Liquid Fluoride Thorium Reactor

Aim High!

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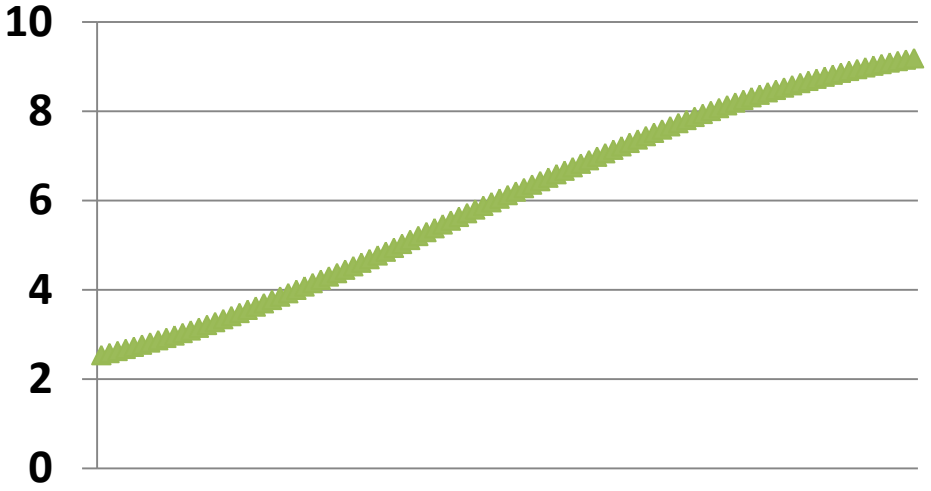
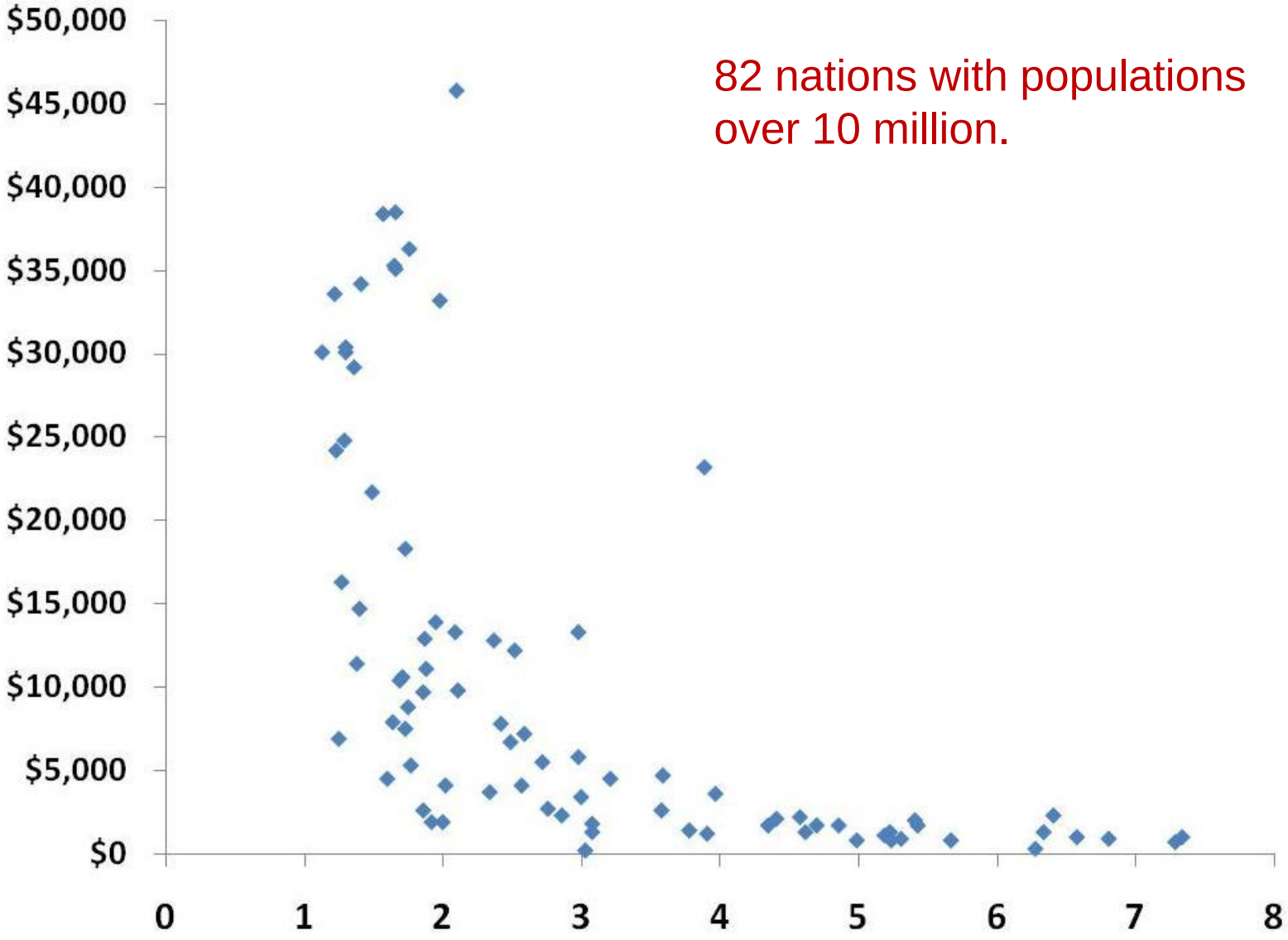
Global warming, overpopulation, and resources competition are increasing.



Prosperity stabilizes population.

GDP per capita



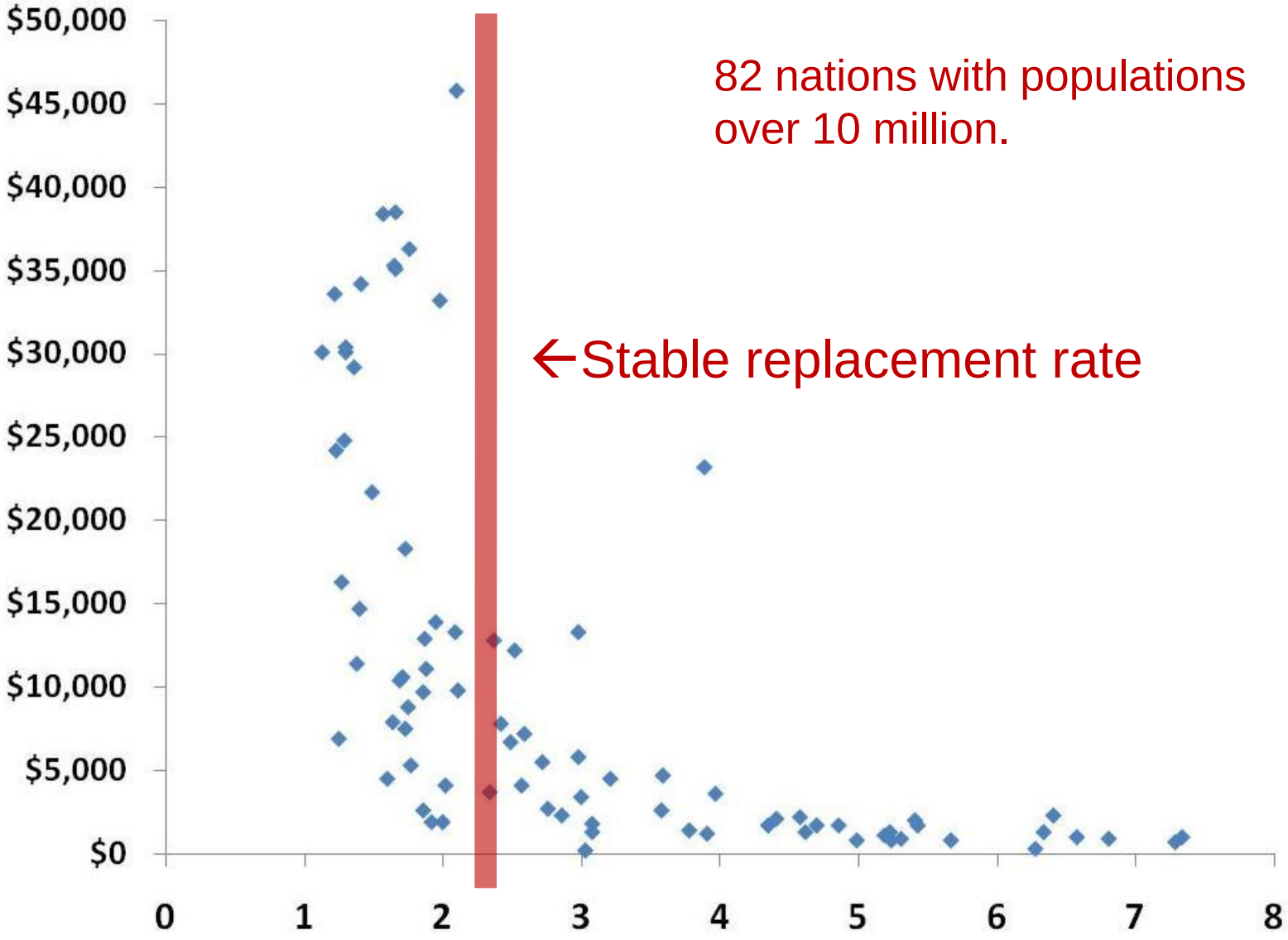
82 nations with populations over 10 million.

Children per woman

https://www.cia.gov/library/publications/the-world-factbook/docs/rankorderguide.html

Prosperity stabilizes population.

