# Five Myths about Nuclear Power

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22 January 2019

# Why Nuclear Power?

Nuclear power is

> *. . . the energy source that can save our planet from another possible disaster: catastrophic climate change. . . .*
> *Nuclear energy is the* **only** *large-scale, cost-effective energy source that can reduce these emissions [of $CO_2$] while continuing to satisfy a growing demand for power. . . .*

– Patrick Moore, founder of Greenpeace Canada
cofounder of Greenpeace International, 2006

http://www.washingtonpost.com/wp-dyn/content/article/2006/04/14/AR2006041401209.html

# Why Nuclear Power?

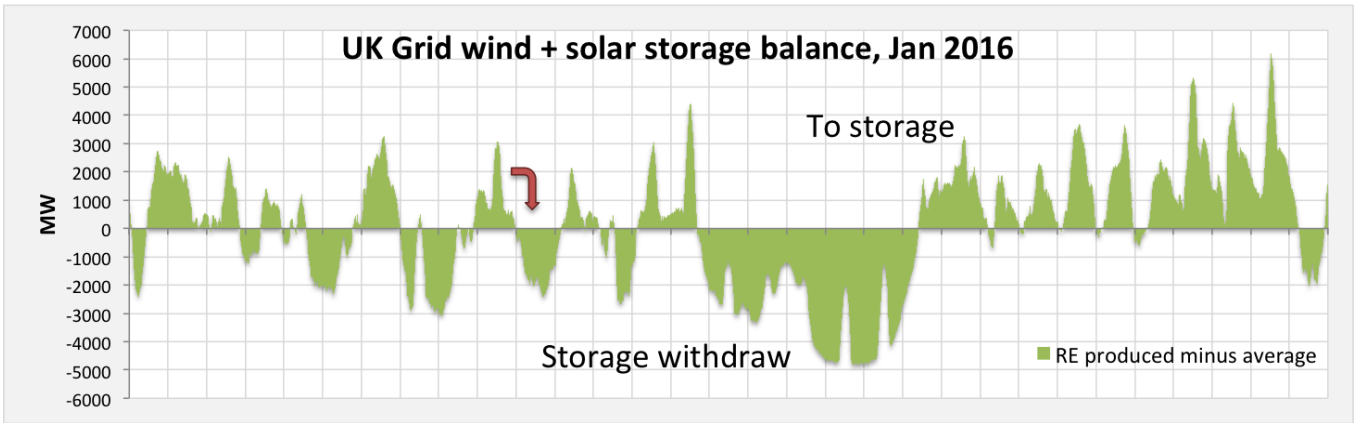
## 100%-renewable electricity systems can't work

> *"While many modelled scenarios have been published claiming to show that a 100% renewable electricity system [that excludes nuclear power] is achievable, there is* **no empirical or historical evidence that demonstrates that such systems are in fact [physically] feasible.**"
> *[my emphasis]*

B.P. Heard, B.W. Brook, T.M.L. Wigley, C.J.A. Bradshaw, *Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems*, **Renewable and Sustainable Energy Reviews 76**, Elsevier (2017), pp 1122-1133.

# Why Nuclear Power?

Using data with 30-minute resolution for wind and solar for England and Scotland for all of 2016, Euan Mearns calculated that 390 watt-hours of storage are needed for every average watt of installed wind and solar capacity, to provide firm power.




http://euanmearns.com/grid-scale-storage-of-renewable-energy-the-impossible-dream

# Why Nuclear Power?

Assuming the same variability and 1,700 GWe average capacity, an all-renewable American energy economy would need 630,000 GWe-hours storage.

The Big South Australian Battery provided 0.129 GWh storage at a cost of $0.517/Wh. Tesla recently raised the price of PowerWall 2 to $0.578/Wh. Batteries last about five years. An all-renewable American energy economy would spend **$76 trillion per year for batteries alone – 3.95 times 2017 GDP!**

**Will human civilization survive an all-renewable energy economy when Mount Tambora erupts again, giving us another 1816, the "year without a summer?"**

# Why Nuclear Power?

**Power systems were severely damaged by an electromagnetic pulse (EMP)** when the Sun belched out several trillion cubic miles of super-hot plasma in 1969. Aurora were seen as far south as Cuba.

The Sun does this every sixty years or so.

Solar panels and windmills are inherently vulnerable to EMP. The enormous amount of wiring necessary to collect dispersed sources would be a giant EMP antenna. **An all-renewable energy system would be catastrophically damaged. Recovery would take decades.**

**Nuclear power plants**, inside four-foot-thick concrete domes, laced with steel rebar, **are inherently invulnerable to EMP**.

