HONR 229L: Climate Change: Science, Economics, and Governance

Discussion #15: Nuclear Energy

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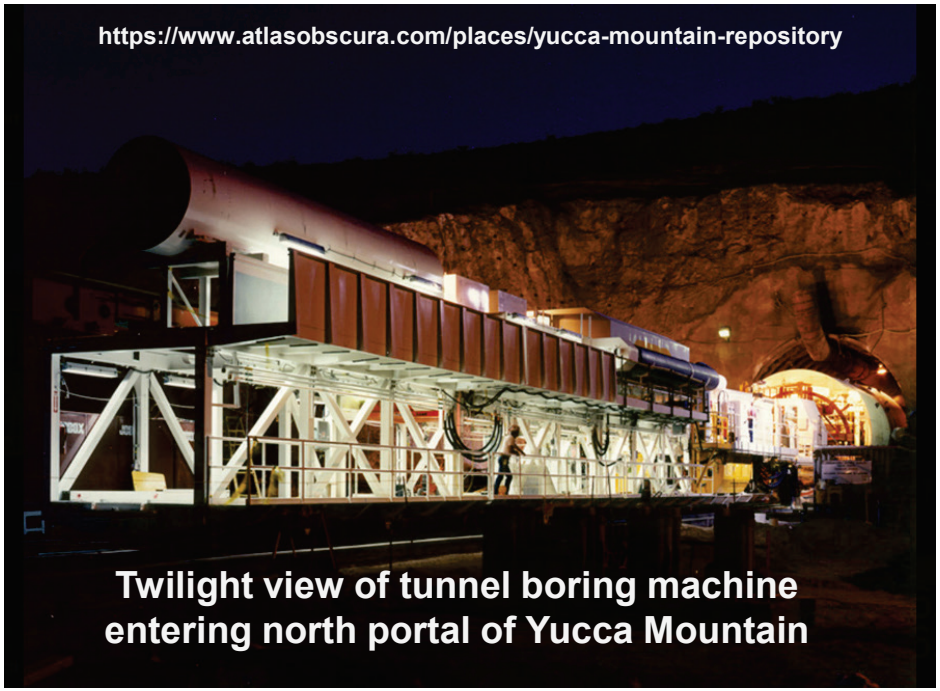
Class Web Site: http://www.atmos.umd.edu/~rjs/class/honr229L

ELMS Page: https://myelms.umd.edu/courses/1269254



22 October 2019

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AT 14, Q1. Hydroelectricity is currently the world's most used renewable energy source for electricity.

a)what was the percentage share of hydroelectricity for world electricity production in 2005?

b)what percentage of the overall potential of world hydroelectricity was being tapped in 2005?

c)if the world's governments decided to fully exploit the available potential to generate electricity via hydroelectric plants, approximately how much of the world electricity demand could be met?

a) 16% or 17%, depending on whether using the text or a figure as basis for answer

b) 18%

c) **18 / 100 = 17 / x**

18 x = (17 * 100)

x = (17*100)/18 = 94% **if you had answered 17% to a)**

- OR -

x = (16*100)/18 = 89% **if you had answered 16% to a)**

Some students wrote "about 100%", which is a perfectly fine answer.

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AT 14, Q2. What would be some of the criticisms, both socially and environmentally, to a decision by the world's governments to fully exploit the available potential to generate all needed electricity via hydroelectric plants?

- **Heavy upfront cost**
- **Relocates large populations**
- **Cultural impacts by altering marine environment**
- **Increases flood risk in plains around the dam**
- **Flooding destroys beautiful landscapes or treasured historical cities**
- **Decrease soil nutrient levels downstream, affecting fertile farmlands**
- **Accelerate erosion upstream**
- **Affects salmon migration**
- **Can lead to extinction of species**
- **Reduces biodiversity**
- **Degrades water quality**
- **In tropical regions, water can be a breeding ground for malaria-bearing mosquitoes and other water borne diseases**
- **Dams and artificial lakes can both release pollution into the nearby environment and trap soil nutrients, causing switch to harmful, artificial fertilizers**

It is estimated that hydrological changes due to dams have affected how many people, world-wide, during the past six decades:

a) 4 to 8 million
b) 20 to 40 million
c) 40 to 80 million
d) 400 to 800 million: roughly 10% of humanity

https://www.internationalrivers.org/human-impacts-of-dams

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Hydroelectric Dam Threatens to Wipe Out World's Rarest Ape

A hydroelectric plant and dam, already in the works, could drive the newly identified Tapanuli orangutan to extinction.

BY **STEPHEN LEAHY** PUBLISHED AUGUST 9, 2018

THE WORLD'S RAREST great ape, discovered only in 2017, will not survive the building of a $1.6 billion hydroelectric power plant and dam in the middle of its remaining habitat in Sumatra, Indonesia, wildlife experts warn.

Only 800 of the newly identified Tapanuli orangutans remain in the wild, all in northern Sumatra's Batang Toru Forest. It's one of the most biodiverse spots in Indonesia, home to such rare species as Sumatran tigers and the critically endangered Sunda pangolin.

In this same area, forest clearing has already begun for the hydro project, which is being financed and built by state-controlled Chinese companies under China's Belt and Road. This multi-trillion-dollar initiative involves more than 7,000 infrastructure projects around the world.

Sumatra's Tapanuli orangutan is a new species of great ape that was identified in 2017. Just 800 of these extremely wary tree-dwelling apes remain in the wild, and a hydroelectric power plant and dam are being built in their remaining habitat.

https://www.internationalrivers.org/human-impacts-of-dams

https://www.theatlantic.com/international/archive/2017/10/china-belt-and-road/542667

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AT 14, Q3.

a) What gas constitutes 90% of the effluent of a geothermal plant?

b) What is the ratio of the release of this gas from a geothermal plant compared to the amount generated by a typical fossil fuel power station?

c) What can be done about the release of this gas to the atmosphere from geothermal plants?

d) Are you surprised to learn about this nuance of geothermal plants?

a) CO_2

b) Release of CO_2 from fossil fuel plants is between 3 and 10 times greater than CO_2 emissions from geothermal plants.

c) New technologies can capture some of the CO_2 and convert it to other chemicals including methanol.

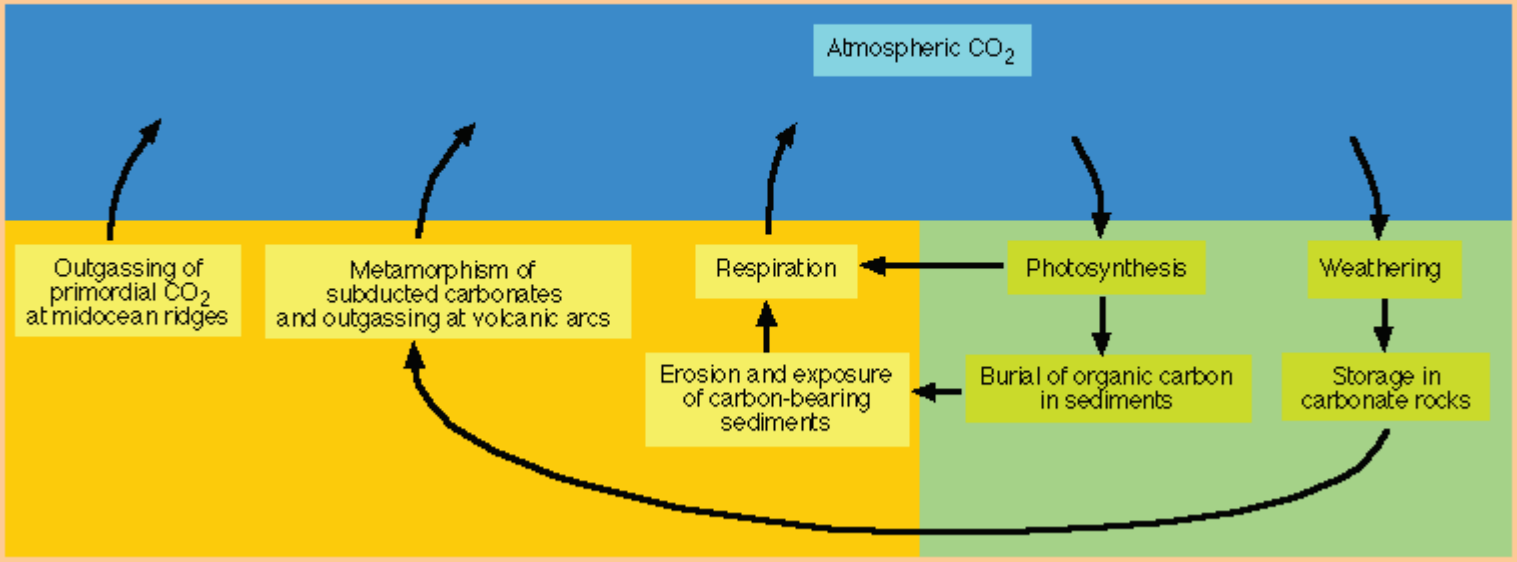
d) I was surprised to read that geothermal plants produced such large quantities of CO_2 (although less than fossil fuel plants) and that there were methods to capture and recycle the CO_2. I didn't think this type of technology existed yet, but I'm glad we have a starting point that can hopefully be improved upon/ made more efficient.

Metamorphism of Carbonate Rocks

Some of the carbon in limestone is converted to CO_2 by reaction with silica (SiO_2), particularly in places where continental plates collide.

The CO_2 can be returned to the atmosphere by volcanic outgassing or release of gases via the deep earth geothermal energy.

$$CaCO_3 + SiO_2 \rightarrow CO_2 + CaSiO_3$$



http://www.columbia.edu/~vjd1/carbon.htm

Volcanic Release of CO_2

The best estimate of contemporary release of atmospheric CO_2 by volcanoes and deep sea vents reveals release of about 0.26 Gt of atmospheric CO_2 per year (Marty and Tolstikhin 1998), less than 1 % of the human burden. Interestingly and with touching irony for those who refuse to accept the human influence on global warming, the volcanic release of CO_2 during the 9 h explosive phase of Mt. Pinatubo on 15 June 1991 likely matched the total, global release of CO_2 by humans ***on that day*** (Gerlach 2011). More than 20,000 days have passed since the start of modern measurements of atmospheric CO_2. On one day and one day only, global human release of atmospheric CO_2 was likely matched by a volcano. Human release of CO_2 has dwarfed volcanic release on the other 19,999 days.

