
Why New Nuclear Energy Should Be in
Our Energy Future
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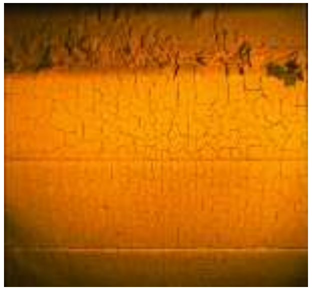
a short nuclear primer

^{235}U - splits (fissions) easily
^{238}U - does not fission easily

Uranium-ore

Yellowcake
U_3O_8



Natural uranium (ore) is 0.7% ^{235}U and 99.3% ^{238}U

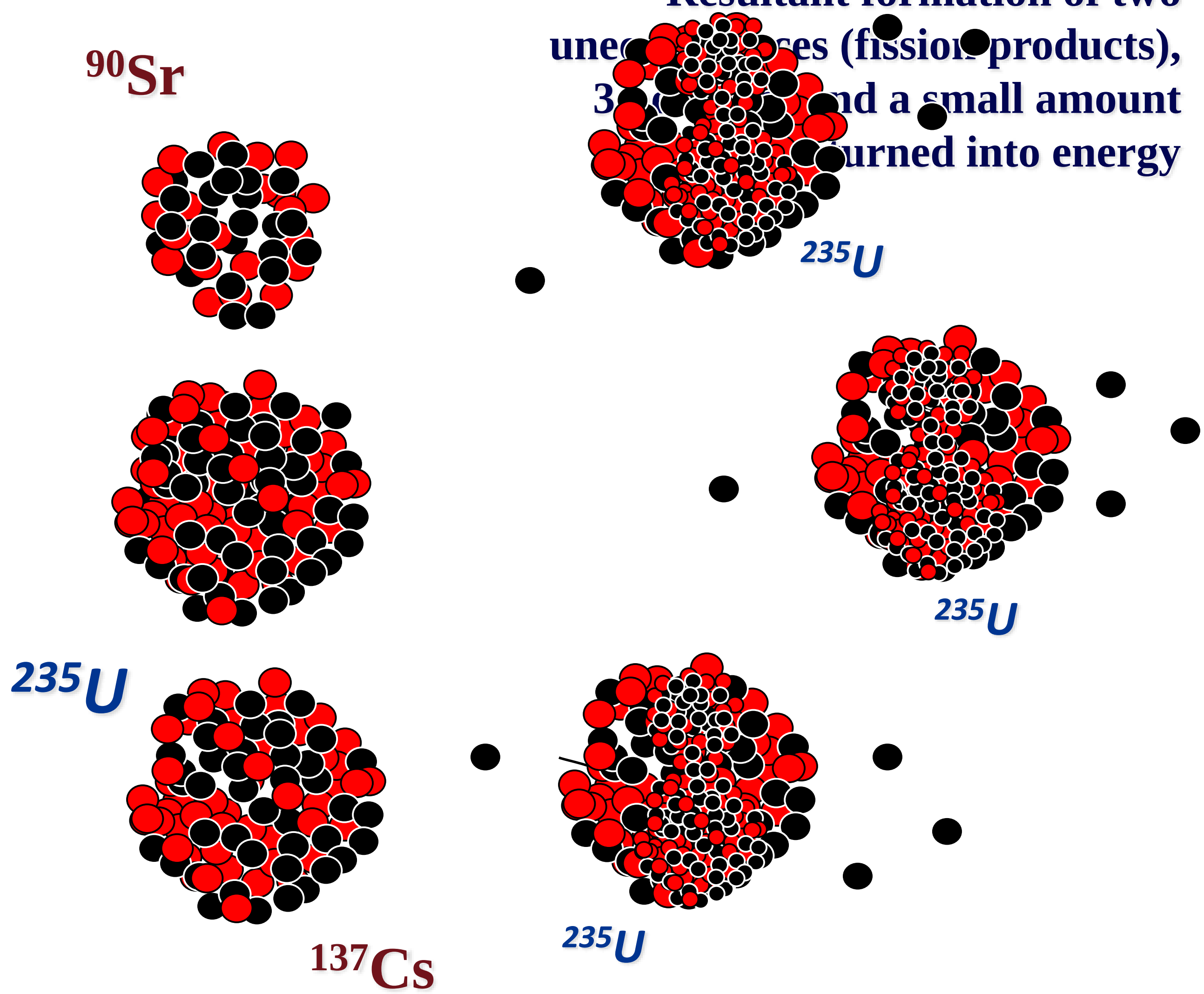
Nuclear fuel is enriched to ~4% ^{235}U, with ~96% ^{238}U

Nuclear weapons must be enriched to >93.5% ^{235}U

Fission of ^{235}U

proton

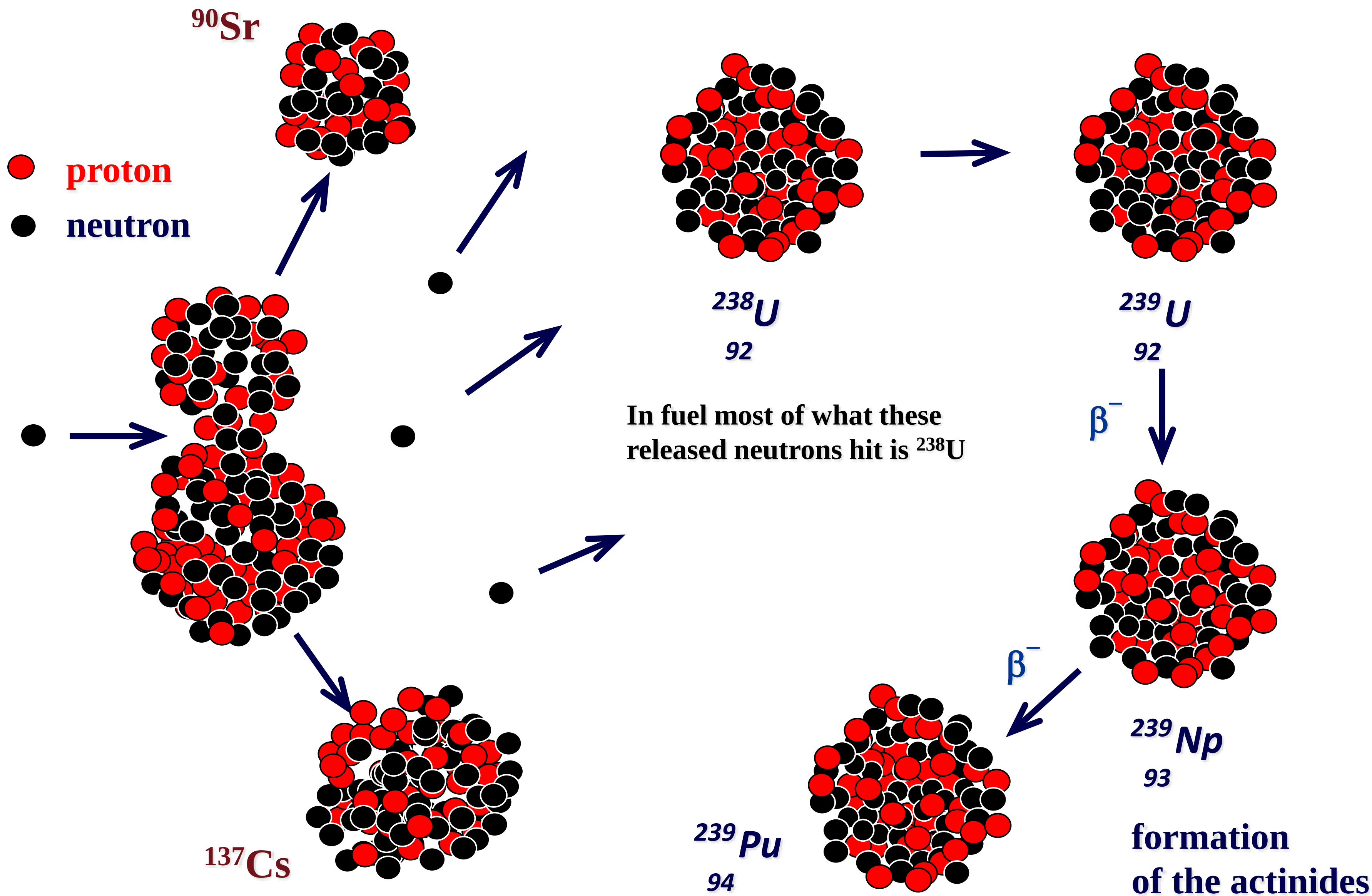
neutron



92 protons
\+ 143 neutrons

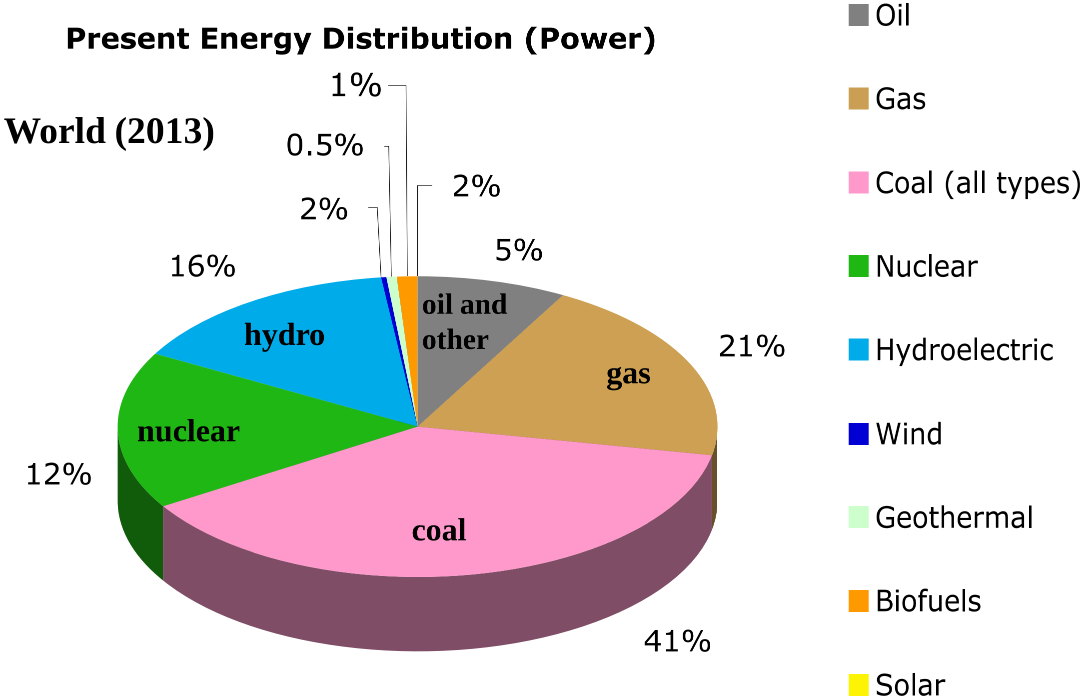
235 total

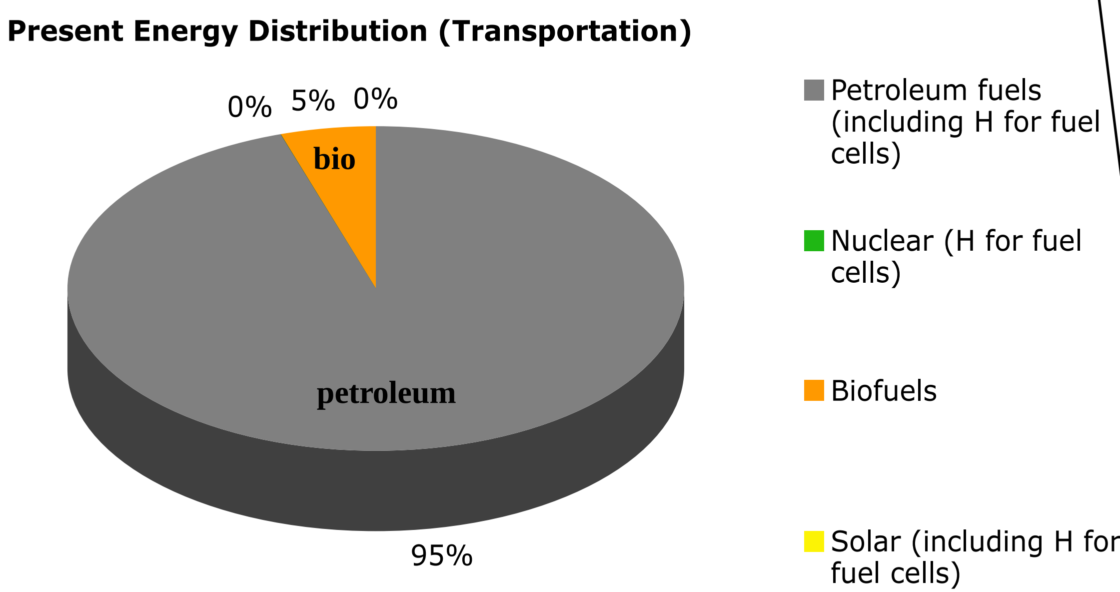
Neutron Capture by $^{238}U \Rightarrow {}^{239}Pu$