# Why Nuclear Power?

- **No one knows how to make an all-renewable electrical grid work.**
- **Storage is not economically viable.**
- **Human civilization cannot build enough storage to survive a major volcanic eruption or meteorite strike.**
- **Solar, wind, and enormous wiring are inherently vulnerable to electromagnetic pulse (EMP).**

**100% renewable is too dangerous to consider seriously!**

# Why NOT Nuclear Power?

# The Five Myths

Everything you've been told about nuclear power:

- It's too dangerous
- No one knows what to do about waste
- It's too expensive
- It leads to weapons proliferation
- There isn't enough uranium

**Is False!**

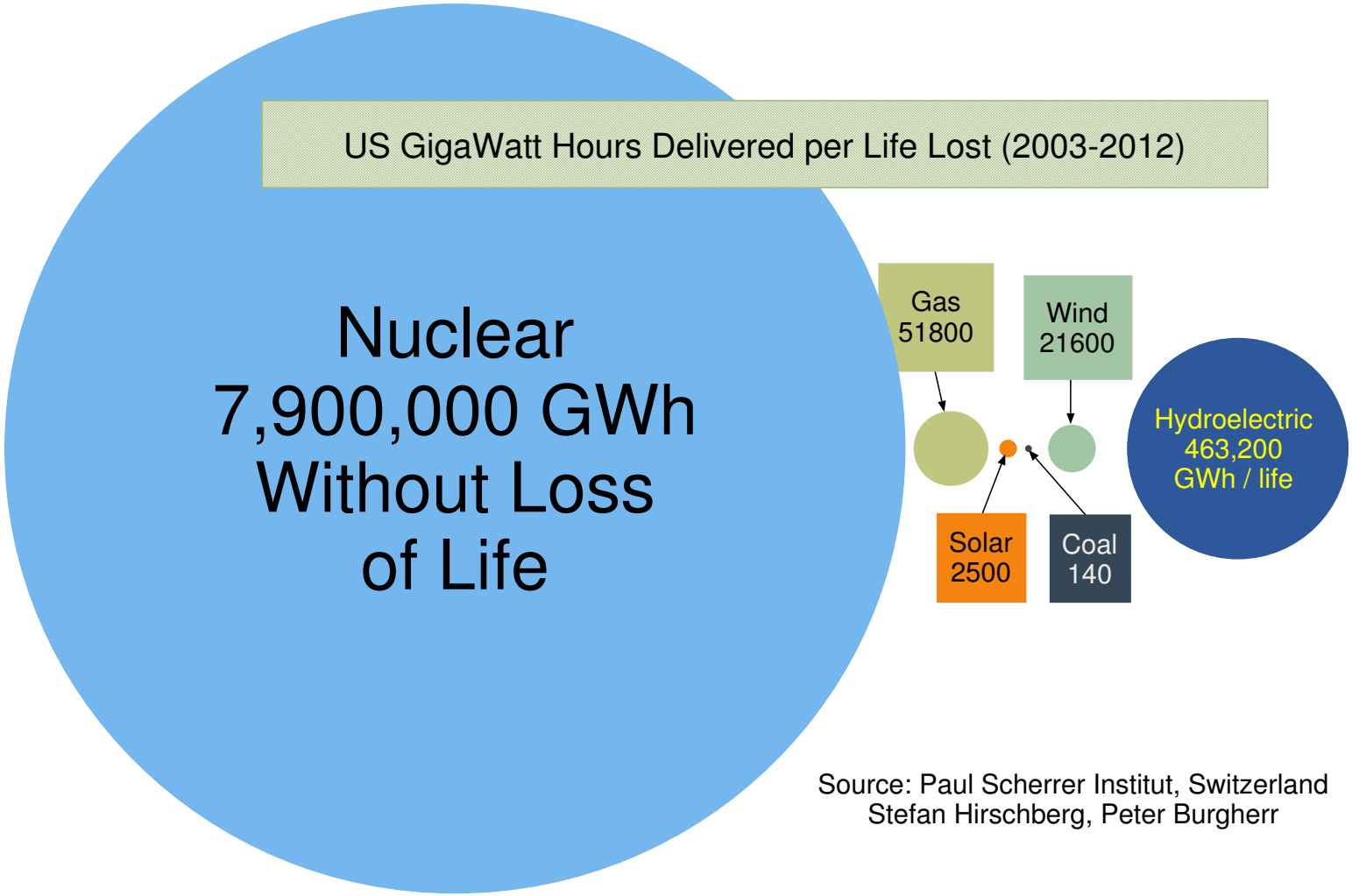
# It's Too Dangerous (no it's not)

# It's Too Dangerous (no it's not)

- **No one** was injured (except financially) or killed by Three Mile Island and **no radioactive materials were released.**
- **No one** was made ill or killed by Fukushima, and residents could return to their homes without risk.
- 28 plant workers and emergency responders at Chernobyl died from Acute Radiation Syndrome. Three died from causes not related to radiation. Out of 6,000 cases of thyroid cancer reported in Eastern Europe during the next fifteen years, UNSCEAR blamed fifteen fatal cases on Chernobyl.

**43 radiation-related deaths in the entire six-decade worldwide history**, all caused by a reactor that would never have been licensed outside the Soviet Union, of a design that will never be repeated.