GDP per capita



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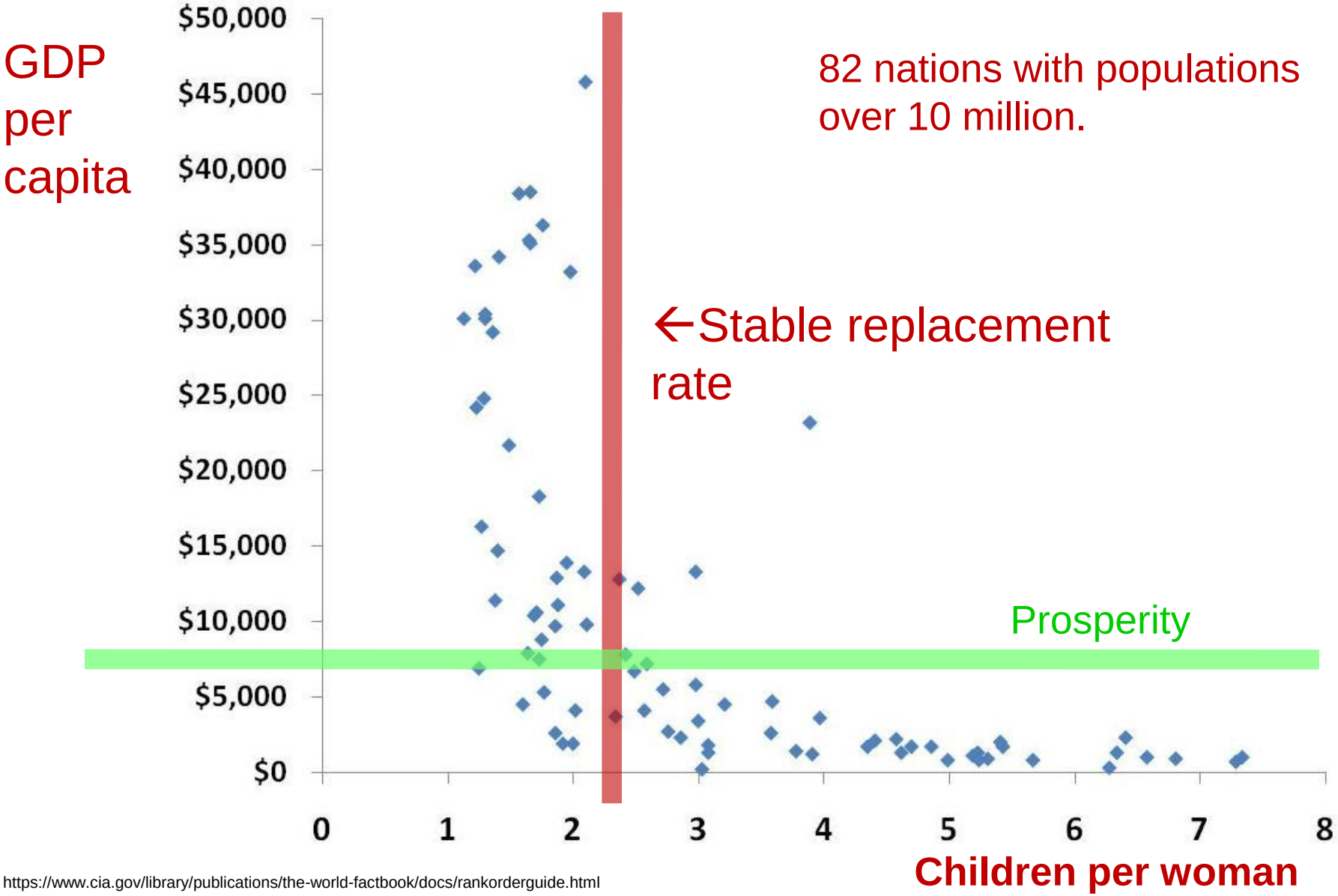
←Stable replacement rate

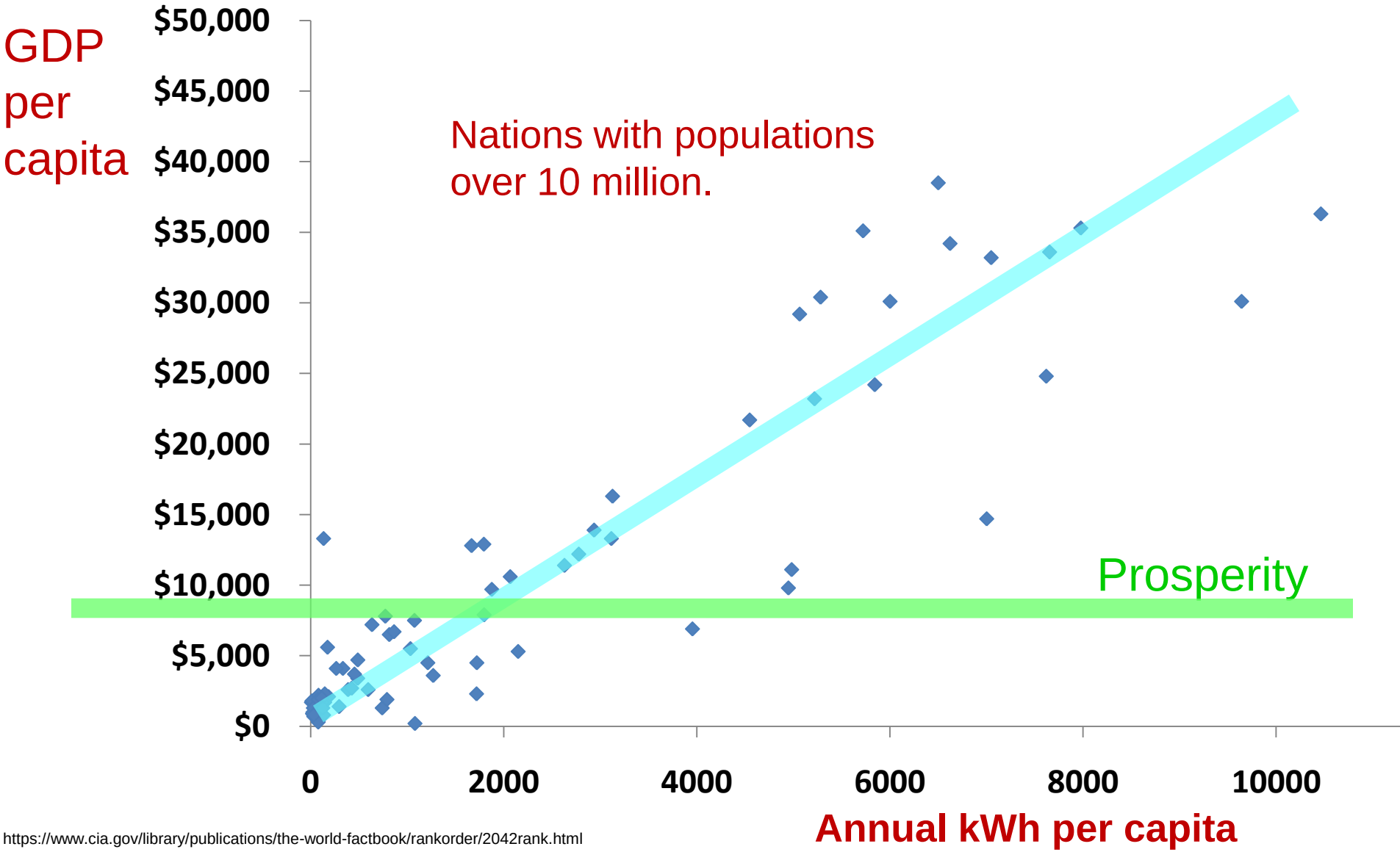
https://www.cia.gov/library/publications/the-world-factbook/docs/rankorderguide.html

Prosperity stabilizes population.



https://www.cia.gov/library/publications/the-world-factbook/docs/rankorderguide.html

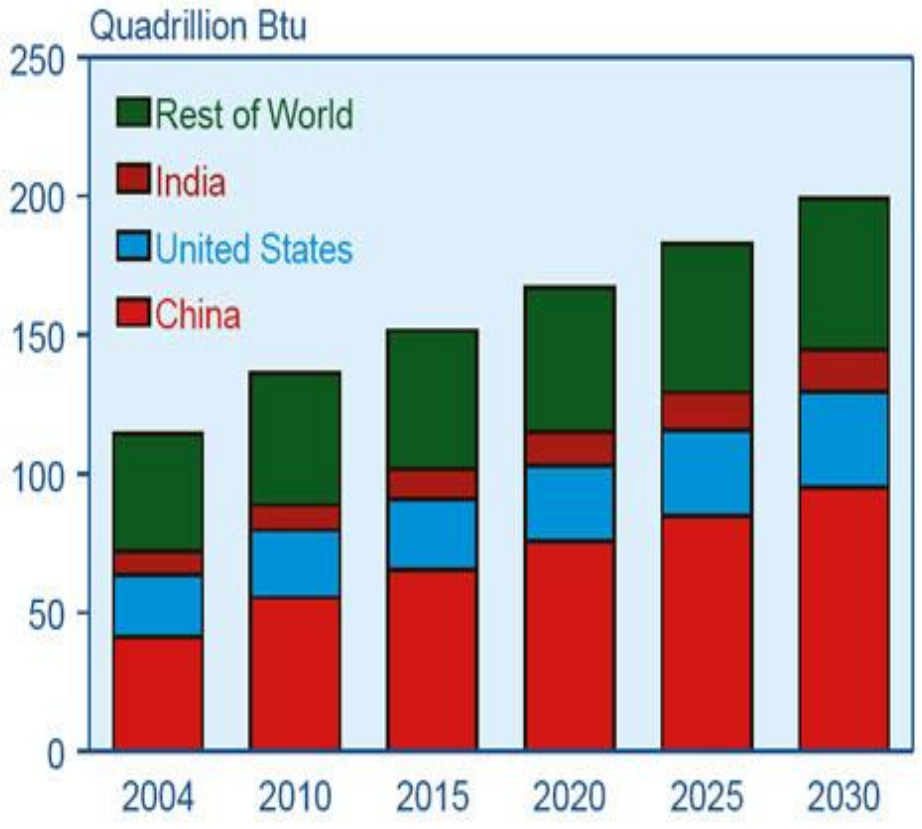
Prosperity depends on energy.



https://www.cia.gov/library/publications/the-world-factbook/rankorder/2042rank.html

Energy and coal use is growing rapidly in developing nations.