Paris Climate Agreement: Beacon of Hope
Chapter 1: Earth's Climate System
https://link.springer.com/book/10.1007/978-3-319-46939-3

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AT 14, Q4. According to Olah et al. electricity from wind is the fastest-growing energy source in the world.

a) What is the ratio of installed wind capacity at the end of 2007 compared to 1992, and where has most of this growth occurred?

b) According to the reading, what are some of the challenges that must be overcome if the world is to more fully realize the promising future for electricity generation via wind?

a) Factor of 36 rise, with much of the growth occurring in Europe

b)

- **Intermittency**
- **Connection to the grid from remote locations**
- **Cost of offshore installation**
- **Need lots of land, so that turbines don't interfere with each other**
- **Visual impact**
- **Noise**
- **Bird fatalities**
- **Small changes in wind speed/ air flow results in large changes in energy generation so investigations of areas have to proceed before installation.**

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AT 14, Q5a. Write a short essay about the situation involving wind energy in Scotland

Scotland has one of the most successful wind energy programs in the world. Specifically, from January to June of 2019, Scotland produced more than double the amount of electricity that it needed during that span from wind power alone. This electricity can be utilized to power much of England as well if things keep going the way they're going. Also during this time, Scotland went the longest it has ever gone without coal power since the Industrial Revolution (only a week but nonetheless very impressive).

In Scotland, one of the larges wind farms was constructed of the coast of Wick in which 84 windmills are used to generate enough electricity to power 450,000 homes. Scotland was able to accomplish this construction ahead of schedule and 100 million pounds under budget.

Scotland is also combining the use of algae with wind farms so that *excess energy* from the turbines is not wasted and is used to *power photo-bioreactors to grow algae that can feed farmed salmon* (a nutritional food source).

Note: One of the wind farms mentioned in the BBC article (*Gwynt y Mor*) is in my mum's hometown in Wales and you *can see it from my grandparent's kitchen window*

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AT 14, Q5a. Write a short essay about the situation involving wind energy in Maryland.

Maryland's Eastern Seaboard wind efforts have a history of being beset with *delays* and *political conflict*, but in July of 2019, the project finally got off the ground. Funding for this project was first approved by Maryland's General Assembly in 2013 appropriated a $1.7 billion dollar subsidy for an offshore windfarm. Since then, two companies have been approved to build wind turbines - Orsted and U.S. Wind. Orsted will lease land from Tradepoint Atlantic at the historic Sparrows Point on which it is expected to spend $13.2 million to develop wind turbine assembly infrastructure. Despite pushback from U.S. Rep. Andrew P. Harris based on concerns of a unfavorable view from Ocean City, the project generally received support and is expected to create 1,400 jobs in the region. Officials hope that Orsted's Sparrows Point production facility will become a hub for Atlantic turbine assembly and will spur the region's economic growth for many years to come.

Nuclear Power: Waste

U.S.

- 1997: Federal Government Designated Yucca Mountain, Nevada (not far from Las Vegas) as sole site for long-term, high level nuclear waste storage
- Nevada opposed
- 2002: Senate gave final approval for Yucca Mountain Site based on EPA 10,000 year radiation compliance assessment
- 2004: U.S. Appellate Court ruled compliance must address N.A.S. study that peak radiation could be experienced 300,000 yrs after site had been filled and sealed
- 2009: EPA published in Federal Register a final rule, increasing compliance period to **1,000,000** years
- 2011: Obama administration stopped financial support for Yucca, after $54 billion has been invested for capacity of 70,000 tons of spent fuel plus 8000 tons of military waste
- 2019: Trump Admin has $116 million budget request to process DOE license to open Yucca site. Bills moving through House & Senate that would open Yucca as a permanent waste repository

https://www.cbsnews.com/news/in-nevada-trump-administration-revives-a-radioactive-campaign-issue

https://www.reviewjournal.com/news/politics-and-government/nevada/nevada-braces-for-renewed-fight-over-yucca-storing-nuclear-waste-1656701

Members of a congressional tour make their way through the north portal of Yucca Mountain near Mercury on Saturday, July 14, 2018.

Chase Stevens Las Vegas Review-Journal

Nuclear Power: Waste

By Gary Martin Las Vegas Review-Journal

September 26, 2019 - 5:22 pm

WASHINGTON — A House subcommittee passed a bill Thursday that would authorize preparation of Yucca Mountain in Nevada to store nuclear waste, although the House and Senate have not included funds in spending bills.

The House Energy and Commerce subcommittee on environment and climate change passed a bill that would allow the Department of Energy to undertake "infrastructure activities" for operation of Yucca Mountain as a radioactive waste repository.

Chairman Frank Pallone, D-N.J., said communities "across the country are expressing frustration" as nuclear power plants close and there are no permanent or interim facilities to store spent fuel.

The bill, sponsored by Rep. Jerry McNerney, D-Calif., and Rep. John Shimkus, R-Ill., now goes to the full committee and then the House floor for a vote.

The legislation faces an uphill battle.

Funding proposed by the Trump administration to continue the licensing process needed for a construction permit for Yucca Mountain was stripped from a House appropriations bill this year.

Nevada's entire congressional delegation has opposed funding for the project.

https://www.reviewjournal.com/news/politics-and-government/house-subcommittee-approves-yucca-mountain-bill-1857820/

Nuclear Power: Waste

By Gary Martin Las Vegas Review-Journal

September 26, 2019 - 5:22 pm

A Senate spending bill also does not include the funds for the licensing process, which are needed to move the project forward.

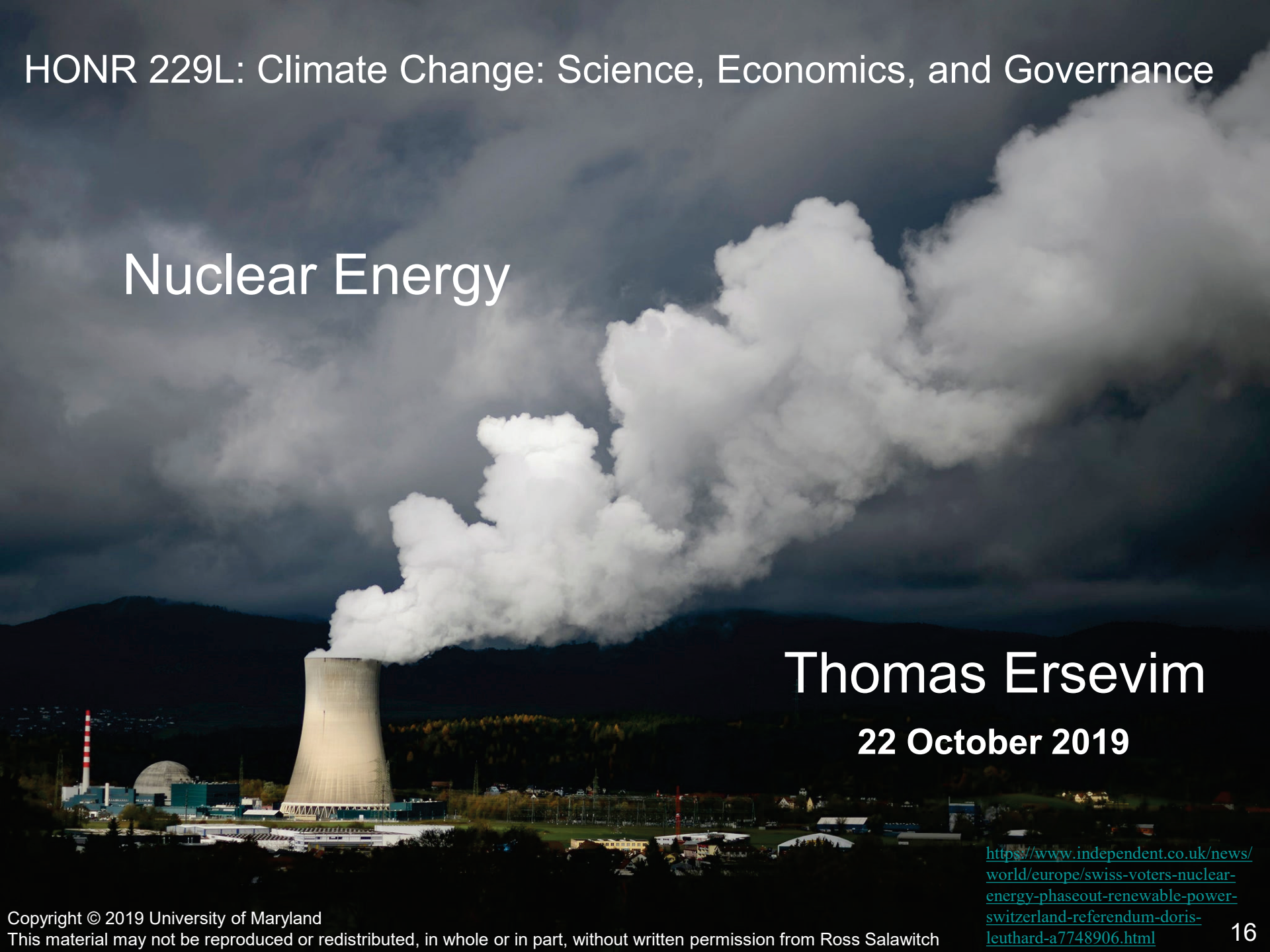
Yucca Mountain was designated in 1987 by Congress as the sole site for nuclear waste storage produced by power plants. Political opposition and research has delayed the project for three decades.

The licensing process was halted in 2011 when the Obama administration and Congress cut funding for hearings needed to settle challenges filed by stakeholders. The state of Nevada currently has more than 200 challenges to the project.

