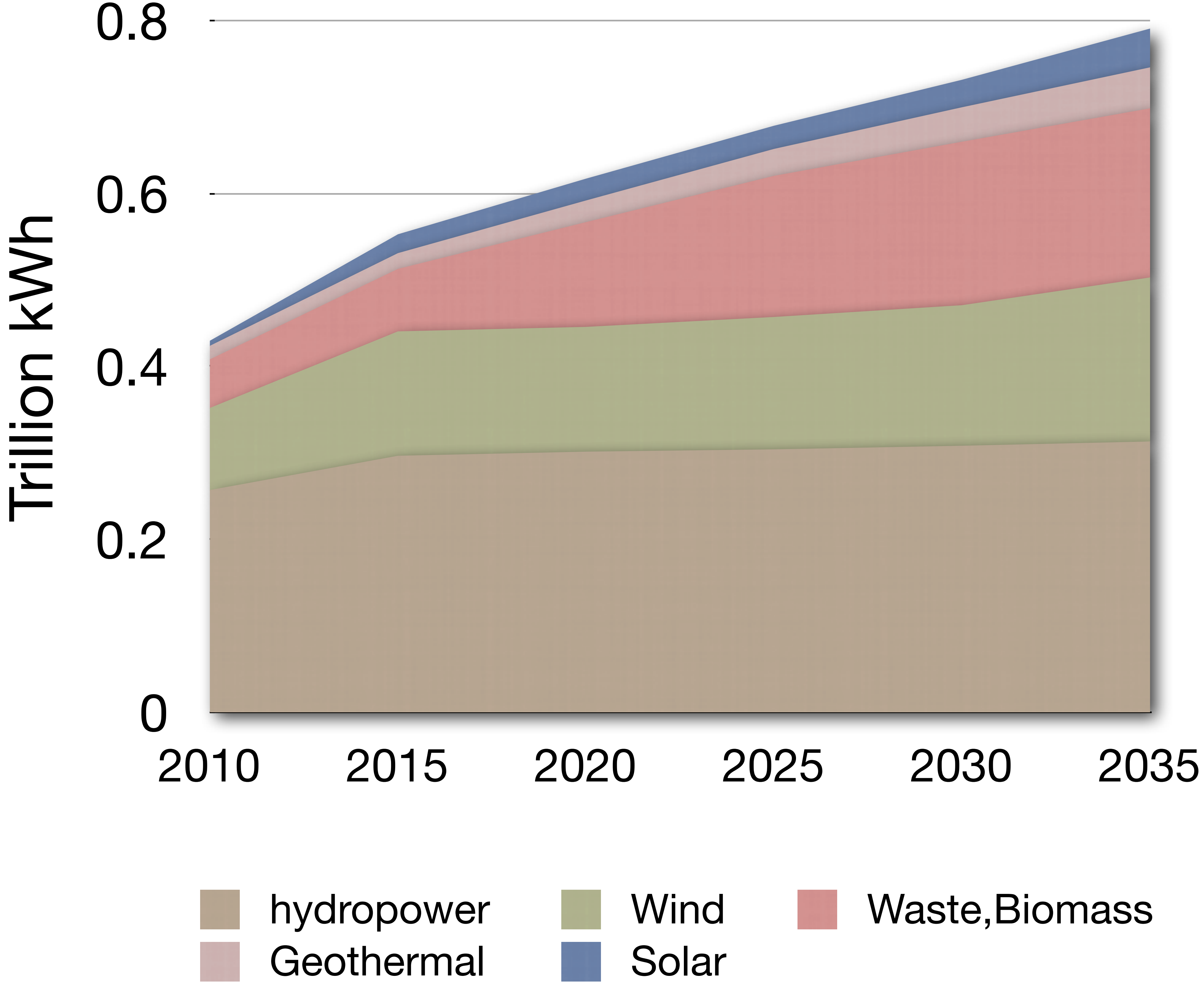
US Renewables Projected (eia)