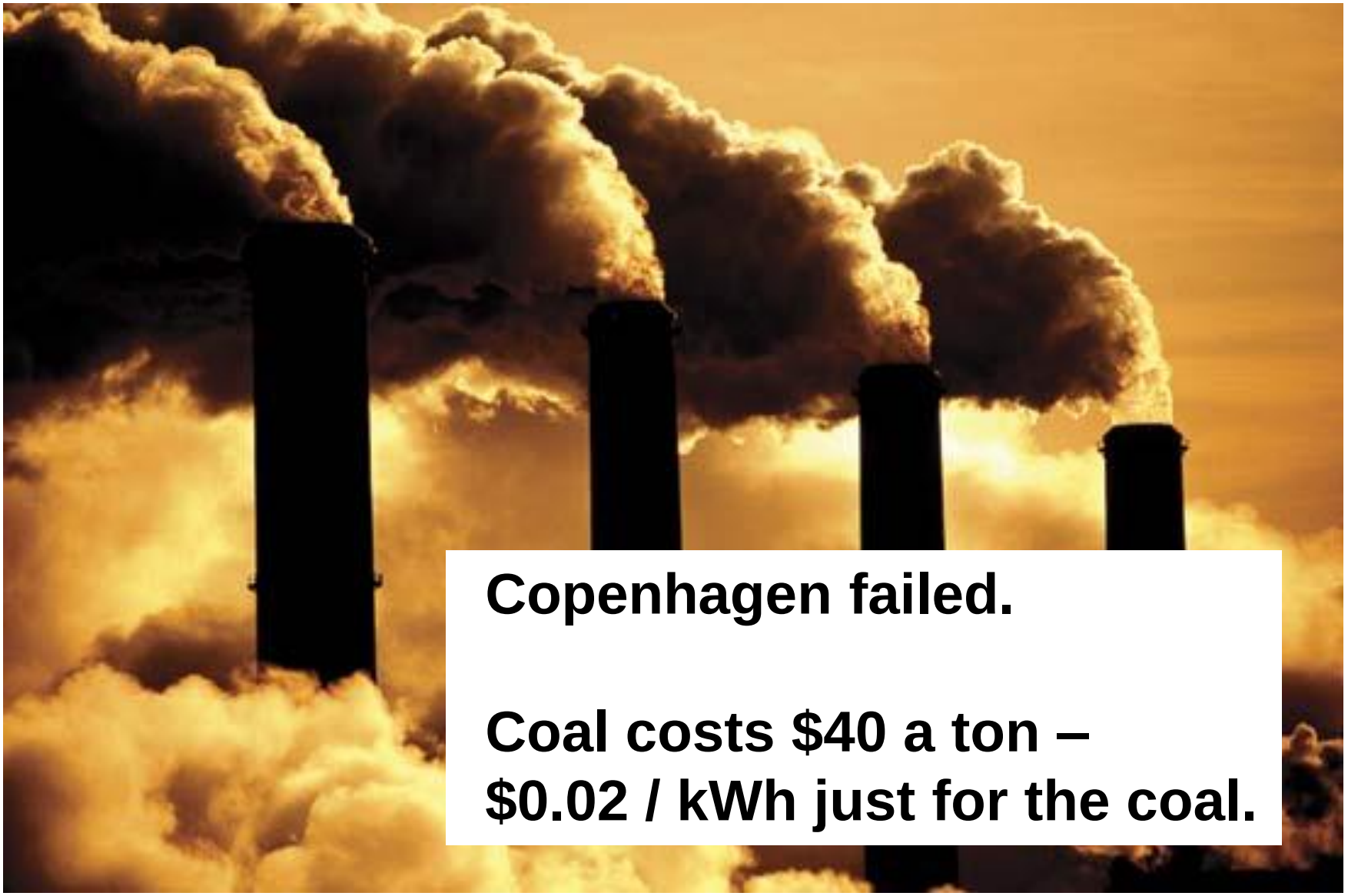
Non-OECD energy use



World coal use

http://www.eia.doe.gov/oiaf/ieo/world.html

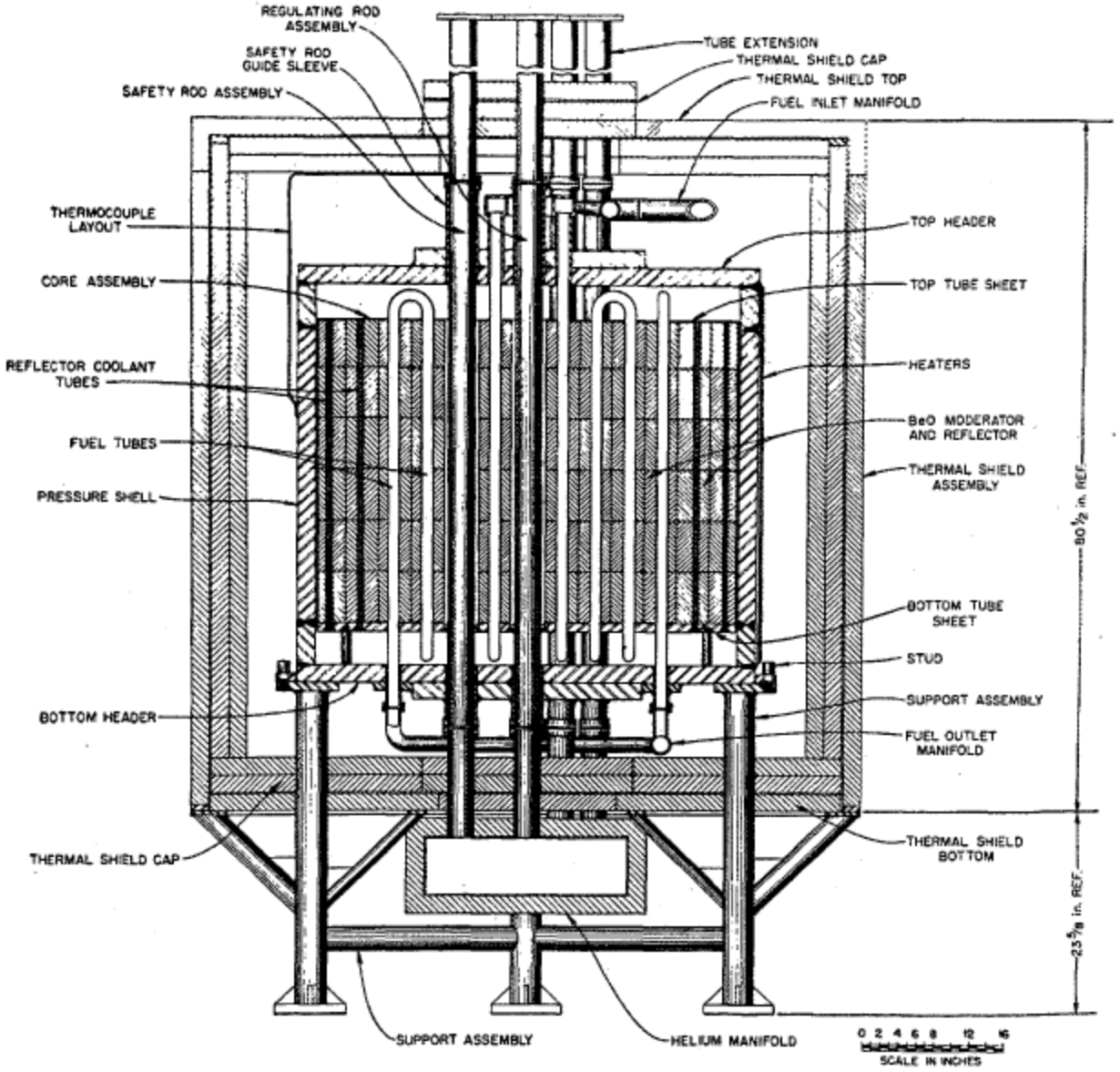
Can energy be cheaper than from coal?



Copenhagen failed.

Coal costs $40 a ton –
$0.02 / kWh just for the coal.

Weinberg and Oak Ridge developed the first molten salt nuclear reactor in 1954.



860 C

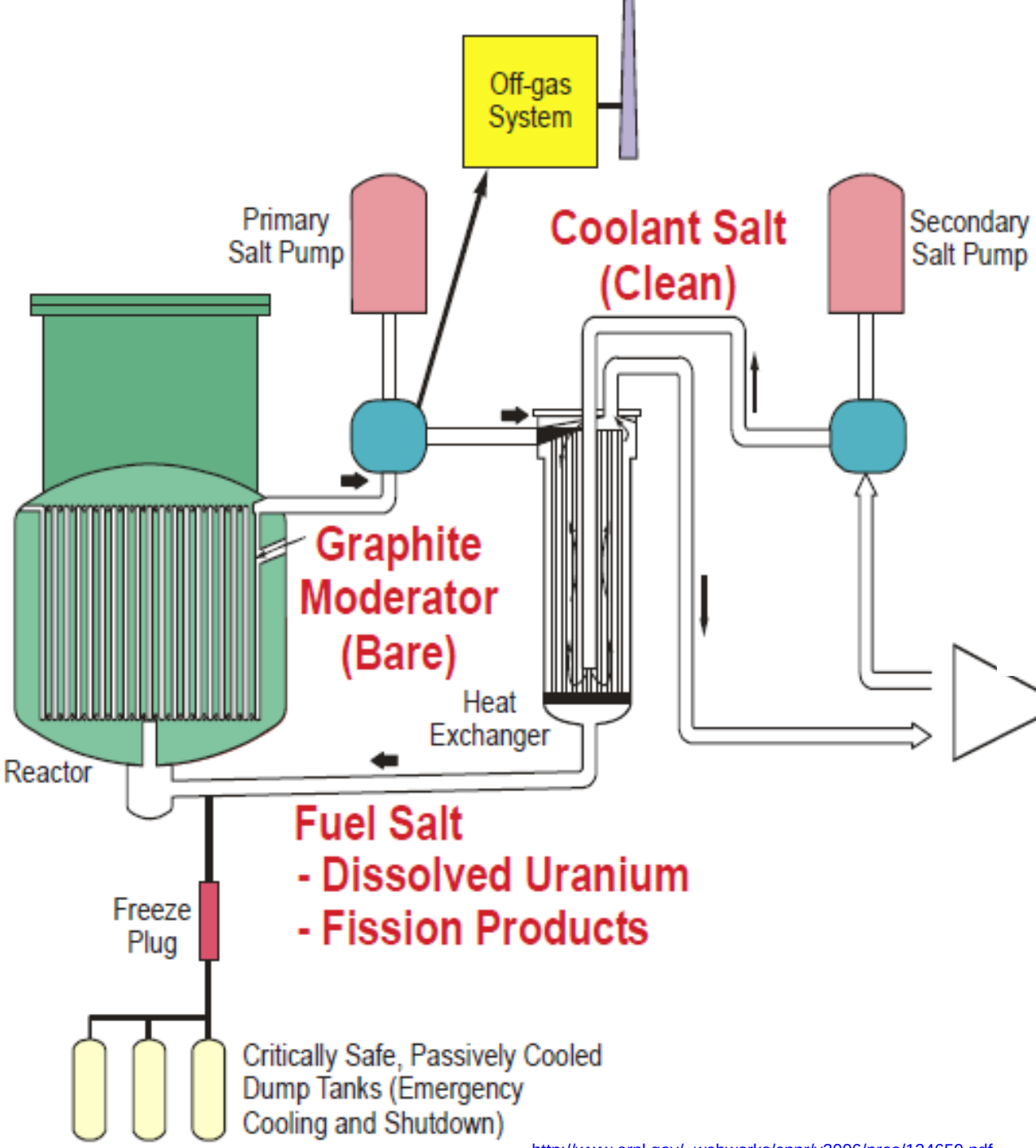
Red hot!