Although the project is favored by Nye County, where Yucca Mountain is located, and several rural counties, the state of Nevada, tribal leaders, conservation groups and business leaders oppose transporting and storing nuclear waste just 90 miles northwest of Las Vegas.

https://www.reviewjournal.com/news/politics-and-government/house-subcommittee-approves-yucca-mountain-bill-1857820/

Nuclear Energy

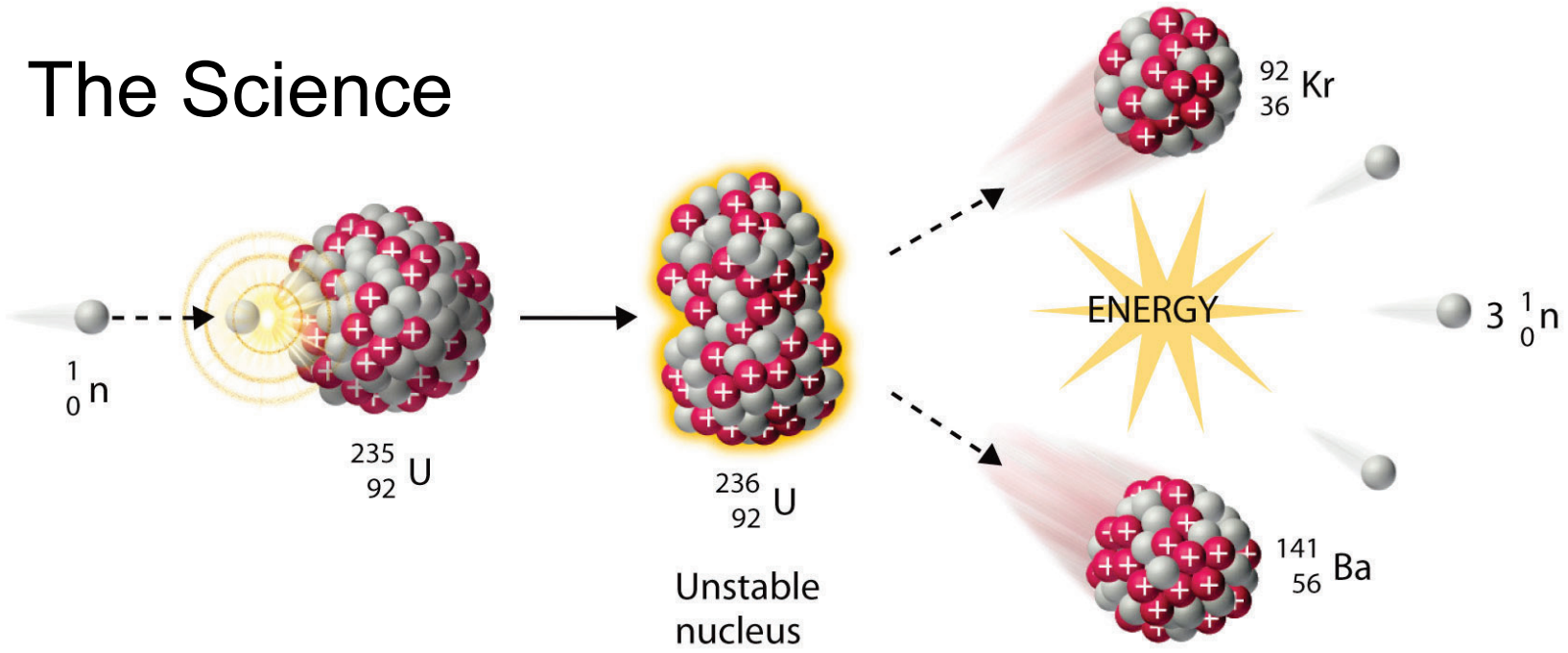


Thomas Ersevim

22 October 2019

https://www.independent.co.uk/news/world/europe/swiss-voters-nuclear-energy-phaseout-renewable-power-switzerland-referendum-doris-leuthard-a7748906.html

The Science



https://www.zmescience.com/science/difference-fusion-fission/

Table 8.2 Energy content of various fuels.

Source: Nuclear Energy Agency (Nuclear Energy Today, Nuclear Energy Agency, OECD publications, Paris 2003, Available from: http://www.nea.fr/html/pub/nuclearenergytoday/welcome.html).

Fuel	Average energy content in 1 g (kcal)
Wood	3.5
Coal	7
Oil	10
LNG	11
Uranium (LWR, once through)	150000

$$E = mc^2$$

Nuclear Power History

- Use of nuclear power developed by military; currently around 150 ships, globally
  - allowed submarines to stay underwater for extended periods of time
  - 1954: *U.S.S. Nautilus*, first nuclear powered submarine
- 1956: first commercial nuclear power plant, U.K.
- 1957: first U.S. commercial nuclear power plant, Shippingport, Pa

Operational 18 Dec 1957 to 1 Oct 1982 for 80,324 hours

http://www.phmc.state.pa.us/portal/communities/pa-heritage/atoms-for-peace-pennsylvania.html

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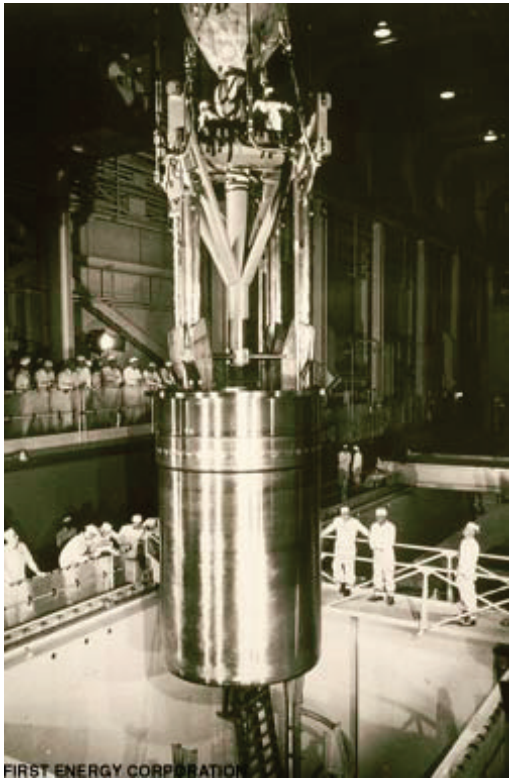
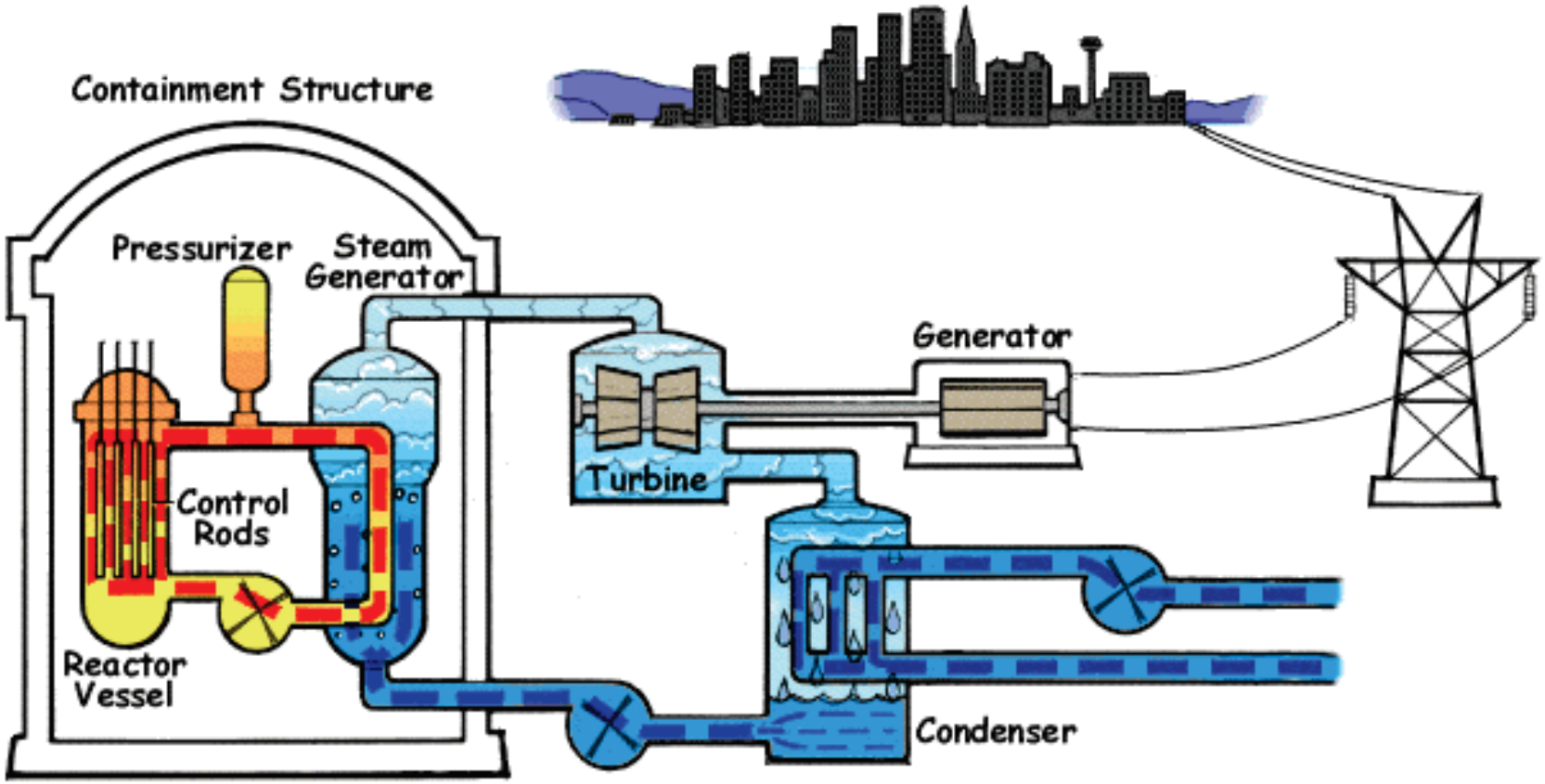