Global Energy Distribution

as indicated by nighttime electricity use





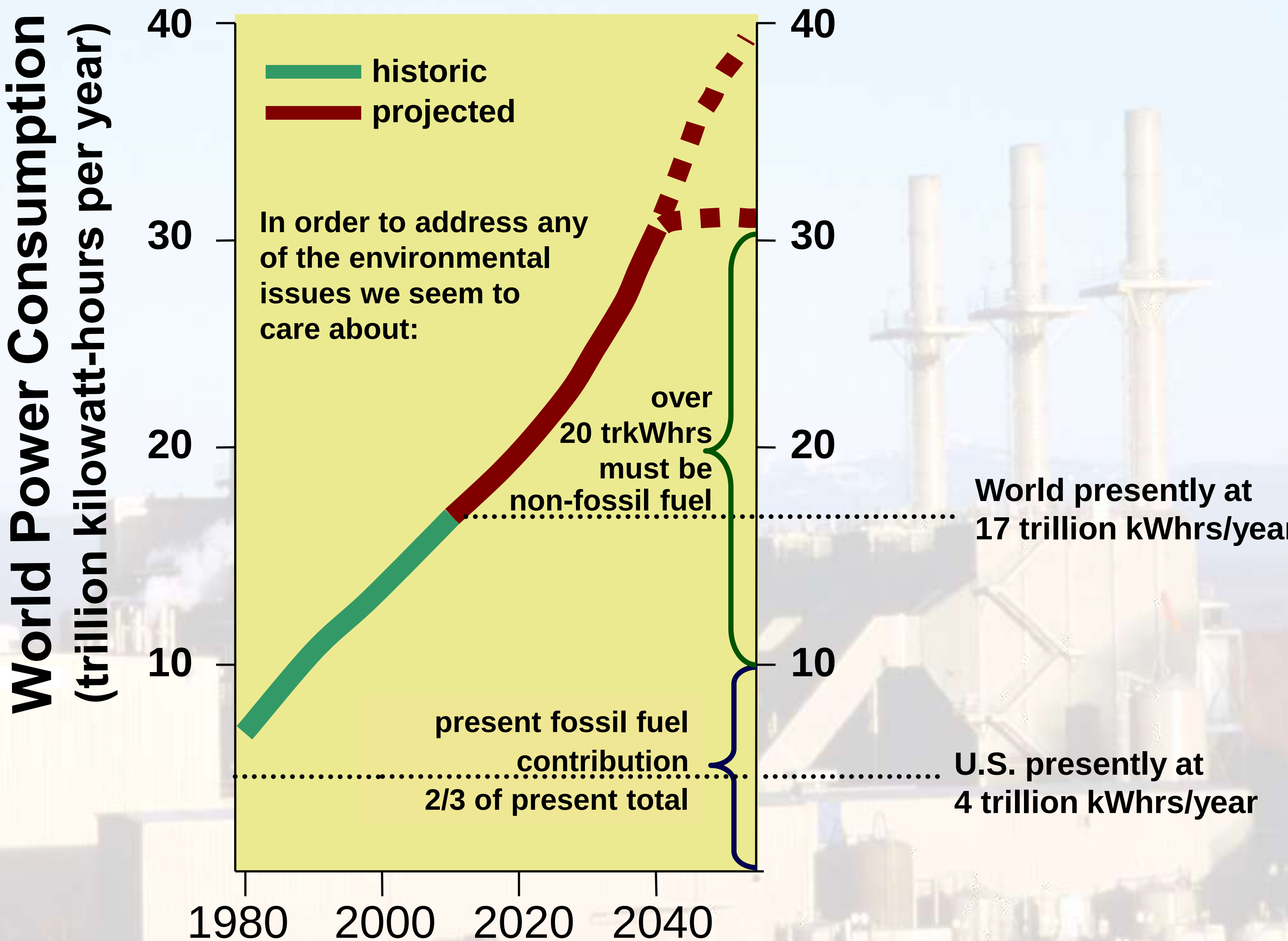
United States
39% coal
27% gas
19% nuclear
7% hydroelectric
4% wind 4% other

Washington	**Kentucky**	**Illinois**
4% coal	93% coal	43% coal
3% gas	4% gas	1% gas
8% nuclear	0% nuclear	49% nuclear
79% hydro	2% hydro	7% renew.
6% renew.	1% renew.	

European Union
30% coal
20% gas
28% nuclear
9% hydroelectric
3% oil 10% renewables

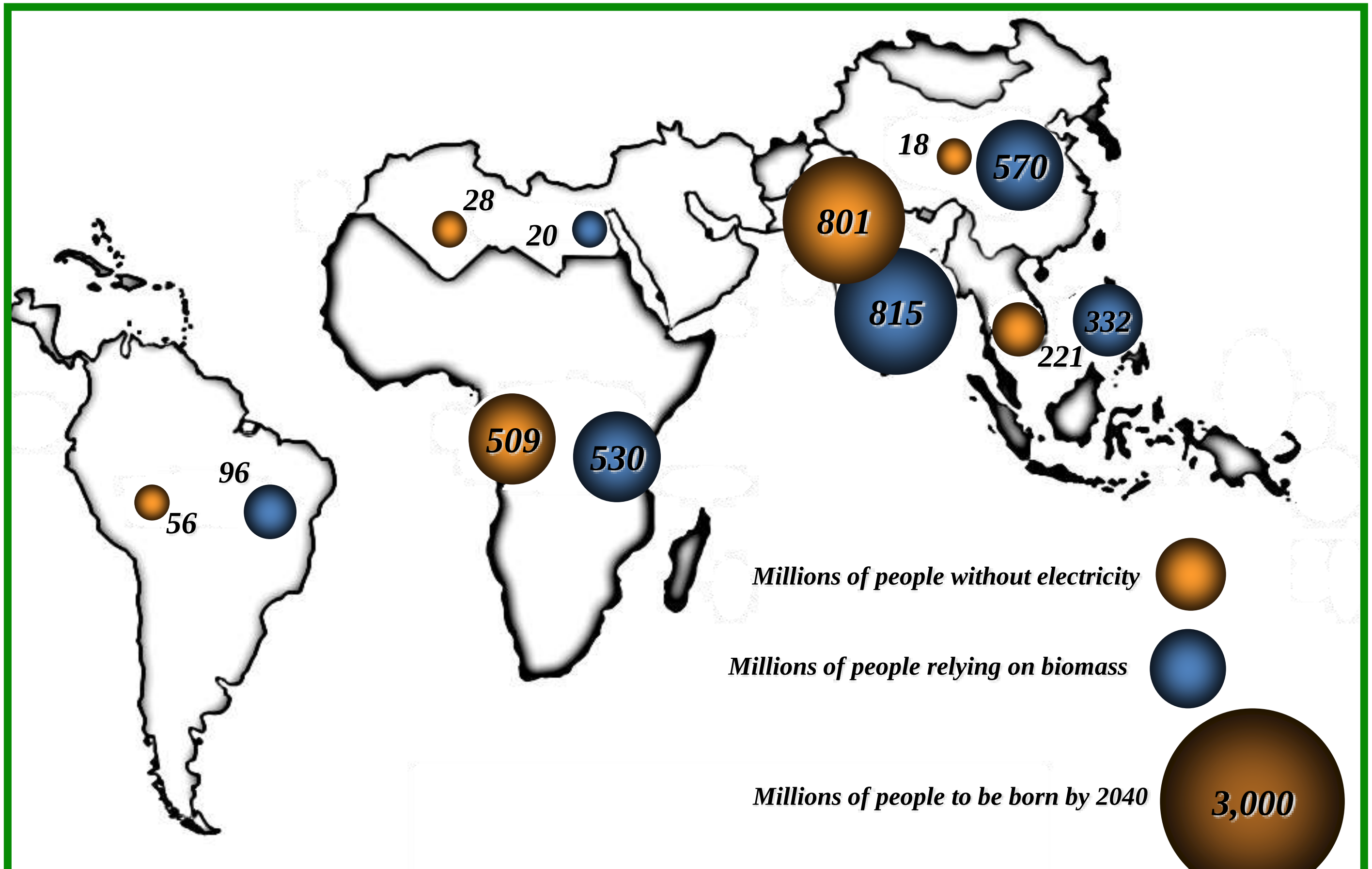
Korea
26% coal
23% gas
7% oil
36% nuclear
8% hydro + renewables

China
70% coal
3% gas
5% wind
1% nuclear
18% hydro 3% other



World Power Consumption
(trillion kilowatt-hours per year)
40
30
20
10
historic
projected
In order to address any of the environmental issues we seem to care about:
over 20 trkWhrs must be non-fossil fuel
World presently at 17 trillion kWhrs/year
present fossil fuel contribution
2/3 of present total
U.S. presently at 4 trillion kWhrs/year
1980
2000
2020
2040

Map of Global Energy Poverty



Source: United Nations; McFarlane 2006

1.6 billion people have no access to electricity, 80% of them in South Asia and sub–Saharan Africa.

2.4 billion people burn wood and manure as their main energy source.

3 billion more people will be born by 2040

Source: ©2005 Kay Chernush for the U.S. Department of State

With modern efficiencies, conservation and technologies, 3,000 kWh/year can provide an HDI > 0.8; > 6,000 kWh/year is unnecessary and wasteful

Access to energy is essential to quality of life

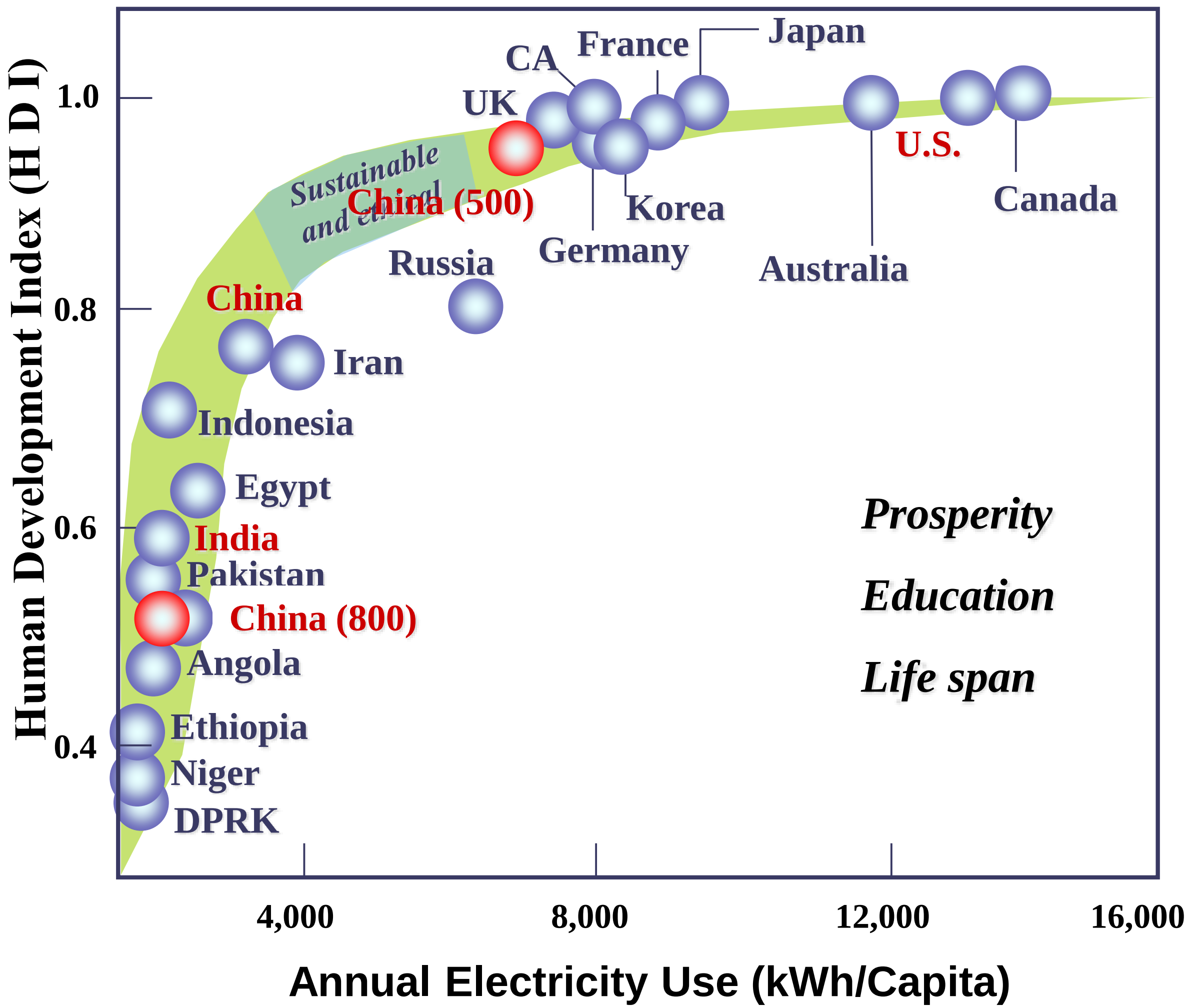
It requires about 3,000 kWhrs/yr to have what we consider a good life.

An adult human can generate about 11 kWhrs/year of useful muscular work on 2,500 Calories/day.

Simple tools increase by 5x

Horses and oxen increase by 25x

Diesel backhoe increase >100x



80% of the world's population of over 6 billion people is below 0.8 on the U.N. Human Development Index (HDI)

Source: United Nations Development Program; McFarlane 2006

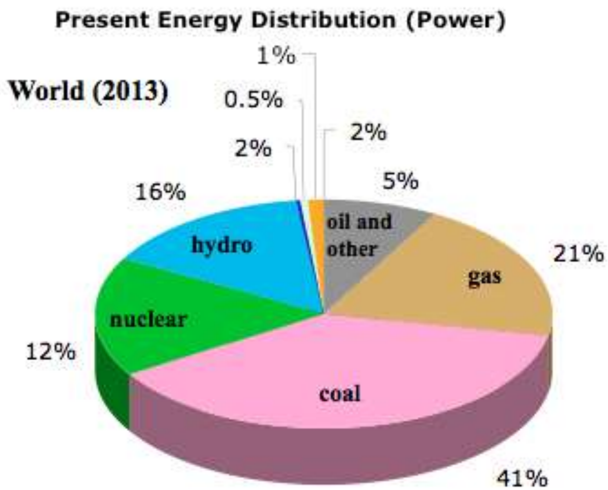
How much energy do we need by 2040? - what levels are needed to end poverty, war and terrorism, i.e., raise everyone up to 0.8 HDI?