100 hours

2.5 MW

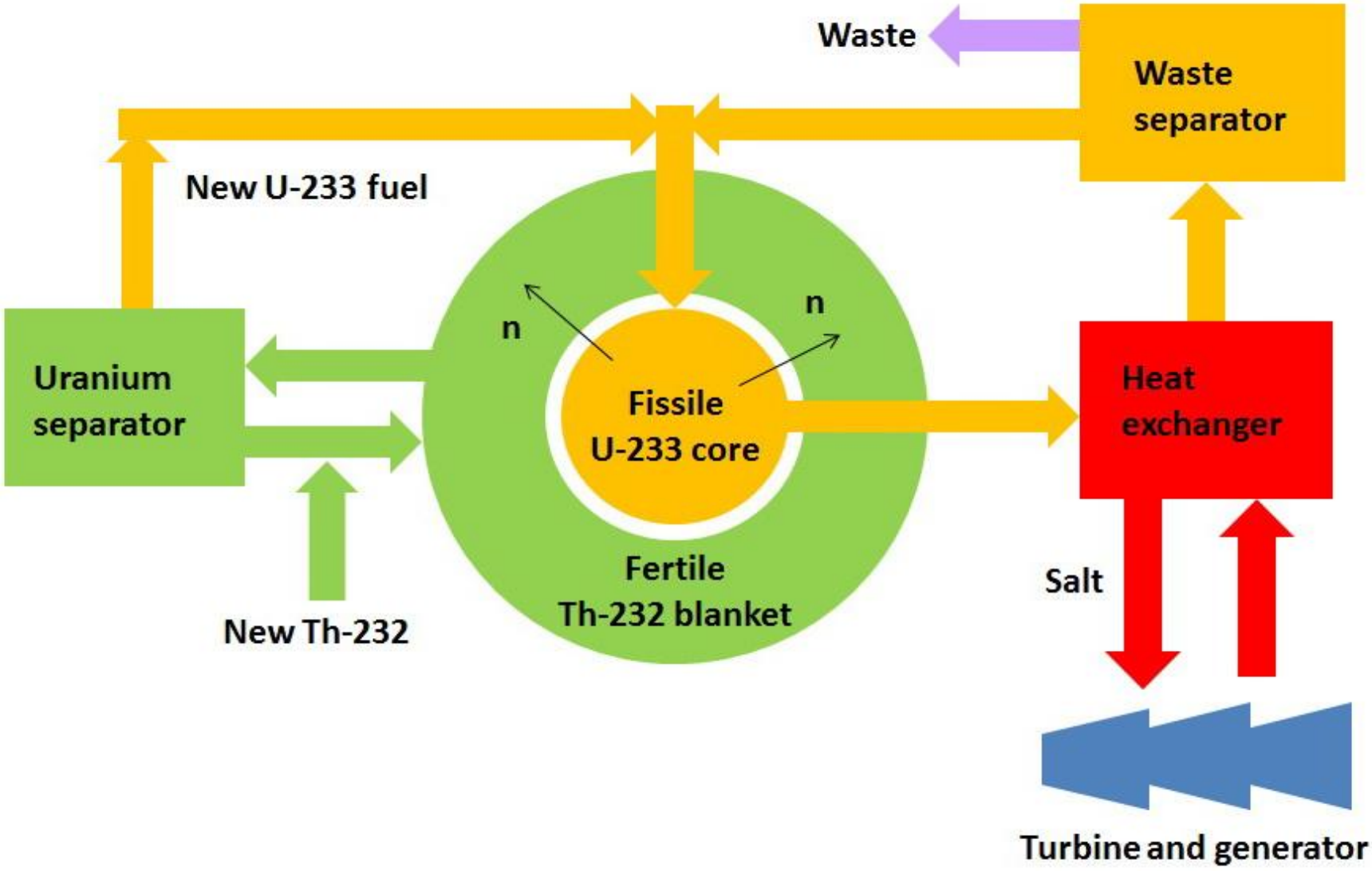
The Molten Salt Reactor Experiment succeeded.

Hastelloy
Xe off-gas
Graphite
Pumps
Fluorination
Dump tanks
U-233
17,655 hours

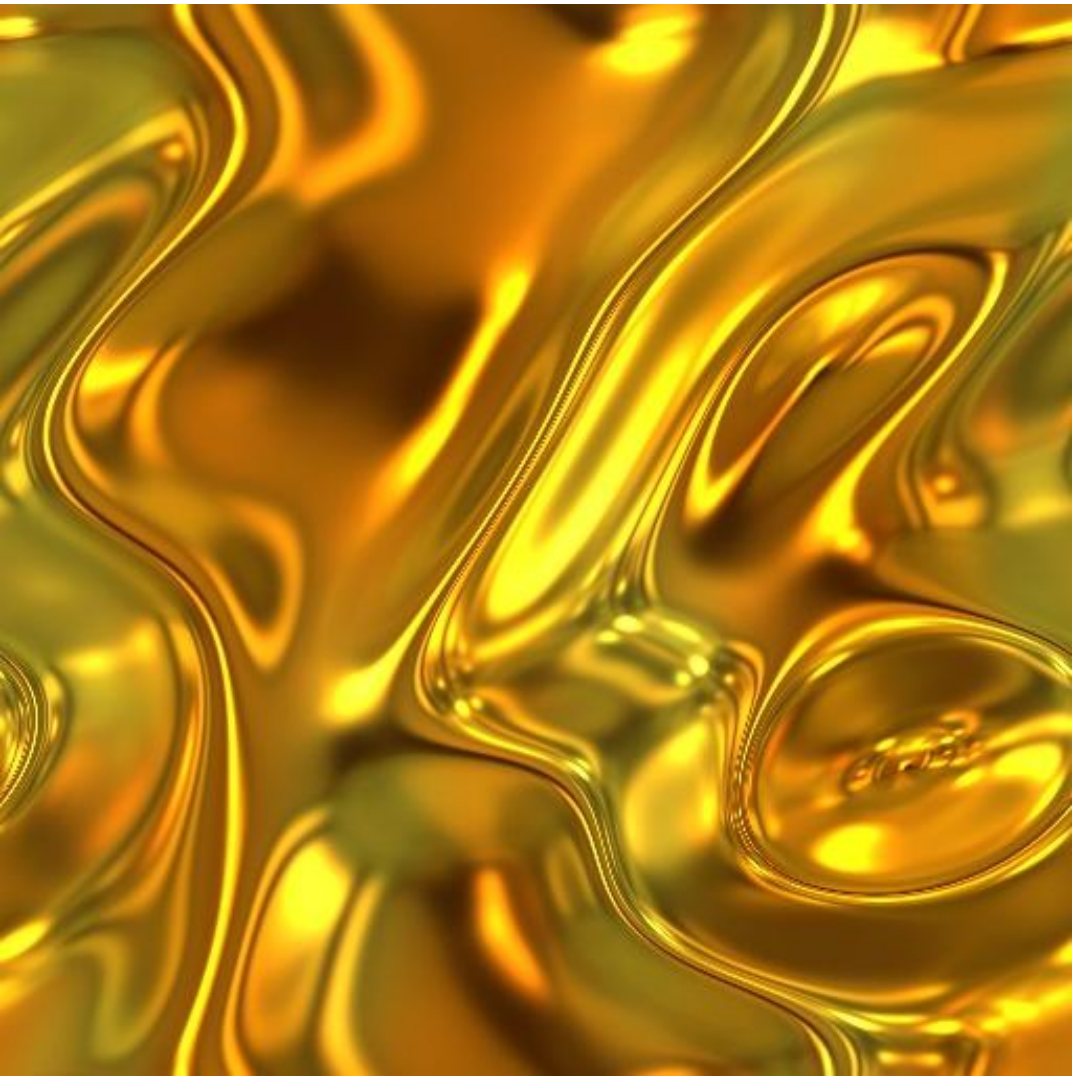


http://www.ornl.gov/~webworks/cppr/y2006/pres/124659.pdf

In a liquid fluoride thorium reactor the Th-232 blanket becomes the U-233 core.



Liquid Fluoride Thorium Reactor fuel is dissolved in liquid.



Molten fluoride salt mix: LiF and BeF_2

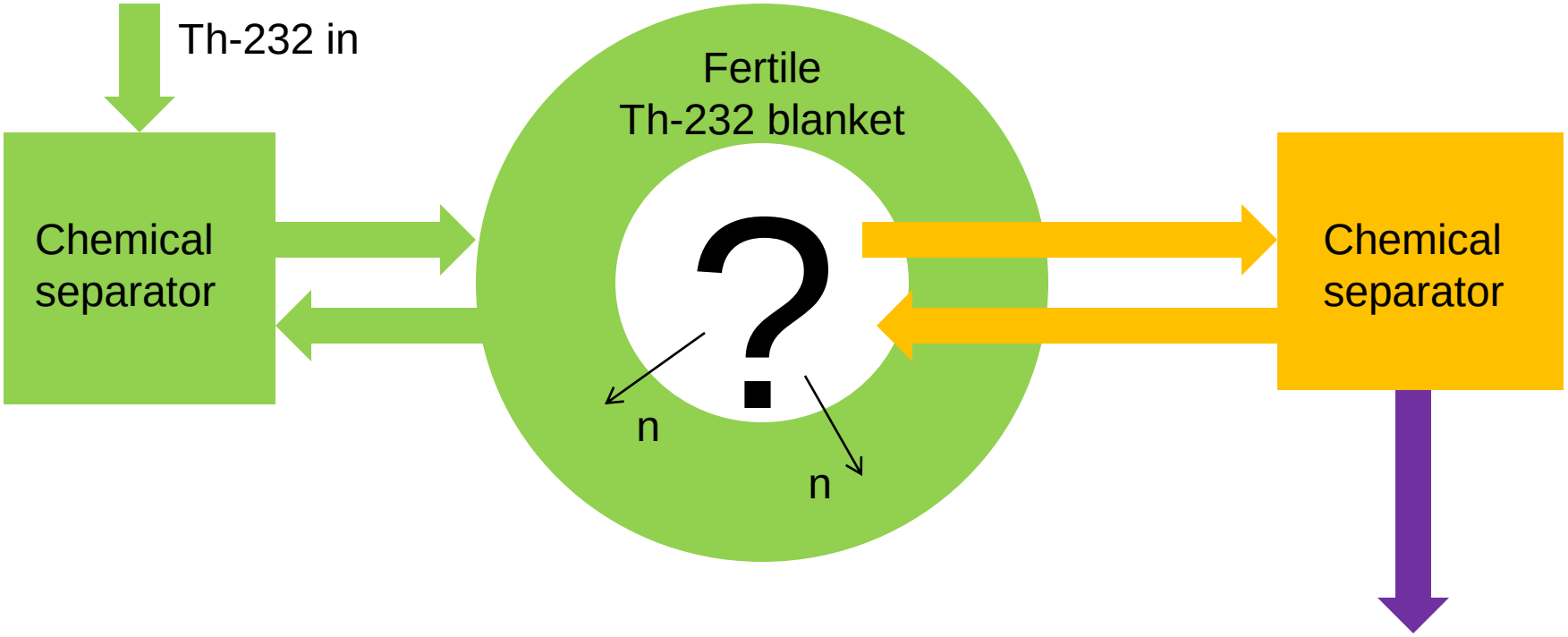
Excellent heat transfer

Continuous chemical processing

Atmospheric pressure

Room temp solid

Start up the LFTR with a fissile fuel.