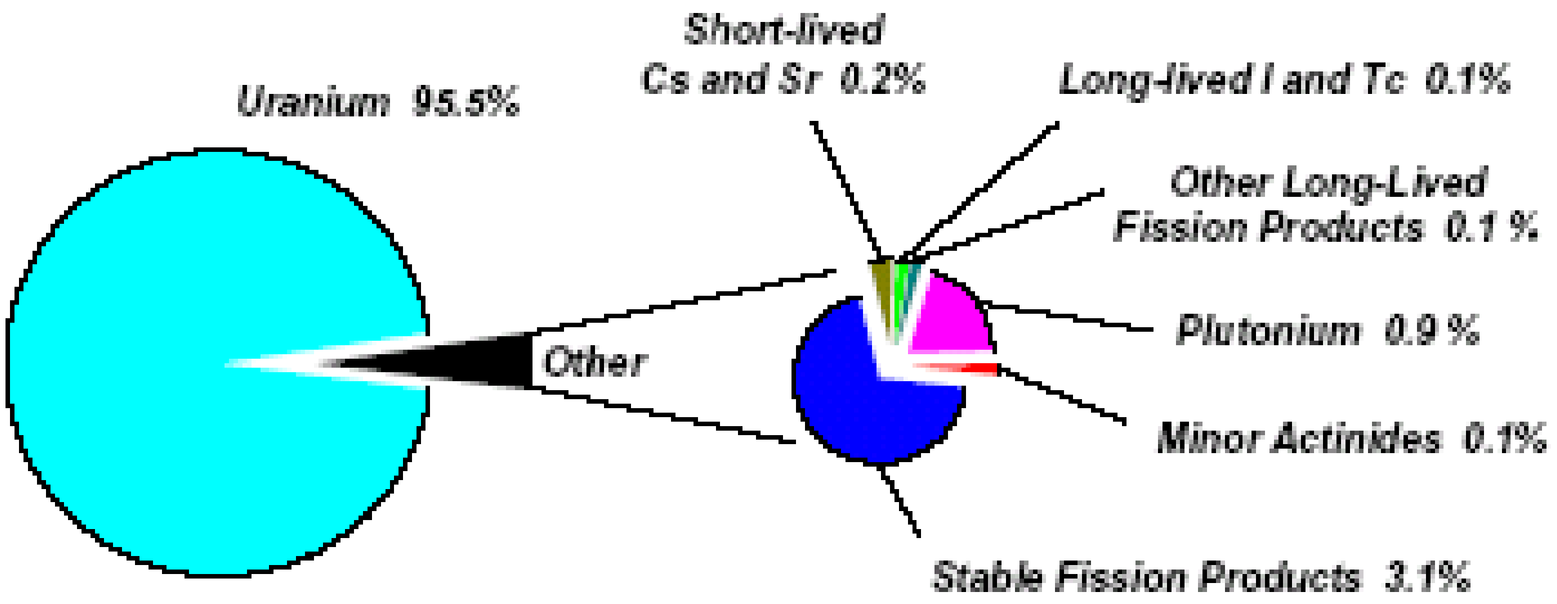
US Renewables Projected (eia)



US Renewables Projected (eia)



Composition of Spent Nuclear Fuel (Standard PWR 33GW/t, 10 yr. cooling)



Most of the hazard stems from Pu, MA and some LLFP when released into the environment, and their disposal requires isolation in stable deep geological formations.

A measure of the hazard is provided by the radiotoxicity arising from their radioactive nature.

1 tonne of SNF contains:

955.4 kg U
8,5 kg Pu

Minor Actinides (MAs)
0,5 kg ^{237}Np
0,6 kg Am
0,02 kg Cm

Long-Lived fission Products (LLFPs)
0,2 kg ^{129}I
0,8 kg ^{99}Tc
0,7 kg ^{93}Zr
0,3 kg ^{135}Cs

