

HOW MANY BANANAS IS A TRANS-ATLANTIC FLIGHT : WHY NUCLEAR POWER WON'T KILL YOU

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Physics Department at UB
Professional atom smasher

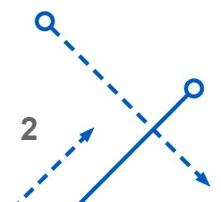
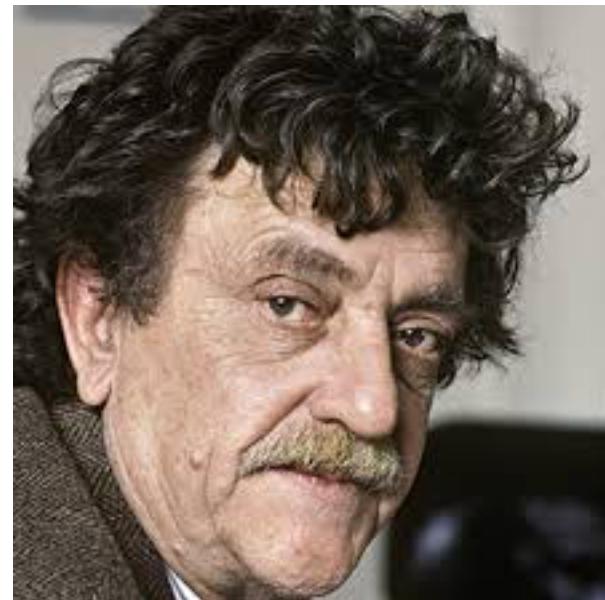
My policy statement is here:

<http://www.acsu.buffalo.edu/~srrappoc/NuclearPower.html>



[Humans] have now all but destroyed this once salubrious planet as a life-support system in fewer than 200 years, mainly by making thermodynamic whoopee with fossil fuels.

— Kurt Vonnegut



IPPC Statement

The report finds that limiting global warming to 1.5°C would require “rapid and far-reaching” transitions in land, energy, industry, buildings, transport, and cities. Global net human-caused emissions of carbon dioxide (CO₂) would need to fall by about

45 percent from 2010 levels by 2030, reaching ‘net zero’ around 2050. This means that any remaining emissions would need to be balanced by removing CO₂ from the air.

We need to do SOMETHING

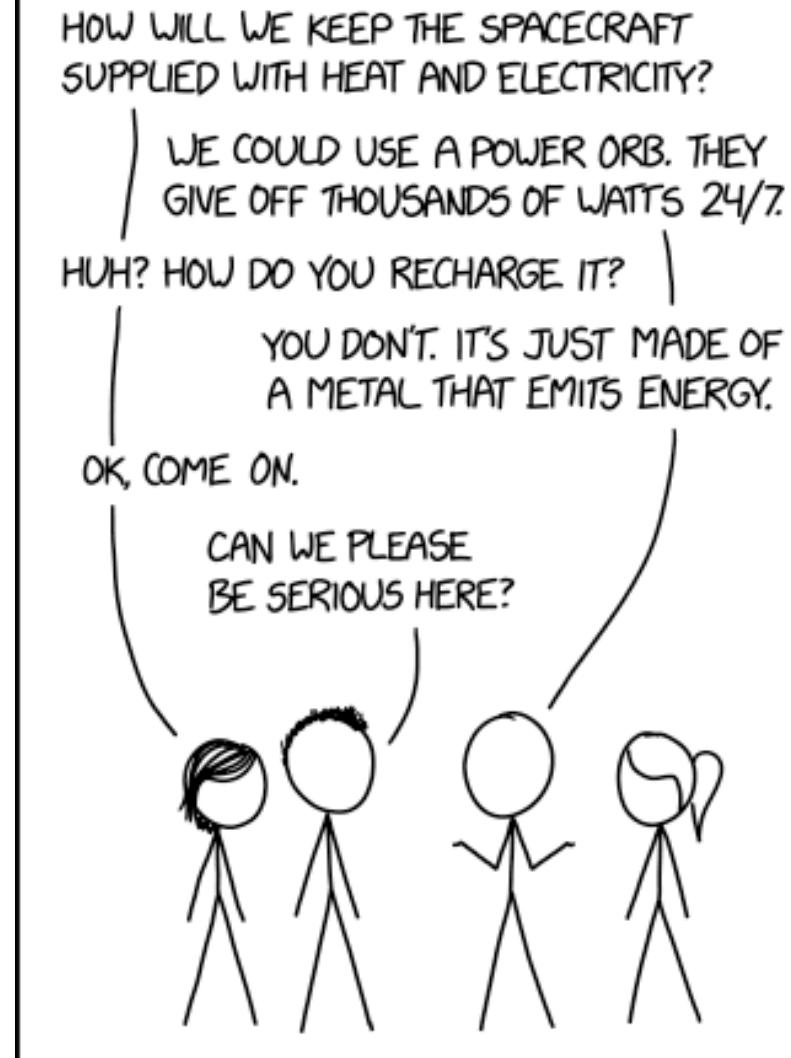
[http://www.ipcc.ch/
news_and_events/
pr_181008_P48_spm.shtml](http://www.ipcc.ch/news_and_events/pr_181008_P48_spm.shtml)

How to stop making thermodynamic whoopee: The Green New Deal

- The most serious plan any politician currently has. 😊
- It probably won't work without nuclear power. 😕



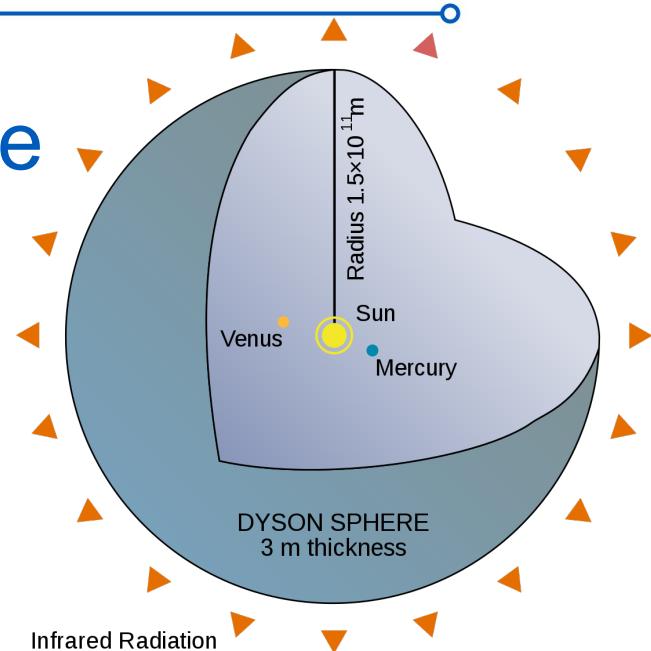
Why?
Because nuclear power
is like magic.



FOR SOMETHING THAT'S REAL,
PLUTONIUM IS SO UNREALISTIC.

Challenges facing energy storage

- No problem with electricity generation
-



We get 174,000 times as much energy as we use here on earth

Challenges facing energy storage

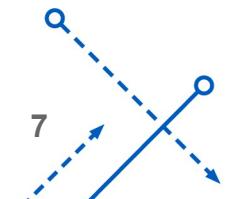
- No problem with electricity generation
- Problem with energy STORAGE
 - Store <1% of energy produced in the grid

US Stored energy / day: 8280000000000 J
US use / day: 1000000000000000000 J

Every joule of energy you use needs to be produced instantaneously

https://www.eia.gov/energyexplained/?page=us_energy_home

<https://www.ucsusa.org/clean-energy/how-energy-storage-works#bf-toc-1>



https://en.wikipedia.org/wiki/Grid_energy_storage

Challenges facing energy storage

- No problem with electricity generation
- Problem with energy STORAGE
 - Store <1% of energy produced in the grid
- Options:
 - Mechanical
 - Chemical
 - Electromagnetic
 - Nuclear
-

Convert kinetic energy to potential energy, then release it

Examples:

Moving water uphill, letting it fall.

Moving heavy rocks uphill, letting them fall.

Gigantic windup toys.

Moving squirrels uphill, letting them fall.

https://en.wikipedia.org/wiki/Grid_energy_storage

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- These three are real ideas

This one isn't

Convert kinetic energy to potential energy, then release it

Examples:

- Moving water uphill, letting it fall.
- Moving heavy rocks uphill, letting them fall.
- Gigantic windup toys.
- Moving squirrels uphill, letting them fall.

https://en.wikipedia.org/wiki/Grid_energy_storage

Challenges facing energy storage

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 - Mechanical
 - **Chemical**
 - Electromagnetic
 - Nuclear
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Convert to chemical energy
(from kinetic or electric)

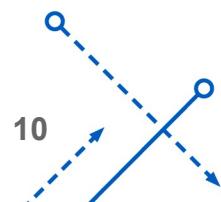
Current state of art:
Lithium ion batteries
(13.5 kW-hr, \$5.9k)

Other ideas: make hydrogen

Can supply
a suburban
family of 4
for ~8-12 hrs
(~overnight)

Still some way to go technologically

What about the equity of this solution?
We need #EnergyJusticeForAll, not just wealthy homeowners.



https://en.wikipedia.org/wiki/Grid_energy_storage

Challenges facing energy storage

- No problem with electricity generation
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 - Store <1% of energy produced in the grid
- Options:
 - Mechanical
 - Chemical
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Currently nothing deployed.

Options:

- Giant capacitors
- Giant electromagnets (superconducting?)

Extremely expensive.
Extremely dangerous.



Damage from superconducting magnet destroying steel at the LHC

https://en.wikipedia.org/wiki/Grid_energy_storage

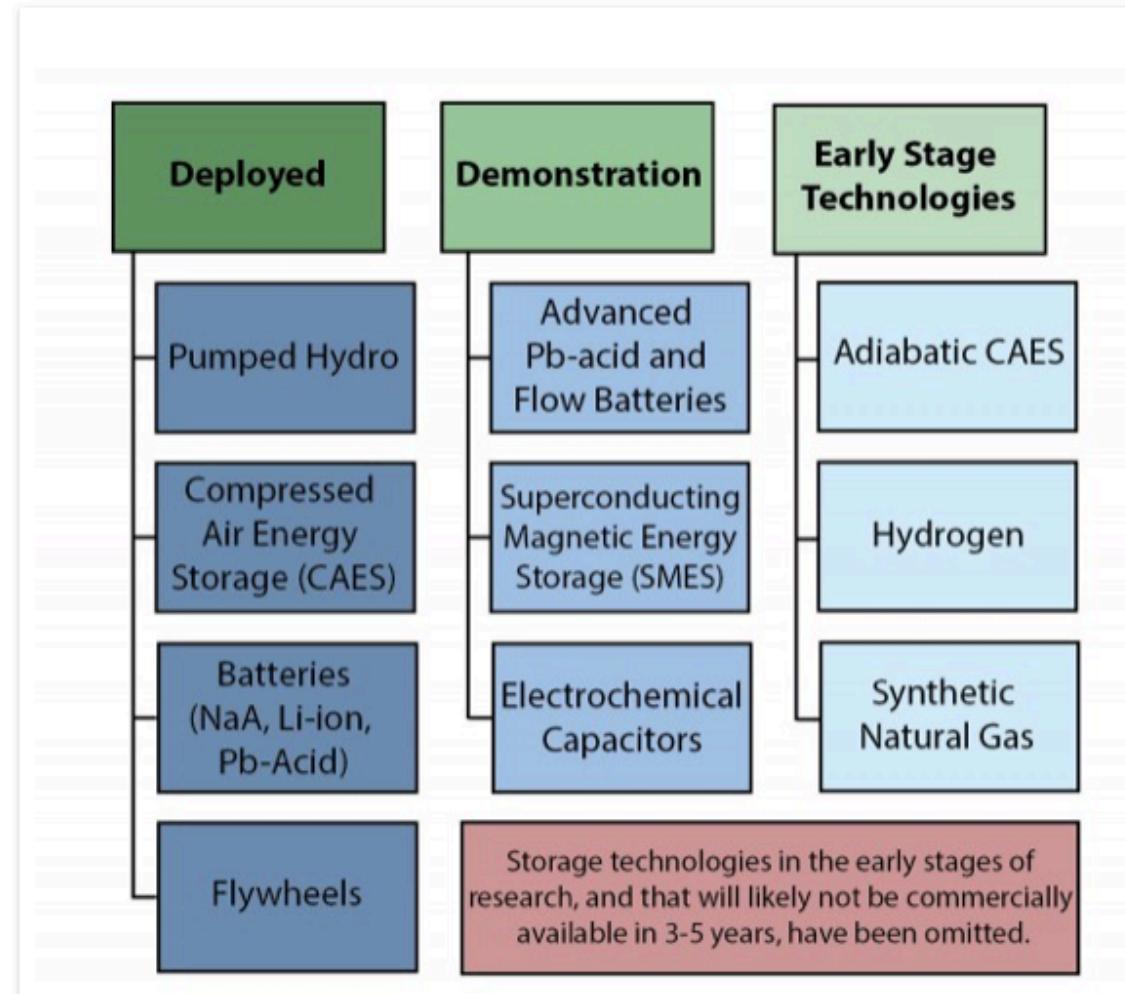
Challenges facing energy storage

- No problem with electricity generation
- Problem with energy STORAGE
 - Store <1% of energy produced in the grid
- Options:
 - Mechanical
 - Chemical
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Nuclear storage is
stupid, because
nuclear power
generation is like
magic.