US DOE already has 500 kg of U-233.

Or use U-235, or spent LWR fuel.

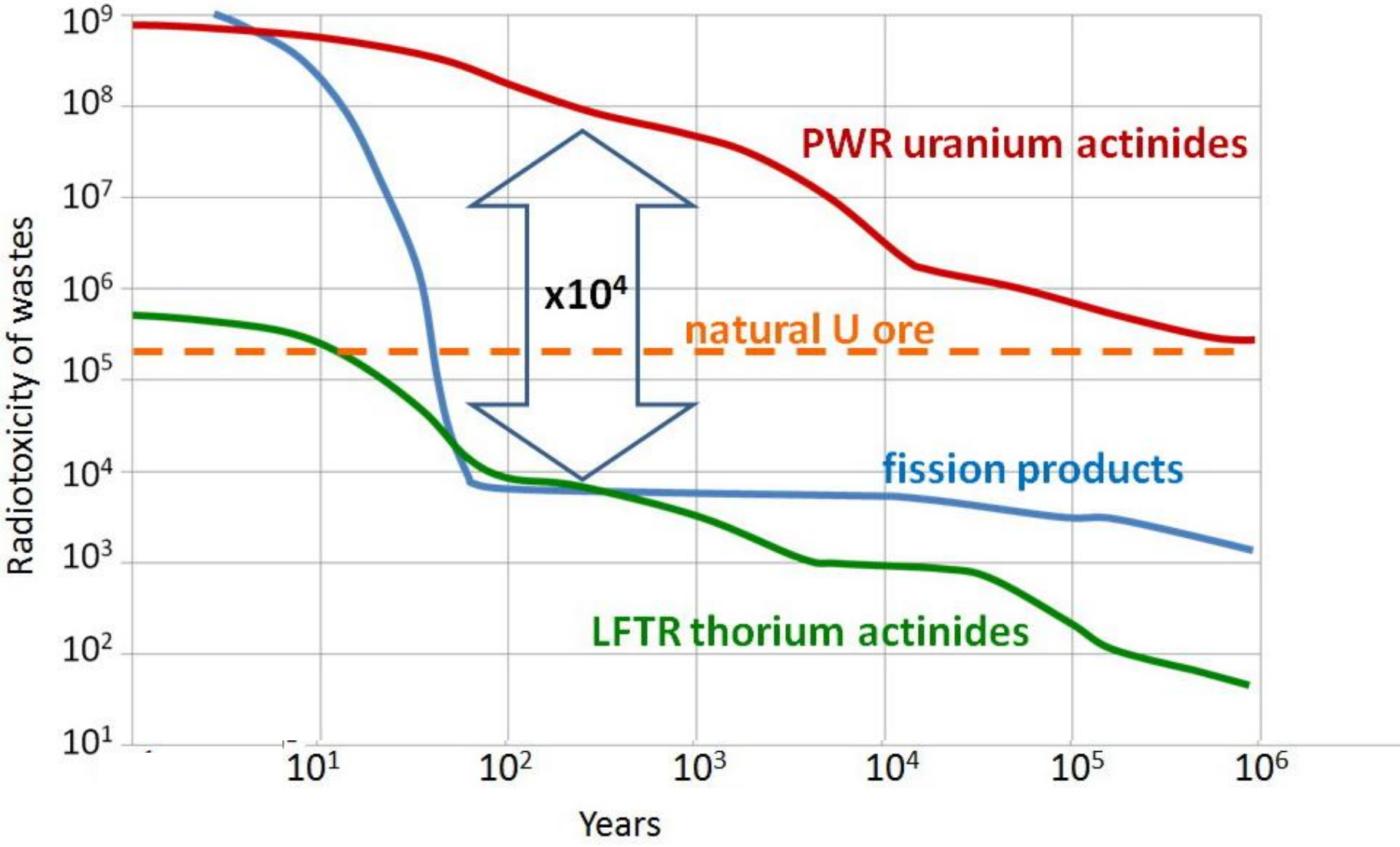
Lemhi Pass has enough thorium to power the US for millennia.

Thorium Energy, Inc. claims 1,800,000 tons of high-grade thorium ore at Lemhi Pass.

500 tons of thorium can supply all US electricity needs for one year.

The US has 3,200 tons stored in the Nevada desert.

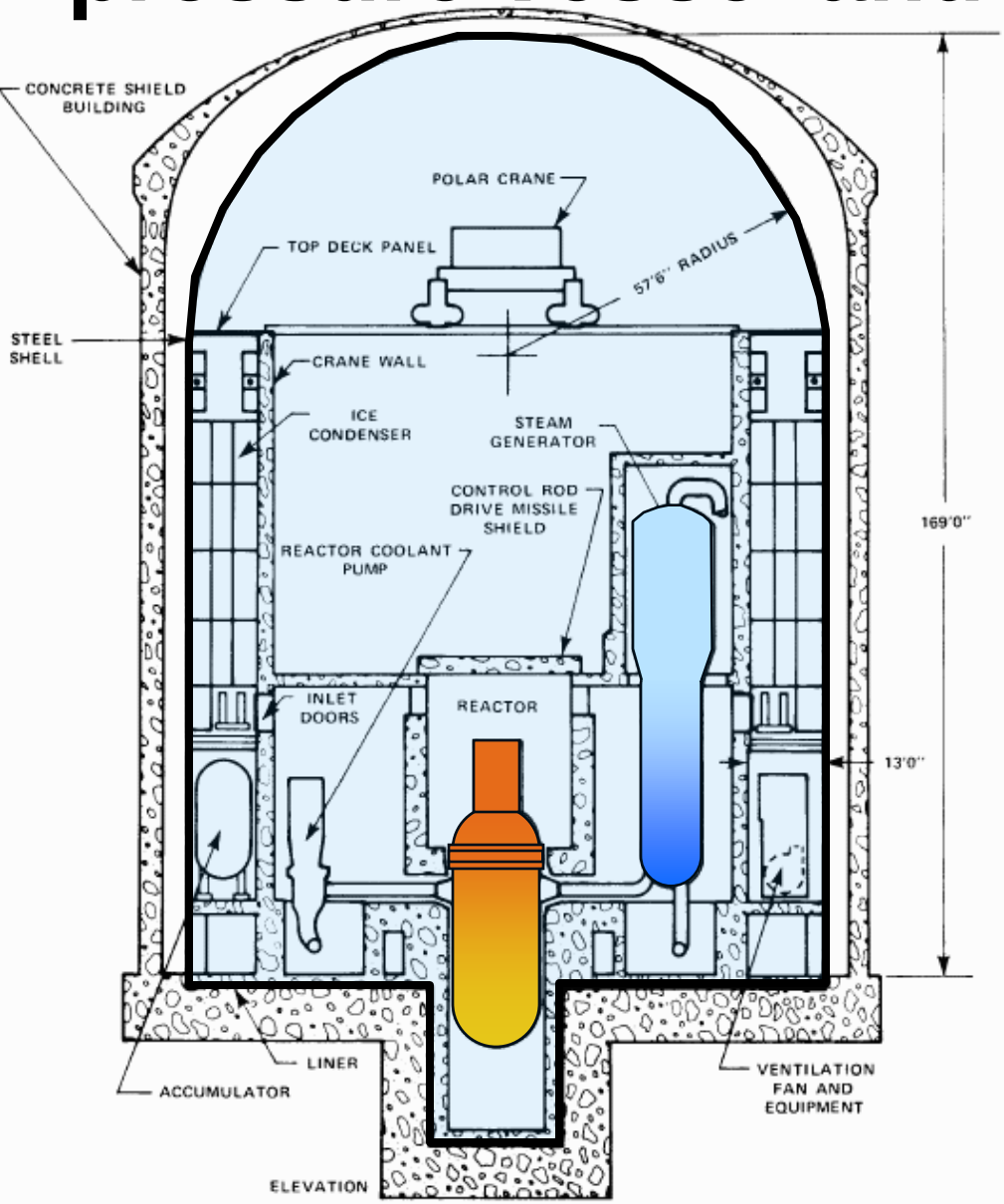
LFTR produces much less long lived radiotoxic actinide waste.

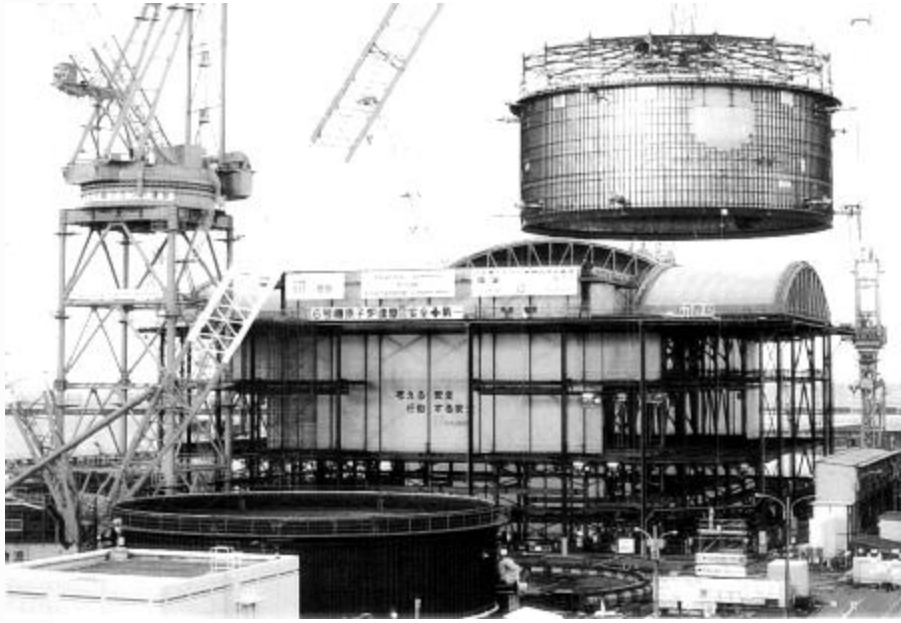


Energy can be cheaper than from coal.

Estimate	Year	$/watt	2009 $/watt
Sargent & Lundy	1962	0.650	4.64
Sargent & Lundy ORNL TM-1060	1965	0.148	1.01
ORNL-3996	1966	0.243	1.62
Engel et al, ORNL TM7207	1978	0.653	2.16
Moir	2000	1.580	1.98

LFTR needs no costly 160-atmosphere pressure vessel and containment dome.