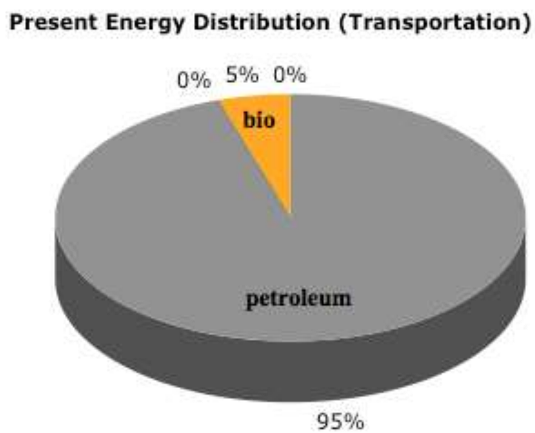
Subpopulation group		*Energy/capita needed to raise HDI to >0.8 or maintain at 0.9*	*Approximate subpopulation*	*Annual energy requirement*
Industrialized world -	**cut to**	**6,000 kWhrs/yr**	**1,000,000,000**	**6 tkW-hrs**
Intermediate -	**maintain**	**3,000 kWhrs/yr**	**1,000,000,000**	**3 tkW-hrs**
Developing world -	**increase to**	**3,000 kWhrs/yr**	**4,000,000,000**	**12 tkW-hrs**
Those born by 2040 -	**achieve**	**3,000 kWhrs/yr**	**3,000,000,000**	**9 tkW-hrs**
		Total Annual Global Energy Requirement		**30 tkW-hrs**

World Target → a Third, a Third and a Third - 1/3 fossil fuel, 1/3 renewables and 1/3 nuclear

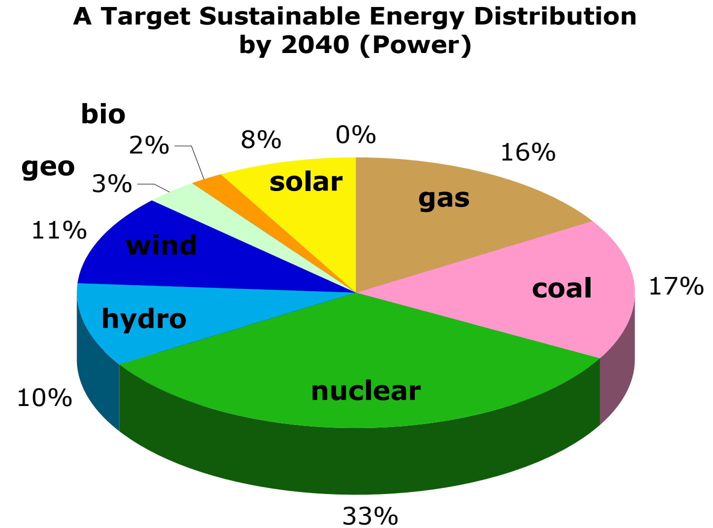
This requires renewables and nuclear worldwide to quadruple over what anyone is expecting by 2040:
4 million+ MW wind turbines; over 1,700 new nuclear reactors; a 100 bbl of biofuels; 3 tkWhrs from hydro; 4 tkWhrs from other

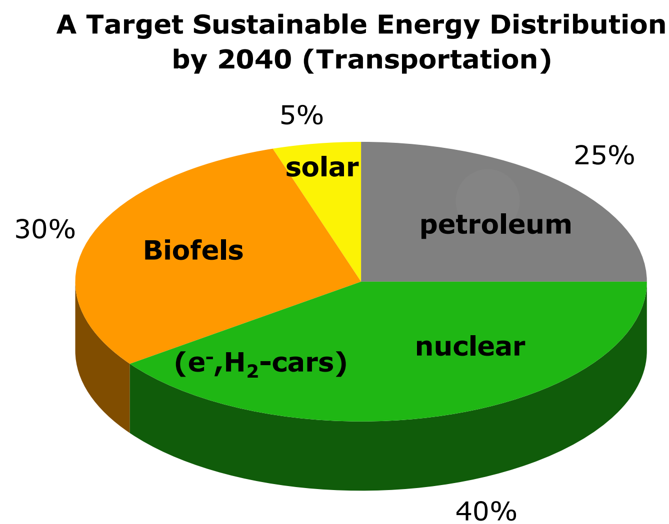
World (2013)
17 tkWhrs/yr





World (2040)
30 tkWhrs/yr



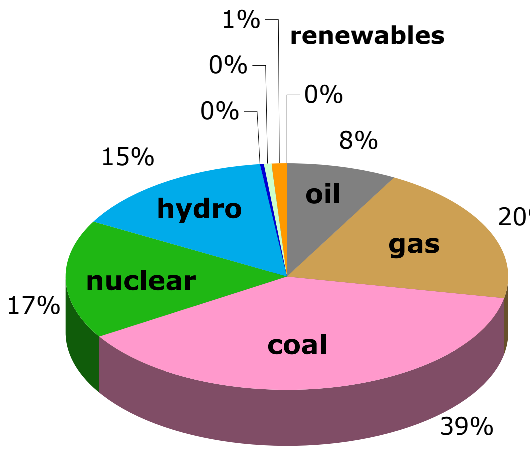


The most likely scenario given the direction of present investment, development and policy

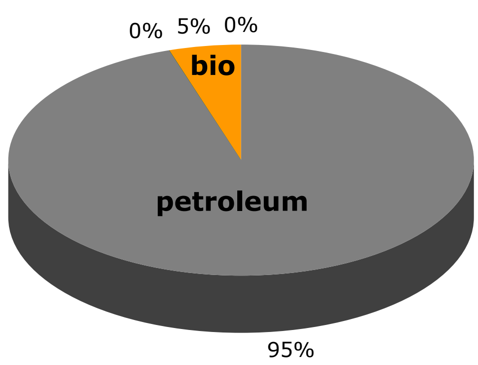
Dramatic increase in gas, coal and development of unconventional fossil fuels

World (2013)
15 tkWhrs/yr

Present Energy Distribution (Power)

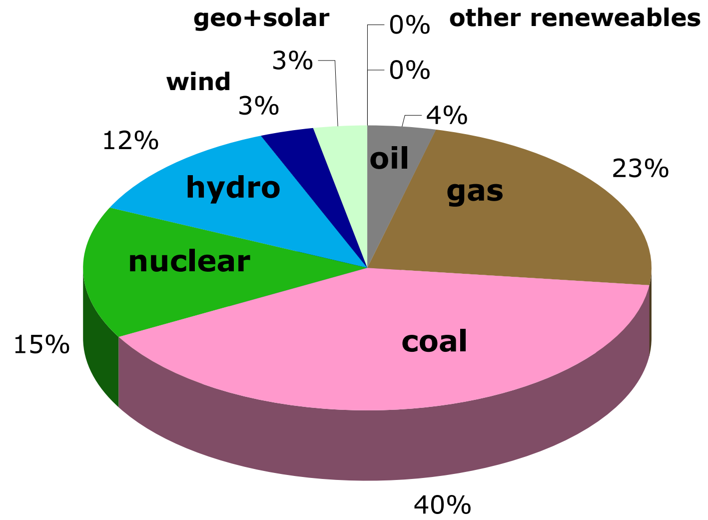


Present Energy Distribution (Transportation)

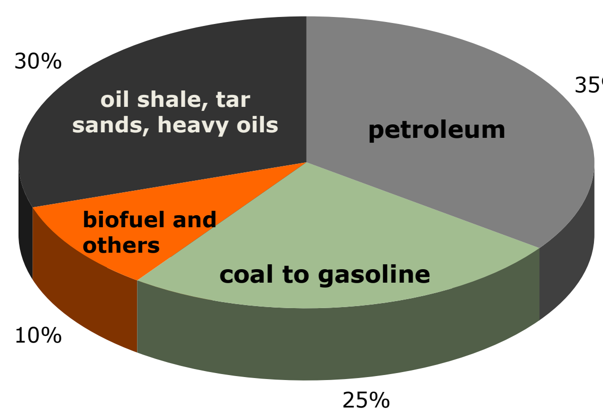


World (2040)
30 tkWhrs/yr

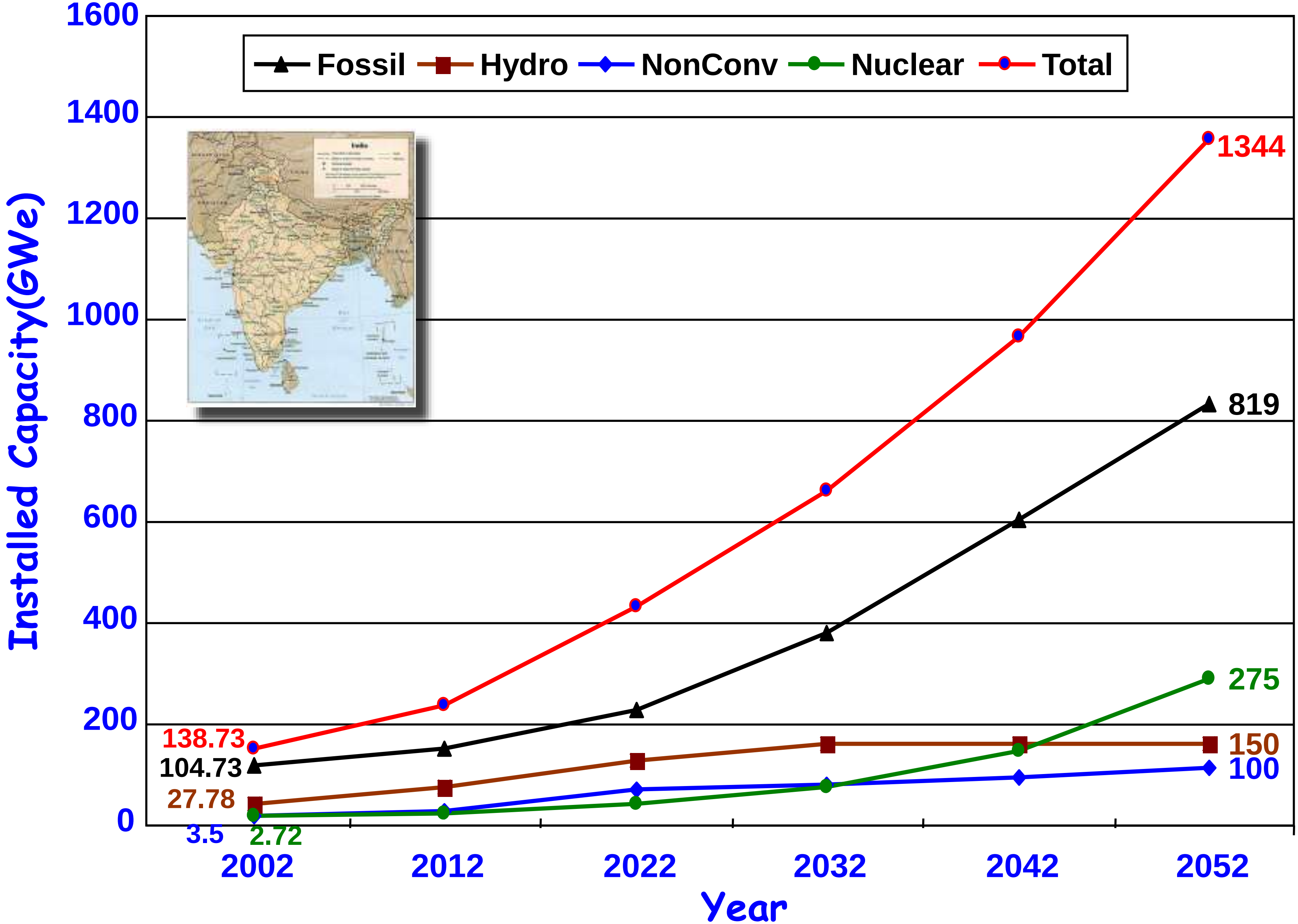
An Industry Energy Distribution by 2040 (Power)



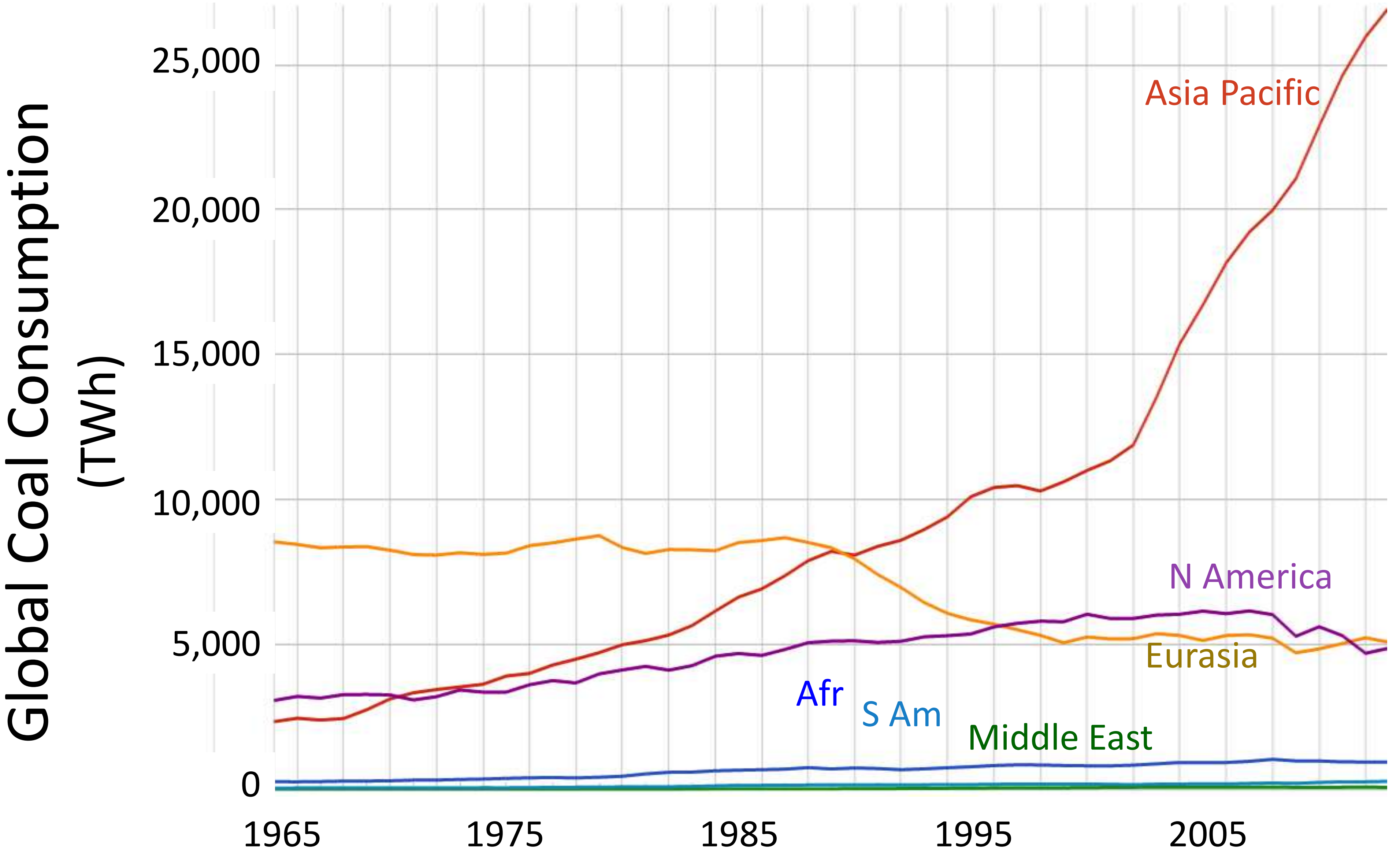
An Industry Energy Distribution by 2040 (Transportation)