<http://css.umich.edu/factsheets/us-grid-energy-storage-factsheet>

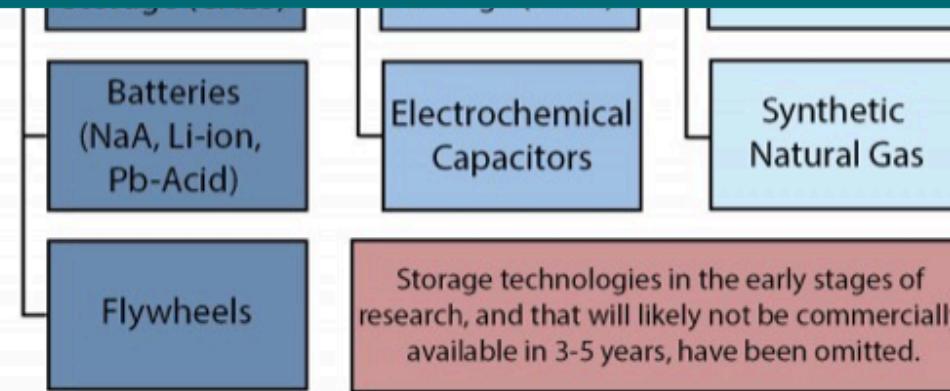
Challenges facing energy storage



<http://css.umich.edu/factsheets/us-grid-energy-storage-factsheet>

Ch

Energy storage isn't sufficient and is not going to solve the problem in 12 years



https://en.wikipedia.org/wiki/Capacity_factor

Quantify this: Capacity factor

$$C = \frac{\text{Actual energy output}}{\text{Total possible energy output}}$$

To solve climate change, we
need high-capacity solutions
deployable within 12 years



Capacity factor : how often can it run?

Source	Capacity factor (%)	
Nuclear	92.2	Almost always runs
Geothermal	76.4	Good idea! Requires large open space
Hydro	45.2	Not everyone lives near Niagara Falls
Wind	36.7	Wind doesn't always blow
Solar PV	27.0	
Solar CSP	21.8	
Biomass + wood	50.7	Plant, burn, capture: can REDUCE CO2
Landfill	70.9	Dumpster fire
Natural Gas (CC)	53.5	Thermodynamic whoopee
Petroleum Liquids	13.0	UUgggghhhh

Capacity factor : how often can it run?

Source	Capacity factor (%)	
Nuclear	92.2	Almost always runs
Geothermal	76.4	Good idea! Requires large open space
Hydroelectric	15.2	Falls
Petroleum Liquids	13.0	Bugggggnnnnn

But Chernobyl! But Fukushima!

[https://en.wikipedia.org/wiki/Chernobyl_\(miniseries\)](https://en.wikipedia.org/wiki/Chernobyl_(miniseries))

“the true story of one of
the worst man-made
catastrophes in history”



Godzilla will come from Chernobyl!



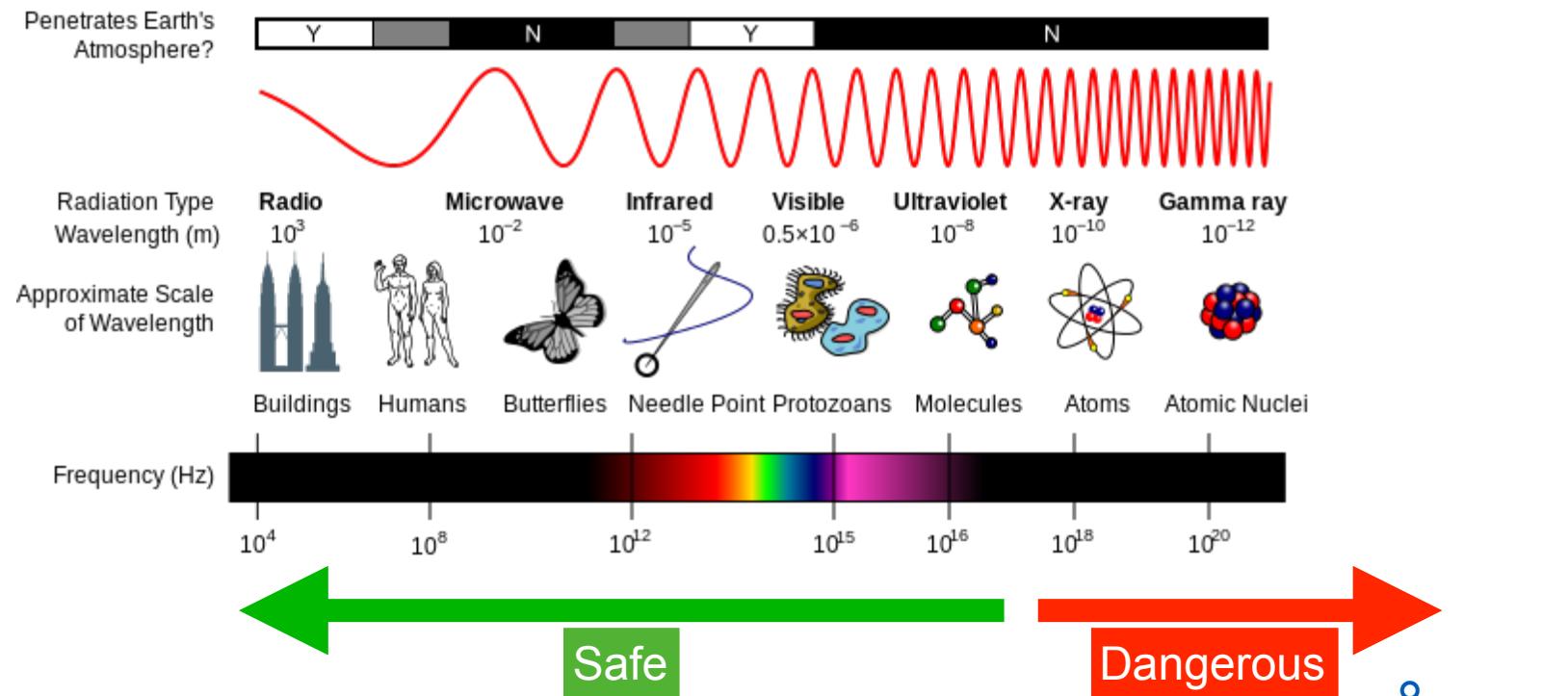
Nuclear Power versus Nuclear Weapons

Not Scary

Scary

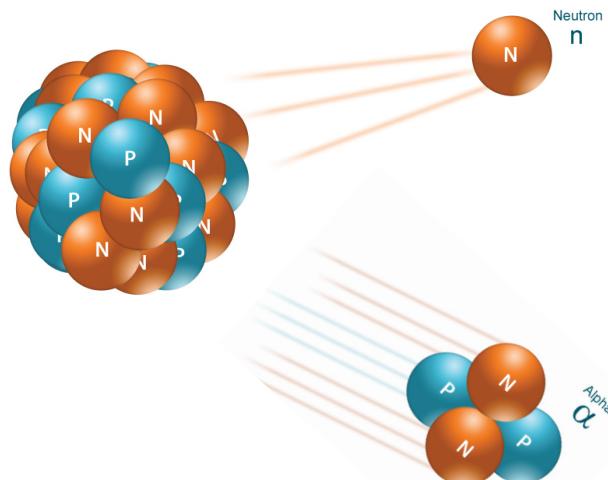
What is radiation?

- Particles moving through space
 - Example: Photons



What is radiation?

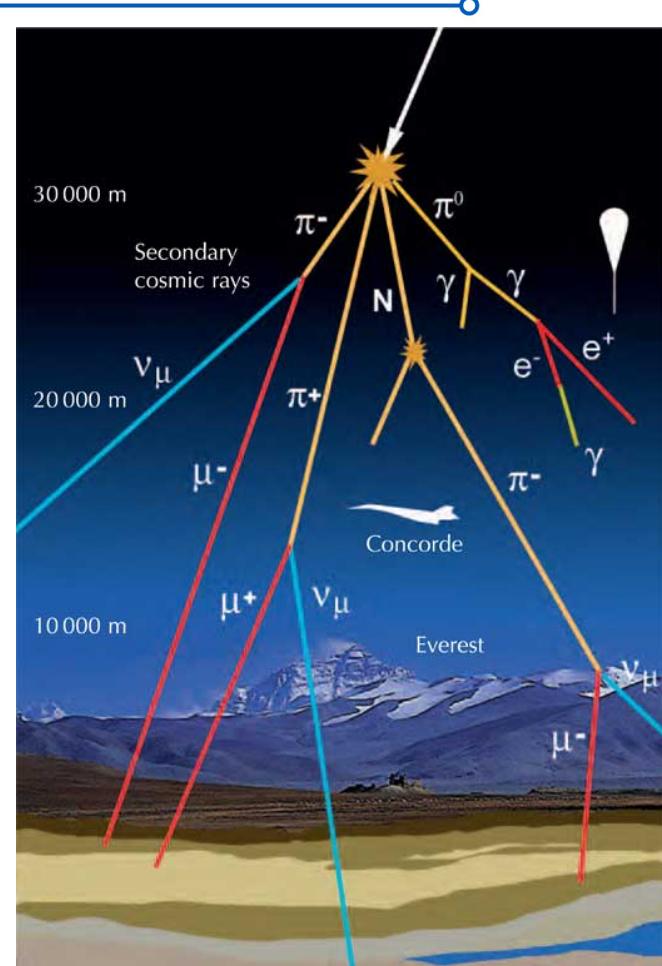
- Particles moving through space
 - Other types: Positrons (beta particles, like electrons). neutrons. helium nuclei (alpha)