Operational 18 Dec 1957 to 1 Oct 1982 for 80,324 hours

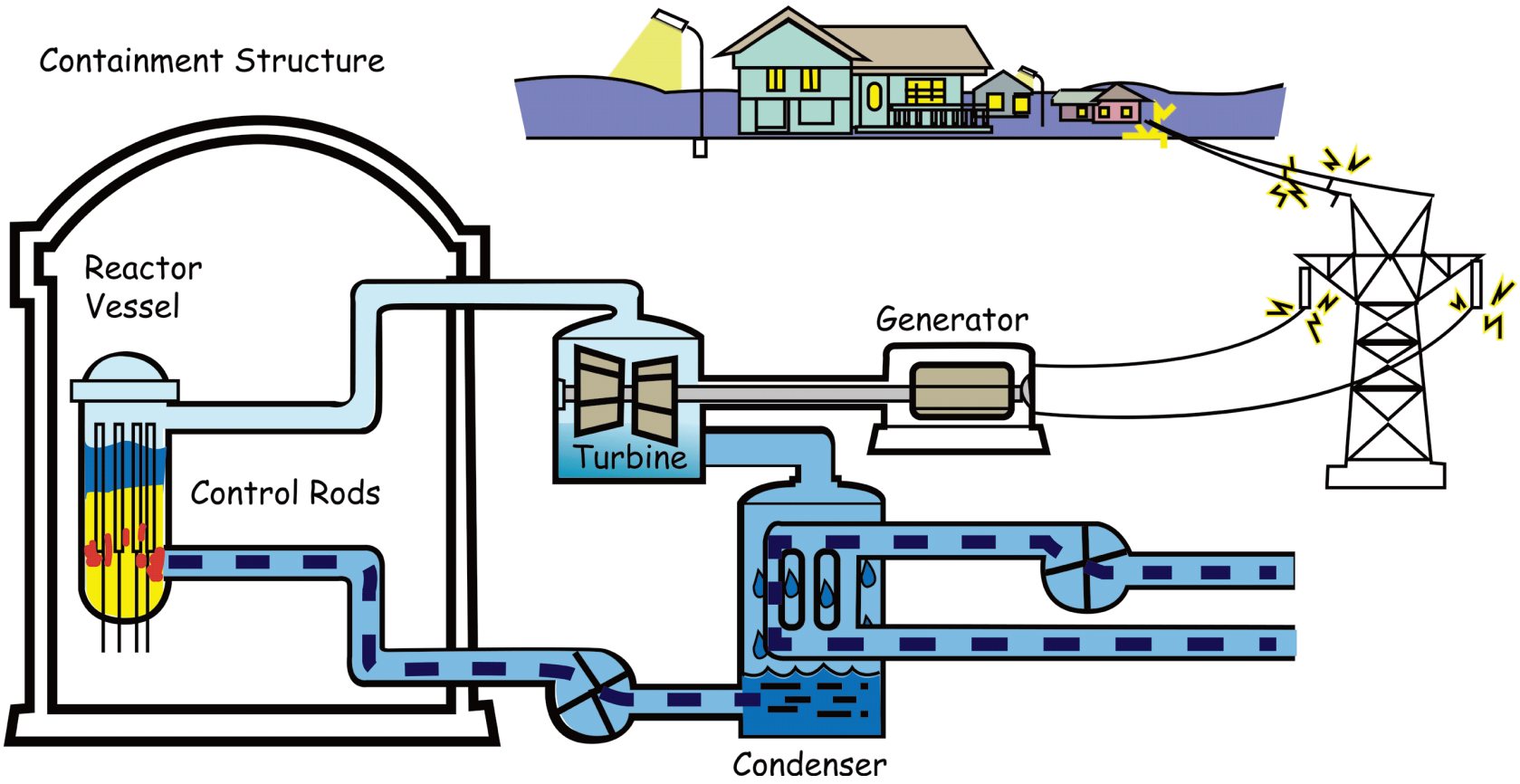
http://www.phmc.state.pa.us/portal/communities/pa-heritage/atoms-for-peace-pennsylvania.html

Pressurized Water Reactor (PWR)



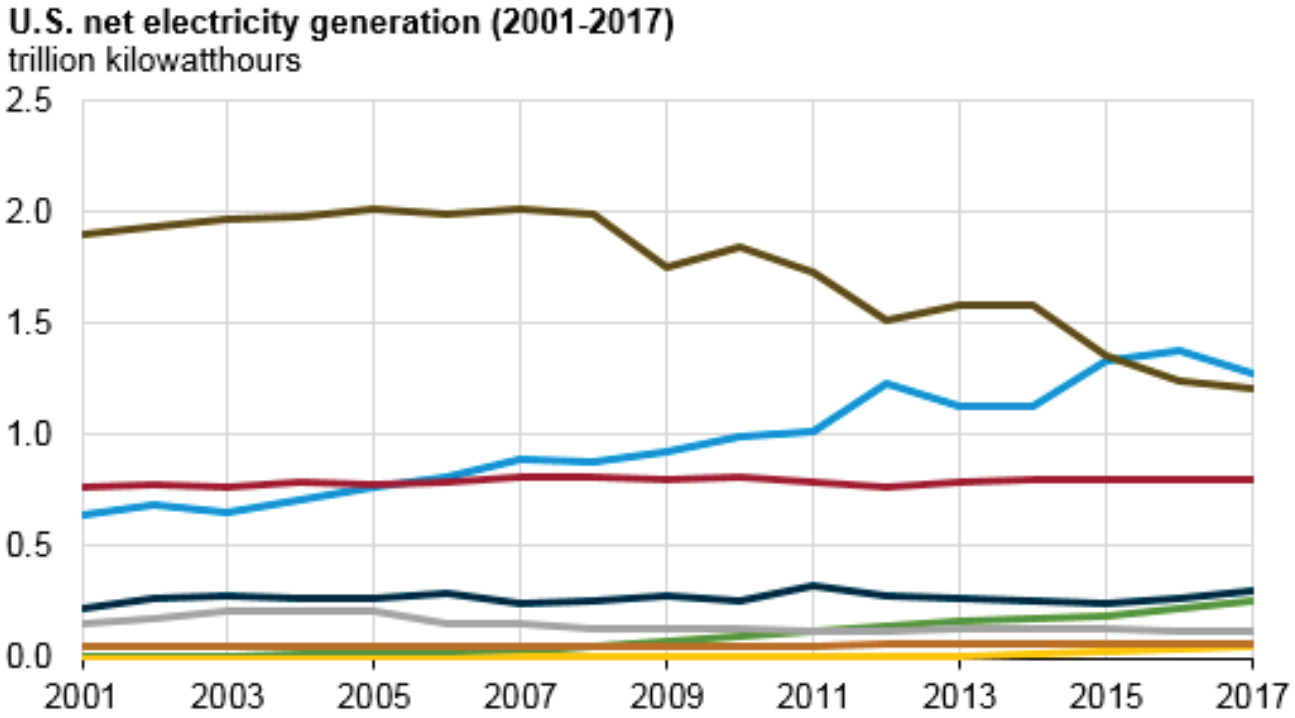
https://www.nrc.gov/reading-rm/basic-ref/students/animated-pwr.html

Boiling Water Reactor (BWR)