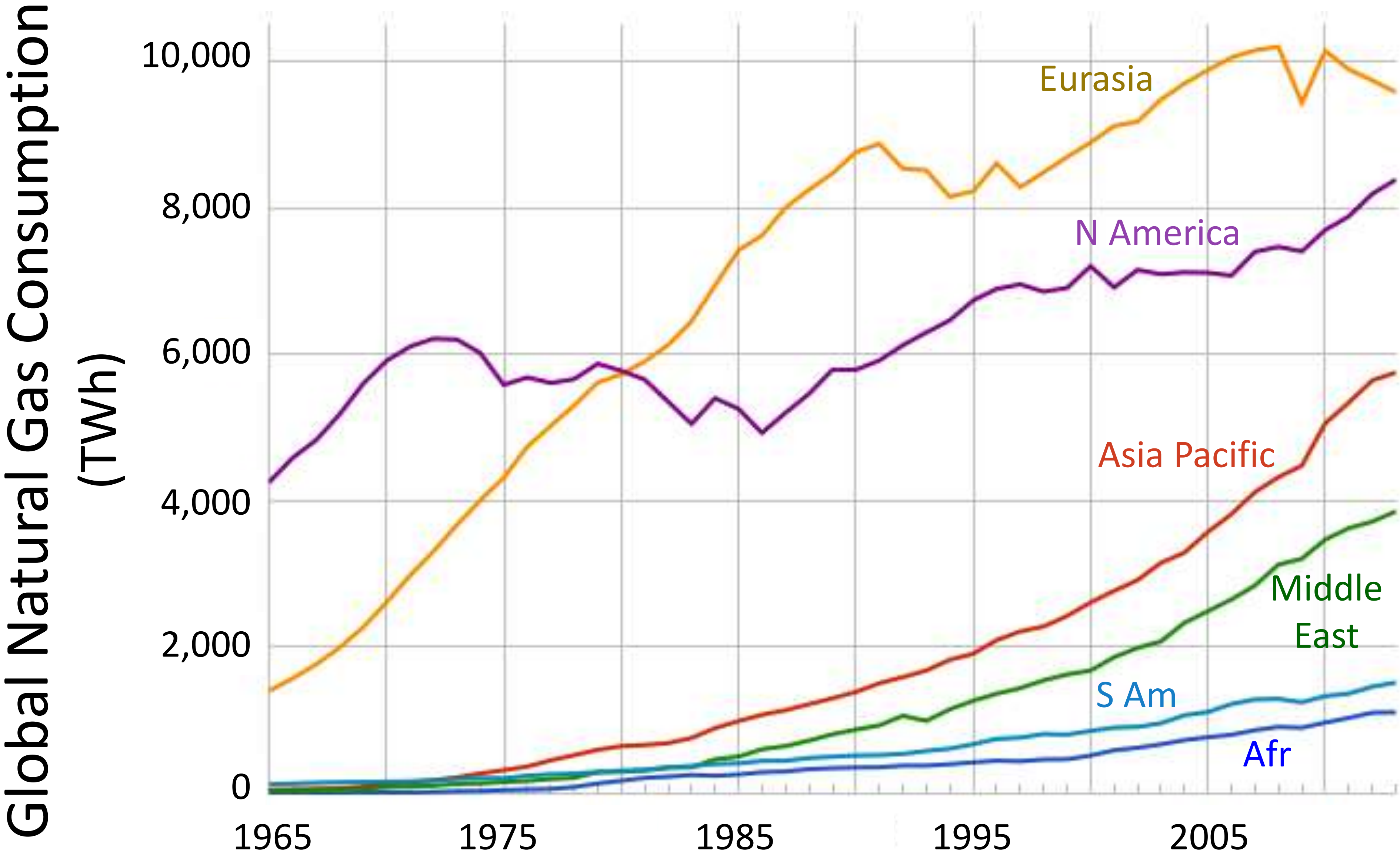
India's planned power capacity



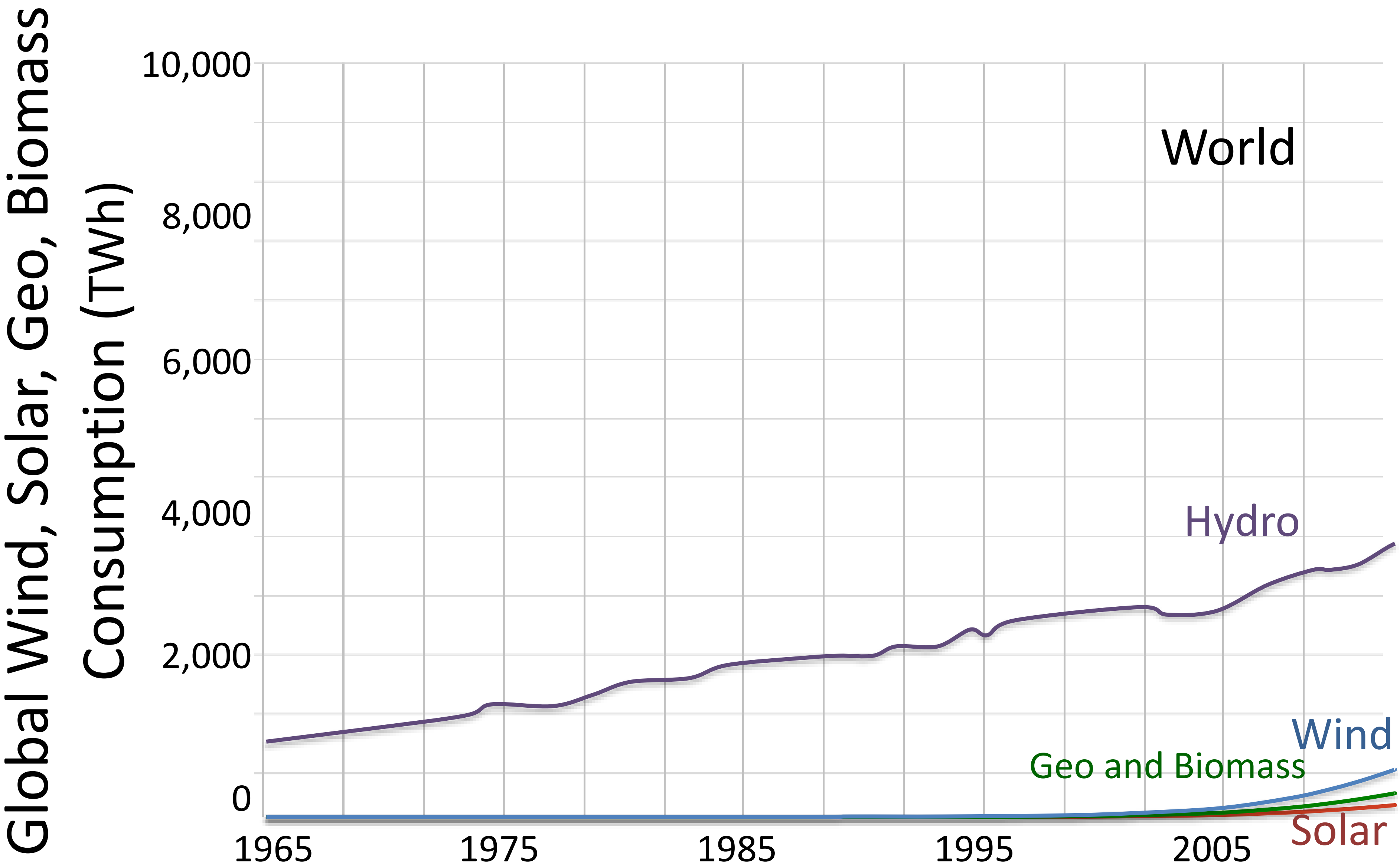
What is the fastest growing energy source?



What is the next fastest growing energy source?



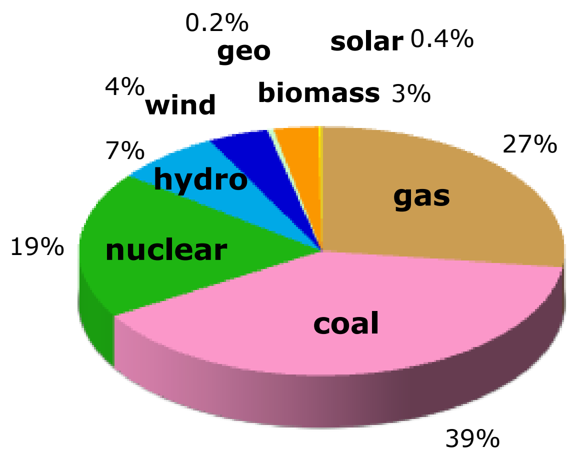
How fast are the other sources growing?



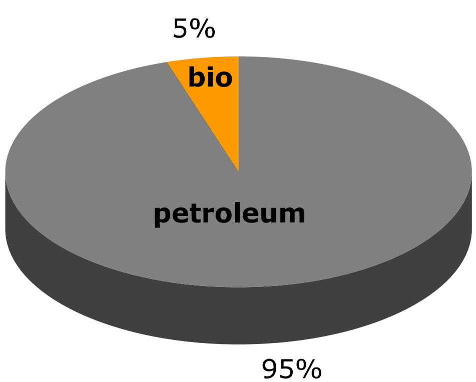
U.S. Target → a Third, a Third and a Third - 1/3 fossil fuel, 1/3 renewables and 1/3 nuclear

U.S. (2013)
4 tkWhrs/yr

Present Energy Distribution (Power)

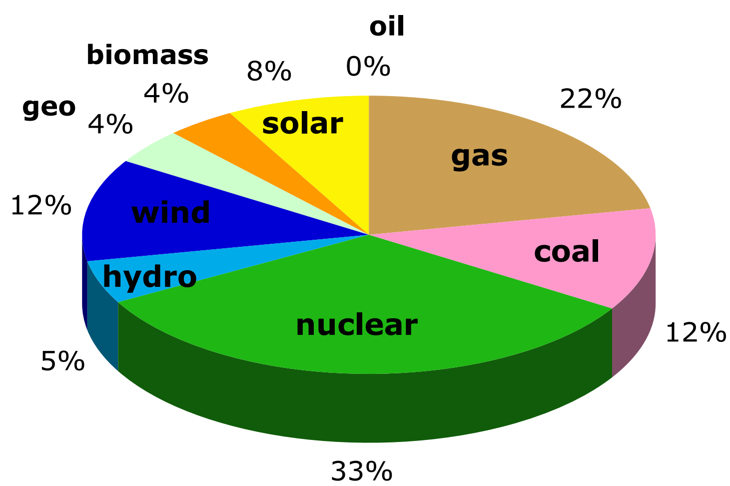


Present Energy Distribution (Transportation)

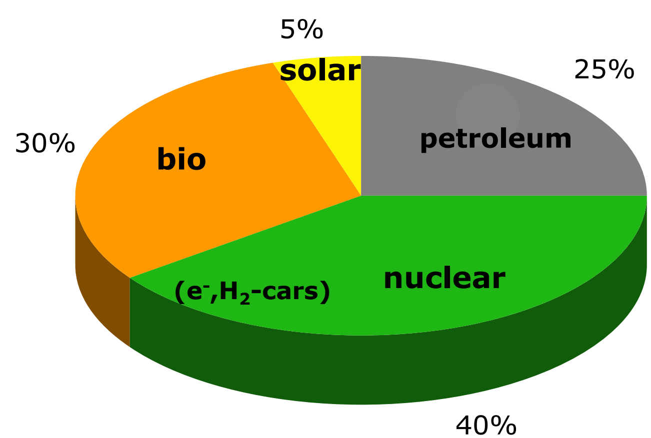


U.S. (2040)
6.5 tkWhrs/yr

A Target Sustainable Energy Distribution by 2040 (Power)



A Target Sustainable Energy Distribution by 2040 (Transportation)



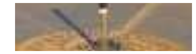
How much will any future energy mix cost?

$7

What will it cost to produce this much energy?