# It's Too Dangerous (no it's not)




Source: Paul Scherrer Institut, Switzerland
Stefan Hirschberg, Peter Burgherr

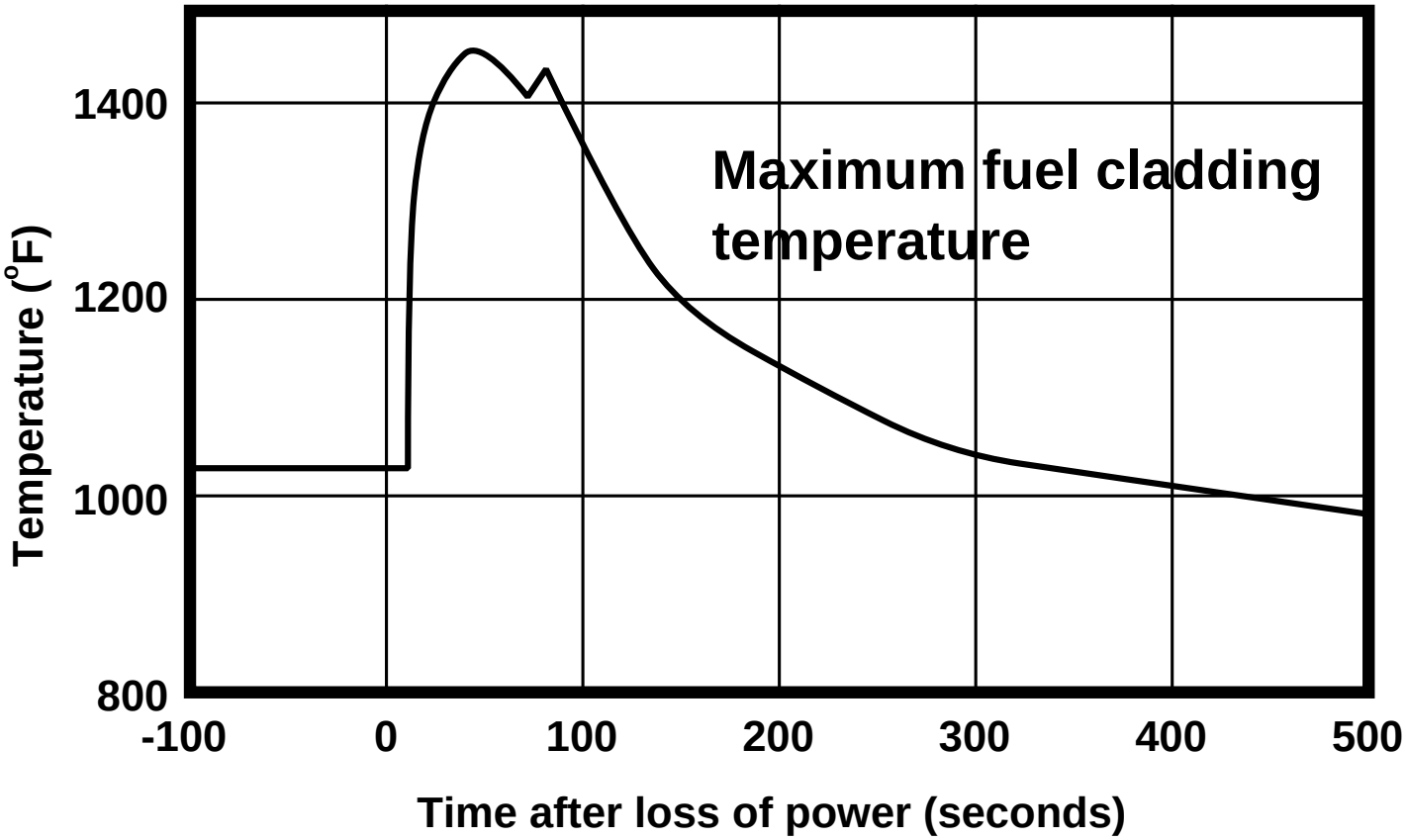
# It's Too Dangerous (no it's not)

Scientists, engineers, chemists, and metallurgists at Argonne National Laboratory and Idaho National Laboratory set out to **solve all the world's energy problems** with one system that

- Is inherently safe,
- Consumes existing nuclear waste, effectively destroying it,
- Is economical to build and operate,
- Is extremely resistant to diversion for nefarious purposes, and
- Creates more fuel than it consumes.

**And they did it! Then the Clinton administration canceled the project in 1993, when it was an inch from completion, at more cost than finishing it. Clinton pandered "I know; it's a symbol."**

# It's Too Dangerous (no it's not)




## Result of 1986 safety test at EBR-II

Coolant boils at 1620°F. Fuel cladding melts at 3360°F.