https://www.nrc.gov/reading-rm/basic-ref/students/animated-pwr.html

U.S. Electricity Production: All Sources



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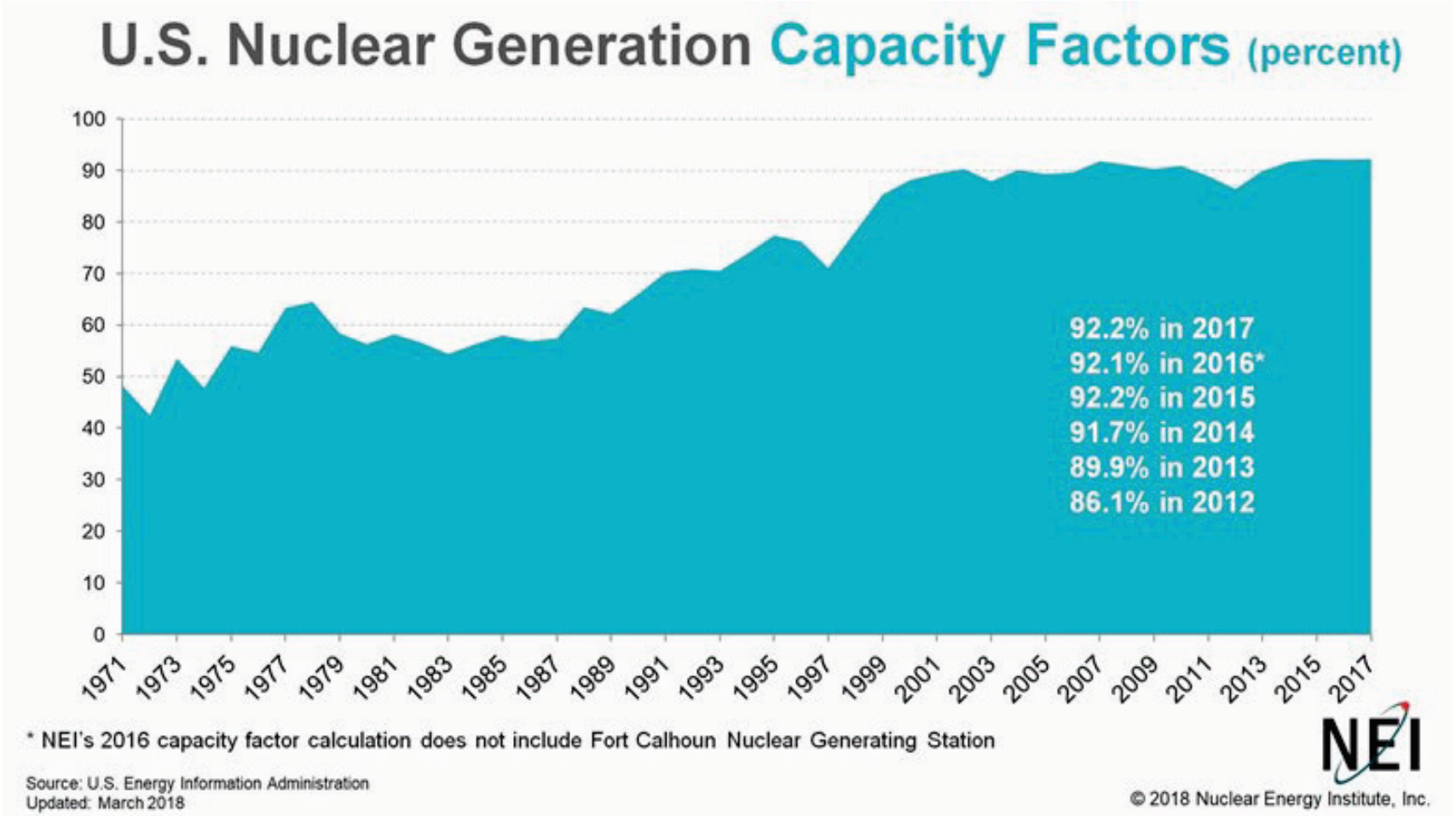
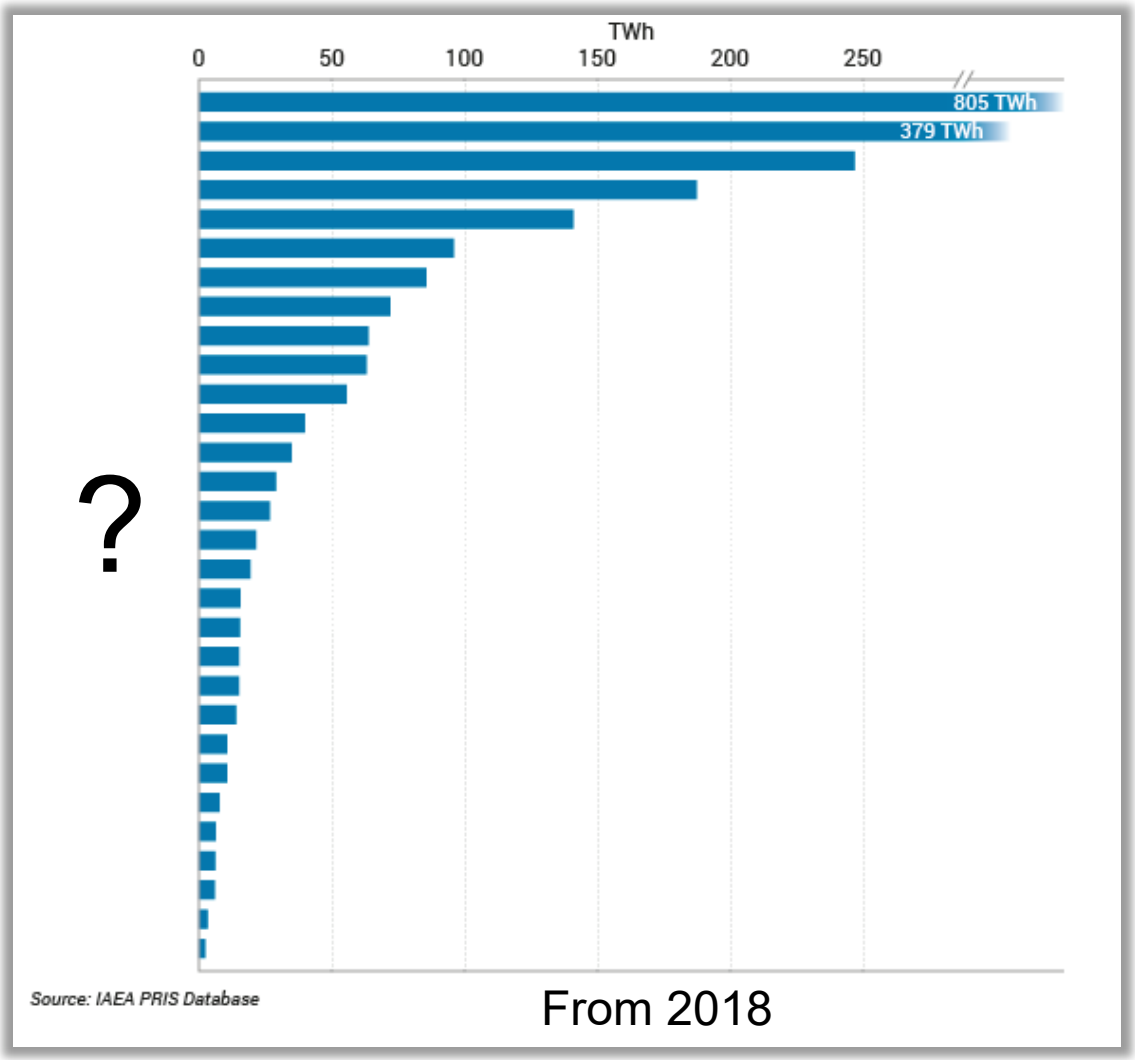
https://blogs.scientificamerican.com/plugged-in/u-s-electricity-natural-gas-and-coal-fall-as-renewables-continue-to-rise/