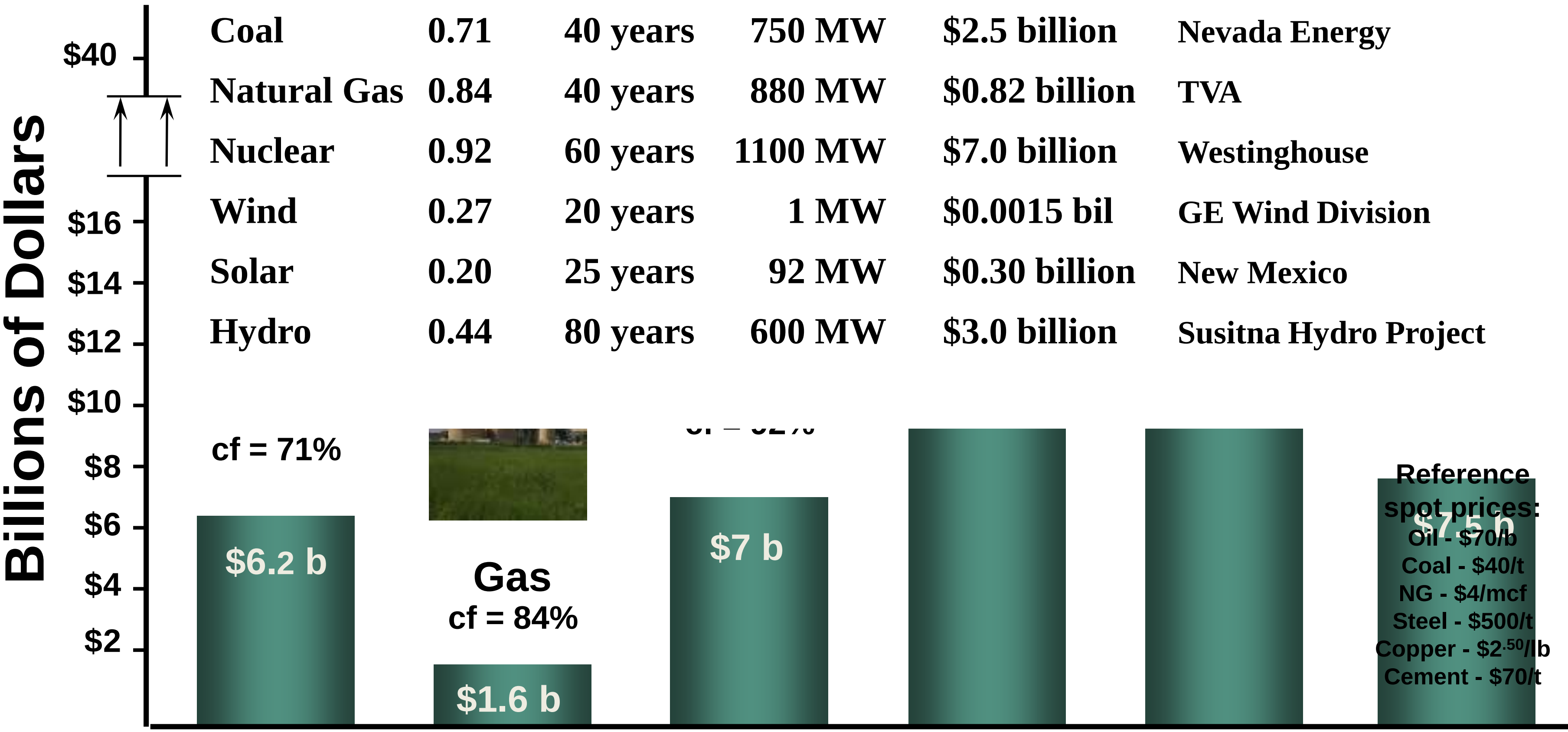
(actual costs, not financing costs, subsidies, production credits, mandates)

-when comparing, costs must be corrected for capacity factor and lifespan



Key assumptions for different energy systems from recent builds and buys

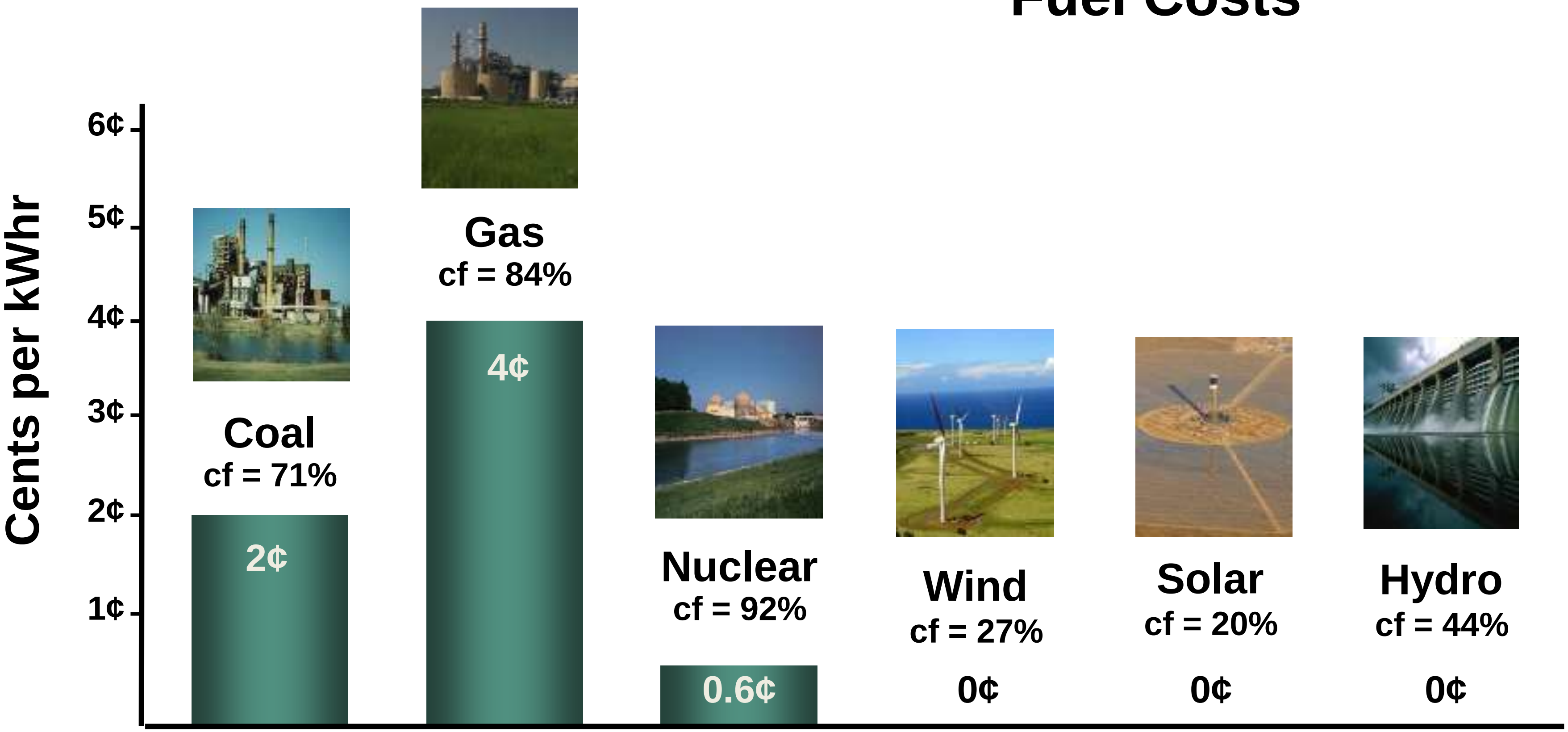
	cf	Lifespan	Inst. Cap.	Inst. Costs	Source
Coal	0.71	40 years	750 MW	$2.5 billion	Nevada Energy
Natural Gas	0.84	40 years	880 MW	$0.82 billion	TVA
Nuclear	0.92	60 years	1100 MW	$7.0 billion	Westinghouse
Wind	0.27	20 years	1 MW	$0.0015 bil	GE Wind Division
Solar	0.20	25 years	92 MW	$0.30 billion	New Mexico
Hydro	0.44	80 years	600 MW	$3.0 billion	Susitna Hydro Project



2012($) Construction Costs to produce similar power (469 bkWhrs)

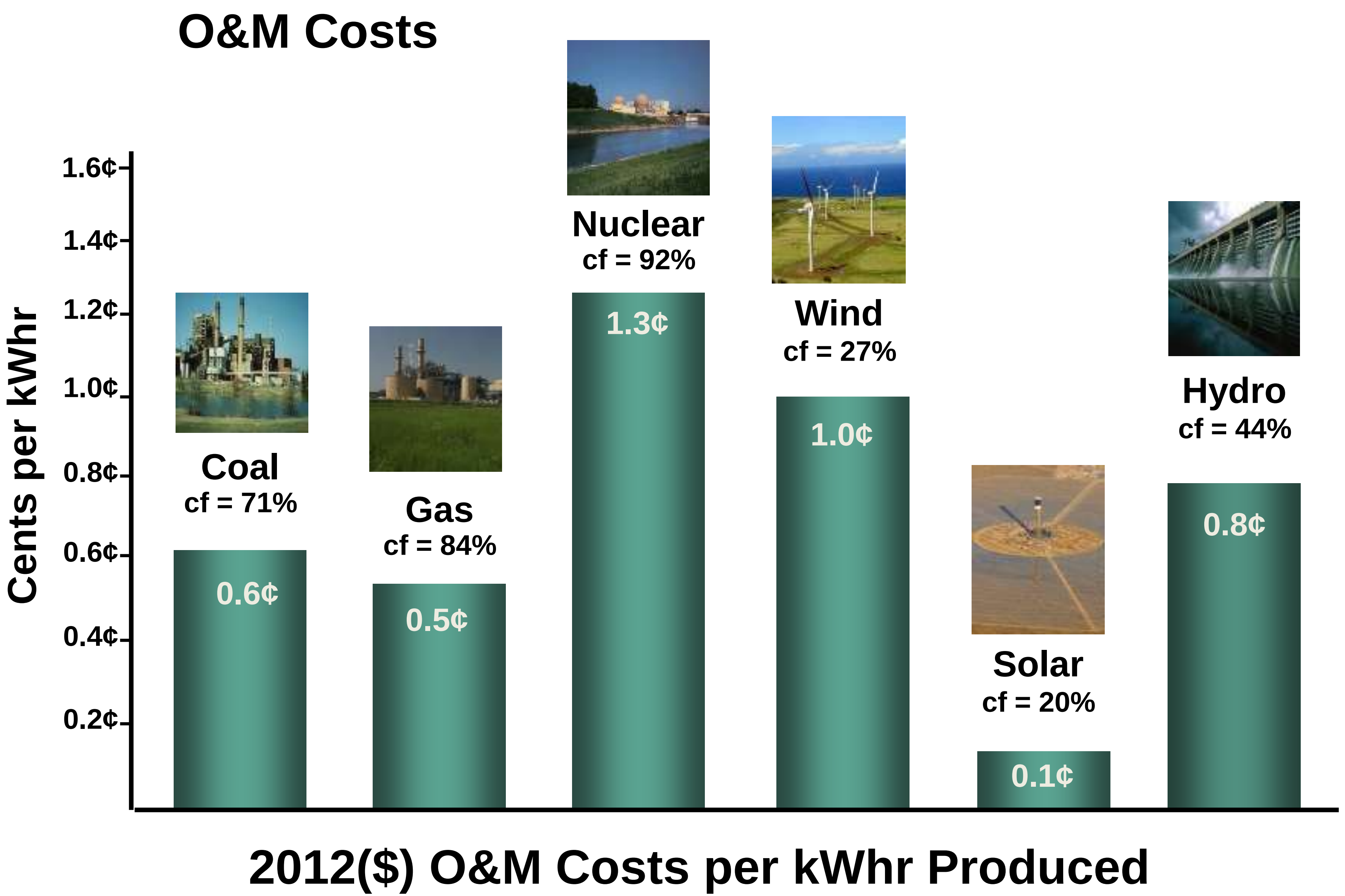
function of installation cost, installed capacity (kW), capacity factor (cf), lifespan, 8,766 hours/year

Fuel Costs



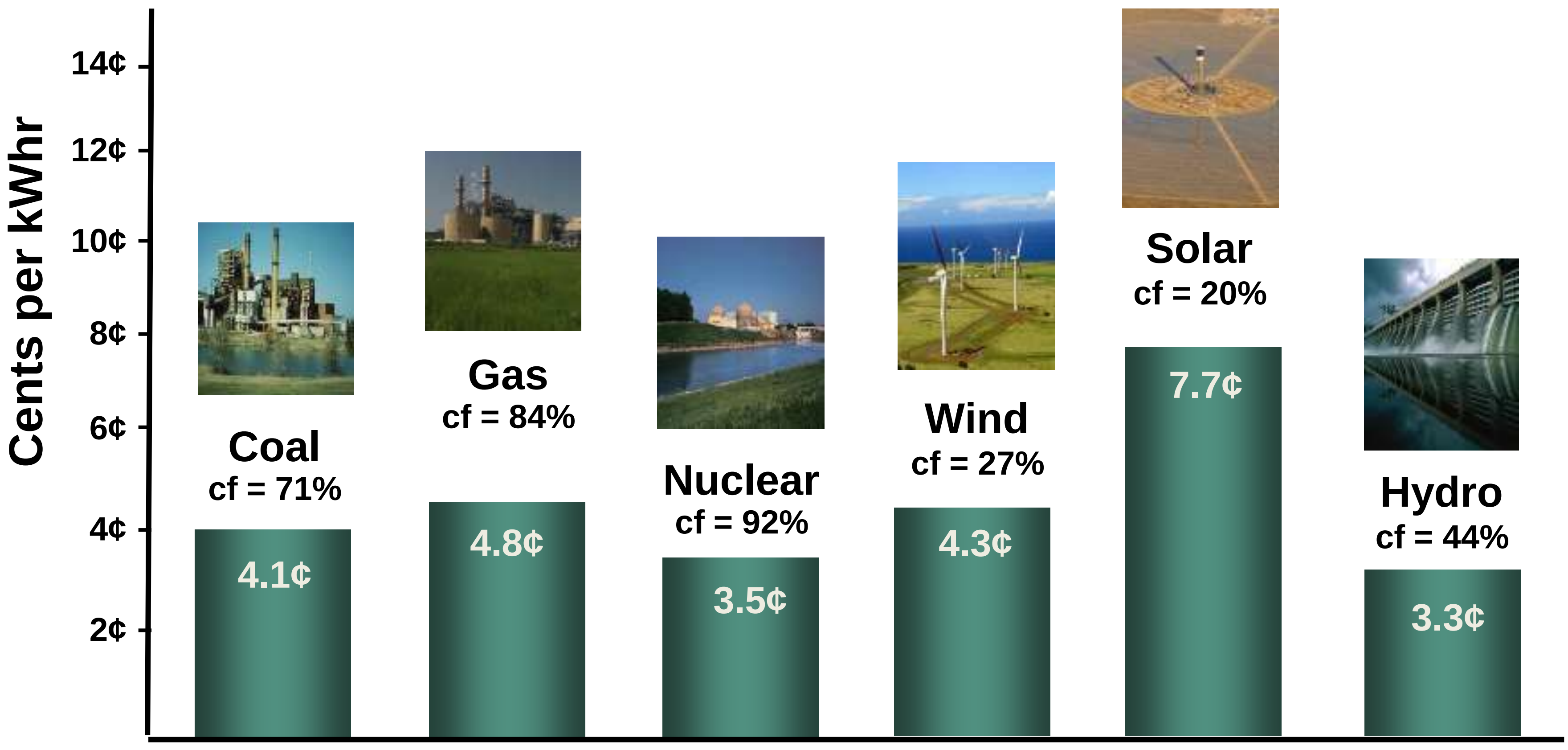
2012($) Fuel Costs per kWhr Produced

Coal - $40/t   NG - $4/mcf   U - $100/lb yellowcake


O&M Costs
Cents per kWhr
1.6¢
1.4¢
1.2¢
1.0¢
0.8¢
0.6¢
0.4¢
0.2¢
Coal
cf = 71%
0.6¢
Gas
cf = 84%
0.5¢
Nuclear
cf = 92%
1.3¢
Wind
cf = 27%
1.0¢
Solar
cf = 20%
0.1¢
Hydro
cf = 44%
0.8¢
2012($) O&M Costs per kWhr Produced