David Baurac, *Passively safe reactors rely on nature to keep them cool*, **Logos 20** (2002)
http://www.ne.anl.gov/About/hn/logos-winter02-psr.shtml

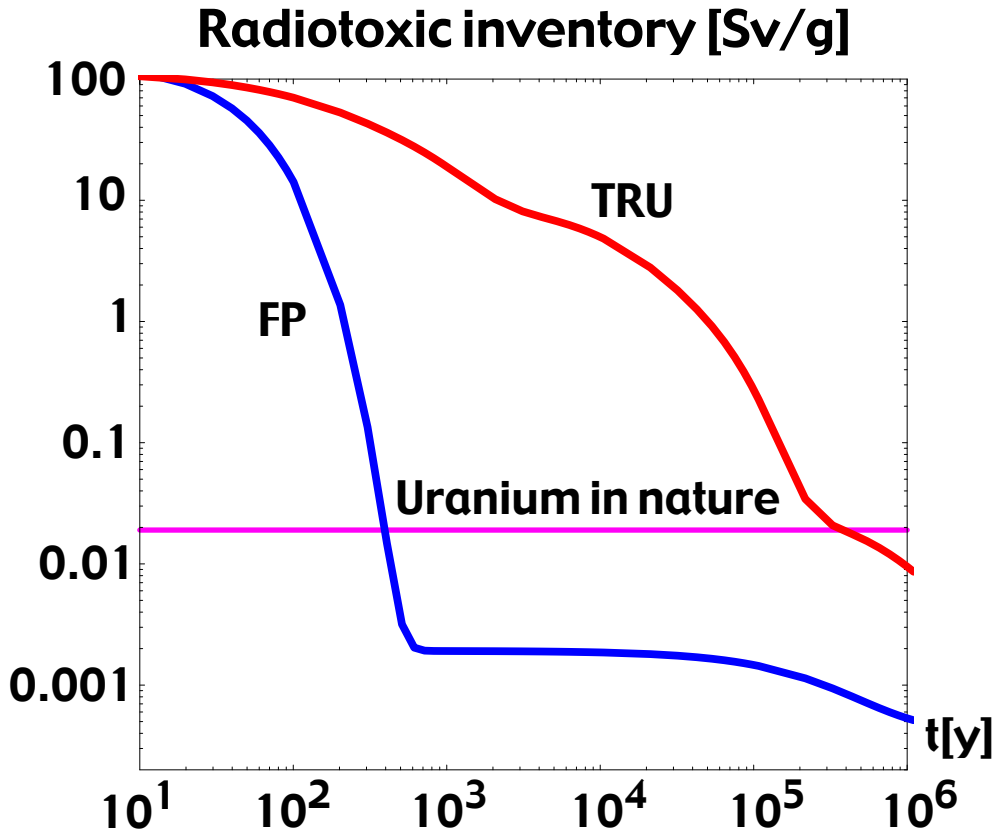
# No One Knows What to Do about Nuclear Waste (yes we do)

# No One Knows What to Do about Nuclear Waste

Spent fuel consists of **5% fission products** and **95% unused fuel**.

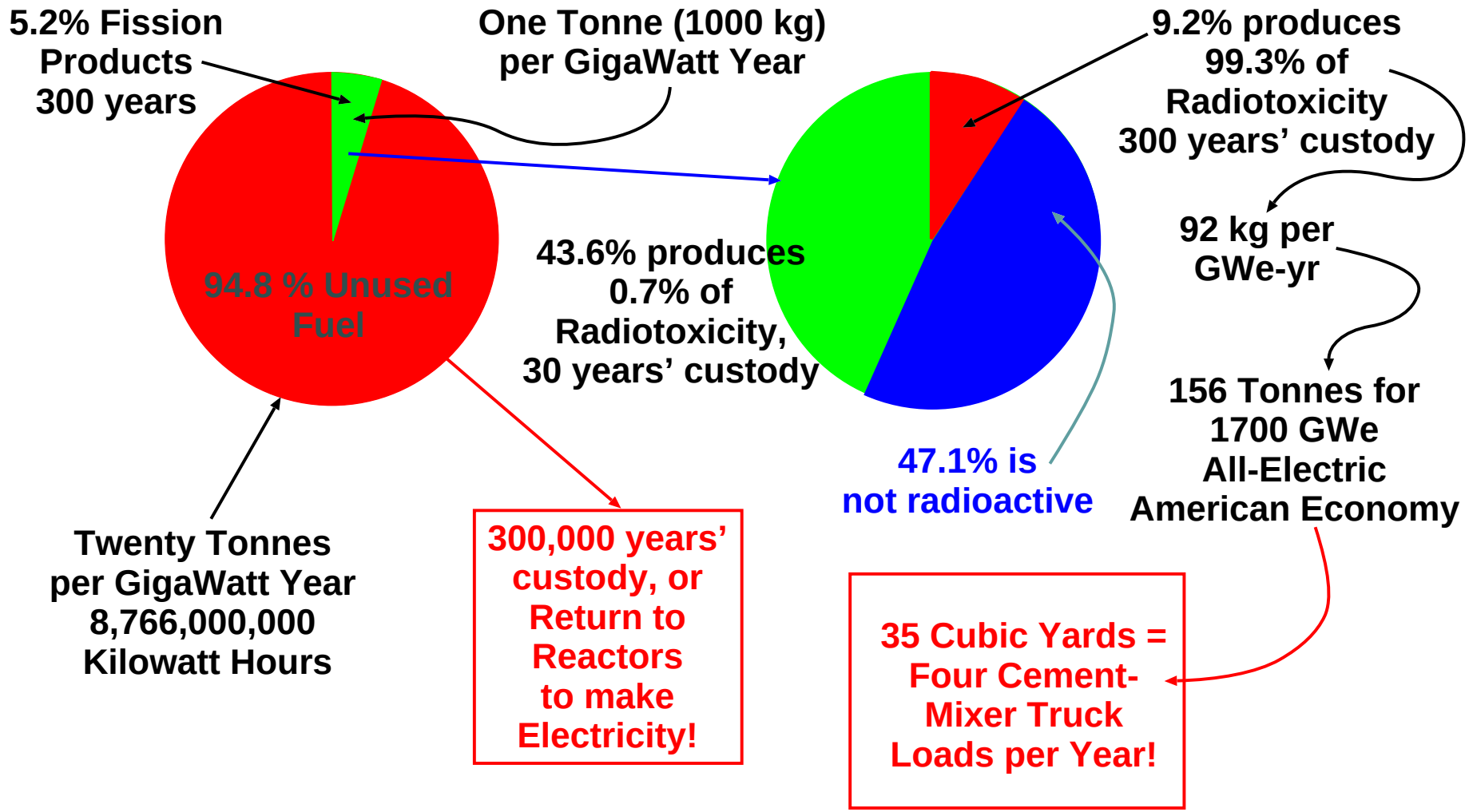
**Unused fuel is dangerously radiotoxic for 300,000 years.**

