Five Myths about Nuclear Power

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4 January 2018

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, cofounder of Greenpeace, 2006

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

Why Nuclear Power?

"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."

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?

From the abstract of *Burden of Proof*:

> *Our review of 24 studies of 100% renewable electricity systems finds that none individually, nor the literature in aggregate, provide compelling evidence for even the basic [physical] feasibility. . . . Our review gave no assessment whatsoever of important [economic] viability aspects such as financial cost, planning constraints, technology assumptions, governance and policy requirements and land use conflicts. The true costs of 100% renewable electricity systems cannot be determined on the basis of systems that are not even technically feasible, yet at this time that is all the literature offers.*

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

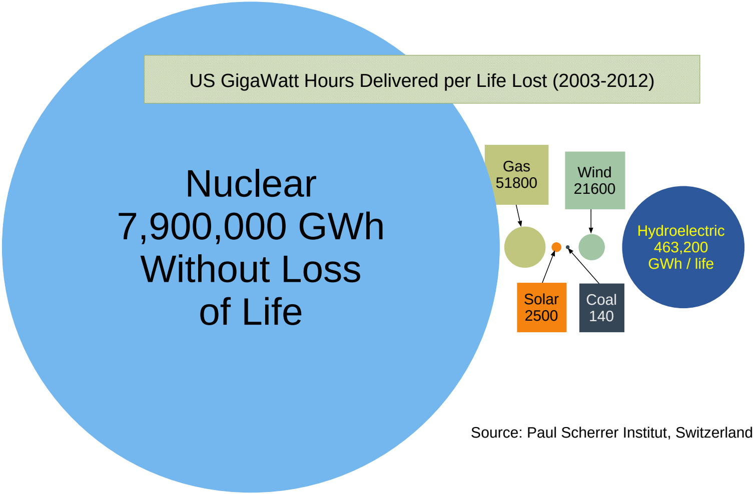
Is False!

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

- **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)



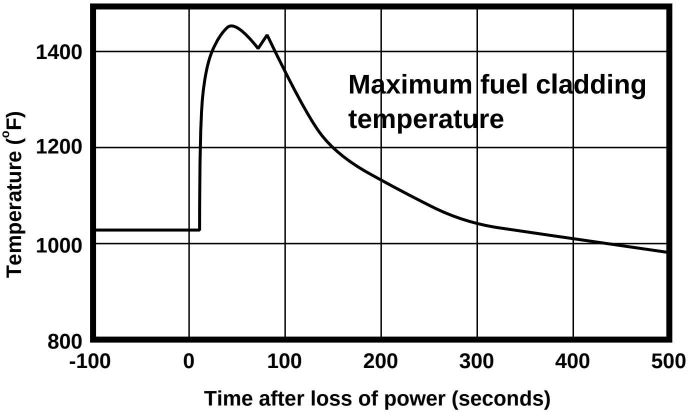
It's Too Dangerous (no it's not)

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 1994, when it was an inch from completion, at more cost than finishing it. Clinton pandered "I know; it's a symbol."

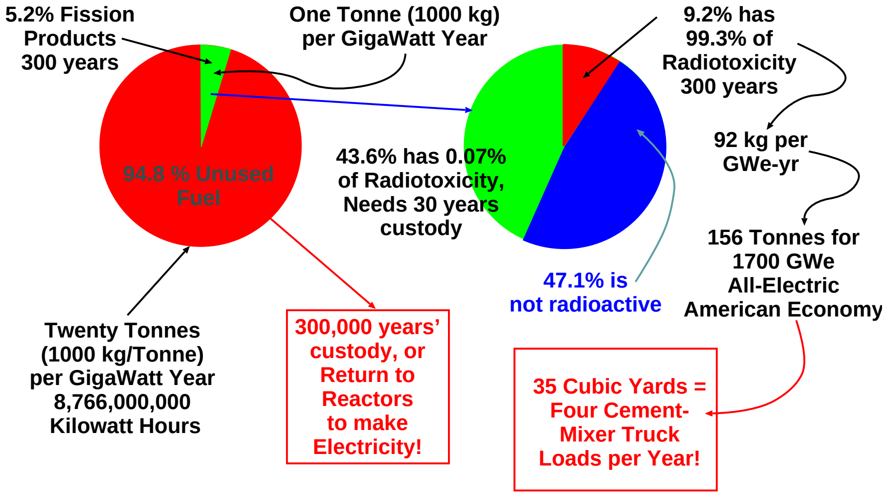
It's Too Dangerous (no it's not)



Result of 1986 safety test at EBR-II

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

No One Knows What to Do about Nuclear Waste

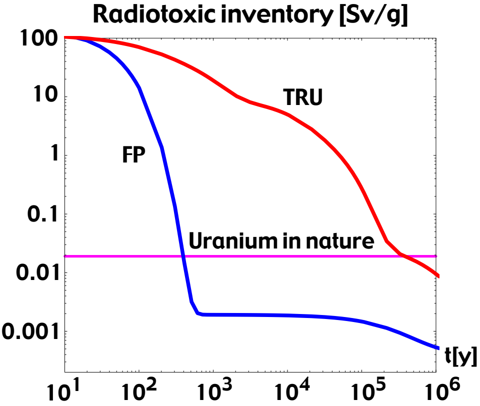


No One Knows What to Do about Nuclear Waste

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

PUREX separates only plutonium and uranium from used fuel, leaving higher transuranics with fission products.