But to produce 6.5 tkWhrs/year by mid-century in the United States with the ⅓ - ⅓ - ⅓ mix (fossil-renewable-nuclear) will cost about $7.4 trillion of which $3.4 trillion is capital investment

However, this mix uses half of the fossil fuel (saves 2 billion tonsCO_2/yr) and the health care savings alone from lower coal and gas (~$3 trillion) more than pays for the extra capital investment



2012($) Actual Costs per kWhr Produced

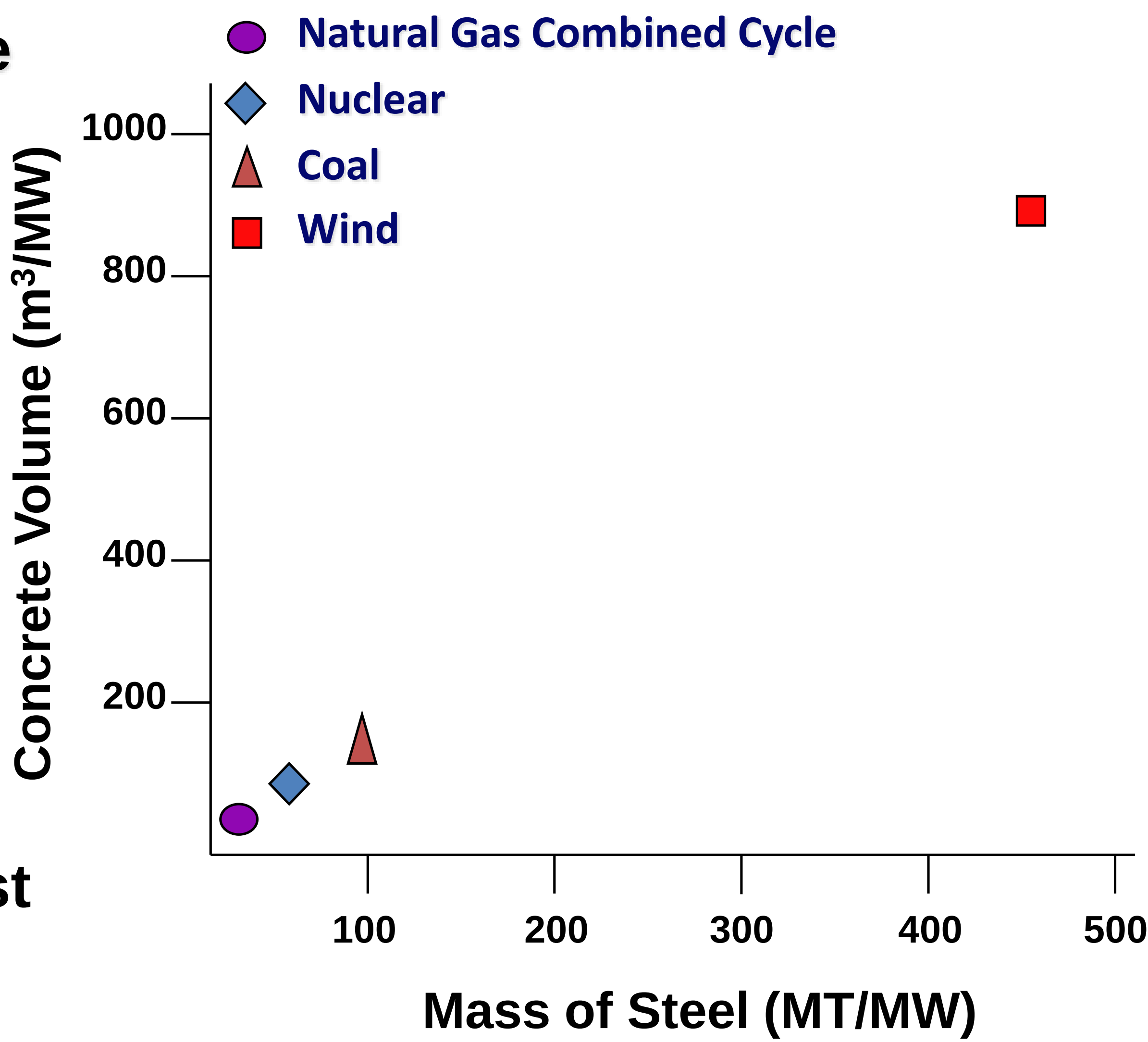
What can change these costs?

Concrete + steel + copper are > 98% of construction inputs, and become more expensive in a carbon-constrained economy

The materials, resource and capital needs:

- the price of oil
- the price of natural gas
- the price of steel
- the price of concrete
- the price of copper

The most sensitive to these prices is wind energy, followed by coal, then gas. The least affected is nuclear.



Energy Source	**Mortality Rate (deaths per trillion kWh)**	
Coal – global average	100,000	(50% of global electricity)
Coal – China	170,000	(75% of China's electricity)
Coal – U.S.	10,000	(44% of U.S. electricity)
Oil	36,000	(36% of global energy, 8% of global electricity)
Natural Gas	4,000	(20% of global electricity)
Biofuel/Biomass	24,000	(21% of global energy)
Solar (rooftop)	440	(< 1% of global electricity)
Wind	150	(~ 1% of global electricity)
Hydro – global average	1,400	(15% of global electricity, 171,000 Banqiao dead)
Nuclear – global average	40	(17% of global electricity w/Chernobyl&Fukushima
Nuclear – U.S.	0.01	(20% of U.S. electricity)

Sources –World Health Organization; CDC; 1970 - 2011

Social - risks facing Americans over the past 5 years

alcohol consumption

automobile driving

coal industry

construction

murder

mining

iatrogenic

nuclear industry

food poisoning

police work

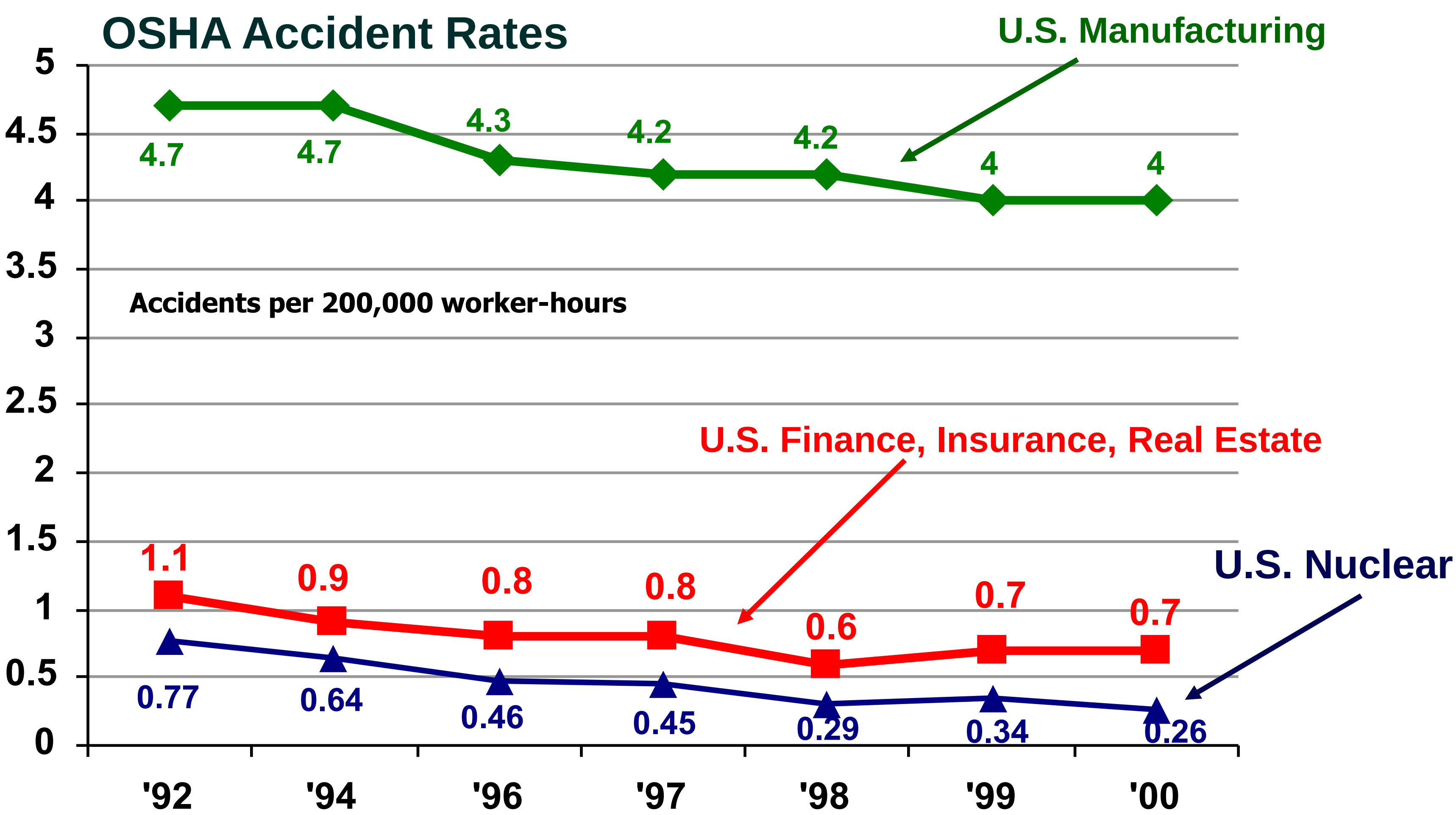
smoking tobacco

The average citizen thinks that smoking and the nuclear power industry are the most dangerous activities in America.

Activity	Number of Deaths in U.S. over the past 5 years
iatrogenic *(medicine gone wrong)*	950,000
smoking	760,000
alcohol	500,000
automobile accidents	250,000
coal use (~ 50% of U.S. power)	60,000
murder	80,000
food poisoning	25,000
construction	5,000
police work	800
mining	360
nuclear industry (~ 20% of U.S. power)	1

Activity	Number of Deaths in U.S. Normalized to Sub-Population	Relative Danger Index
1) smoking (43.4 million smokers)	760,000	0.01751
2) alcohol (60 million impacted Americans)	500,000	0.00833
3) iatrogenic (180 million receive medical treatment per/yr)	950,000	0.00527
4) automobile accidents (190 million drivers)	250,000	0.00138
5) police work (680,000 police officers)	800	0.00118
6) mining (350,000 miners)	360	0.00103
7) construction (7.7 million workers)	5,000	0.00065
8) murder (300 million impacted)	80,000	0.00027
9) coal use (240 million impacted)	60,000	0.00025
10) food poisoning (304 million eat every day)	25,000	0.00008
11) nuclear industry (~ 20% of U.S. power) (60 million)	1	0.0000001

Even non-lethal routine accidents are dramatically lower in the nuclear industry than in any other industry



Why is Everyone So Afraid of Nuclear Energy?

1) **Incorrect, but intentional, association with nuclear weapons during the Cold War - 1945**

Because we told them to be!

2) **Inaccurate and purposefully simplistic modeling of health effects of low radiation doses (LNT) - 1959**

3) **Misunderstanding of the nature and amount of nuclear power waste - 1976**
    - not much of it (< 1 km^3 worldwide)
        - over 20,000 km^3 of direct solid coal waste
    - we know what to do with it - 1999

There is not much of it.

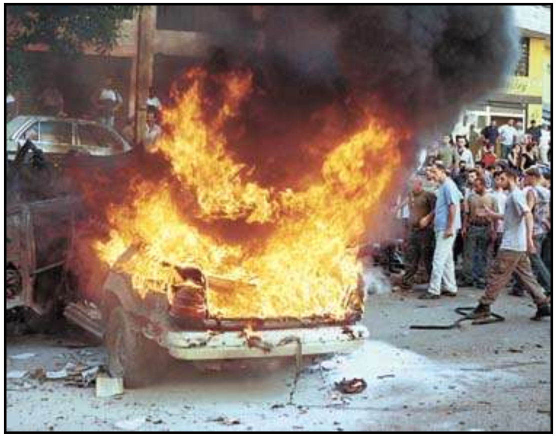
All the commercial nuclear waste in the world ever produced in history would fit in any high school football stadium.