Short-Lived fission products (SLFPs)
1 kg ^{137}Cs
0,7 kg ^{90}Sr

Stable Isotopes
10,1 kg Lanthanides
21,8 kg other stable

BLUE RIBBON COMMISSION ON AMERICA'S NUCLEAR FUTURE






Report to the Secretary of Energy

JANUARY 2012

BLUE RIBBON COMMISSION
ON AMERICA'S NUCLEAR FUTURE

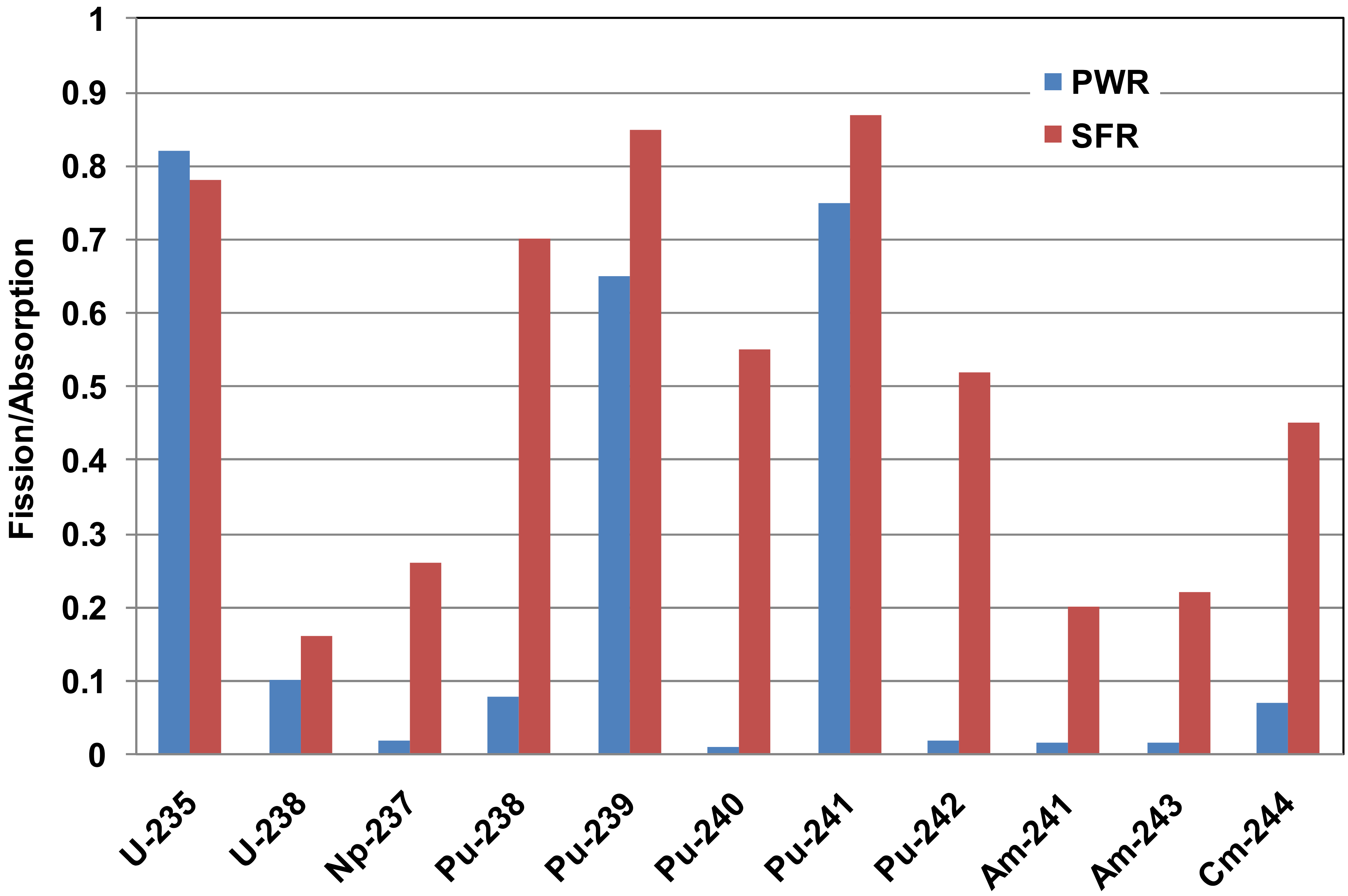
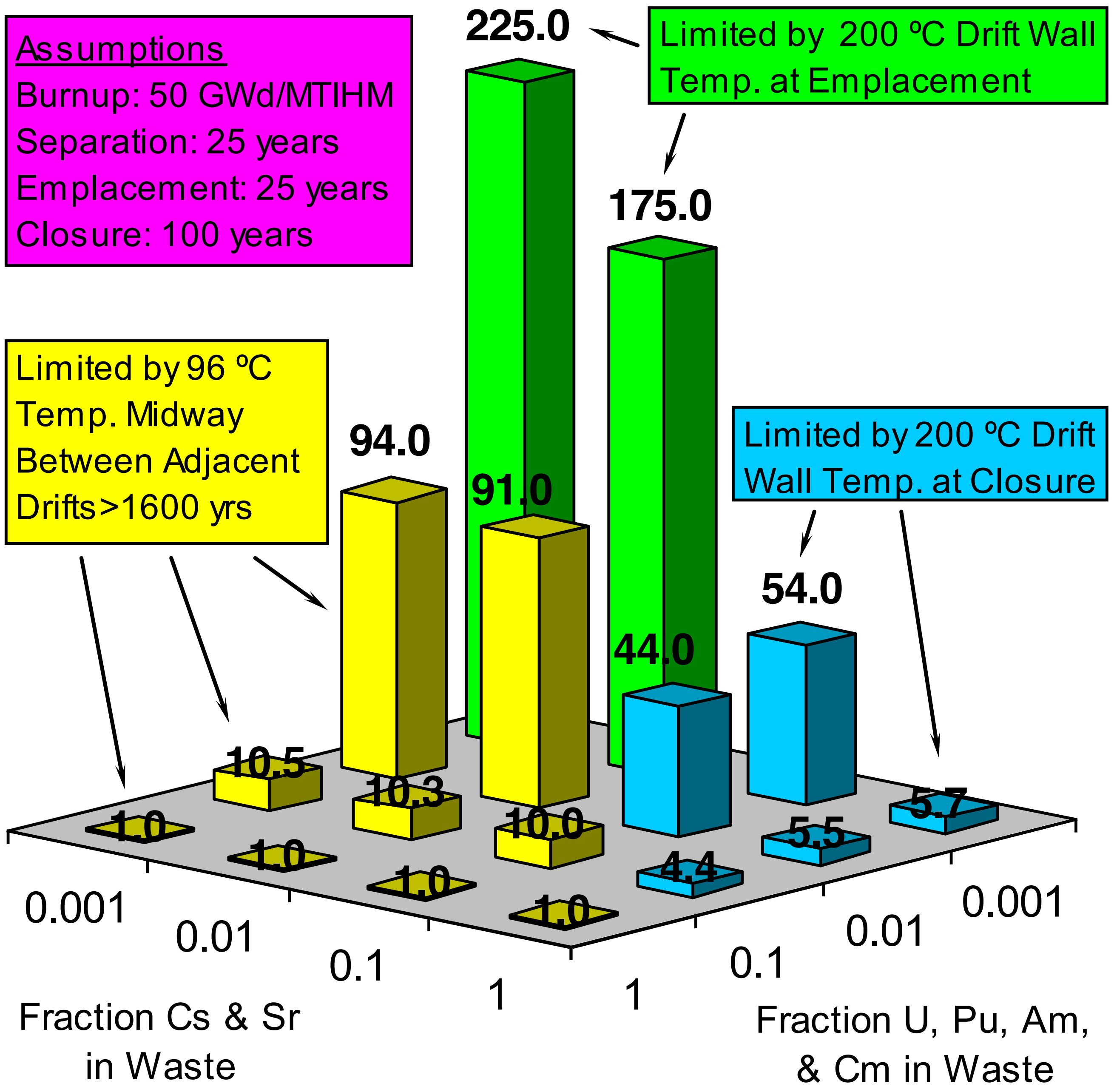