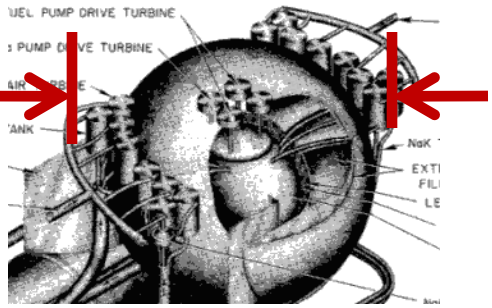




GE-Hitachi ABWR
39 months
1,356 MW
36 x 29 meter containment
1,000 ton crawler cranes

The Westinghouse AP-1000 is massively larger than LFTR.

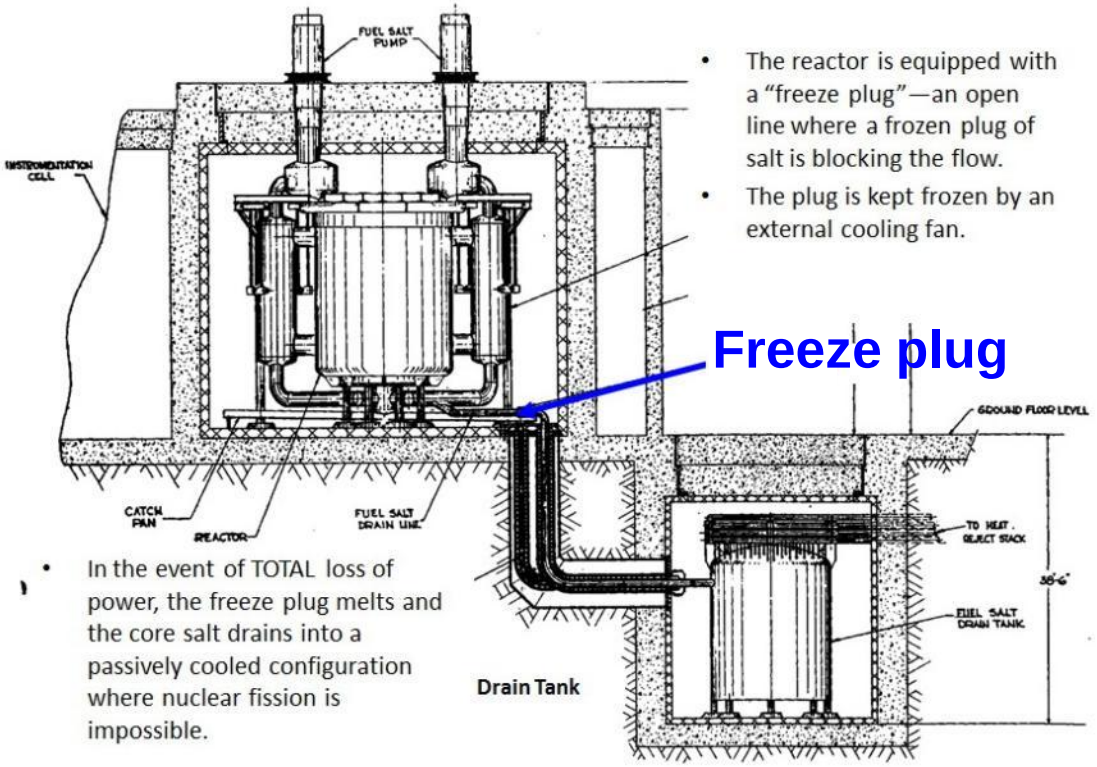
1.4 m



1.4 m

AP-1000
Samen, China
Jan 2010

LFTR relies on simple, intrinsic safety systems, not costly defense in depth.



- The reactor is equipped with a "freeze plug"—an open line where a frozen plug of salt is blocking the flow.
- The plug is kept frozen by an external cooling fan.

Freeze plug

- In the event of TOTAL loss of power, the freeze plug melts and the core salt drains into a passively cooled configuration where nuclear fission is impossible.

Stable reactivity.

Fuel already melted.

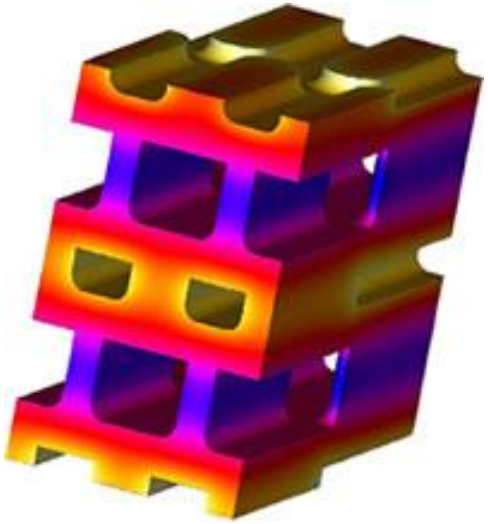
Atmospheric pressure.

Salt from rupture or leak will solidify.

Melting freeze plug dumps salt to tank.

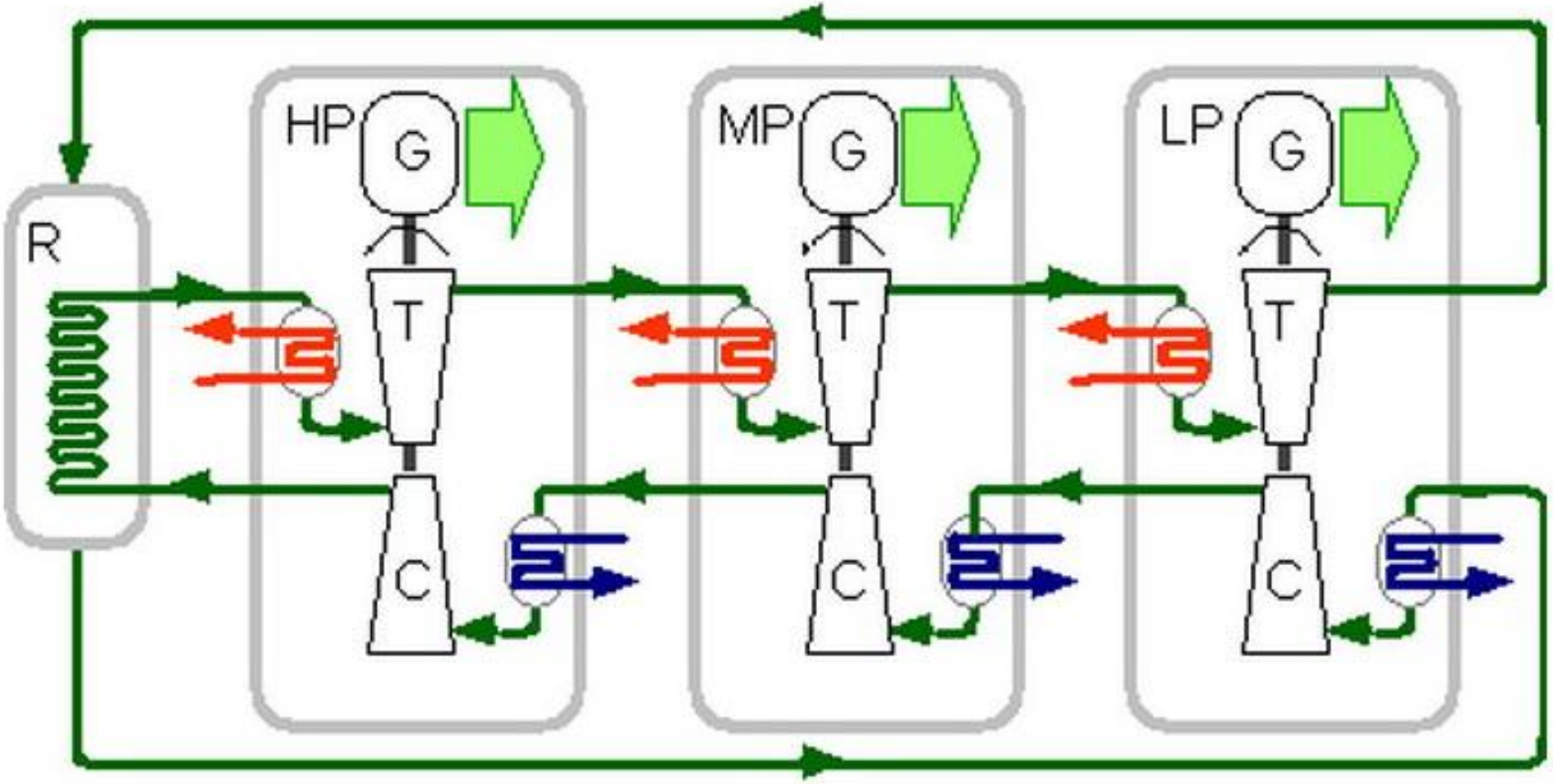
High thermal energy efficiencies keep LFTR compact and low cost.

Molten salt is a high thermal capacity heat exchange fluid, better than water, sodium, or helium.



Carbon composite heat exchangers presage future higher temperatures.

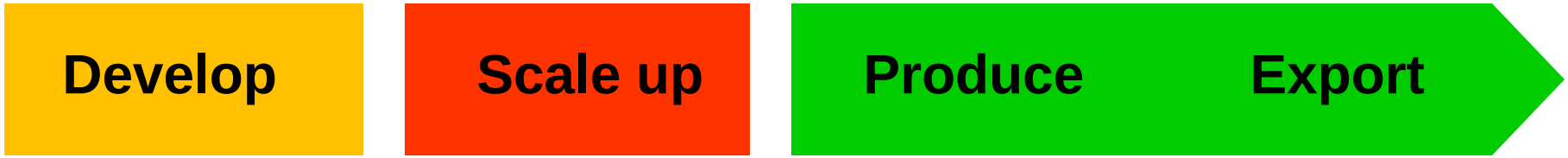
Closed cycle Brayton turbine raises power conversion efficiency to 45+%.



Halving rejected heat enables air cooling.

Boeing makes one $200 million aircraft per day.

One-a-day production of 100 MW LFTRs can be a $70 billion industry.