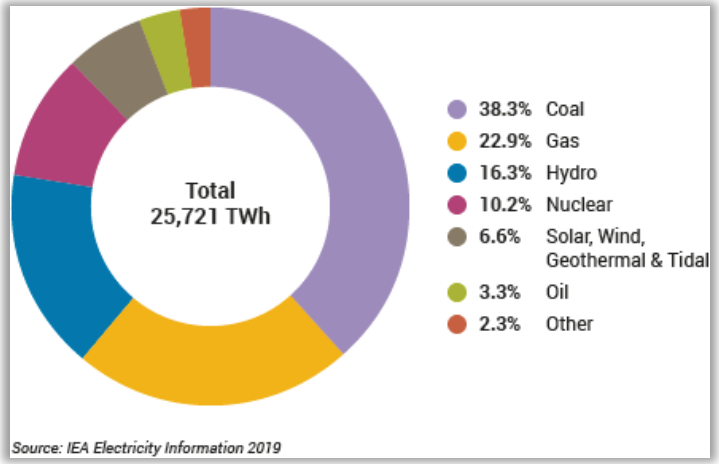
U.S. Electricity Production: Nuclear



https://www.nei.org/resources/statistics/us-nuclear-industry-capacity-factors

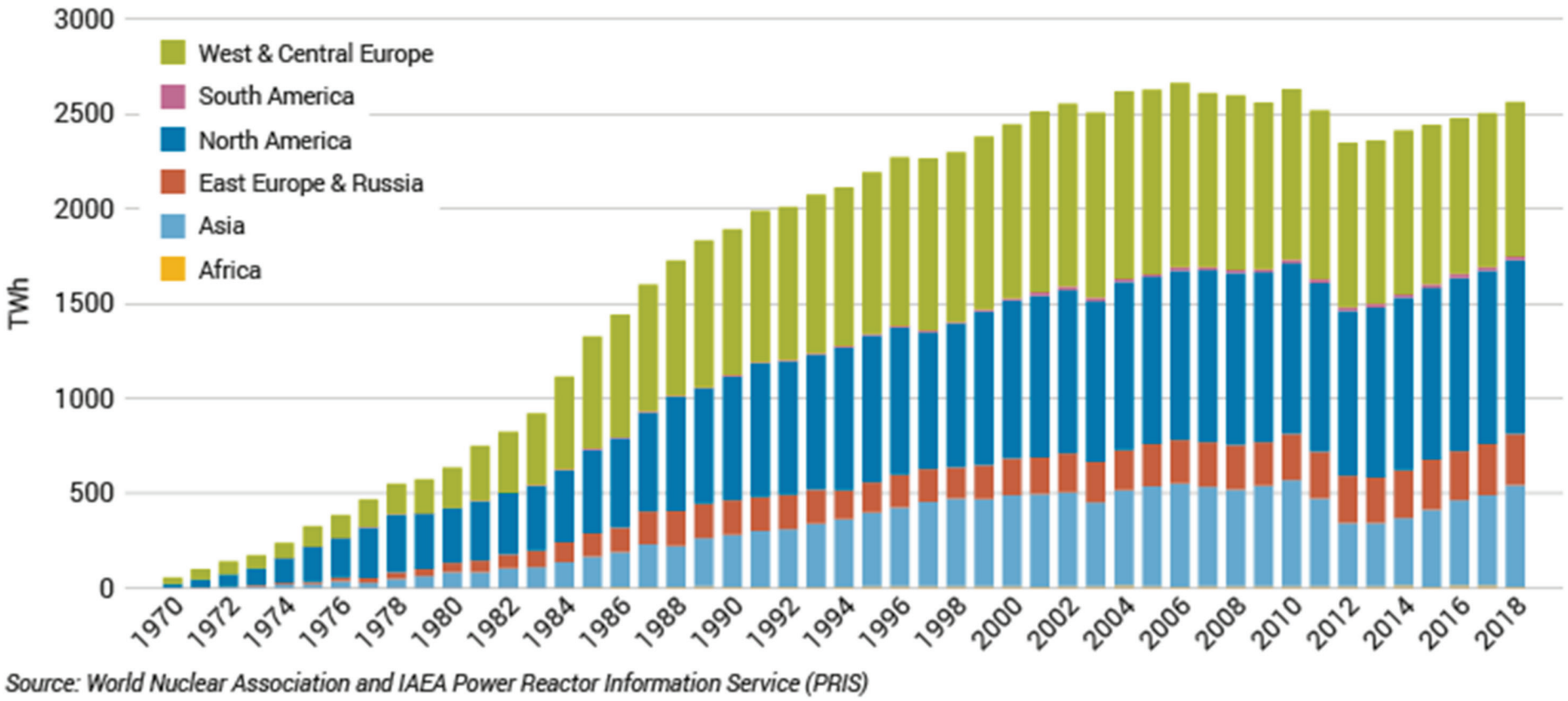
Global Electricity Production: Nuclear





https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

Global Electricity Production: Nuclear

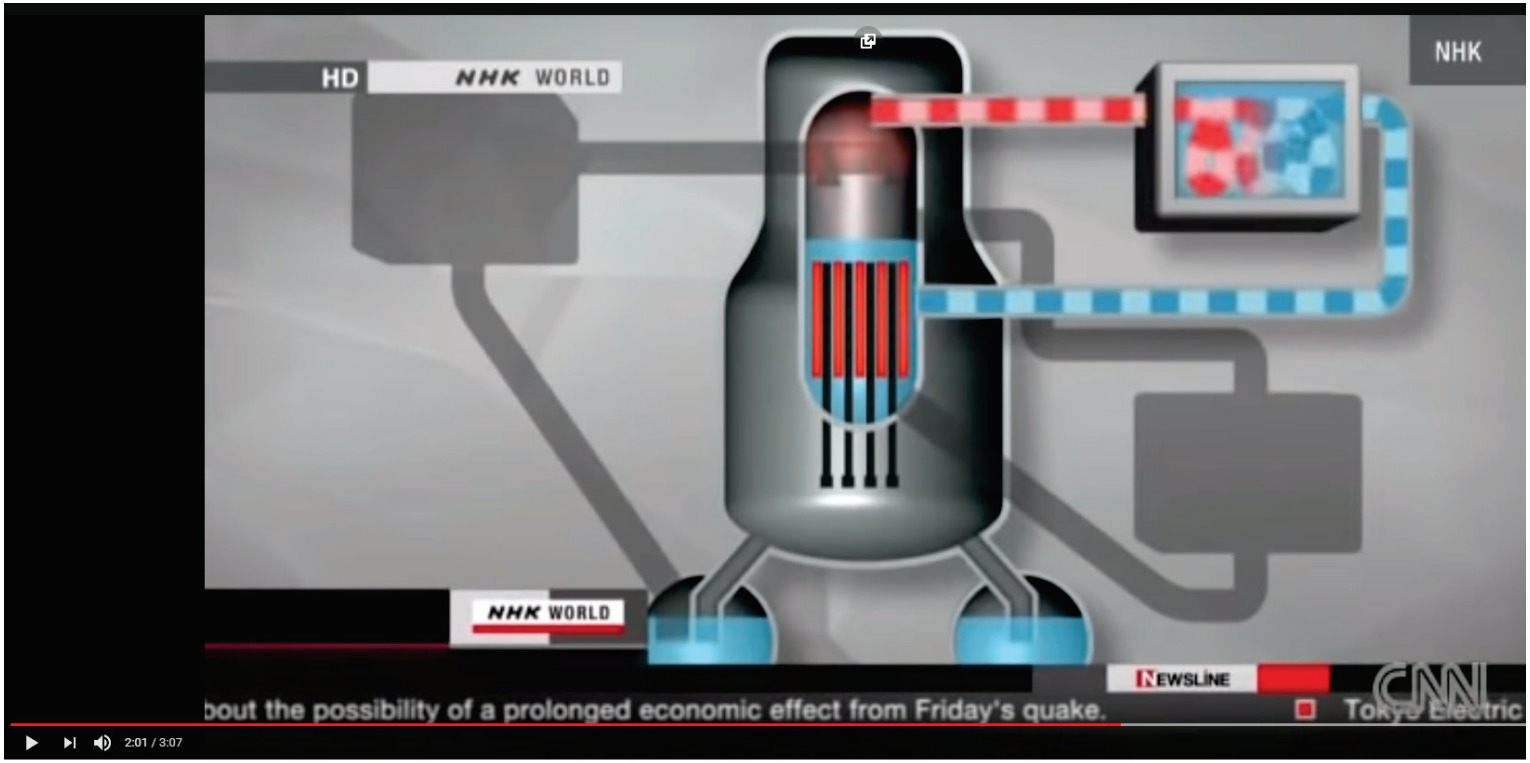


https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

Nuclear Power: Fukushima

Fukushima

- 11 March 2011, Earthquake off the coast. Reactors undamaged – go into containment isolation
- Diesel generators power emergency cooling systems
- Reactors designed to withstand 6.5 meter tsunami – reactor complex hit by 14 meter tsunami
- Cooling system powered by electricity
- Loss of electricity power led to pressure build up, coolant turned to steam, fuel rods exposed to air; and began to burn

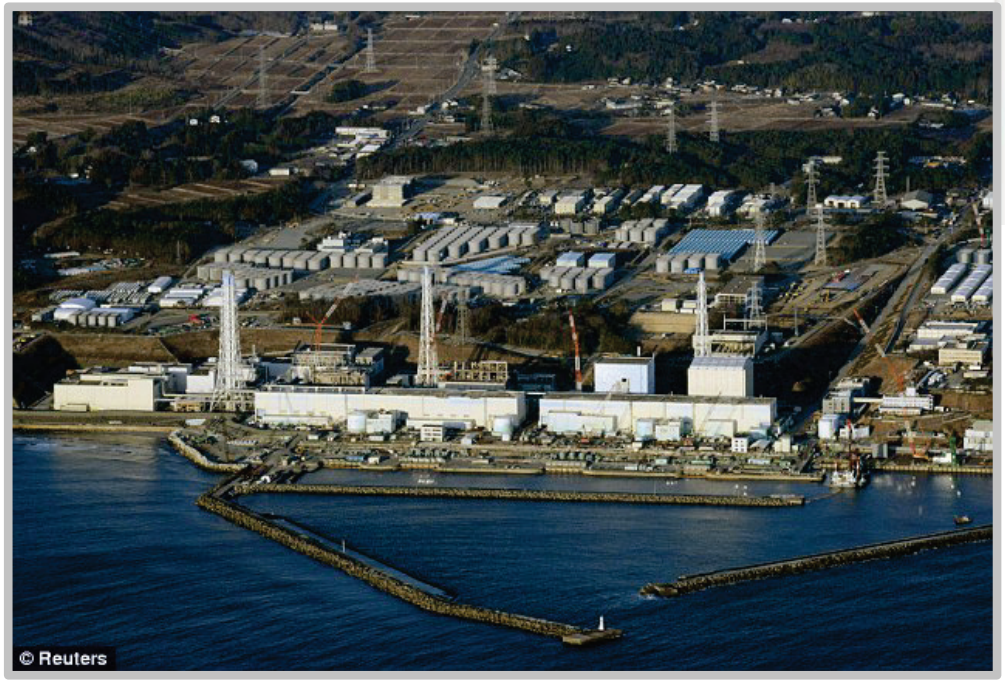


https://www.youtube.com/watch?v=BdbitRIbLDc

Fukushima: Could this have been avoided?

- Diesel generators were located in basement
- Fuel located in above ground, external fuel tanks
- Tsunami flooded generators, wiped out fuel tanks

If generators had been on upper level of the building and fuel buried or kept at a higher elevation, we wouldn't be having this discussion!!!



The red box shows location of the destroyed back-up fuel tanks.

http://www.forbes.com/sites/bruceupbin/2011/03/16/idiotic-placement-of-back-up-power-doomed-fukushima
See also https://www.washingtonpost.com/world/new-report-blasts-japans-preparation-for-response-to-fukushima-disaster/2012/07/05/gJQAN1OEPW_story.html

Could another Fukushima happen?

National Geographic, 23 March 2011

For a world on the brink of a major expansion in nuclear power, a key question raised by the Fukushima disaster is would new reactors have fared better in the power outage that triggered dangerous overheating?

The answer seems to be: Not necessarily.

The nuclear industry has developed reactors that rely on so-called "passive safety" systems that could address the events that occurred in Japan: loss of power to pump water crucial to cooling radioactive fuel and spent fuel

But these so-called Generation III designs are being deployed in only four of the 65 plants under construction worldwide. (Four reactors that are in the site-preparation phase and still awaiting regulatory approval in Georgia and South Carolina in the United States would make that eight of 69 plants.)

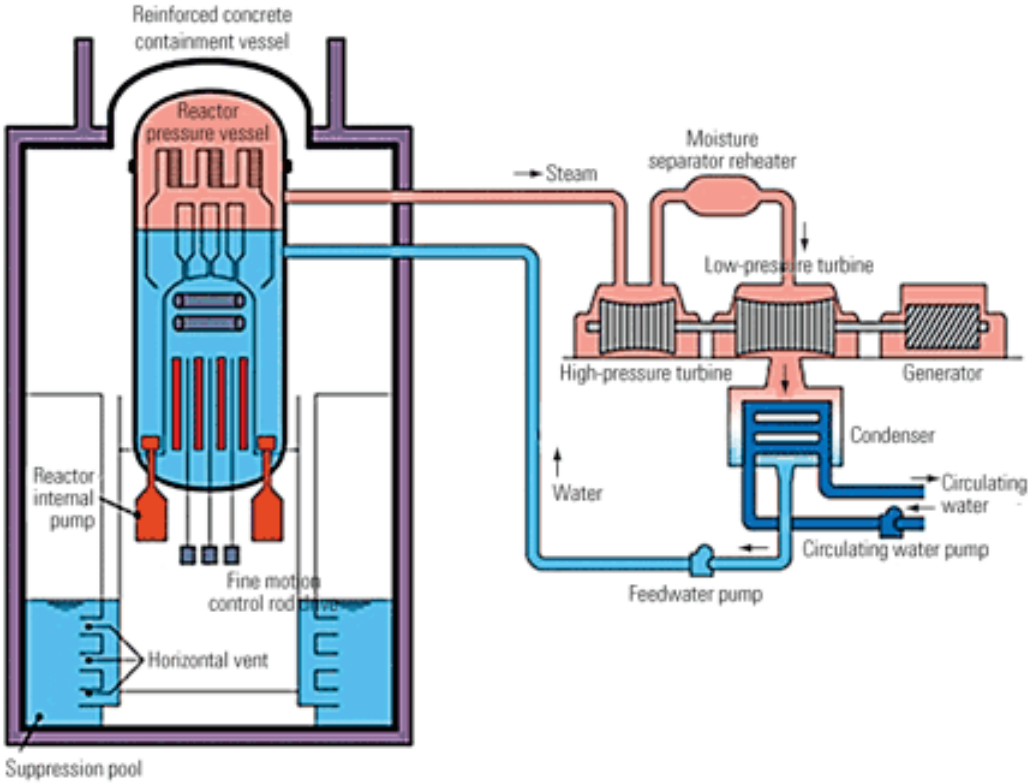
The vast majority of plants under construction around the world, 47 in all, are considered **Generation II reactor** designs—the same 1970s vintage as Fukushima Daiichi, and **without integrated passive safety systems**.