Fig. 5. Comparison of fission/absorption ratio for PWR and SFR [5].

Decay Heat and Yucca Mountain Repository Loading



Assumptions
Burnup: 50 GWd/MTIHM
Separation: 25 years
Emplacement: 25 years
Closure: 100 years

Limited by 200 ºC Drift Wall Temp. at Emplacement

Limited by 96 ºC Temp. Midway Between Adjacent Drifts>1600 yrs

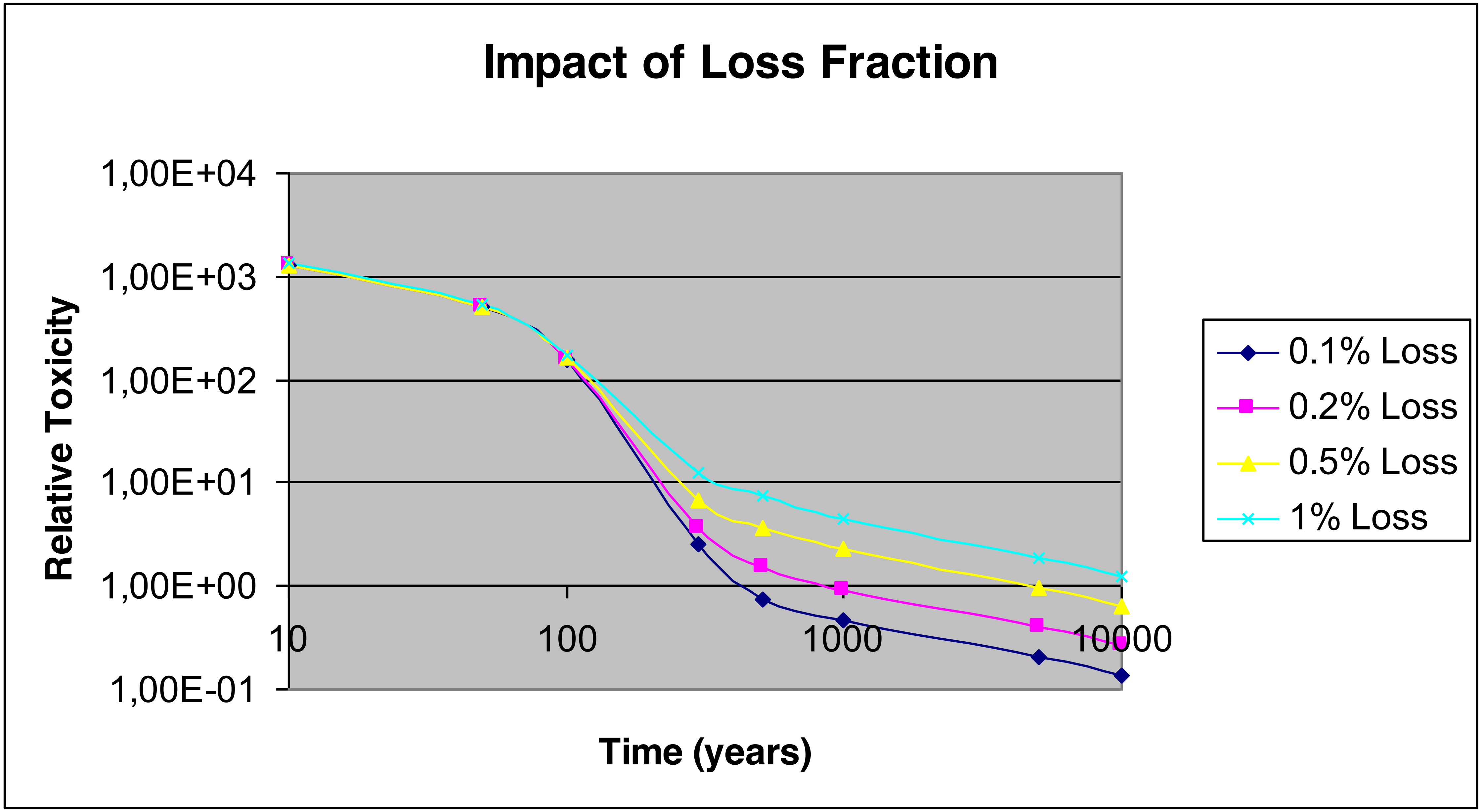
Limited by 200 ºC Drift Wall Temp. at Closure

- **The figure shows the potential increase in drift loading as a function of the inventory of actinides and fission products in the waste stream**
  - **Removal of Pu/Am/Cm (decay heat) and U (volume) would permit the waste from about 5.7 times as much spent fuel to be placed in the space that spent fuel would require**
  - **Removal of Cs & Sr only would have no impact**
  - **Removal of the U/Pu/Am/Cm and Cs & Sr would permit the waste from up to about 225 times as much spent fuel to be placed in the space that the spent fuel would require**
- **Suitable waste forms would need to be available to fully realize such benefits**
- **Other repository environments could respond differently**