**Fission products are dangerously radiotoxic for 300 years.**

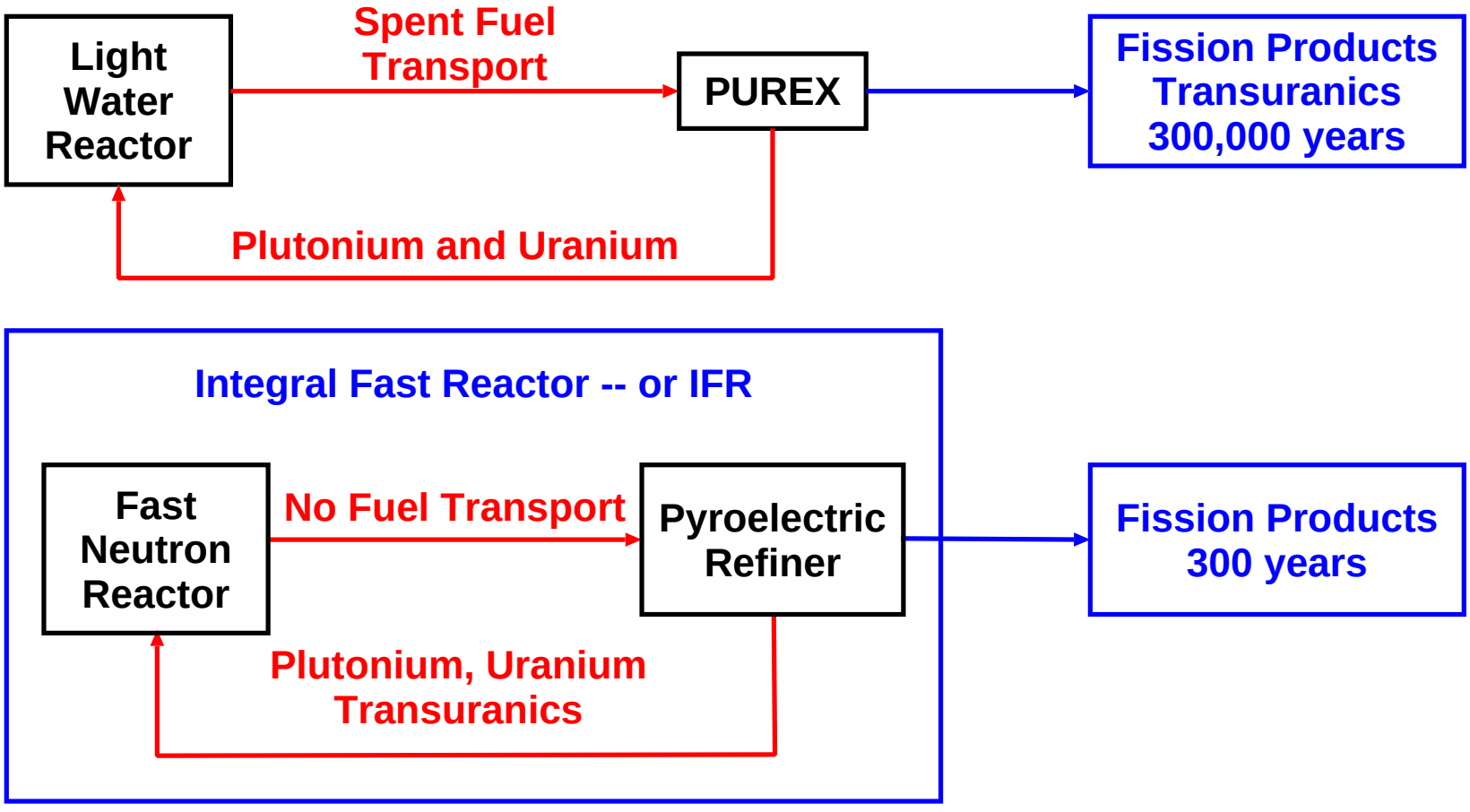



*Återanvändning av långlivat avfall och sluten bränslecykel möjlig i nya reaktortyper*, **Nucleus** (April 2007), page 15

# No One Knows What to Do about Nuclear Waste



# Integral Fast Reactor




**Canceled by the Clinton administration in 1993 after 30 years' flawless operation, when it was an inch from completion**, at more cost than completing it. **Clinton pandered "I know; it's a symbol."**

**Solar panels and windmills cannot destroy nuclear waste**

**(nothing but the right kind of reactor can)**

# It's Too Expensive
# (usually the lowest cost)

# It's Too Expensive

## Compared to what?

Many scientists have computed that wind cannot provide more than 15% of today's total energy use.

Hydro provides 7% of US electricity, or 1.4% of total energy, there aren't any good sites left, and environmentalists don't like dams.

Waves, tides, ocean currents, geothermal, biofuels, unicorns, pixie dust, vigorous hand waving, or any other environmentalist's favorite, are all irrelevant.

The only "renewable" source that can in principle provide all our energy is solar.

If we want to eliminate $CO_2$ emissions, it doesn't make sense to compare nuclear to coal or gas.

# It's Too Expensive

## Compared to what?

Solar cells cost $1.80 per peak watt but have 15% capacity factor = $12 per average watt or $12,000/kW. If amortized over 25 years at 5%, removing 4.5 year energy payback period (about 5.9 MWh/kW), **the unsubsidized capital cost for cells (not deployed panels) is 11.7¢/kWh**.