Pyroelectric refiner developed at Argonne National Laboratory separates all transuranics from fission products.

Pyroelectric refiner is far smaller and far less expensive than PUREX.

Current reactors cannot consume all of the unused fuel, but a fast neutron reactor such as EBR-II can consume it.

Fast neutron reactor plus pyroelectric refiner = *Integral Fast Reactor* (IFR), canceled after 30 years' flawless operation by the Clinton administration in 1994, when it was an inch from completion, at more cost than completing it. Clinton pandered "I know; it's a symbol."

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.

2013 Federal subsidies for electricity generation, ¢/kWh.

Coal	Gas	Hydro	Nuclear	Wind	Solar PV
0.057	0.060	0.146	0.210	3.533	23.121

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

It's Too Expensive

Compared to what?

Solar cells cost \$1.80 per peak watt but have 15% capacity factor $=$ \$12 per average watt. If amortized over 25 years at 5%, removing 4.5 year energy payback period (about 5.9 MWh/kW), the capital cost is 11.7¢/kWh. Adding batteries and doubled panel capacity to charge them, is 50-60¢/kWh.

Nuclear power plants' capacity factors $>$ 90%.

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

Diablo Canyon produces electricity for 5¢/kWh. Palo Verde cost \$1.79/watt and produces electricity for 4.3¢/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

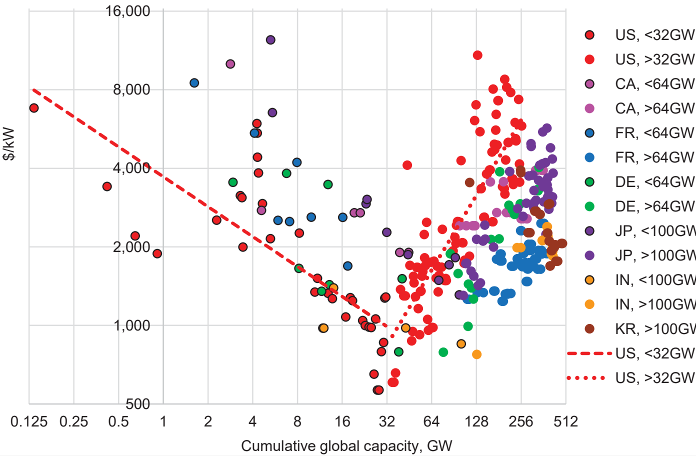


Figure 1: Overnight construction cost (in 2010 US$/kW) plotted against cumulative global capacity (GW), based on construction start dates, of nuclear power reactors for seven countries, including regression lines for US before and after 32 GW cumulative global capacity.

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's Too Expensive

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.

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

The Big South Australian Battery provided 0.129 GWh storage at a cost of $50 million. Lithium batteries last about five years. An all-renewable American energy economy would spend **$60 trillion per year for batteries alone – 2.8 times 2016 GDP!**

Will humanity survive an all-renewable energy economy when Tambor erupts again, giving us another 1816, the "year without a summer?"

100% renewable is too dangerous to consider seriously!

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 reactors does not exist!

It Leads to Nuclear Weapons Proliferation

**Even if "Weapons-ready material" existed
"Proliferation" is 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

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 power is an inexhaustible energy source!

More Food for Thought

IFR is called a breeder because it can make 5% more plutonium than it consumes. In 14 years, it could produce enough – 8 to 10 tonnes, or about a cubic yard – to start a new 1-GWe reactor.

With breeder reactors, it will never again be necessary to enrich uranium. Any one who claims to need it for municipal electricity service would be exposed as a liar who has a weapons program.

With on-site reprocessing there would be no need to ship used fuel, and only small and infrequent shipments of actinides to start new reactors, or fission products as impervious insoluble ceramics.

A study by Ben Heard and colleagues concluded that none of the published schemes for an all-renewable non-nuclear energy economy are physically feasible. A study by Samuel Jenkins and Jesse Thernstrom assumed they are physically feasible, and concluded that getting beyond 50% decarbonization without nuclear power would be enormously expensive.

More Food for Thought

Current US inventory of fissionable material is 1125 tonnes, enough to start 110-140 GWe capacity, and there are **no other ideas for its use**. At the IFR 5% breeding rate, 1,700 GWe capacity could be reached in 50-60 years without mining, milling, refining, or enriching any new uranium.

Plutonium-239 is not the most toxic substance known. It is less chemotoxic than lead, and far far far less chemotoxic than ricin, but 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

A study led by Sir Nicholas Stern (vice chairman and chief economist of the World Bank) concluded developed nations should spend 1% of GDP to reduce CO_2 emissions by 25-70%, and another 1% to cope with climate change. 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 such as wind and solar would add $4-5 trillion. Storage to mitigate variability would have additional unknown cost.

Deploying 1,700 GWe of IFR capacity would cost $2.1-3.7 trillion, depending upon how quickly experience and economies of scale reduce costs, and would reduce net CO_2 emissions by well over 95%.

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.

Solar, wind, hydro, and minor renewable players such as tides, waves, geothermal, ocean currents, and biofuels – and conservation – cannot do anything to mitigate the "nuclear waste" problem.

Conclusions

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

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

Should the United States develop the technology, 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.

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