Potential increase in drift loading on an energy-generated basis

M. Salvatores

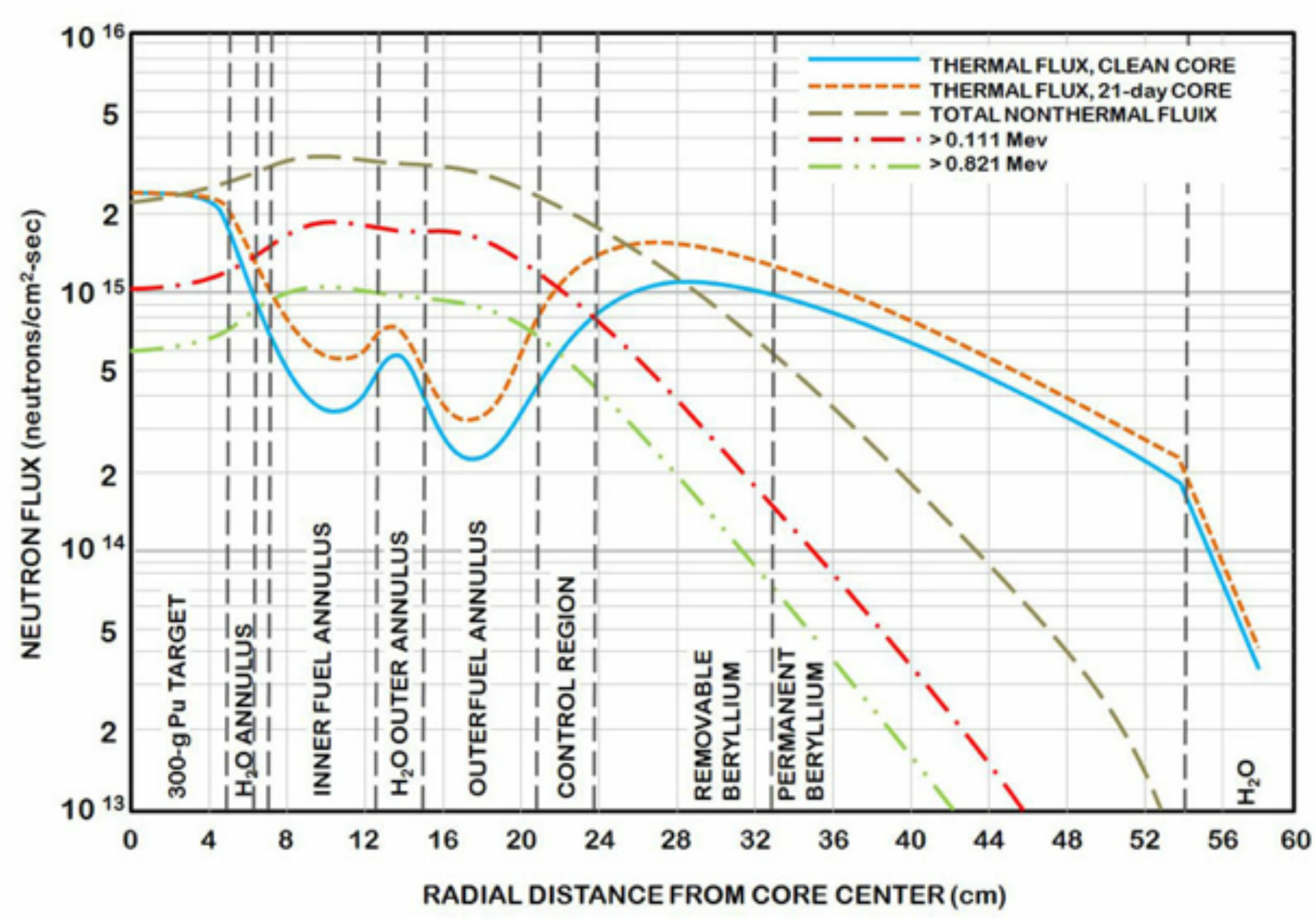
Importance of Processing Loss Fraction



Radiotoxicity goal cannot be achieved if loss fraction increases beyond 0.2%, and extends to 10,000 years at 1% losses

M. Salvatores

Fuel Design


THERMAL FLUX, CLEAN CORE
THERMAL FLUX, 21-day CORE
TOTAL NONTHERMAL FLUIX
> 0.111 Mev
> 0.821 Mev
NEUTRON FLUX (neutrons/cm²-sec)
10 16
5
2
10 15
5
2
10 14
5
2
10 13
300-gPu TARGET
H2O ANNULUS
INNER FUEL ANNULUS
H2O OUTER ANNULUS
OUTERFUEL ANNULUS
CONTROL REGION
REMOVABLE BERYLLIUM
PERMANENT BERYLLIUM
H2O
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
RADIAL DISTANCE FROM CORE CENTER (cm)

High-power operational experience at the Spallation Neutron Source (SNS)