Using Mearns's 390 Wh/W figure for sufficient storage for firm power, and the Big South Australian Battery's cost ($50 million) and capacity (129 MWh), the capital cost for storage is $151,162.79/kW. Assuming batteries must be replaced every five years, and amortizing their cost over 5 years at 5%, **the cost per kW-year (8766 kWh) for storage is $34,914.79, or $3.98/kWh (34 times the cost of the cells)**. We can't build enough pumped storage for a 1,700 GW all-electric American energy economy. The cost for batteries alone would be $59.35 trillion per year, about 3.2 times US 2016 GDP ($18.57 trillion).

# It's Too Expensive

Nuclear power plants' capacity factors $> 90\%$. No storage needed.

2009 MIT study concluded nuclear power plants could be built for \$4/watt and produce electricity for 6¢/kWh.

- Diablo Canyon: 5¢/kWh.
- Palo Verde cost \$1.79/watt and produces electricity for 4.3¢/kWh.
- Columbia Nuclear Generating Station: 4.7 – 5.2¢/kWh.
- Fully-amortized plants produce electricity for 2¢/kWh (1.5¢ for operations, 0.5¢ for fuel).
- California utility average: 15.34¢/kWh.
- Solar with storage: \$4.10/kWh.

First-of-a-kind 300 MWe fast neutron reactor might cost \$8/watt.

GE says they can build 380 MWe modules for $<$ \$2/watt. If amortized at 5% for 50 years, the capital cost is 1.25¢/kWh.

# It's Too Expensive

## Nuclear power is artificially inexpensive because of subsidies (no, it's not)

2018 direct Federal subsidies for electricity generation
(latest year available from EIA)

| | Coal | Gas | Hydro | Nuclear | Wind | Solar PV |
|---|---|---|---|---|---|---|
| ¢/kWh | 0.071 | 0.066 | 0.0127 | 0.020 | 0.563 | 2.453 |
| per nuclear $ | 2.158 | -3.285 | 0.635 | 1.000 | 42.59 | 112.65 |

Yes, the government made a profit on gas

https://www.eia.gov/analysis/requests/subsidy/

Solar and wind subsidies, and mandates on utilities to buy solar and wind power, are driving utilities that own nuclear power plants into bankruptcy.