At the San Onofre Nuclear Station on the Southern California coast, modifications have been made that allow the operators to use a gravity-driven system to circulate the water to cool the plant for a period of time upon loss of power … But there are limits to such retrofits. "This is a huge volume of water," says Adrian Heymer, executive director of strategic programs for the NEI. "What happens to that tank in an earthquake?“

That's why there's been an effort to integrate a fully passive system from the get-go of the design process, he said. There is no ready reference list of which plants around the world have been modified with gravity-driven or other safety features. And as for new nuclear plants with integrated passive safety systems, deployment is slow.

http://news.nationalgeographic.com/news/energy/2011/03/110323-fukushima-japan-new-nuclear-plant-design/

Generation III



- Standard design – cheaper and quicker to build and license
- Simpler, rugged design easier to operate and less prone to accidents
- Redundant safety features
- Longer operational lifetime
- Includes many **passive safety features** that decrease likelihood of meltdown

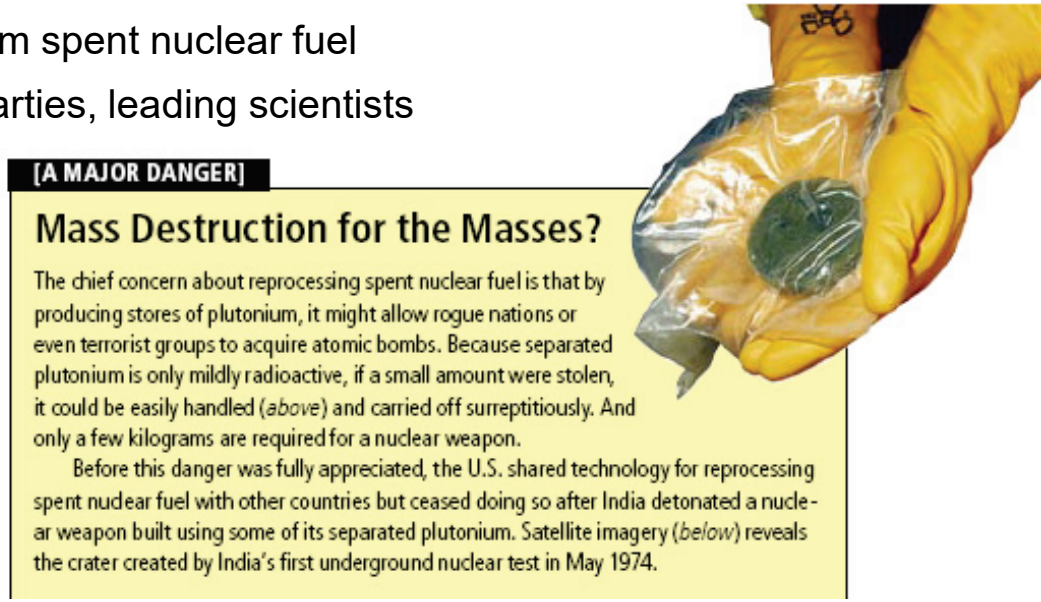
http://editors.eol.org/eoearth/wiki/Nuclear_power_(About_the_EoE)

https://www.youtube.com/watch?v=rvxVCl2rZnU

Generation IV

- Initiated by DOE in 1999
- Focusing on "fast spectrum" reactors that cool using sodium
- Fast spectrum refers to use of "fast neutrons", which convert ^{238}U to ^{239}Pu
- Operate at atmospheric pressure but ~1000°C
- Lower pressure reduces risk of explosion
- Liquid sodium cooled
- ***But***: sodium + water would generate lots of energy (fire!!!) ->safety concerns focused on prevention of this chemical reaction!
- Can recover more than 99% of energy from spent nuclear fuel
- Supported by members of both political parties, leading scientists
- Plutonium would be separated in process

Good News: resulting waste would only have to be managed for ~500 years!
Bad News: presently, plutonium is mixed with nasty, shorter lived radionuclids. If plutonium is isolated, it literally can be handled using gloves



[A MAJOR DANGER]

Mass Destruction for the Masses?

The chief concern about reprocessing spent nuclear fuel is that by producing stores of plutonium, it might allow rogue nations or even terrorist groups to acquire atomic bombs. Because separated plutonium is only mildly radioactive, if a small amount were stolen, it could be easily handled (*above*) and carried off surreptitiously. And only a few kilograms are required for a nuclear weapon.

Before this danger was fully appreciated, the U.S. shared technology for reprocessing spent nuclear fuel with other countries but ceased doing so after India detonated a nuclear weapon built using some of its separated plutonium. Satellite imagery (*below*) reveals the crater created by India's first underground nuclear test in May 1974.

von Hippel, *Scientific American*, May 2008.

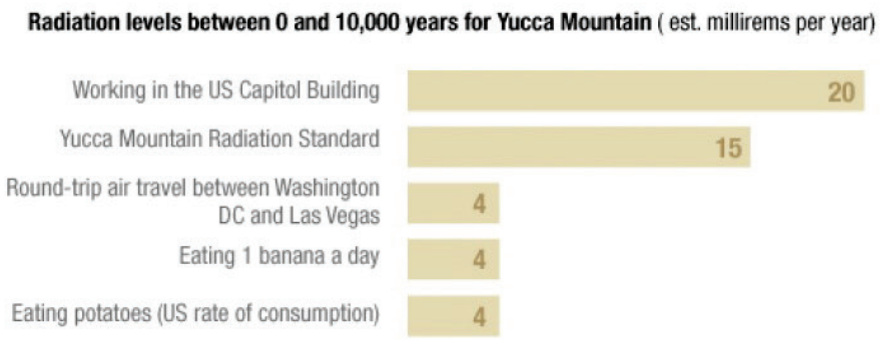
http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/generation-iv-nuclear-reactors.aspx

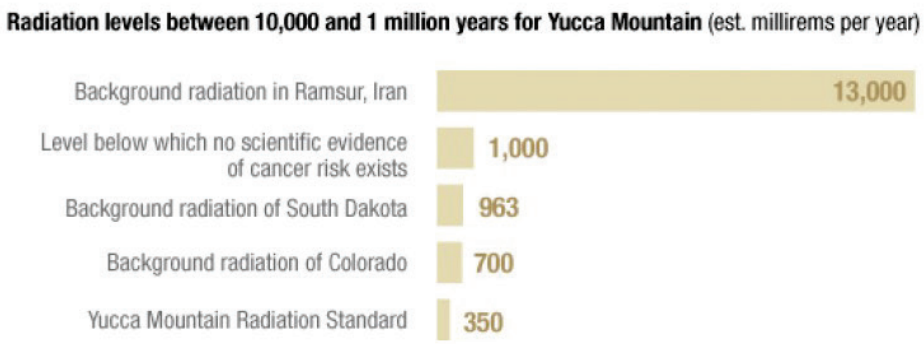
Long Term Storage: Yucca Mountain

Table 8.5 Half-life (years) of some radioactive elements.

Source: Nuclear Energy Agency (Nuclear Energy Today, Nuclear Energy Agency, OECD publications, Paris 2003, Available from: http://www.nea.fr/html/pub/nuclearenergytoday/welcome.xhtml).

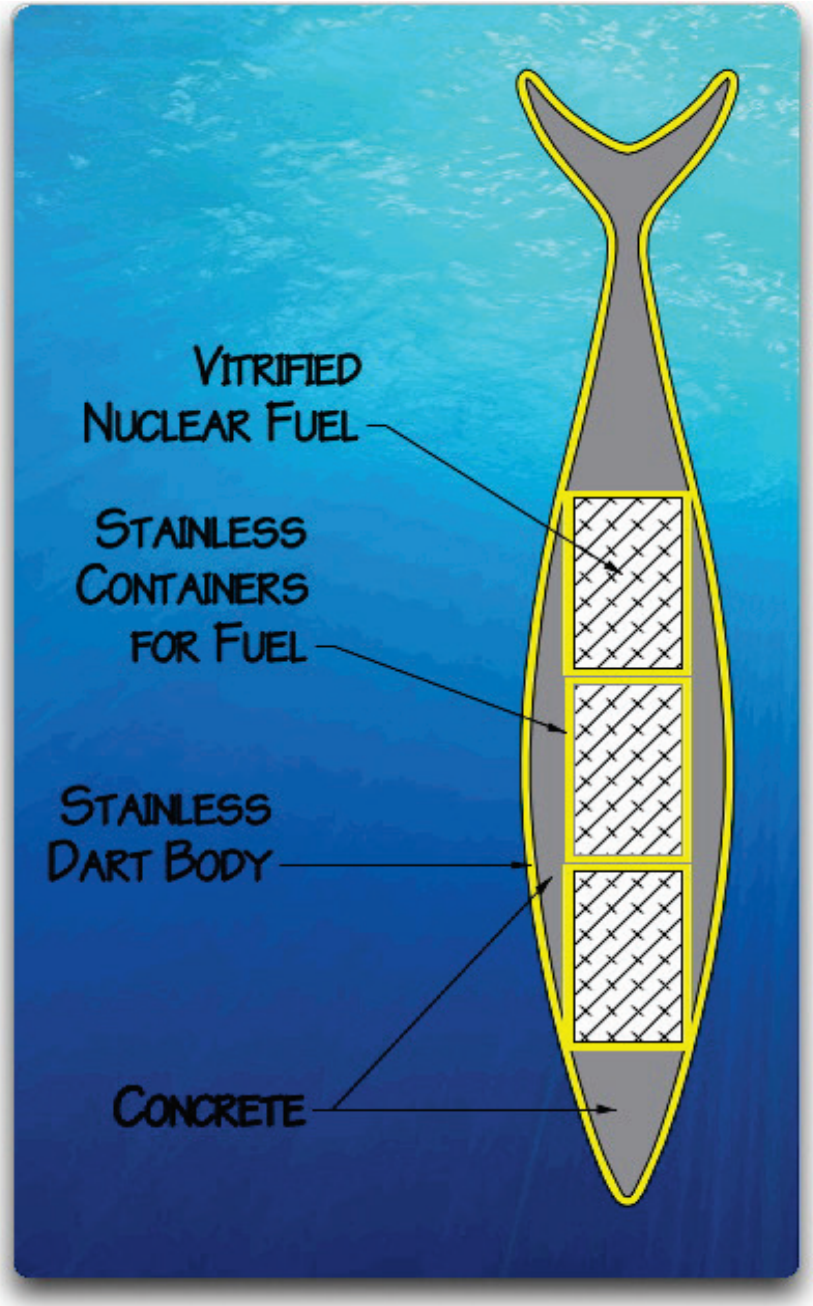
Uranium-238	4470000000
Uranium-235	704000000
Neptunium-23 7	210000
Plutonium-239	24000
Americium-243	7400
Carbon-14	5730
Radium-226	1600
Caesium-137	30
Strontium-90	29
Cobalt-60	5.3
Phosphorus-30	2.55 min