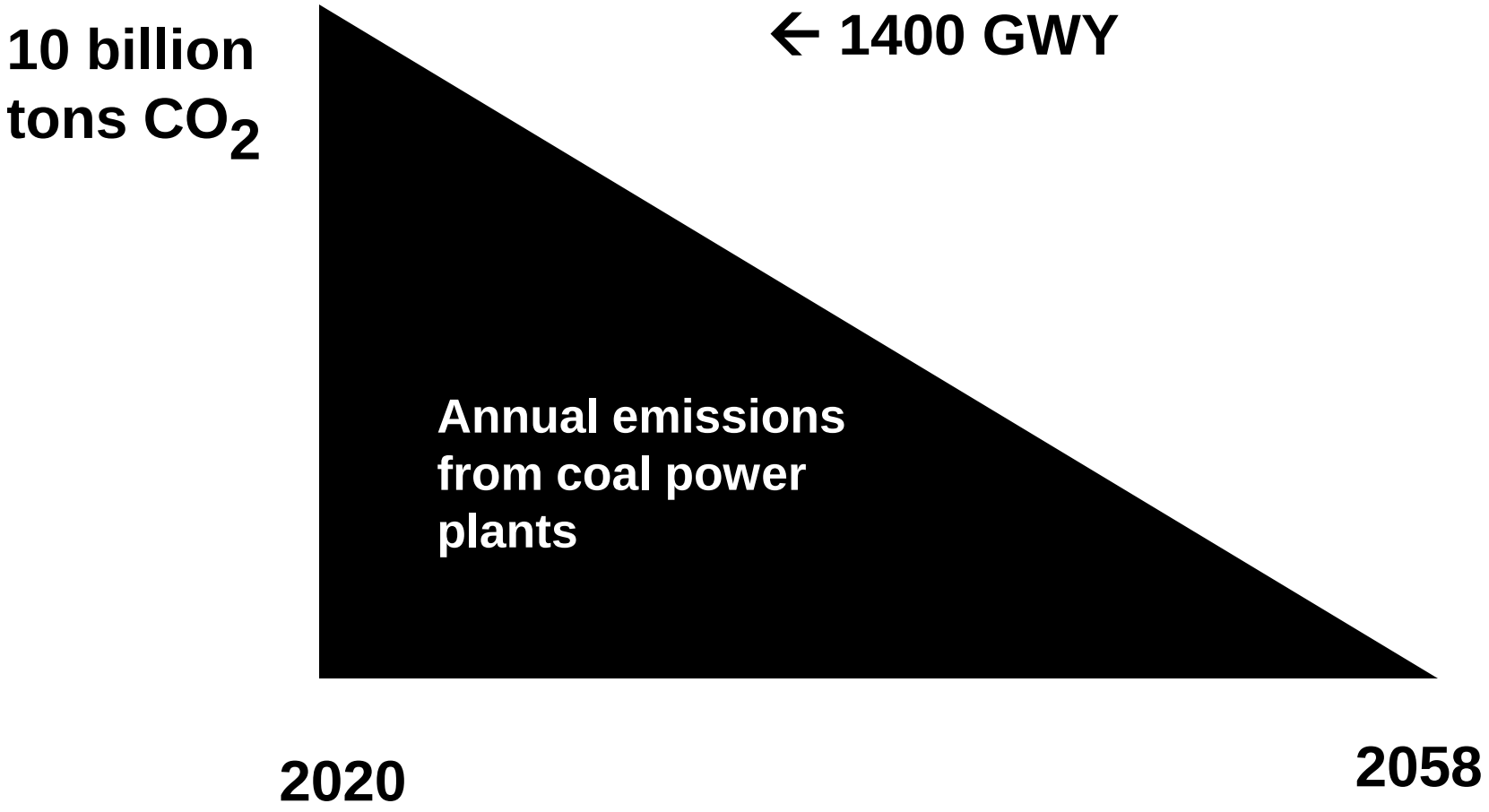


2010 2015 2020

Commercialize

Aim High! Zero coal emissions worldwide.

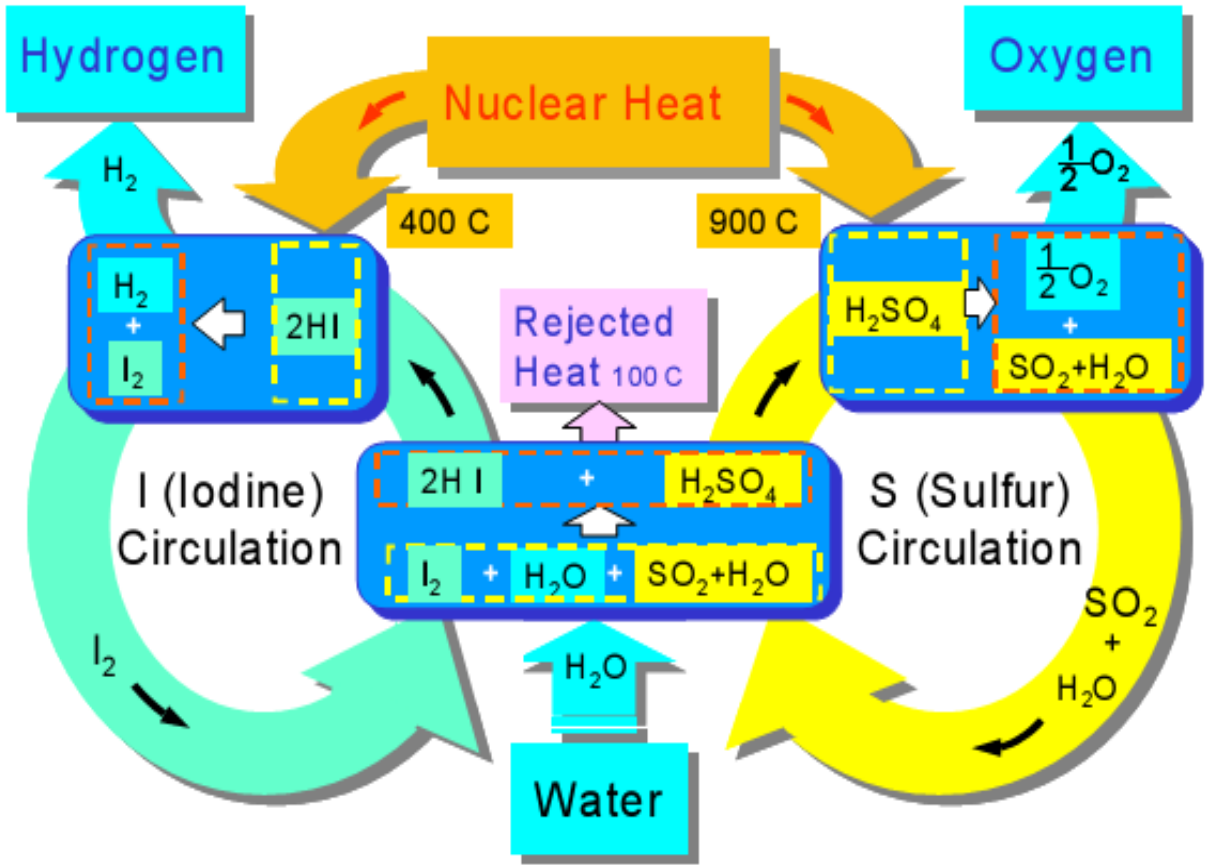
Install one 100 MW LFTR each day, worldwide, to replace all coal power.



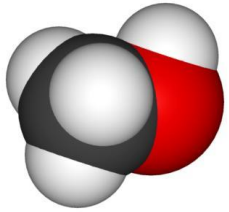
http://www.eia.doe.gov/pub/international/iealf/table63.xls

Aim High! Synthesize fuel and fertilizer.

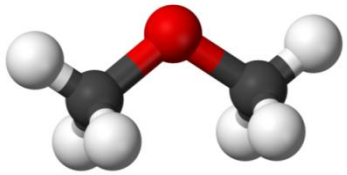
Dissociate water at 900°C to make hydrogen: sulfur-iodine process.



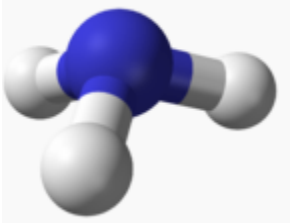
$CO_2 + 3\ H_2 \rightarrow CH_3OH + H_2O$



Methanol for gasoline



Dimethyl ether for diesel

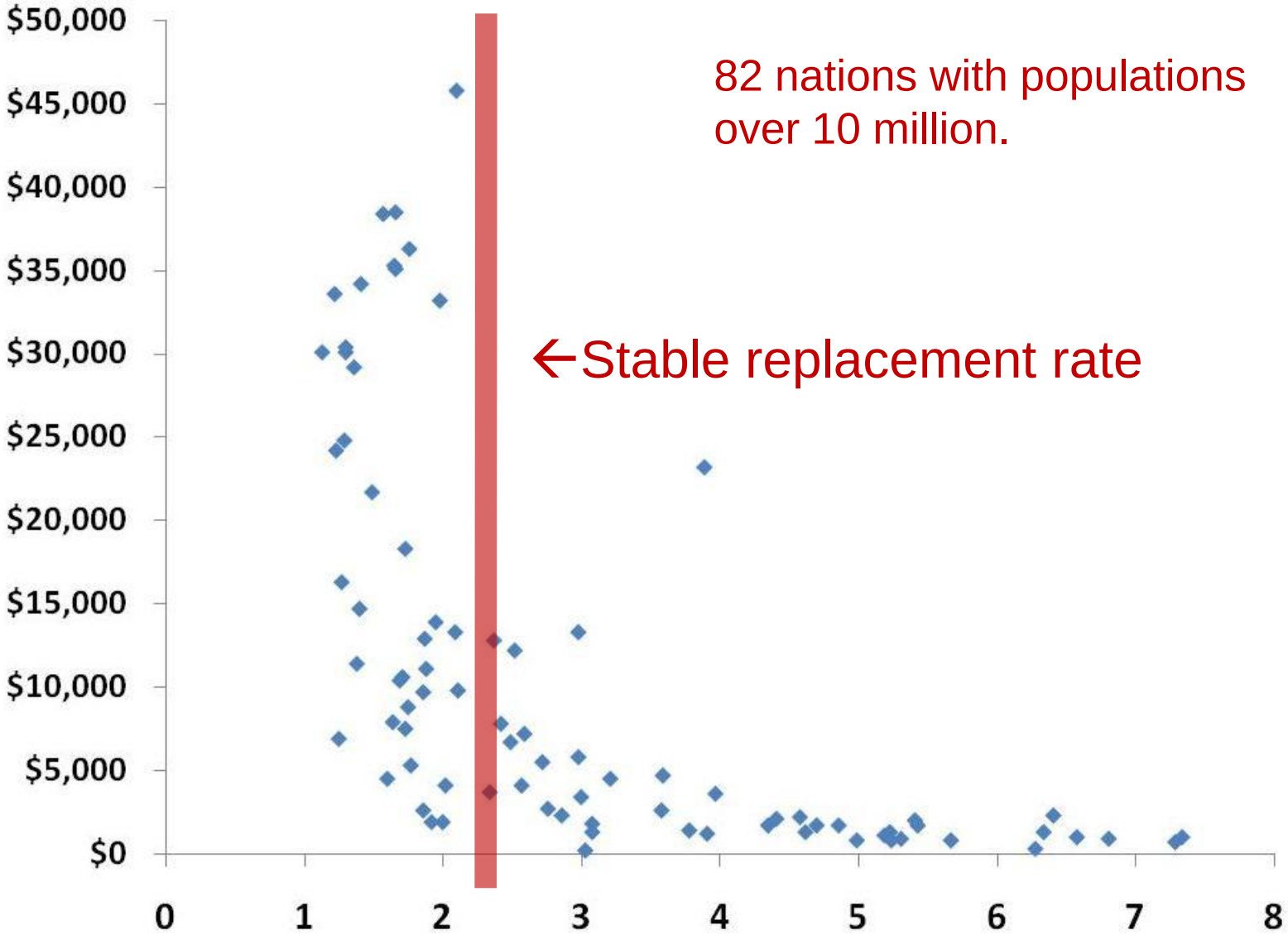


Ammonia for fertilizer

http://wwwtest.iri.tudelft.nl/~klooster/reports/hydro_slides_2003.pdf

Aim High! Stabilize population.