# It's Too Expensive

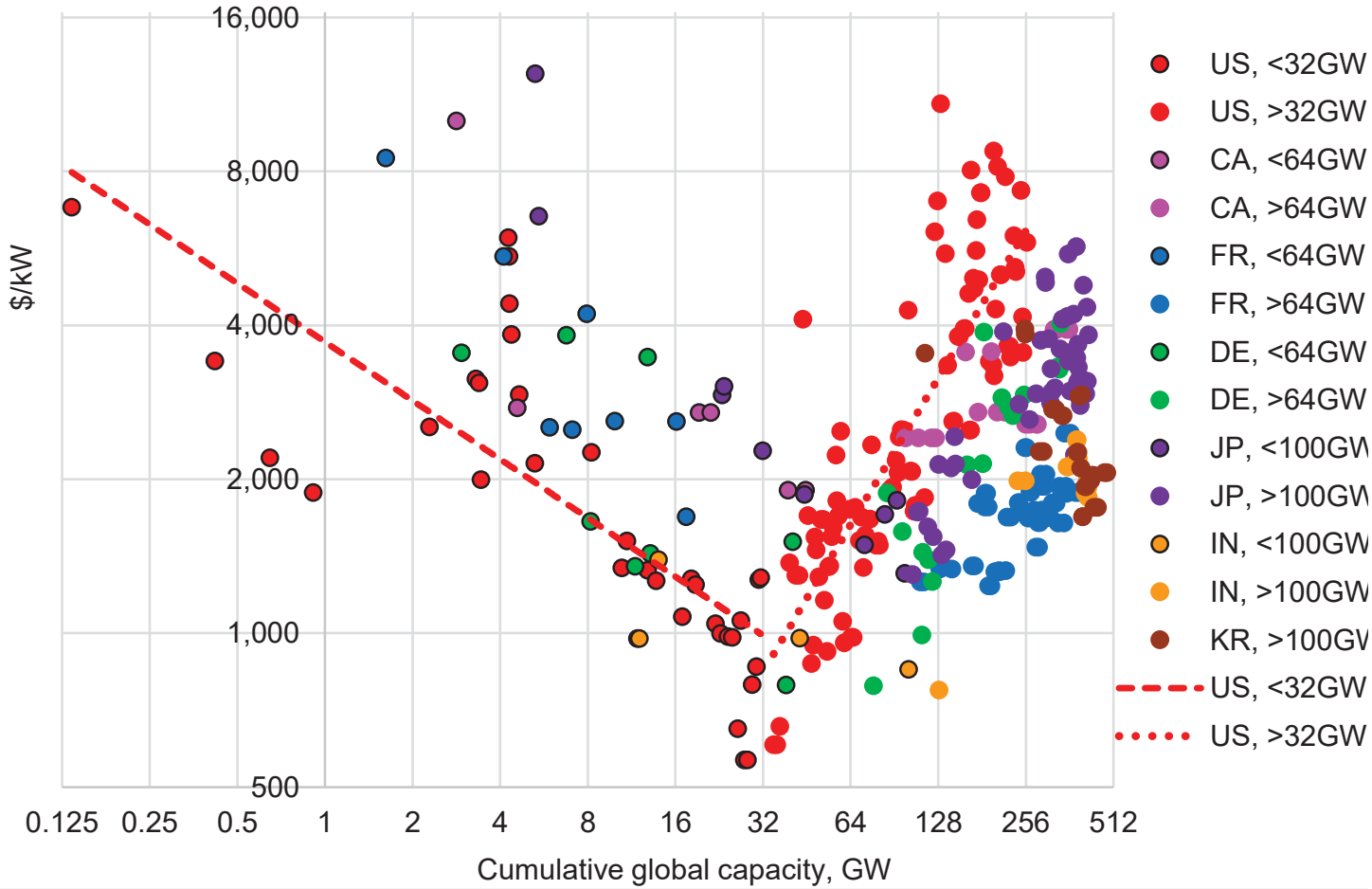



**Figure 1:** Overnight construction cost (in 2010 US$/kW) plotted against cumulative global capacity (GW), based on construction start dates, of nuclear power reactors for seven countries, including regression lines for US before and after 32 GW cumulative global capacity.

Peter Lang, *Nuclear Power Learning and Deployment Rates: Disruption and Global Benefits Forgone*, CAMA Working Paper No. 4/2017(January 15, 2017). Available at http://dx.doi.org/10.2139/ssrn.2899971

# It Leads to Nuclear Weapons Proliferation

# (a giant stinking red herring)

# It Leads to Nuclear Weapons Proliferation

"Weapons grade plutonium" is 93% $^{239}$Pu.

Plutonium from electric power reactors is never more than 55% $^{239}$Pu. Plutonium from electrorefiners is never chemically pure.

Yield of a 63% $^{239}$Pu explosive was much less than the much simpler and much cheaper Hiroshima uranium device. British said "We will not try that again."

Plutonium from IFR-type reactors would have less $^{239}$Pu and more of other isotopes, which produce 50 times more heat, 5,000 times more neutrons, and 100 times more gamma radiation.

Heat and radiation would distort fine tolerances, require remote fabrication, damage chemical explosives, and might cause predetonation.

LLNL report said "spent IFR fuel cannot be used to make a nuclear weapon without significant further processing."

**Weapons-ready material from spent reactor fuel does not exist!**

# It Leads to Nuclear Weapons Proliferation

**Even if "Weapons-ready material" existed "Proliferation" is still a red herring**

No country's municipal reactors or reprocessing affect any other country's ability or desire to make nuclear weapons.