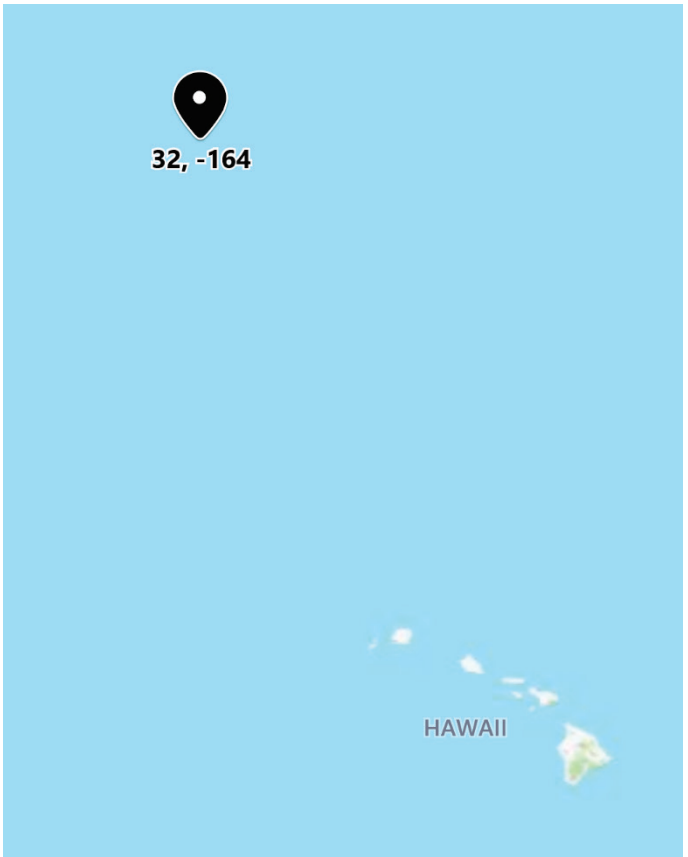




https://www.tunneltalk.com/Nuclear-waste-management-Jun11-Yucca-Mountain-fate.php
https://thumbnails-visually.netdna-ssl.com/yucca-mountain-the-nuclear-waste-repository_50290ccd5431c_w1500.jpg

Long Term Storage: Subseabed Storage





https://nucleotidings.com/?q=article/radioactive-waste-9-ocean-floor-disposal

Nuclear Safety

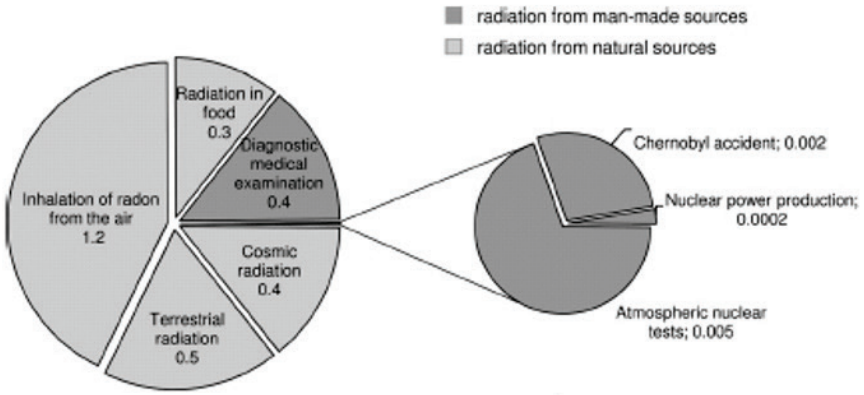
Chance of developing cancer from radiation: 0.05% per 10 mSv (1 in 10,000)

Table 8.4 Radiation exposure from different activities.

Source: UNSCEAR, NEI and R. Morris, The Environmental Casefor Nuclear Power. Economical, Medical and Political Considerations, 2000 [184].

Activity	Exposure (mSv year [n])
Natural background radiation	2.4
Working at a nuclear power plant	1.15
One diagnostic X-ray	0.2
Living in a stone, brick or concrete building	0.07
One round-trip flight Paris–New York	0.05
Living at the gate of a nuclear power plant	0.03
Watching television	0.015
Luminous wrist watch	0.0006
Coal fired power plant, average within 80km	0.0003
Average radiation from nuclear power production	0.0002
Smoke detector	0.00008

Figure 8.22 Average radiation dose to the public (in $mSvyear^{-1}$). (Based on data from UNSCEAR, Sources and effects of ionizing radiation (New York, 2000).)



https://pubs.acs.org/doi/pdf/10.1021/es3051197

WHICH ENERGY SOURCE IS THE SAFEST?

Energy use is a necessity in the modern economy, but the practices of extracting and using energy also create a deadly trade-off.

NUCLEAR IS SAFEST

Even including Chernobyl and Fukushima incidents, nuclear is the safest power source per TWh.

A BRIGHT FUTURE

There are still some deaths attributable to renewables such as accidents and via lifecycle analysis, but they are among the safest forms of energy on earth.

WATER DAMAGE

Hydro is normally very safe, but it has one extreme outlier that skews the data.

In 1975, the Banqiao Dam in China collapsed during a typhoon, killing 171,000 people.

BLACK DEATH

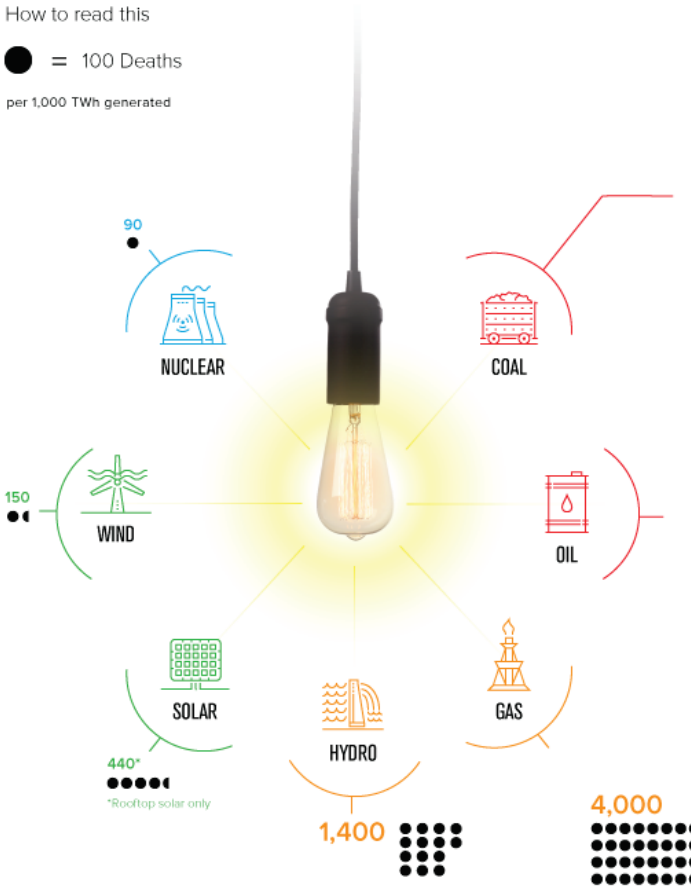
When the human and environmental costs of coal are added up, it's the biggest killer of any energy source by far.

Air pollution alone in China kills over **4,400** people per day.

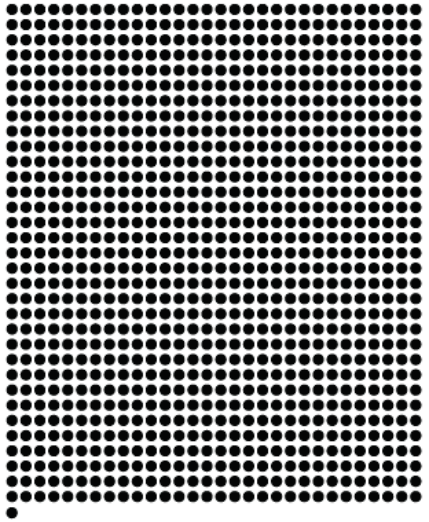
How to read this

● = 100 Deaths

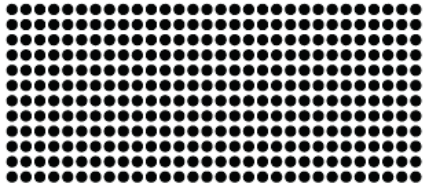
per 1,000 TWh generated



100,000



36,000



Source: Forbes

INTERNATIONAL MINING INVESTMENT CONFERENCE
May 15-16, 2018
Vancouver Convention Centre East

CAMBRIDGEHOUSE INTERNATIONAL | VISUAL CAPITALIST

https://www.visualcapitalist.com/worlds-safest-source-energy/

Debate!

Should spending on nuclear power production be dramatically increased to counter the growing climate crisis?

No! Anti-Nuclear!

3 Major Points:

Yes! Pro-Nuclear!

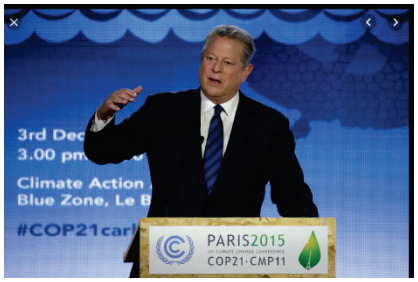
3 Major Points:

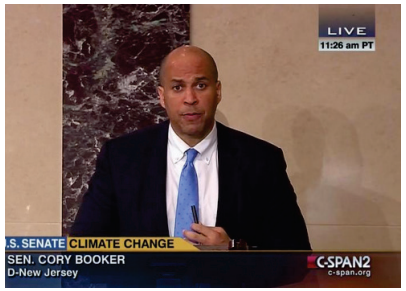
Reading for Thursday

An essay on the virtues of Capitalism, written by Yuval Noah Harai

10/24	The Capitalist Creed	Harari: Chapter 16 (32 pages) Movie Clip 1 Movie Clip 2	AT 16	Samuel R. Template	Discussion 16 Video	WSJ Opinion Piece Musk, Gore, India, & Trump Before The Flood

Movie Clip 1: Sunita Narain





Movie Clip 2: Al Gore & Cory Booker

Can I see Sam, Nyah, and Amanda after class