In the United States:

waste from all nuclear power (19% of U.S. power supply)	**~ 2,000 tons solids generated each year**
waste from all coal fired power plants (32% of U.S. power supply) generated each year	**~ 400,000,000 tons solids** **~ 2,000,000,000 tons CO_2** **25,000 tons of radwaste (emitted)**
chemical and biological waste	**~ 500,000,000 tons**
wastewater requiring treatment	**~ 2,000,000,000,000 gallons**

The five biggest problems cited against nuclear energy are:

1. capital costs
2. operational risks
3. proliferation/terrorist attack
4. waste disposal
5. public fear and misperception



All have, or can be, addressed:

1. **capital costs -** standardized units, removing punitive financing practices and regulatory delays, dramatically reduces costs *which are already low*
   total Life Cycle costs: wind 4.3¢/kWhr, nuclear 3.5¢/kWhr, hydro 3.3¢/kWhr
   (including construction) coal 4.1¢/kWhr, gas 4.8¢/kWhr, solar 7.7¢/kWhr
2. **operational risks -** nuclear energy industry safety record - best of any industry in the history of the world
3. **proliferation/terrorism** - non-proliferable strategies & fuel (isotopic blending or co-extraction Am/Cm, fast reactors, world fuel bank, waste take-back/central global repositories)
   nuclear reactors are already militarily hardened targets
4. **waste disposal -** the WIPP site in New Mexico has shown that deep-geologic disposal of nuclear waste is safe and cost-effective
5. **public perception -** this can only be addressed by education and the media

Five designs competing for U.S. market: *Generation III & III+*

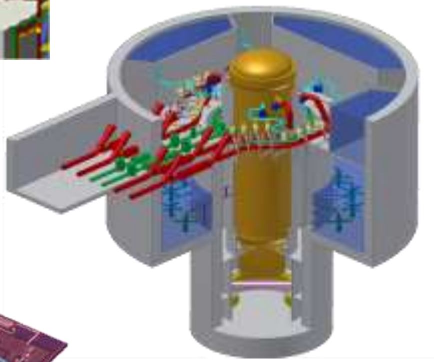
On-schedule for NRC pre-approval and fast-tracking
- 52 new units ordered worldwide; none in the U.S.

Standardized designs based on modularization producing shorter construction schedules and lower costs

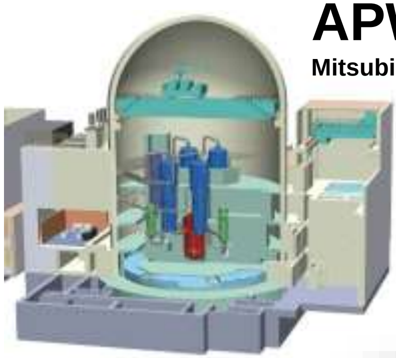
Passive and redundant systems to ensure safety

Easy to protect from terrorist attacks

AP-1000
Westinghouse/Toshiba



ESBWR
General Electric



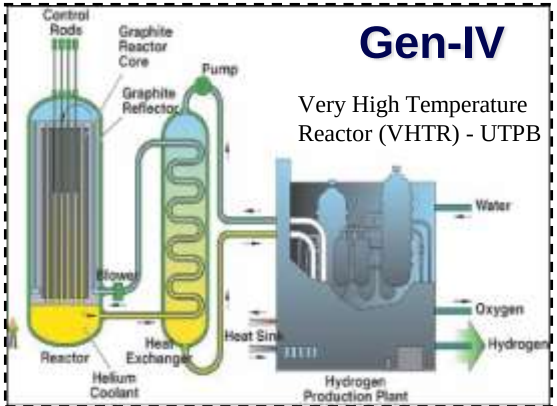
APWR
Mitsubishi

EPR
AREVA

ABWR
Hitachi

Gen-IV

Very High Temperature Reactor (VHTR) - UTPB

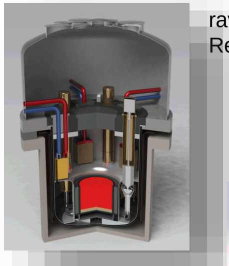


mPower Reactor
Babcock&Wilcox

HPM
Hyperion

NuScale

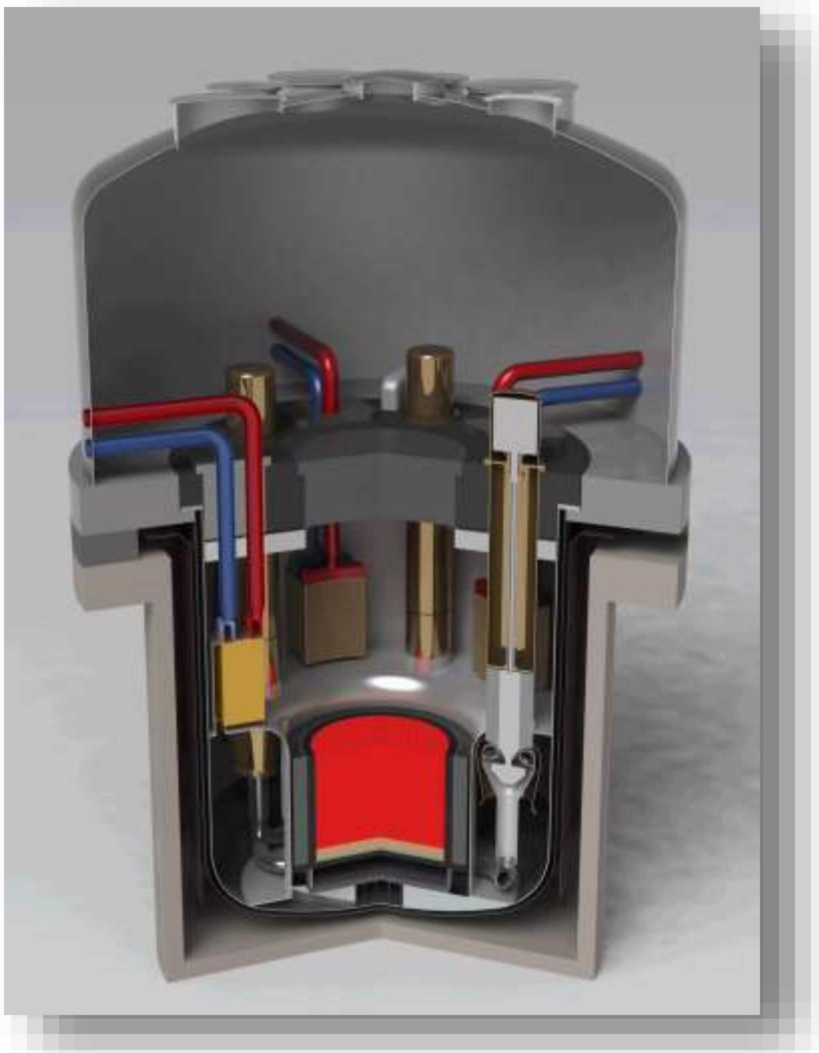
Toshiba 4S reactor



TerraPower Travelling Wave Reactor

General Atomics
EM^2 Reactor

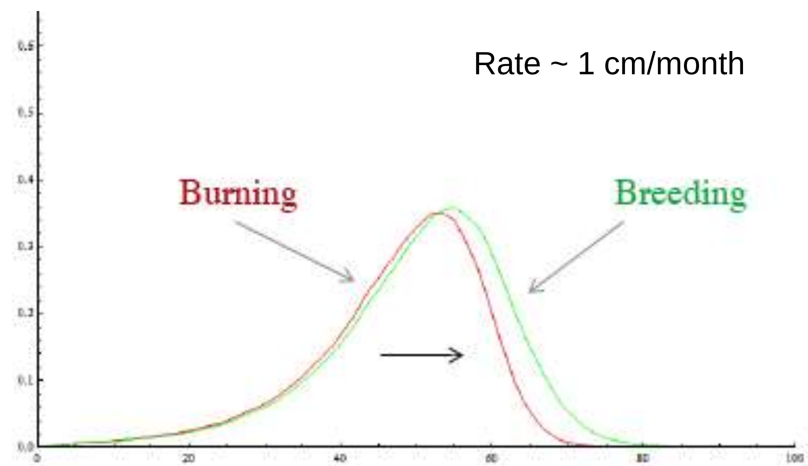
The latest innovative nuclear plant design has been pioneered by John Gilleland of Berkeley and funded by Bill Gates, now partnered with Toshiba



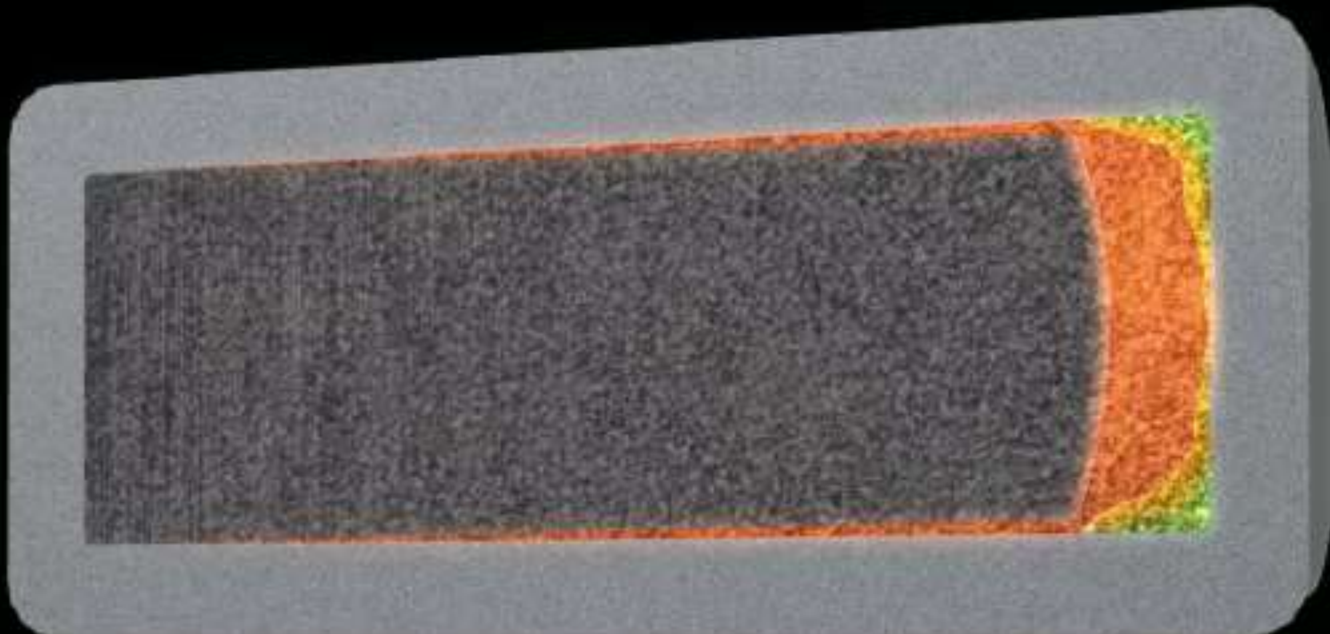
Gen IV

TerraPower

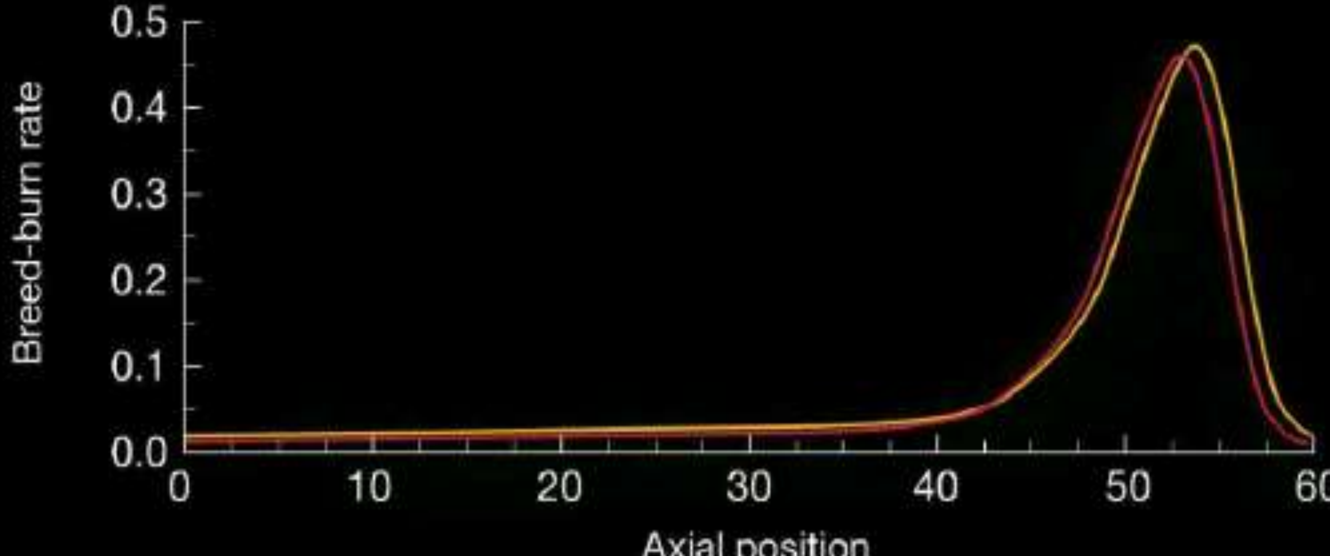
Travelling Wave Reactor



Traveling-Wave reactor - sustains a dual-wave of fission and breeding that travels through the core over 50 to 100 years depending upon design; can use multiple types of fuel, even depleted-U; no refueling and no enriching once it starts up to 1000 MW electric