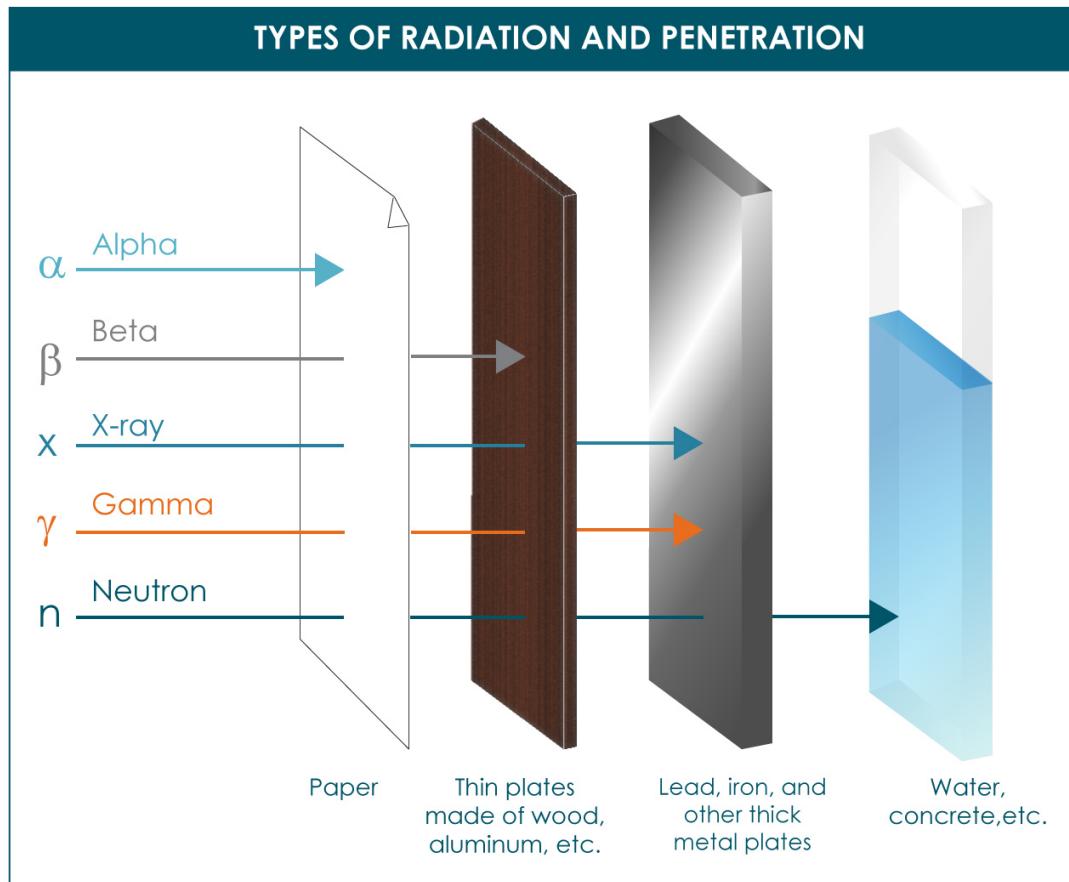
Nuclei emit particles via
radioactive decay
(from the weak interaction!)

What is radiation?

- Particles moving through space
 - Exotic types:
 - Muons (heavy electrons)
 - Pions (like a proton/neutron)
 - Neutrinos
 - Dark matter (yep, 4x more abundant than normal matter)



Protection: distance and shielding



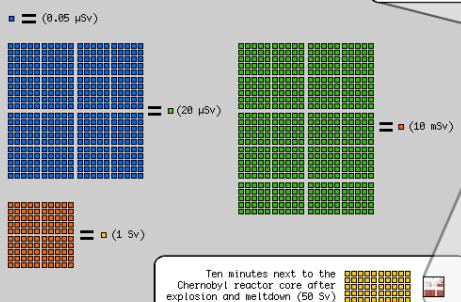
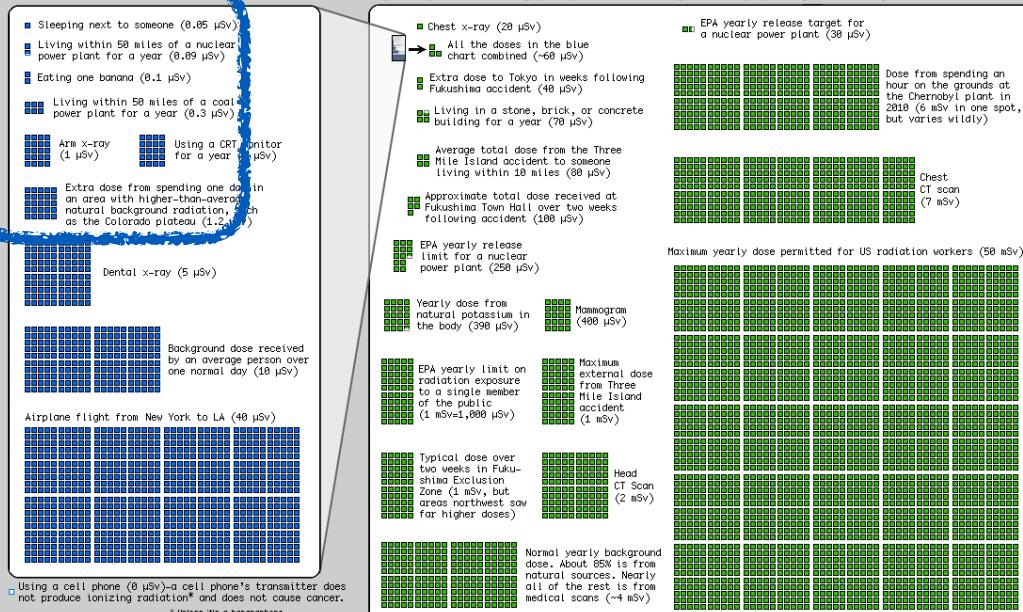
Protection against all radiation:
Hide behind ~1m of concrete
or dirt

Zoom in

Radiation Dose Chart

This is a chart of the ionizing radiation dose a person can absorb from various sources. The unit for absorbed dose is "sievert" (Sv), and measures the effect a dose of radiation has on your body. One sievert (all at once) will make you sick, and too many more will kill you, but we safely absorb small amounts of natural radiation daily.

Note: The same number of sieverts absorbed in a shorter time will generally cause more damage, but your cumulative long-term dose plays a big role in things like cancer risk.



Sources:

- <http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/>
- <http://www.nemone.gov/technological/dose-limits.html>
- http://www.doe-hq.gov/int_overight/radiation/dose_calculator.cfm
- http://www.doe-hq.gov/int_overight/radiation/radiation_guide.cfm
- <http://xkcd.com/248/>
- <http://www.bnl.gov/bnlweb/PDF/03SER/chapter1.pdf>
- http://deis-old.indiana.edu/dest/rpt_Libraries/vert_final.pdf
- <http://people.reed.edu/~economics/radiation.html>
- <http://en.wikipedia.org/wiki/Sievert>
- <http://blog.xkcd.com/2007/12/into-the-zone-chernobyl-project/>
- <http://www.nrc.gov/reading-rm/doc-collections/react-sheets/react-sheets/radiation-risks.html>
- http://www.nrc.gov/component/llmenu/other-detail?contentId=2011-03-18/1303787_174.pdf

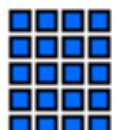
Chart by Randall Munroe, with help from Ellen, Senior Reactor Operator at the Reed Research Reactor, who suggested the idea and provided a lot of the sources. I'm sure I've added in lots of mistakes; it's for general education only. If you're basing radiation safety procedures on an internet PNG image and things go wrong, you have no one to blame but yourself.

Radiation Dose

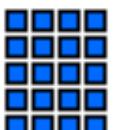
This is a chart of the ionizing radiation dose a person will have on the cells of the body. One sievert (all at once) is a dangerous dose.

Note: The same number of sieverts absorbed in a shorter time is more dangerous than over a longer time.

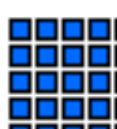
- Sleeping next to someone (0.05 µSv)
- Living within 50 miles of a nuclear power plant for a year (0.09 µSv)
- Eating one banana (0.1 µSv)
- Living within 50 miles of a coal power plant for a year (0.3 µSv)



Arm x-ray
(1 µSv)



Using a CRT monitor
for a year (1 µSv)



Extra dose from spending one day in
an area with higher-than-average
natural background radiation, such
as the Colorado plateau (1.2 µSv)

Yeah, you're getting irradiated right now.

Let's use
“one banana” as a
radiation unit.

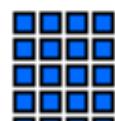
Radiation Dose

This is a chart of the ionizing radiation dose a person will have on the cells of the body. One sievert (all at once) is very dangerous.

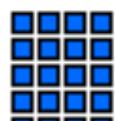
Note: The same number of sieverts absorbed in a shorter time is less dangerous.

- Sleeping next to someone (0.05 μSv)
- Living within 50 miles of a nuclear power plant for a year (0.09 μSv)
- Eating one banana (0.1 μSv)

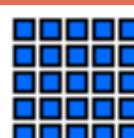
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(1 μSv)



Using a CRT monitor
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https://en.wikipedia.org/wiki/Banana_equivalent_dose

Radiation Dose Chart

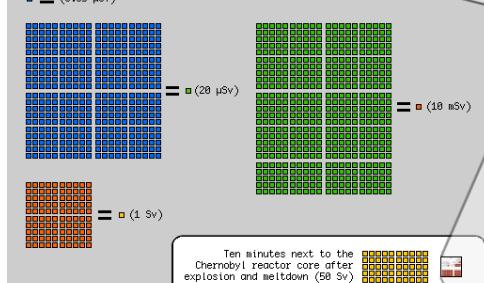
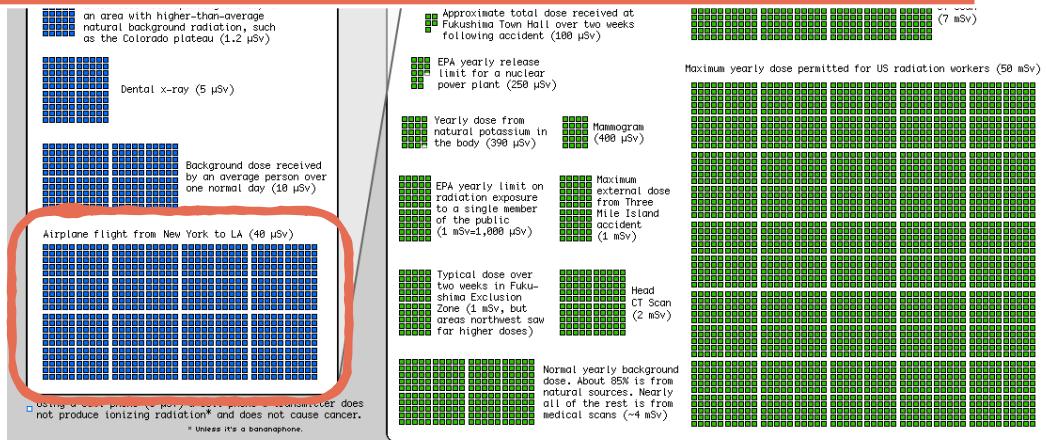
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- Sleeping next to someone (0.05 μ Sv)
- Living within 50 miles of a nuclear power plant for a year (0.09 μ Sv)

- Chest x-ray (20 μ Sv)
- All the doses in the blue chart combined (<60 μ Sv)

- EPA yearly release target for a nuclear power plant (30 μ Sv)

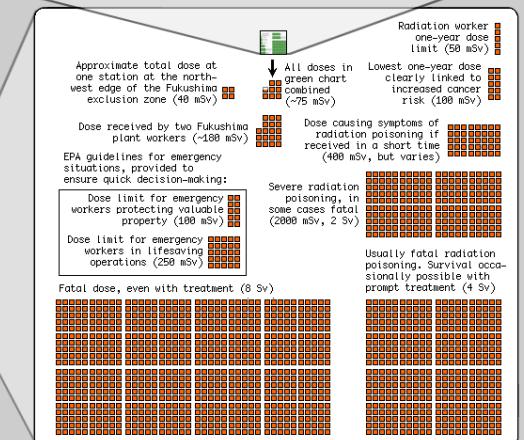
Transatlantic flight: 400 bananas



Sources:

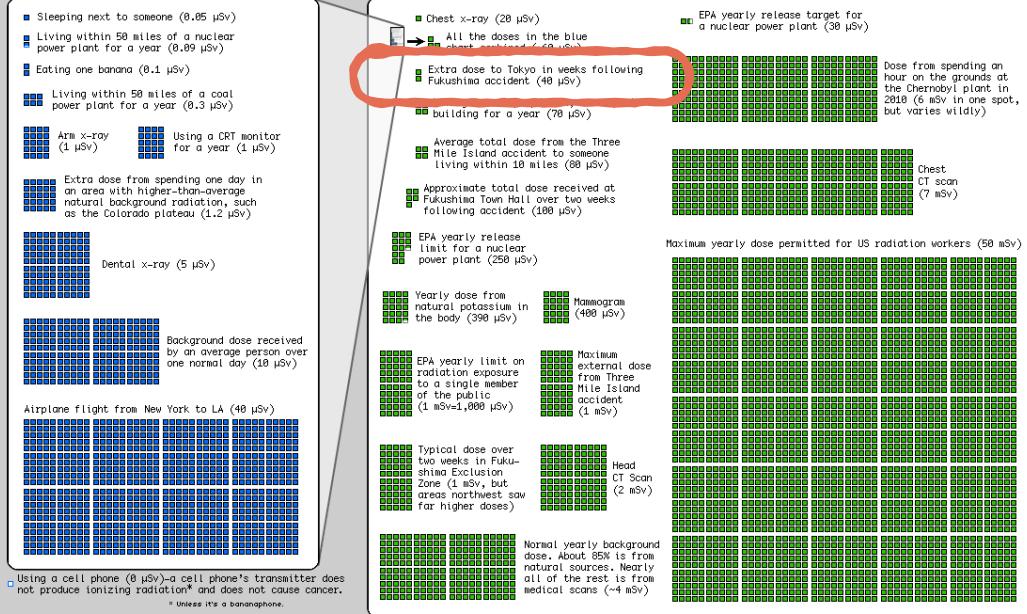
- <http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/>
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- http://www.doeidao.gov/int_overseas/radiation/dose_calculator.cfm
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- <http://www.nrc.gov/reading-rm/doc-collections/reactor-sheets/tritium-radiation-fs.html>
- http://www.nextgen.jp/component/a-menu/other/detail.../icsfiles/onlineid/2011/02/19/1303727_1776.pdf
- <http://radiologyread.org/content/244/1/284>

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Extra dose in Tokyo due to Fukushima incident: 400 bananas (i.e. ~1 transatlantic flight)

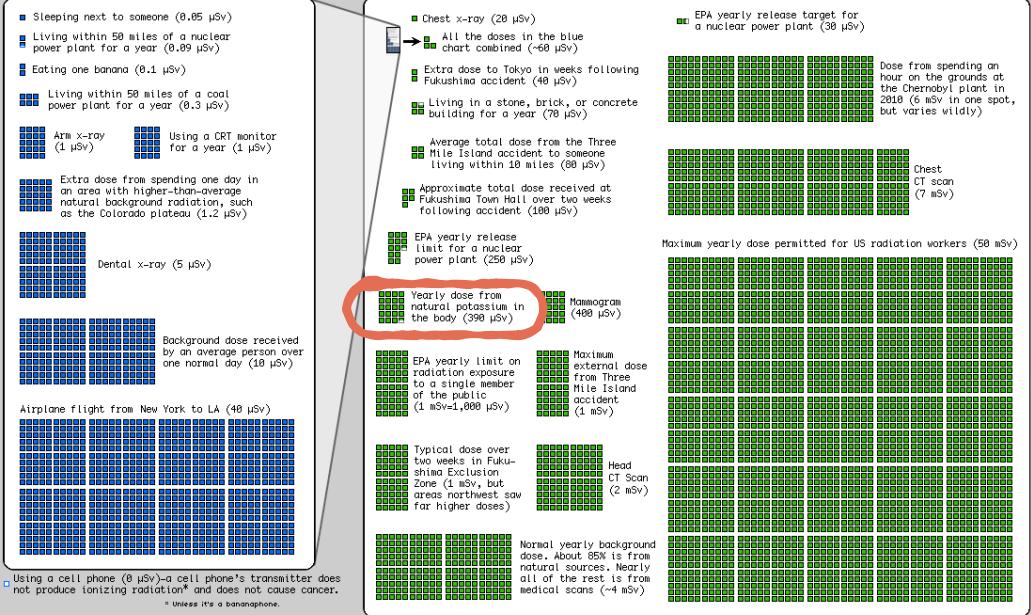
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- <http://www.nrc.gov/technological/dose-sheets.html>
- http://www.doeidao.gov/int_overseas/radiation_dose_calculator.cfm
- http://www.doeidao.gov/int_overseas/radiation_guide.cfm
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- <http://web.doeidao.edu/dsrb/gtCarlets/xref.html>
- <http://people.reed.edu/~emmons/radiation.html>
- <http://en.wikipedia.org/wiki/Sievert>
- <http://blog.vernaskott.com/2010/07/15/info-on-the-zone-chernobyl-priput/>
- <http://www.nrc.gov/reading-rm/doc-collections/react-sheets/tritium-radiation-fs.html>
- http://www.nextgov.com/component/a_menu/other/detail.../files/mediawiki/2011-02-19/1303727_1776.pdf
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Radiation from potassium in your body: ~4000 bananas (~10 transatlantic flights)

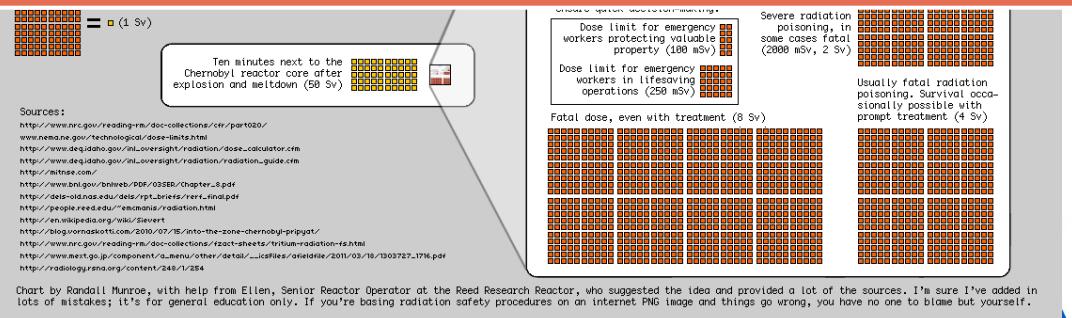
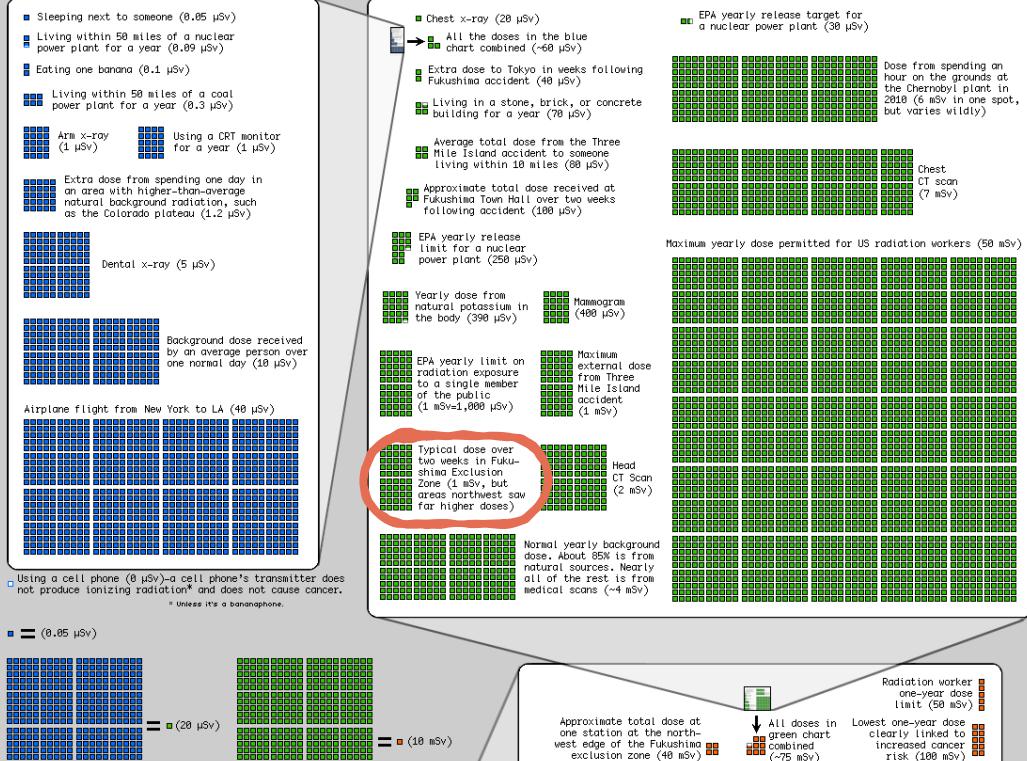


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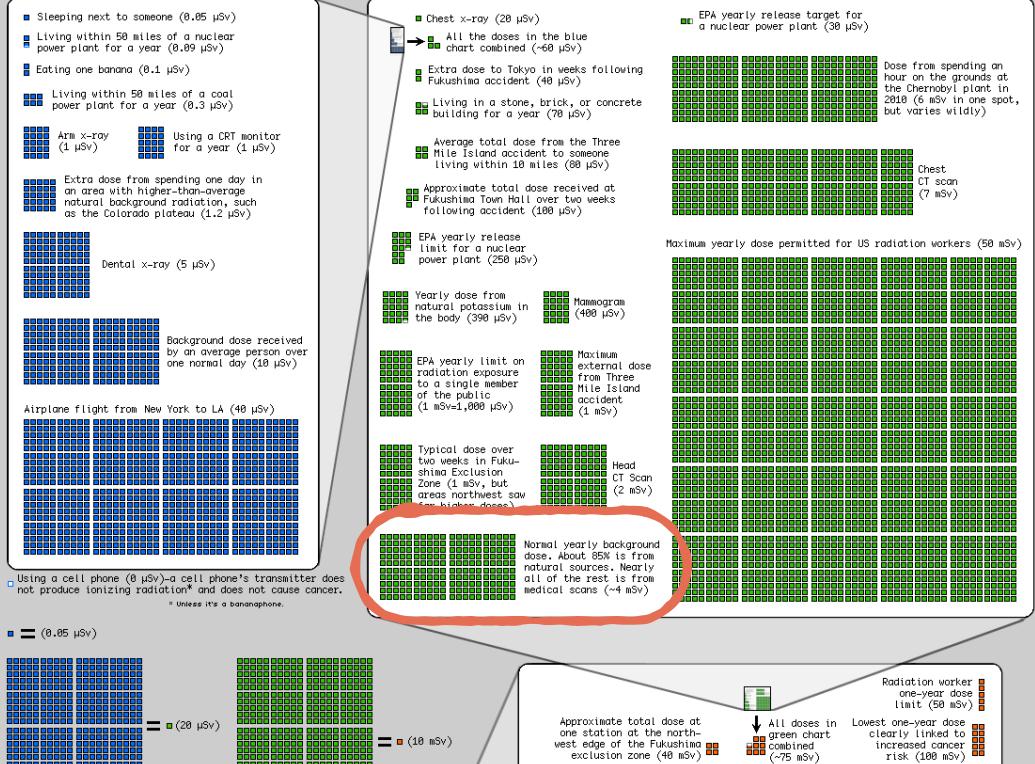
2-week dose in Fukushima exclusion zone: 10000 bananas (~25 transatlantic flights)