GDP per capita



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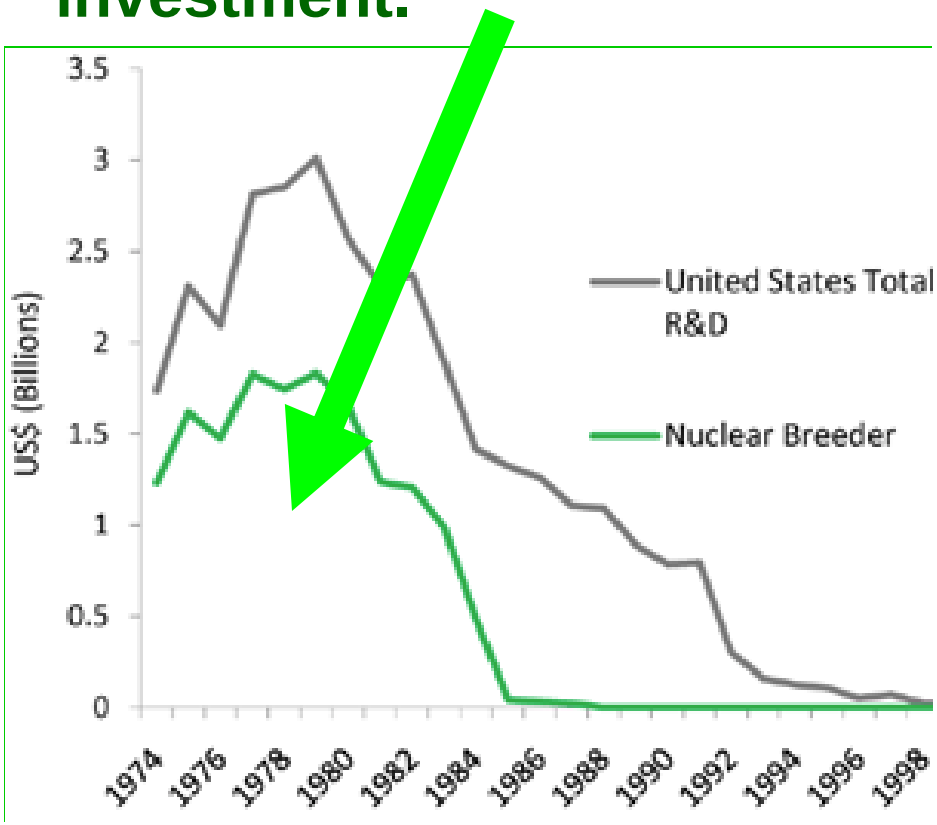
https://www.cia.gov/library/publications/the-world-factbook/docs/rankorderguide.html

But US advanced nuclear fission R&D has dropped – near zero for breeders.

$16 billion ($2011)
Cumulative LMFBR investment.



2011 DOE Nuclear Energy budget items

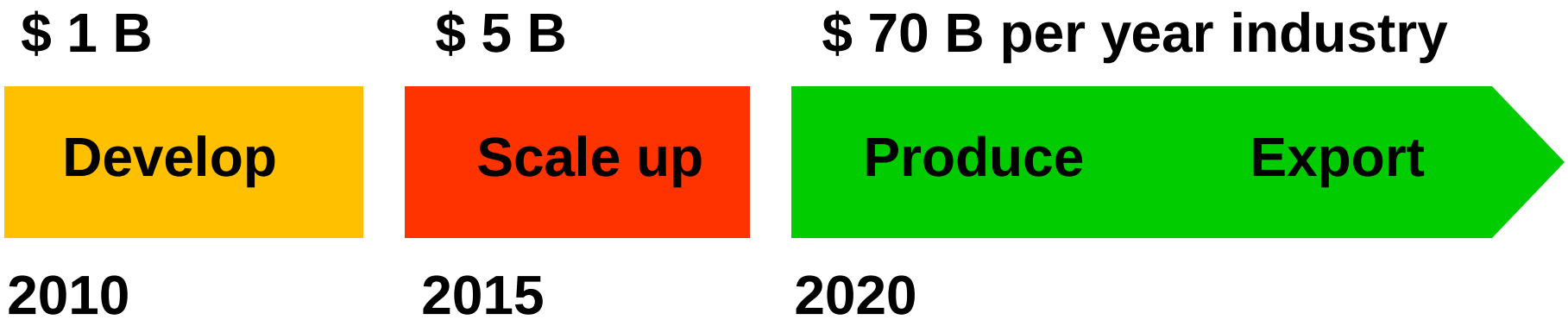
$103 million
NGNP high temperature gas reactor with TRISO fuel.

$22 million
Advanced reactor concepts, principally fast reactors.

$40 million
Advanced fuel cycles, but no liquid fuel, no closed fuel cycle.

IAEA, via Inter. Panel on Fissile Materials Feb 2010

LFTR project results are tangible.



Cut 10 billion tons/year CO_2 emissions to zero by 2058.

Avoid carbon taxes.

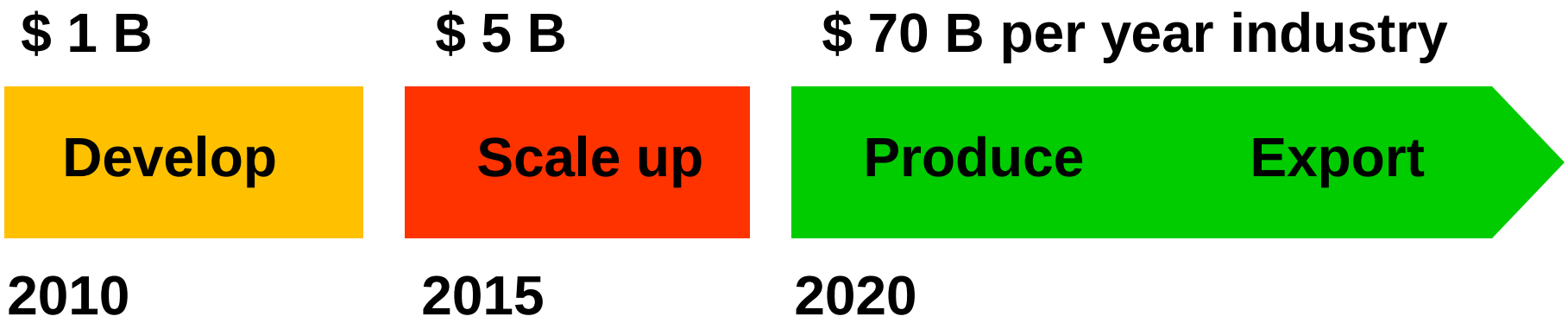
Improve developing world prosperity, and check growth.

Avoid weapons proliferation.

Reduce radiotoxic waste; consume world fissile stocks.

Use inexhaustible thorium fuel, available in all nations.

Thank you.



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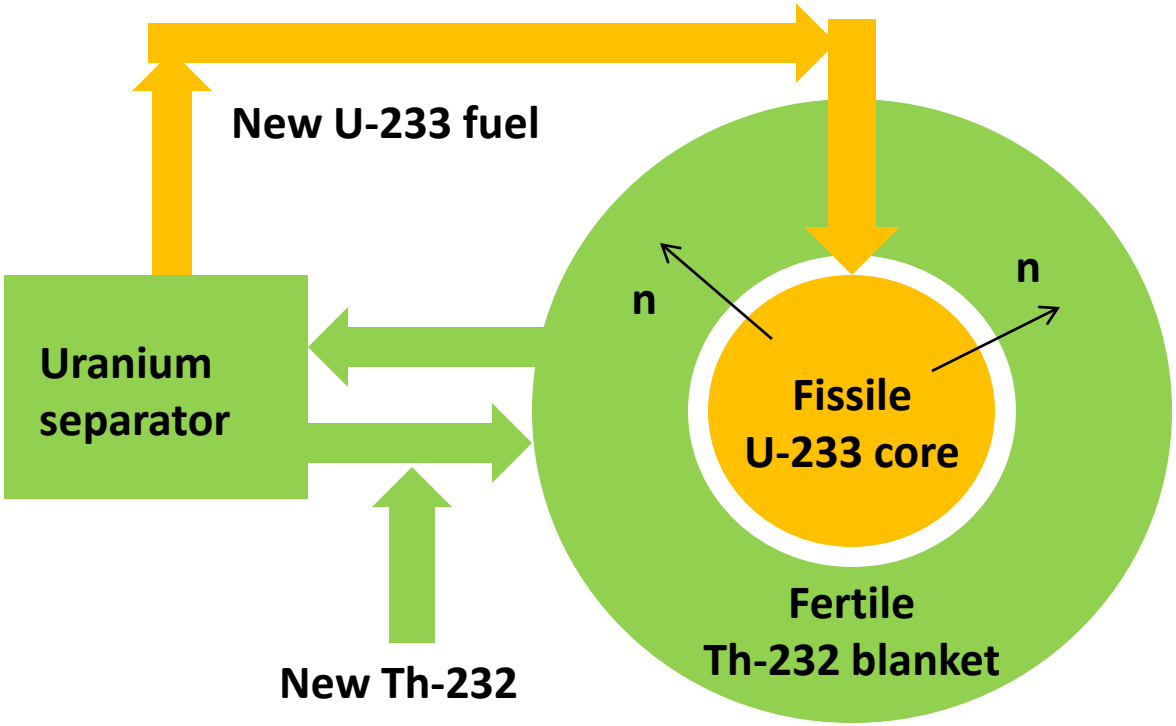
Uranium from a commercial LFTR will not be used for weapons.



Breeds only as much U-233 as it consumes.

Removing any will stop the LFTR.

U-232 contamination will be ~0.13%.

A 5 kg sphere of it radiates 4,200 mrem/hr at 1 meter.

After 72 hours of exposure a weapons worker will likely die.

India, Pakistan, and North Korea demonstrated far less technically challenging and costly paths.

Fission/Absorption Cross Sections