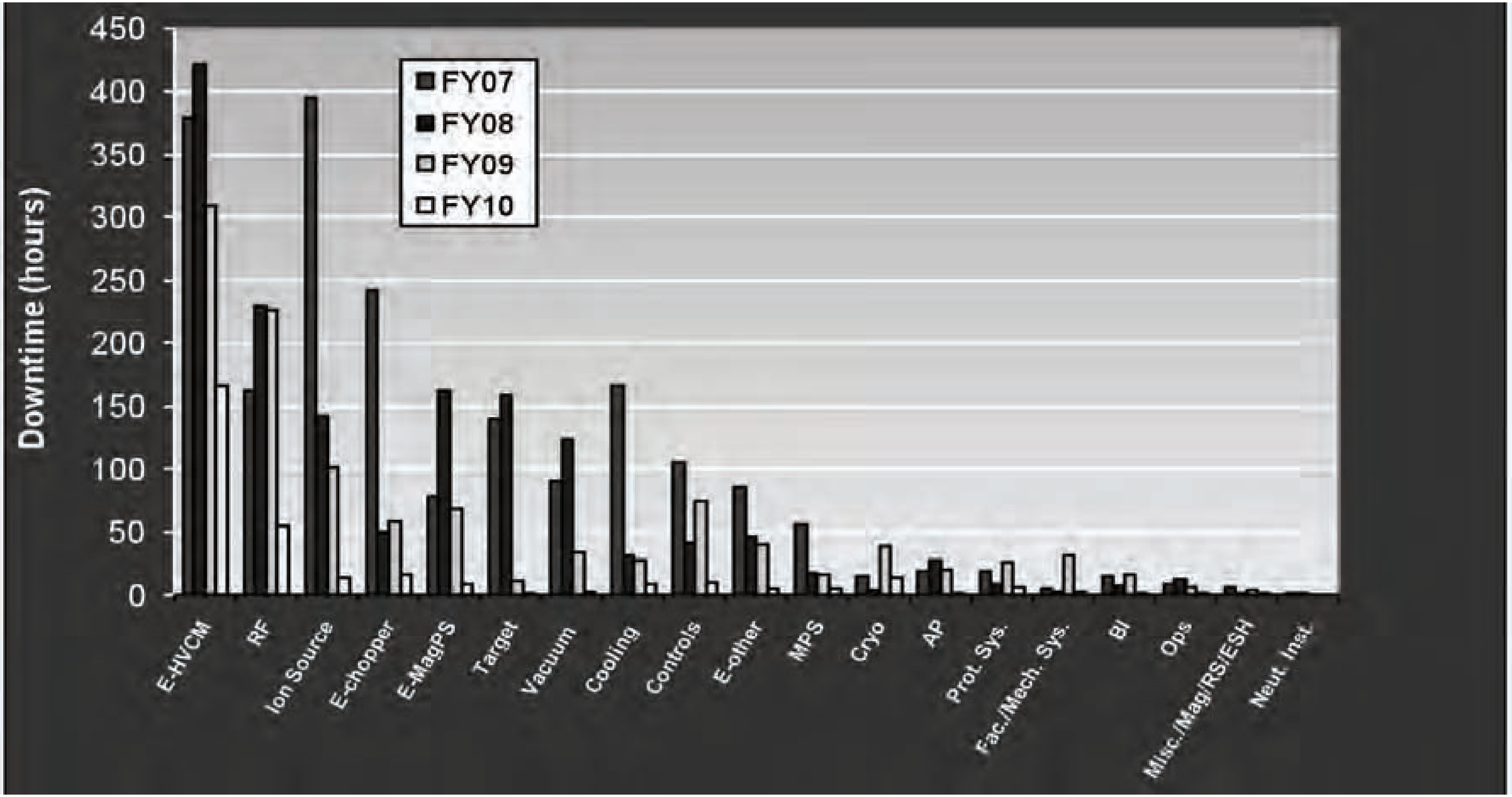


Figure 4: Downtime vs. equipment type and year

Spent Nuclear Fuel and Accelerator Driven Systems

One of the most pressing issues of our time is our global growing need for energy in the context of climate change. Of all realistic sources that may contribute to the solution, one of the more contentious is nuclear energy. Issues of safety, security, cost and spent fuel must be addressed if nuclear energy is to contribute to our energy future. In this talk I will motivate the need to address the issue of spent fuel, specifically the role accelerator driven transmutation may play to mitigate long term geologic storage. I will describe the basics of designing accelerator driven systems (ADS) as well as some of the important technical problems that have yet to be solved. As an example, the MYRRHA experiment at SCK•CEN in Mol, Belgum is one possible ADS design choice that will be mentioned as well as some alternative design ideas gaining momentum in the US National Labs.