http://www.doeidaho.gov/intl_overseas/radiation/radiation_guide.cfm
<http://nireia.com/>
<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3586180/pdf/03586180.pdf>
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<http://www.nrc.gov/reactors/reading-m/docs/collections/rzact-sheets/tritium-radiation-rs.html>
http://www.nextgen.jp/component/a_menu/other/detail.../jcfFiles/alphaedit/2011/02/19/1303727_1776.pdf
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Your typical yearly dose:
40000 bananas (~100 transatlantic flights)

http://www.doeidaho.gov/intl/copyright/radiation/radiation_guide.cfm
<http://nireea.com/>
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3586180/Chapter_8.pdf
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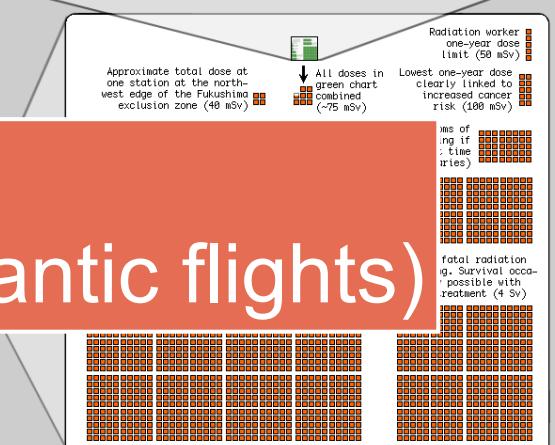
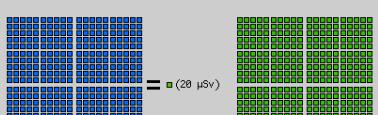
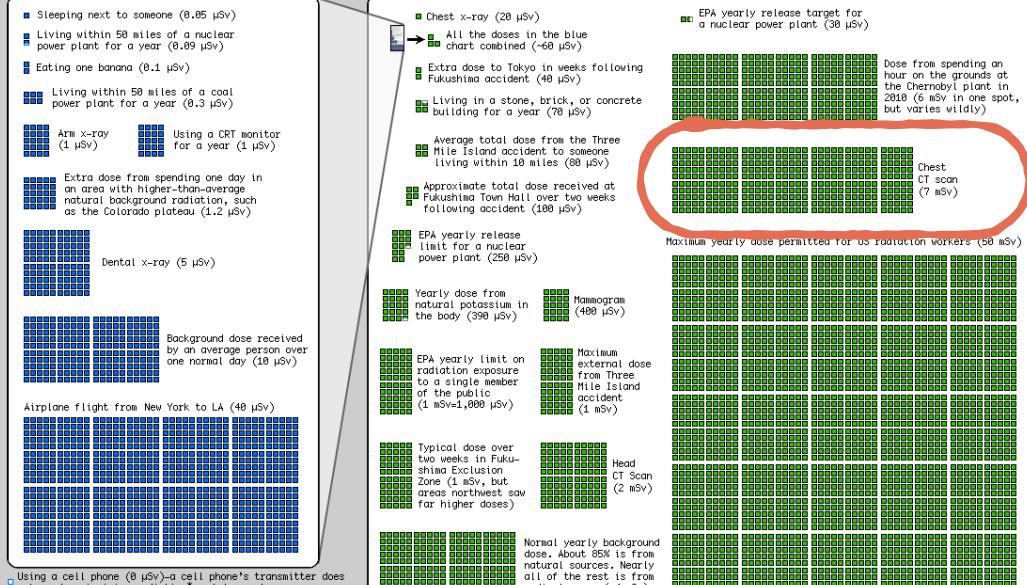
1 hour in Chernobyl grounds: 60000 bananas (~150 transatlantic flights)

http://www.doeidaho.gov/intl_overseas/radiation/radiation_guide.htm
 http://nireea.com/
 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3586185/pdf/03586185-Chapter_8.pdf
 http://web-dosimetry.edu/dosimetrycharts/year.html.pdf
 http://people.reed.edu/~rmonks/radiation.html
 http://en.wikipedia.org/wiki/Sievert
 http://blog.vernaskott.com/2010/07/15/info-on-the-zone-chernobyl-prypti/
 http://www.nrc.gov/reactors/reactor-safety/risksheets/tritium-radiation-rs.html
 http://www.nextgen.jp/component/a_menu/other/detail.../jcfFiles/alphaedit/2011/02/19/1303727_1776.pdf
 http://radiologyread.org/content/244/1/284

Chart by Randall Munroe, with help from Ellen, Senior Reactor Operator at the Reed Research Reactor, who suggested the idea and provided a lot of the sources. I'm sure I've added in lots of mistakes; it's for general education only. If you're basing radiation safety procedures on an internet PNG image and things go wrong, you have no one to blame but yourself.

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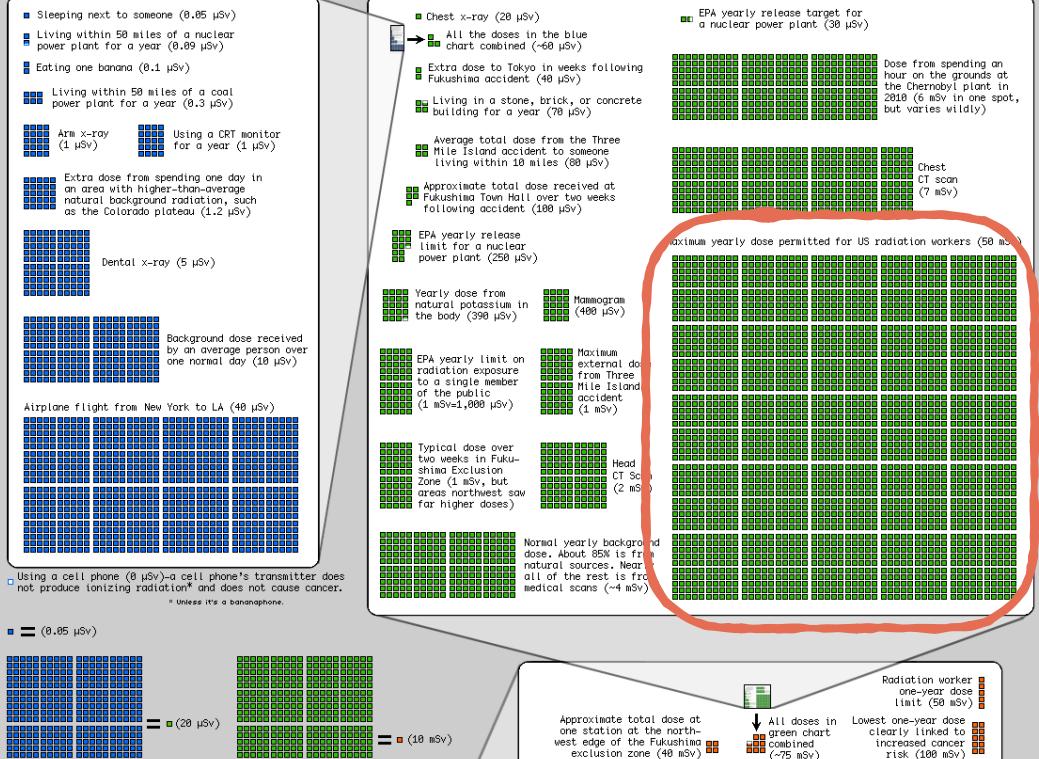
http://www.doeidaho.gov/intl/coversight/radiation/radiation_guide.cfm
<http://mitnece.com/>
<http://www.cancer.org/research/PDF-035EB-Chapter-8.pdf>
<http://web.mit.edu/dsoriano/www/lectures/radiation.pdf>
<http://people.reed.edu/~esimons/radiation.html>
<http://en.wikipedia.org/wiki/Sievert>
<http://blog.vernaskott.com/2010/07/15/into-the-zone-chernobyl-priput/>
<http://www.nrc.gov/readings/m/doccollections/rzct-sheets/tritium-radiation-fs.html>
http://www.nextgen.jp/component/a/menu/other/detail.../jcfFiles/alphaedit/2011-02-19/1303727_17m.pdf
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Chest CT scan: 70000 bananas (175 transatlantic flights)

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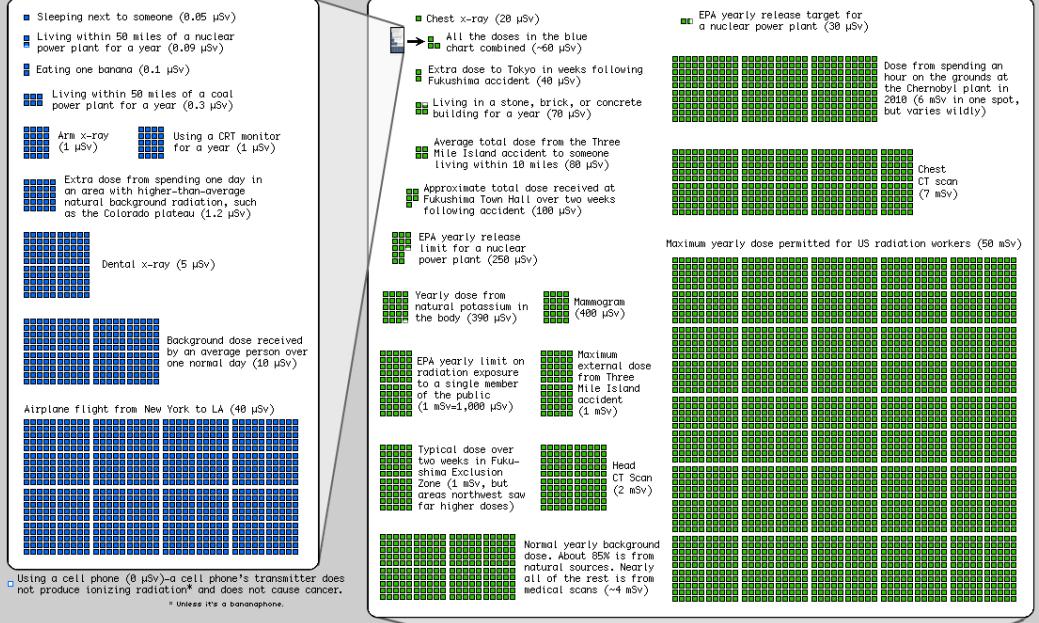
Safe dose for “radiation workers”(like me):
500,000 bananas (1250 transatlantic flights)

<http://peoplefreedom.org/memos/reading.html>
<http://en.wikipedia.org/w/index.php?title=Sievret>
<http://blog.vomrakotti.com/2010/07/15/into-the-zone-of-chernobyl-pripyat/>
<http://www.nrc.gov/reading-rm/doc-collections/zract-sheets/tritium/radiation-fs.html>
http://www.meteo.go.jp/component/e_meteo/other/detail/_lccfiles/arefile01/2011/03/19/1303727-17.htm.pdf
<http://radiationinfo.org/content/248/1/254>

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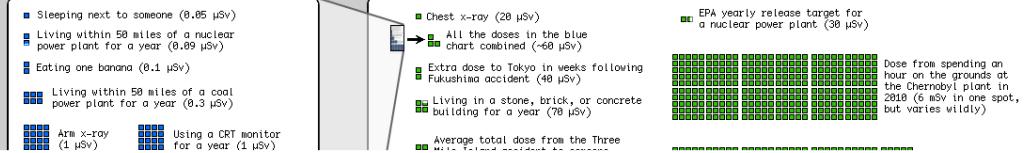


Lowest yearly dose linked to increased cancer risk:
1,000,000 bananas (2500 transatlantic flights)

Radiation Dose Chart

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Note: The same number of sieverts absorbed in a shorter time will generally cause more damage, but your cumulative long-term dose plays a big role in things like cancer risk.