On-site reprocessing in IFR-type reactors implies very few opportunities for diversion or theft.

Plutonium in used fuel in an IFR-type system is in a highly-radioactive and therefore easily monitored state.

Advanced industrial economies already have nuclear weapons, or have the means to make them much more effectively than from used municipal reactor fuel.

# There Isn't Enough Uranium (there's enough for a million years)

# There Isn't Enough Uranium

USA alone has nearly 80,000 tonnes of used fuel, and more than 700,000 tonnes of depleted uranium, enough to power the entire American energy economy for 450 years.

The Australian Uranium Mining Association said enough uranium could be recovered economically at current prices to power the entire world for 1,200 years.

Current reactors extract 0.6% of energy in mined uranium; IFR-type reactors extract 99%.

Uranium contribution to fuel cost would still be 0.001¢/kWh if it cost 167 times more; it would be economical to extract lower-quality ores, and from seawater, where there's 1000 times more.

**Nuclear fission is an inexhaustible energy source!**

# More Food for Thought

- Breeder reactors make 5% more plutonium than they consume, from non-fissionable but plentiful $^{238}$U, or 1% more $^{233}$U from even more plentiful $^{232}$Th.
- In 14 years, they make enough fuel to start a new reactor of the same size (70 years with thorium).
- Breeder reactors can be fueled with natural uranium. It will never again be necessary to enrich uranium.
  **Any one who claims to need to enrich uranium for municipal electricity service would be exposed as a liar who has a weapons program.**
- Plutonium is **not** the most toxic substance known. It is less chemotoxic than lead, and far far far less chemotoxic than ricin, but it is dangerously radiotoxic if inhaled or ingested.
  Yttrium-90 is 94,490 times more radiotoxic.
  Praseodymium-144 is 242,960 times more radiotoxic.

# More Food for Thought

Current US inventory of fissionable material is 1125 tonnes.

- **No one has any idea what to do with it, other than to make electricity from it** – or store it for 300,000 years.
- **Solar panels and windmills cannot make electricity from it.**
- 1125 tonnes could immediately start 110-140 GWe capacity.
- At 5% breeding rate, 1,700 GWe capacity could be reached in 50-60 years without mining, milling, refining, or enriching any new uranium.

# More Food for Thought

- "Developed nations should spend 1% of GDP to reduce $CO_2$ emissions by 25-70%, and another 1% to cope with climate change."

  Sir Nicholas Stern, vice chairman and chief economist of the World Bank.
- Spending 2% of U.S. GDP during the 50-60 years required to deploy an all-IFR energy economy would cost $18-20 trillion.
- Improvements to the electrical grid necessary to use dispersed and variable sources would add $4-5 trillion.
- Storage to mitigate variability would cost **$50 trillion per year – three times US GDP** – too expensive to contemplate seriously.
- Deploying 1,700 GWe of IFR capacity would cost $2.1-3.7 trillion, and would reduce net $CO_2$ emissions by well over 95% (not just 25-70%).

# More Food for Thought

- Russia and France have had sodium-cooled fast-neutron reactors since 1973.
- China has contracted to buy BN-800 from Russia.
- Russia is developing BN-1200.
- India is building a 500 MWe prototype fast-neutron reactor to exploit its huge thorium reserves.
- A South Korean company plans to begin selling a 500 MWe fast-neutron reactor in 2020.
- American nuclear engineers and scientists are retiring and dying faster than new ones are being prepared. America will soon be a third-world country in energy technology.

# Conclusions

**An all-renewable energy system cannot work.**

**The five oft-cited objections to nuclear power are all baseless falsehoods.**

**Renewable sources cannot mitigate the "nuclear waste" problem.**

It is clearly obvious that nuclear power in the form of clean safe fast-neutron breeder reactors with on-site pyroelectric refining *must be* a necessary (and economical) part of the American energy economy.

**Should the United States develop the technology we invented, or buy it from Russia, China, South Korea, and India?**

**The sooner we start, the better off we will be.**

# Additional Reading


William Hannum, Gerald Marsh, and George Stanford, *Smarter Use of Nuclear Waste*, **Scientific American** (December 2005 and online).

Charles E. Till and Yoon Il Chang **Plentiful Energy: The IFR Story**, Amazon (2011) ISBN 978-1466384606.

Tom Blees, **Prescription for the Planet** (2008) ISBN 1-4196-5582-5, ISBN-13 9781419655821.

UNSCEAR, *Scientific Annex D: Health effects due to radiation from the Chernobyl accident*, in **Sources and Effects of Ionizing Radiation, UNSCEAR 2008 Report to the General Assembly, Volume II**, ISBN-13 978-92-1-142280-1 (2011) 179 pp.

UNSCEAR, *Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami*, in **Sources and Effects of Ionizing Radiation, UNSCEAR 2013 Report, Volume I**, ISBN 978-92-1-142291-7 (2014) 321 pp.

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