2 Fukushima plant workers
were exposed to
1,800,000 bananas (4500 transatlantic flights)
1.8 lowest level for slightly increased cancer risk

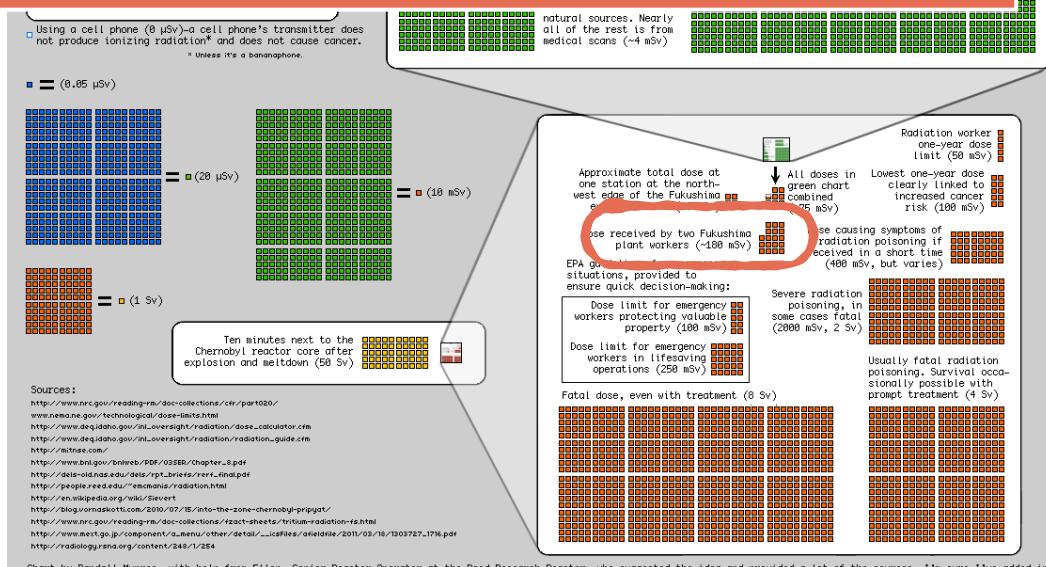
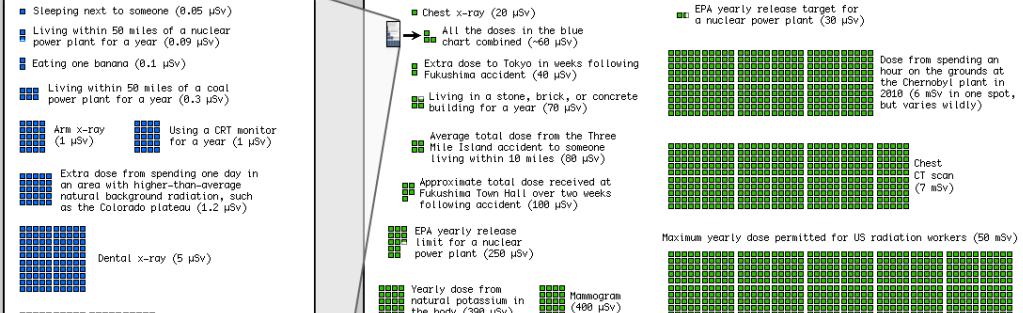


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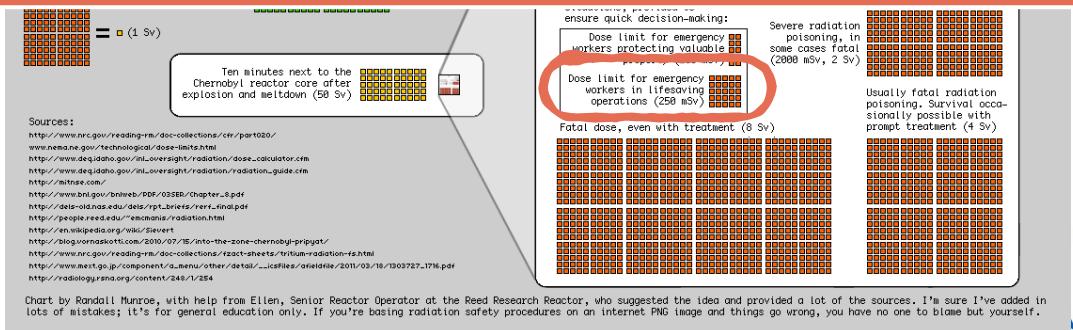
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Note: The same number of sieverts absorbed in a shorter time will generally cause more damage, but your cumulative long-term dose plays a big role in things like cancer risk.



Dose limit for emergency workers:
2,500,000 bananas
6250 transatlantic flights
1.4 Fukushimas
2.5 lowest level for slightly increased cancer risk



Radiation Dose Chart

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Sleeping next to someone (0.05 μ Sv)

Flight ν -ray (20 μ Sv)

EPA yearly release target for

You're gonna die if you get dosage of:
 80,000,000 bananas,
 32 Fukushimas,
 200,000 transatlantic flights,
 133 times normal background radiation

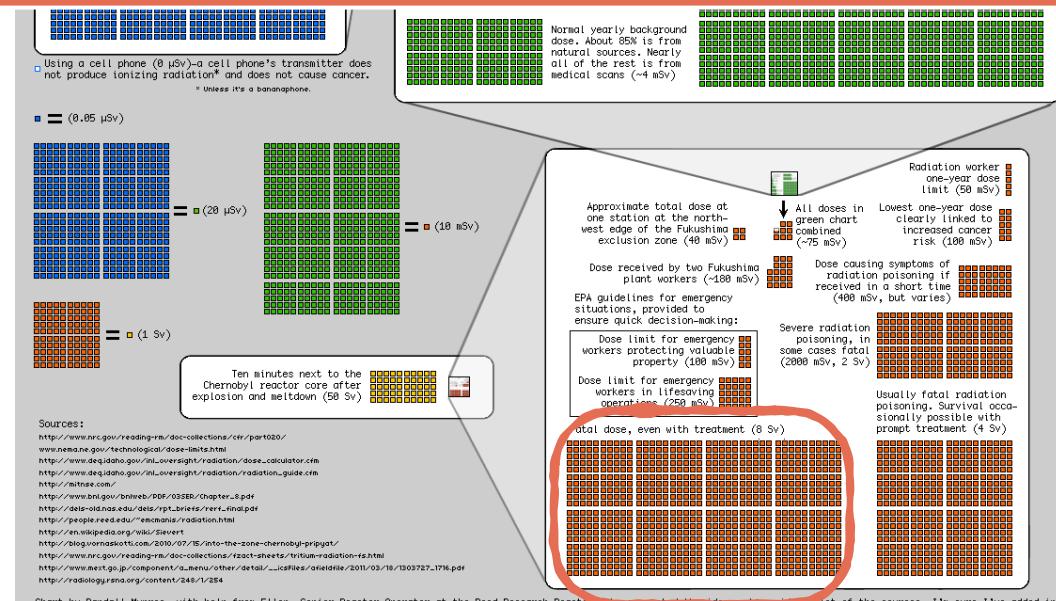


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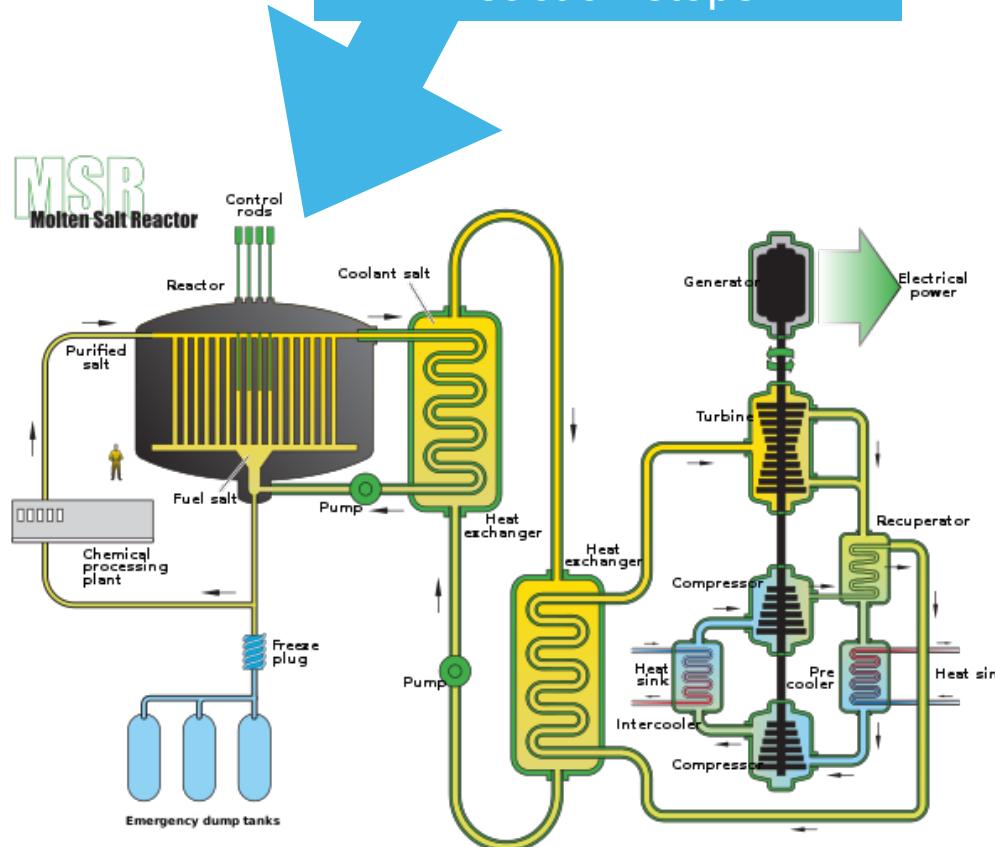
What about waste or meltdown?

If something bad happens,
reaction stops

- Nasty stuff, but frankly easy to contain:
 - Encase it in glass, and bury it.
 - We HAVE a perfect place to store it (Yucca Mountain) but we stopped in 2011 for political reasons and store it on sites now

OR (better) :

- Build Gen 4 nuclear plants to CONSUME existing nuclear waste



Can use thorium
(closed cycle, consume
previous waste)

So How Deadly Is your Kilowatt?

<https://www.forbes.com/sites/jamesconca/2012/06/10/energys-deathprint-a-price-always-paid/#5e5c94f9709b>

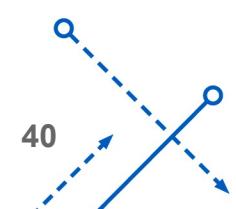
1 trillion kWh powers planet for ~2.7 days

• Mortality Rate : deaths / trillion kWhr		
• Coal – global average	100,000	(41% global electricity)
• Coal – U.S.	10,000	(32% U.S. electricity)
• Natural Gas	4,000	(22% global electricity)
• Solar (rooftop)	440	(< 1% global electricity)
• Wind	150	(2% global electricity)
• Hydro – global average	1,400	(16% global electricity)
• Hydro – U.S.	5	(6% U.S. electricity)

Air pollution

Falling off roofs

Catastrophic
dam collapse



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Place your bets:

(Includes Chernobyl and Fukushima)

- Nuclear— global average:
- Nuclear — U.S.:

(Includes nuclear waste)

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Place your bets:

- Nuclear— global average: 90 (11% global electricity)
- Nuclear — U.S.: 0.1 (19% U.S. electricity)

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- Mortality Rate : deaths / trillion kWhr
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Nuclear power is, by far,
the safest form of electricity

• Nuclear—global average: 90 (11% global electricity)

Place your bets:

- Nuclear—global average: 90 (11% global electricity)
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This blows people's minds. Even when faced with data they find it almost impossible to accept.

"I'd be incredibly surprised if #solarpower industry haven't reduced that rate."

Replying to @srrappoccio

Gosh, genuinely hadn't heard this probably sensible point: do people die falling off roofs installing #solarpanels my #solar friends? As I work on labour stds/#humanrights (incl to safety), I'm curious! And for #windpower installation? Anyone have any cases or stats to share?



Salvatore Rappoccio @srrappoccio · Apr 11

Roofer death rates are around 29.9 deaths per 100,000 full-time equivalent workers:

[elcosh.org/document/1428/...](http://elcosh.org/document/1428/)

Nuclear is literally the safest form of electricity generation:



Apr 11

That data on roofer death rates was from 1992-1998. We are in 2019. Do we have more recent data please? I'd be incredibly surprised if #solarpower industry haven't reduced that rate. @solarcentury ? @SolarEnergyNews ? Thanks!



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It's getting worse, not better:

[bls.gov/opub/ted/2018/...](http://bls.gov/opub/ted/2018/)

To be clear: I would still consider these "acceptable" rates, but nuclear is still a factor of 10 safer than rooftop solar, statistically. Nuclear power is the safest form of power generation there is.



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This person is expecting technological advances in **FALLING DOWN**.

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So what about that fear mongering?

“the true story of one of
the worst man-made
catastrophes in history”

Chernobyl:

Immediate deaths from radiation: 49 people

Increased cancer risk: 6000 cases of thyroid cancer

Fukushima:

Immediate deaths from radiation: 1 person

Increased cancer risk: 2 people

Other human-driven
catastrophes:

Auto fatalities / year:	1250000000
Drunk driving fatalities / year:	10,497
Toddlers shooting people / year:	13

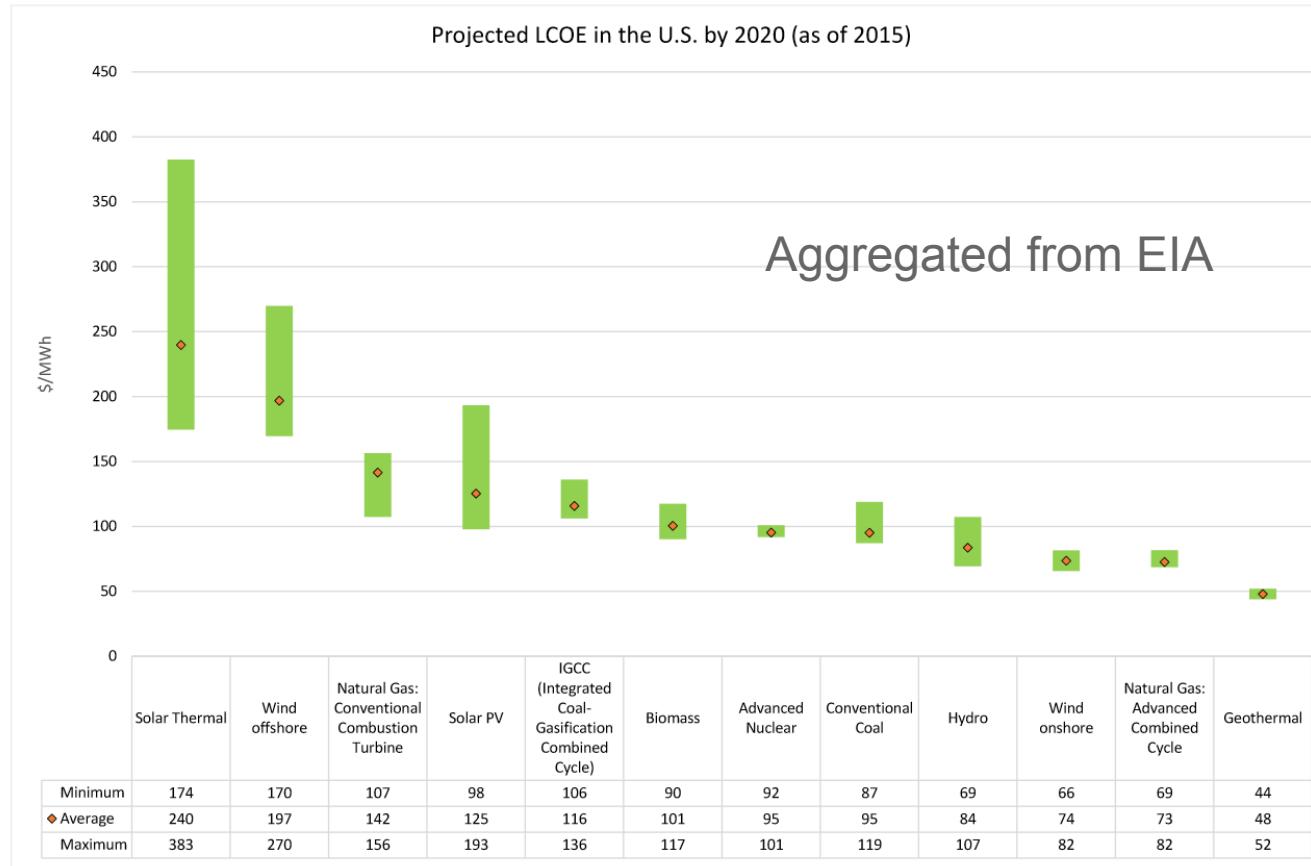
https://en.wikipedia.org/wiki/Deaths_due_to_the_Chernobyl_disaster

https://en.wikipedia.org/wiki/Fukushima_Daiichi_nuclear_disaster_casualties

<https://www.snopes.com/fact-check/toddlers-killed-americans-terrorists/>

Cost: How much will we pay?

- Levelized cost of energy (LCOE):



https://www.eia.gov/outlooks/aoe/pdf/electricity_generation.pdf

https://en.wikipedia.org/wiki/Cost_of_electricity_by_source

Cost: How much will we pay?

- Levelized cost of energy (LCOE):



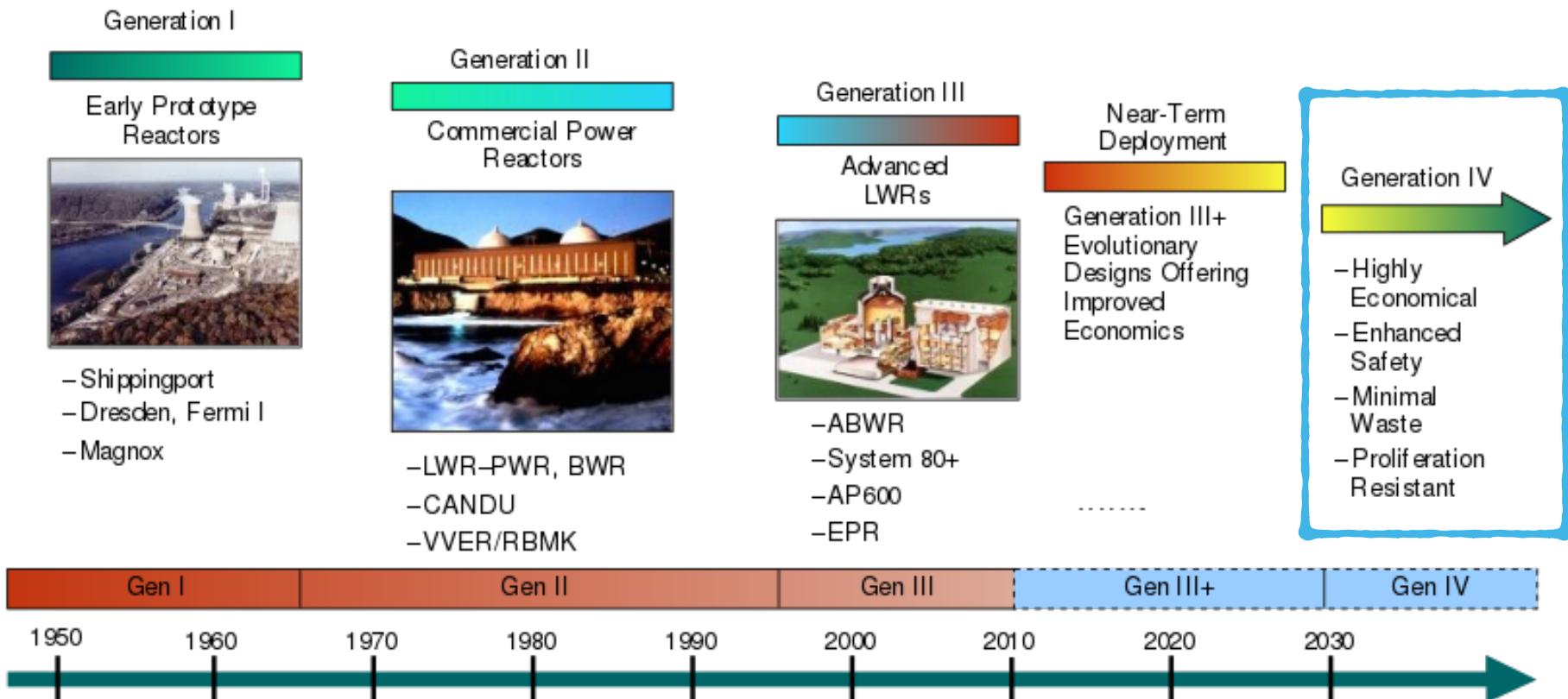
Advanced nuclear is
on the expensive side.
Current nuclear is cheaper.

	Minimum	174	170	107	98	106	90	92	87	69	66	69	44
◆ Average	240	197	142	125	116	101	95	95	84	74	73	48	
Maximum	383	270	156	193	136	117	101	119	107	82	82	52	

https://www.eia.gov/outlooks/aoe/pdf/electricity_generation.pdf

https://en.wikipedia.org/wiki/Cost_of_electricity_by_source

Advanced Nuclear : worth the cost



<http://large.stanford.edu/courses/2016/ph241/xue2/docs/gif-002-00.pdf>
<http://large.stanford.edu/courses/2016/ph241/xue2/>
https://en.wikipedia.org/wiki/Generation_IV_reactor

Advanced Nuclear Options

[Gas-cooled fast reactor](#)

[Lead-cooled fast reactor](#)

[Molten salt reactor](#)

[Sodium-cooled fast reactor](#)

[Supercritical water-cooled reactor](#)

[Very high-temperature gas reactor](#)

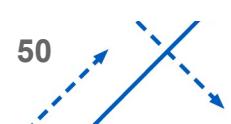
Generation IV reactor designs under development by GIF

	Neutron spectrum (fast/thermal)	Coolant	Temperature (°C)	Pressure*	Fuel	Fuel cycle	Size (MWe)	Use
Gas-cooled fast reactors	fast	helium	850	high	U-238 +	closed, on site	1200	electricity & hydrogen
Lead-cooled fast reactors	fast	lead or Pb-Bi	480-570	low	U-238 +	closed, regional	20-180** 300-1200 600-1000	electricity & hydrogen
Molten salt fast reactors	fast	fluoride salts	700-800	low	UF in salt	closed	1000	electricity & hydrogen
Molten salt reactor - advanced high-temperature reactors	thermal	fluoride salts	750-1000		UO ₂ particles in prism	open	1000-1500	hydrogen
Sodium-cooled fast reactors	fast	sodium	500-550	low	U-238 & MOX	closed	50-150 600-1500	electricity
Supercritical water-cooled reactors	thermal or fast	water	510-625	very high	UO ₂	open (thermal) closed (fast)	300-700 1000-1500	electricity
Very high temperature gas reactors	thermal	helium	900-1000	high	UO ₂ prism or pebbles	open	250-300	hydrogen & electricity

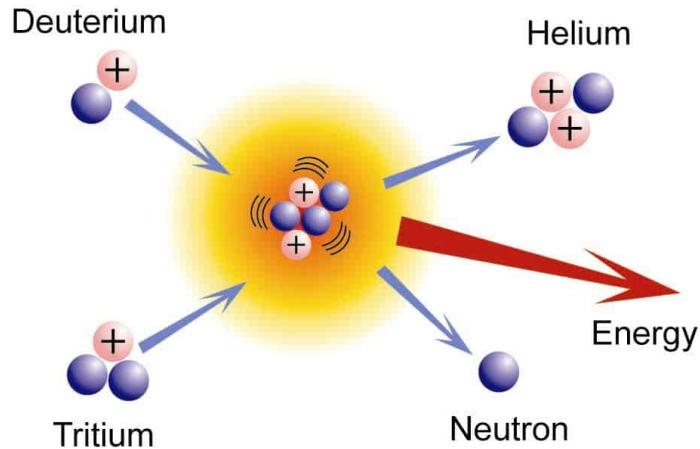
* high = 7-15 MPa

+ = with some U-235 or Pu-239

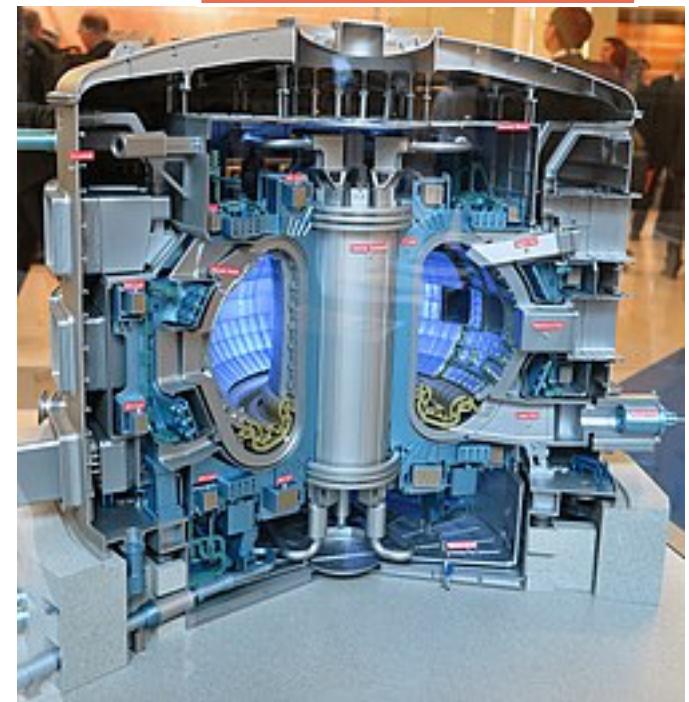
** 'battery' model with long cassette core life (15-20 yr) or replaceable reactor module.



Nuclear fusion?



ITER Reactor:
Tokamak generator



<https://www.nuclear-power.net/nuclear-power/nuclear-fusion/>

<https://en.wikipedia.org/wiki/ITER>

Nuclear fusion?

ITER Reactor:
Tokamak generator

Deuterium



Helium



Promising progress, but we
can't rely on this in the
immediate future.

<https://www.nuclear-power.net/nuclear-power/nuclear-fusion/>

<https://en.wikipedia.org/wiki/ITER>

Tonight: Go carbon free

- Many solutions to go 100% carbon free for your electric needs... today.
 - Example: <https://idtenergy.com/what-we-do/green-energy/>
 - <https://idtenergy.com/what-we-do/your-choice/>

 SmartBudget Fixed Rate
Fixed Rate Program that allows you to take advantage of a fixed per kWh supply rate for a set number of billing cycles.
GET STARTED

 SmartFlex Variable Rate
Get up to \$100 in free electricity supply! Plus Sign up your natural gas account with IDT Energy and get up to an additional \$20 in free natural gas supply.
GET STARTED


Green Electricity
Renewable or "Green Electricity"

Choose to purchase electricity that is 100% matched with renewable energy certificates representing the generation of electricity from renewable resources like running water, wind, solar and biomass.

[GET STARTED](#)

For your phone:



About 12% higher cost than natural gas
Zero guilt about leaving your lights on a bit longer.

NGU 8.210¢ /kWh	 SmartFlex Variable	Intro Rate Then Month-to-Month	NO	 100% Green Energy	Get up to \$100 in free electricity supply!* Plus Sign up your natural gas account with IDT Energy and get up to an additional \$20 in free natural gas supply*
More Information					

Can use the higher capacity factors of nuclear power and geothermal to supplement wind, solar, and hydro

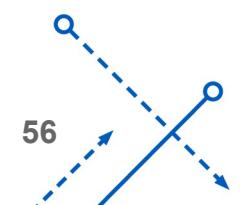
Summary:

- We need to stop thermodynamic whoopee... NOW... or many/all of us are gonna die
- Nuclear power is safe and effective
 - 100% necessary to achieve climate change goals
- Options:
 - Wind?
 - Solar?
 - Nuclear?
 - Geothermal?
 - All of the above?

Go carbon free tonight, please!



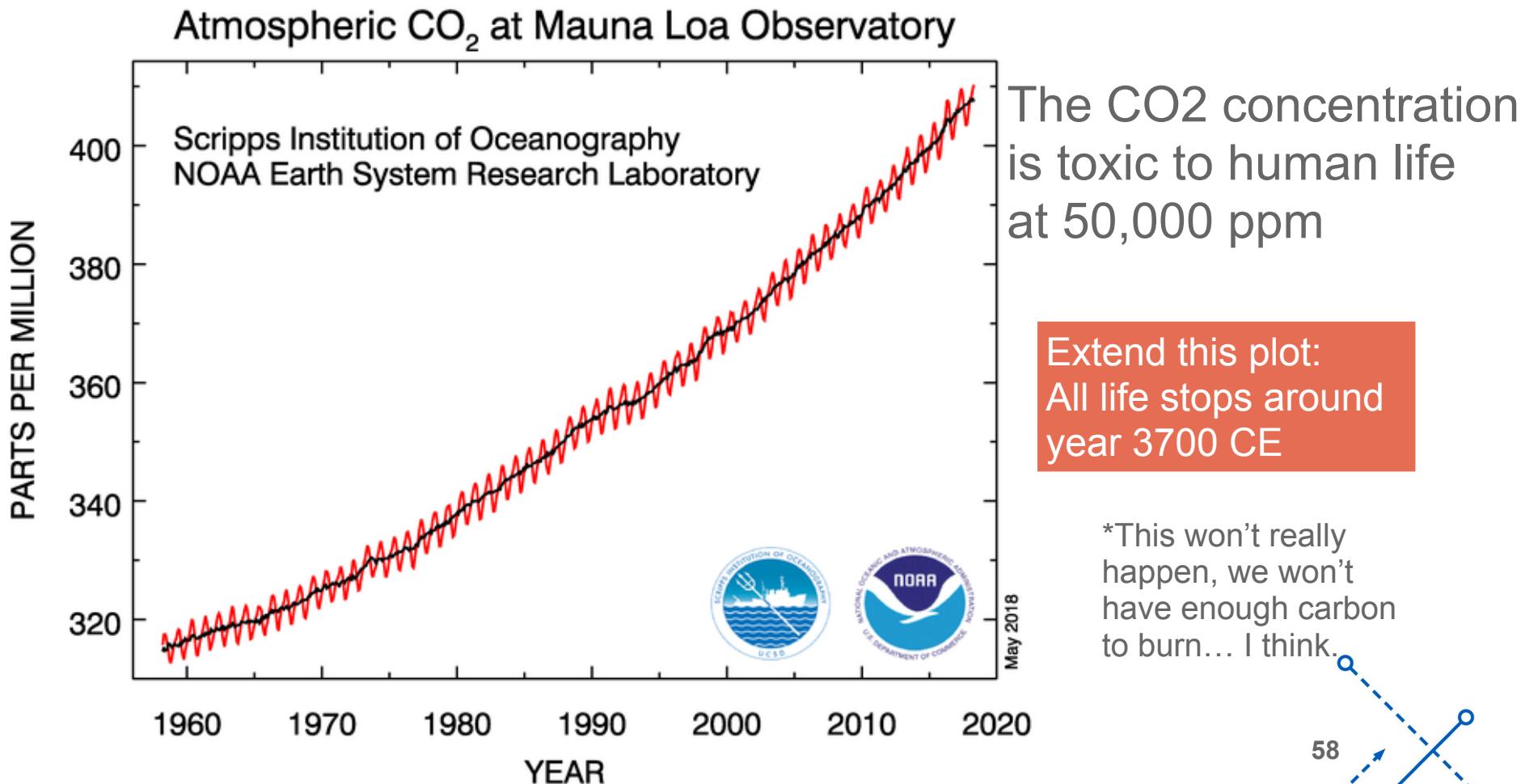
We need a complete solution to climate change. That includes renewables, storage improvements, and nuclear power.



Backups

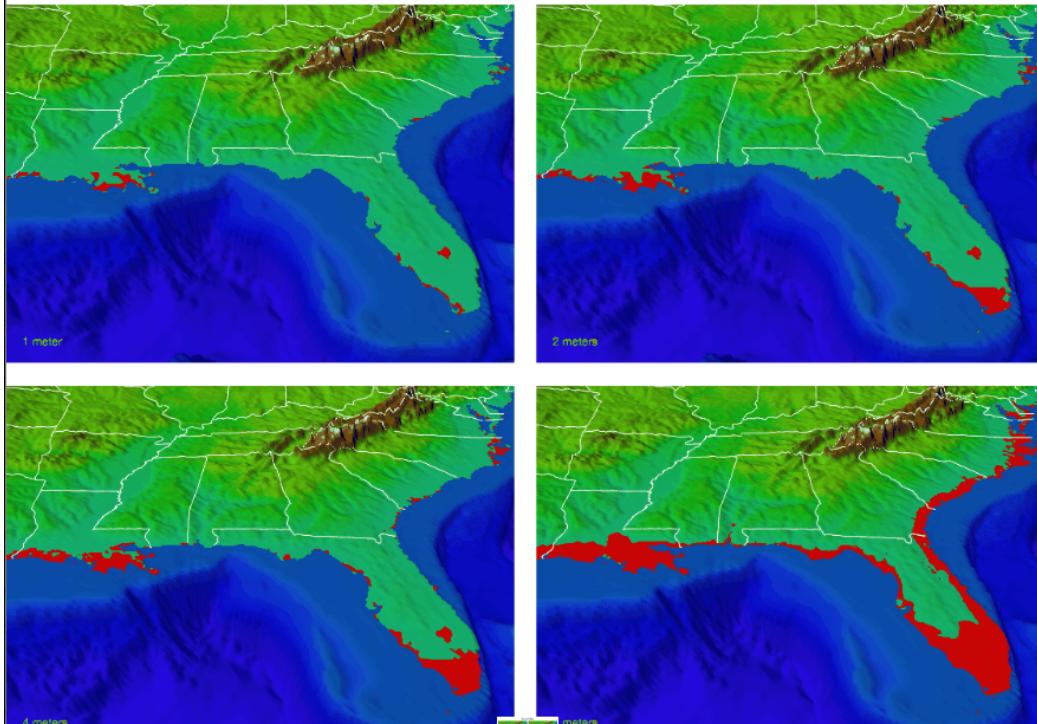
Why we are all going to die* if we keep making thermodynamic whoopee

<https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html>



Why many are going to die* MUCH FASTER if we keep making thermodynamic whoopee

Sea Level Rise



“Limiting global warming to 1.5°C would require rapid, far-reaching and unprecedented changes in all aspects of society.”

— Intergovernmental Panel on Climate Change

[http://www.ipcc.ch/
news_and_events/
pr_181008_P48_spm.shtml](http://www.ipcc.ch/news_and_events/pr_181008_P48_spm.shtml)

[https://web.whoi.edu/coastal-group/
primers/sea-level-rise/#](https://web.whoi.edu/coastal-group/primers/sea-level-rise/#)

* : Caveat: We're not ALL gonna die in 2030. We'll just be severely INCONVENIENCED and just a LOT of people will die.