60 Years

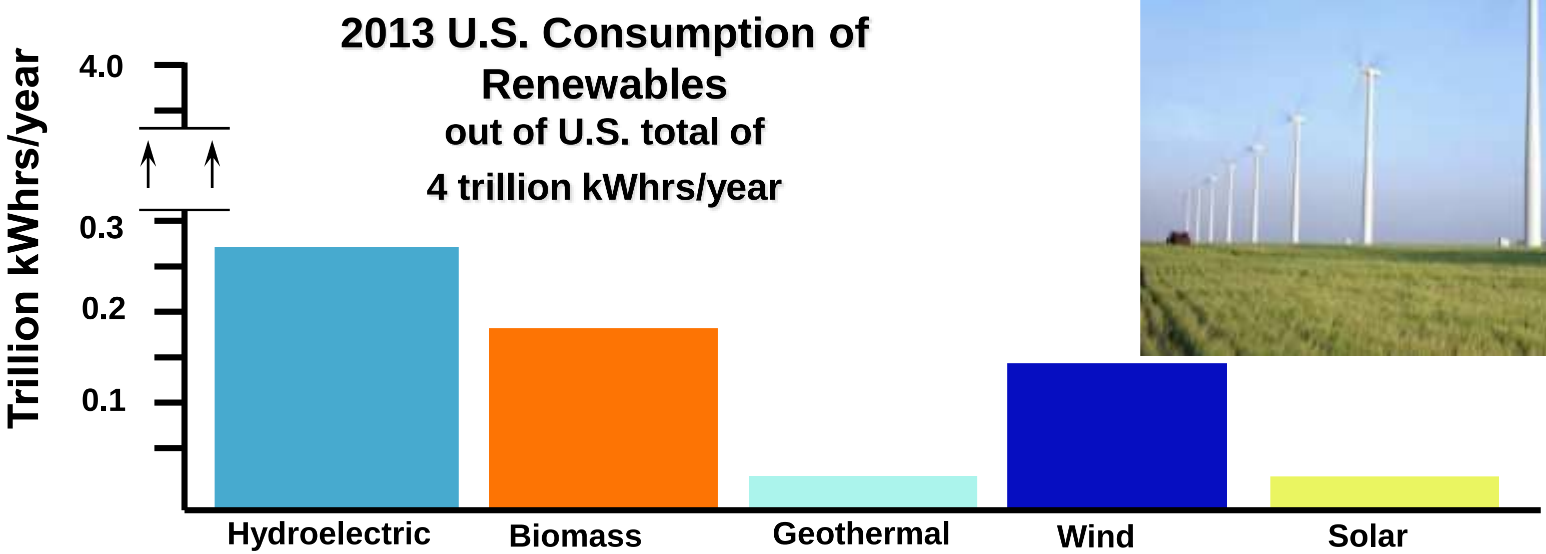


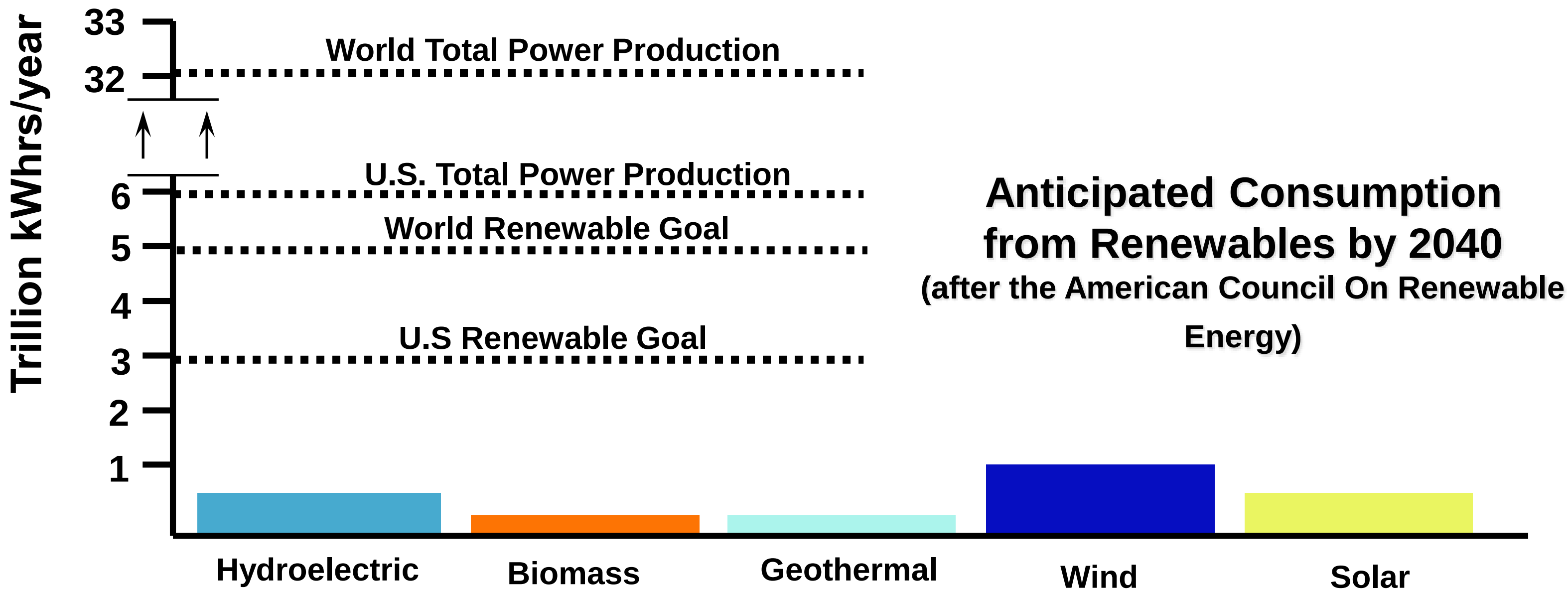
Breed-burn rate
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
60
Axial position

Carbon Footprints

Renewables for 10 trillion kW-hrs

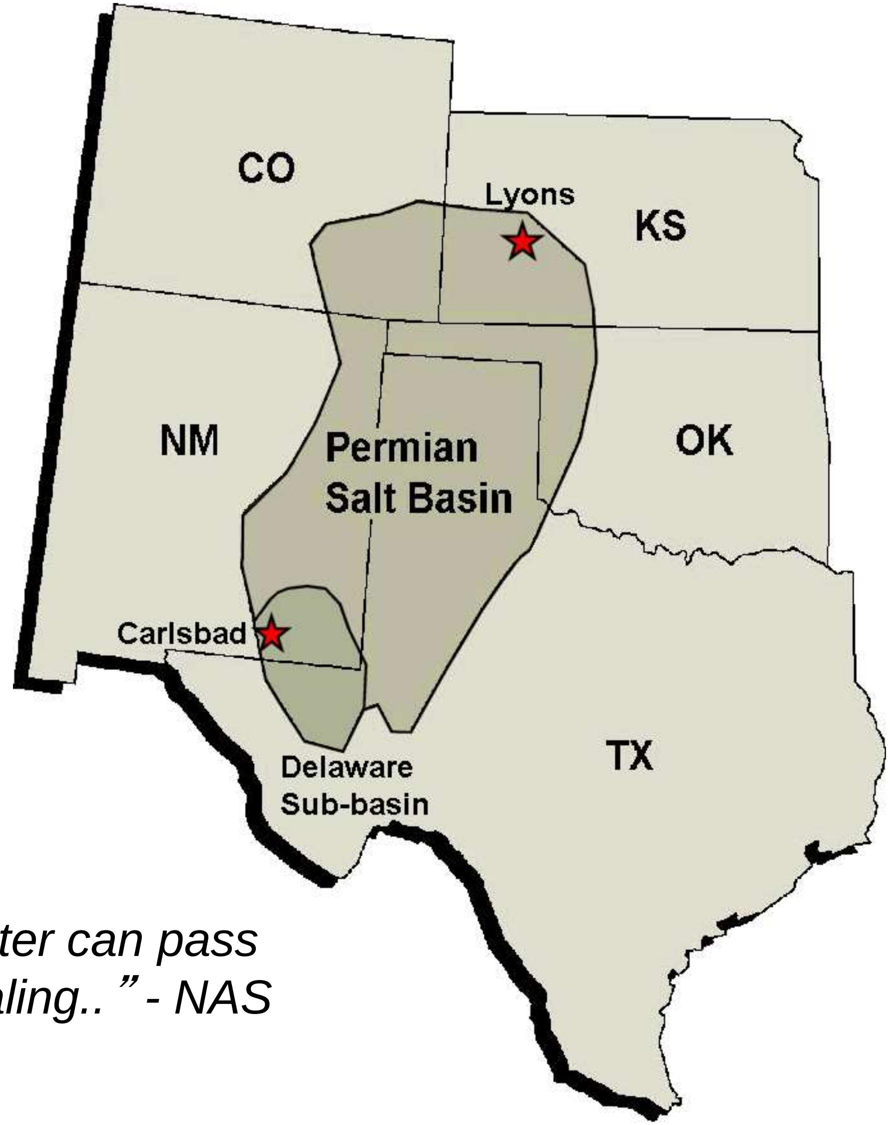
Can Renewables generate 10 trillion kW-hrs/yr? This is the amount of energy presently supplied by all fossil fuels.


2013 U.S. Consumption of Renewables
out of U.S. total of
4 trillion kWhrs/year
Trillion kWhrs/year
4.0
0.3
0.2
0.1
Hydroelectric
Biomass
Geothermal
Wind
Solar


Trillion kWhrs/year
33
32
6
5
4
3
2
1
World Total Power Production
U.S. Total Power Production
World Renewable Goal
U.S Renewable Goal
Anticipated Consumption from Renewables by 2040
(after the American Council On Renewable Energy)
Hydroelectric
Biomass
Geothermal
Wind
Solar

National Academy of Sciences (NAS) concludes in 1957 that the most promising disposal option for all radioactive waste is in bedded salt deposits

1957



"Salt at great depth 'flows.' It will encapsulate any waste placed at depth and isolate it from the surface environment for eons." - NAS

"The great advantage is that no water can pass through salt. Fractures are self healing.." - NAS

Disposal options for different waste streams begins to diverge in the 1970s

1957 - deep geologic disposal adopted; salt chosen as best

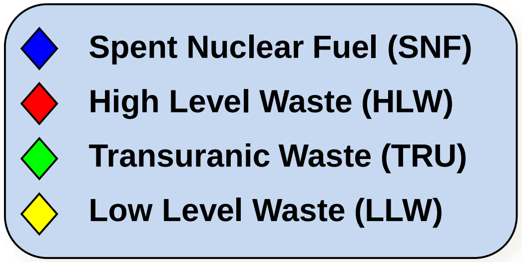
1970 - AEC establishes new category for transuranic waste, distinct from low- and high-level radioactive waste but with significant overlap in radioactivity.

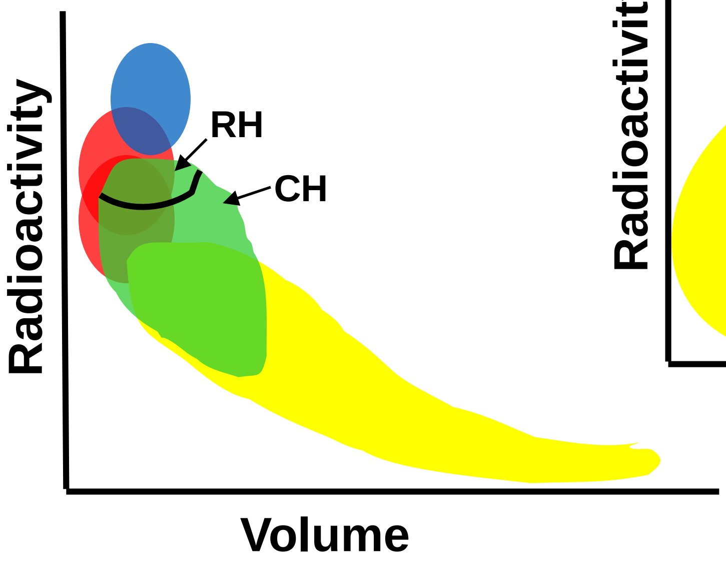
1976 – reprocessing of commercial spent fuel put on hold; retrievable disposal concept is born; salt is out; separate HLW disposal site is sought. TRU still to go into salt.

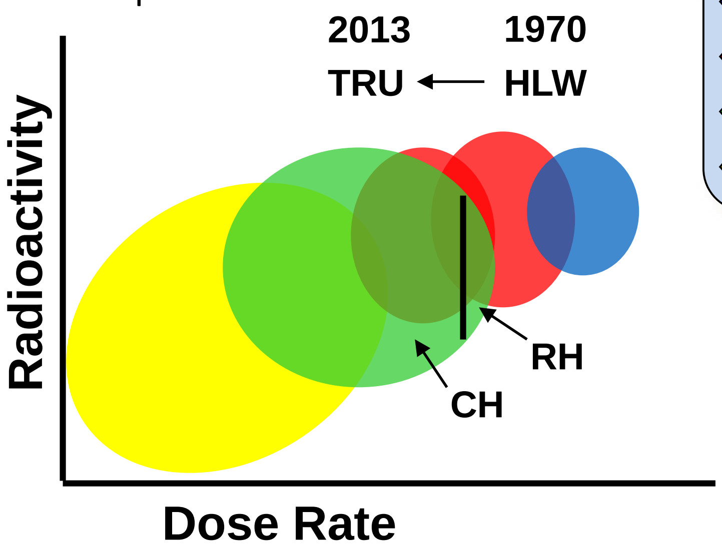
1987 – Yucca Mt chosen. 2008 – YM license application

2010 – Yucca Mt placed on hold. BRC formed.

2012 – BRC recommendations. Path forward possible.



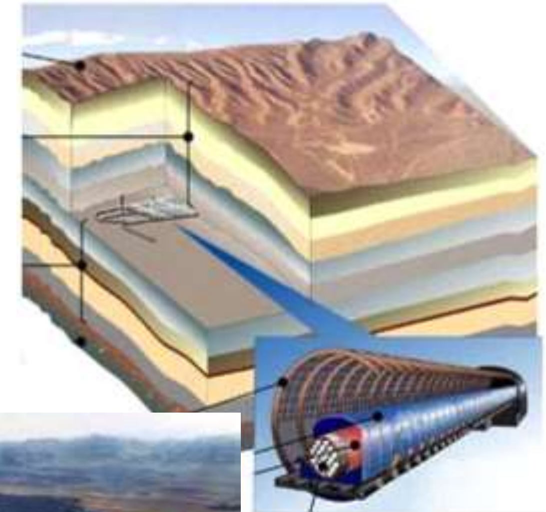




Contact Handled (CH) < 200 mrem/hr < Remote Handled (RH, up to 23 Ci/L)

….nine candidate sites for the high-level and commercial waste selected in 1982, narrowed to three by 1987

- Yucca Mt, Nevada
- Hanford, Washington State
- Deaf Smith, Texas



In 1987, Speaker of the House was Jim Wright from *Texas*, House majority lead was Tom Foley from *Washington* State. A junior, Harry Reid, was from *Nevada*. So Nevada was chosen. Harry Reid is now the Senate Majority Leader and led the effort to have Obama shut down the Yucca Mountain project. In 2010, President Obama put a Blue Ribbon Commission together to study alternatives.

Unknown to most, transuranic waste (bomb waste) continued on into the salt as planned, leading to the Waste Isolation Pilot Plant.

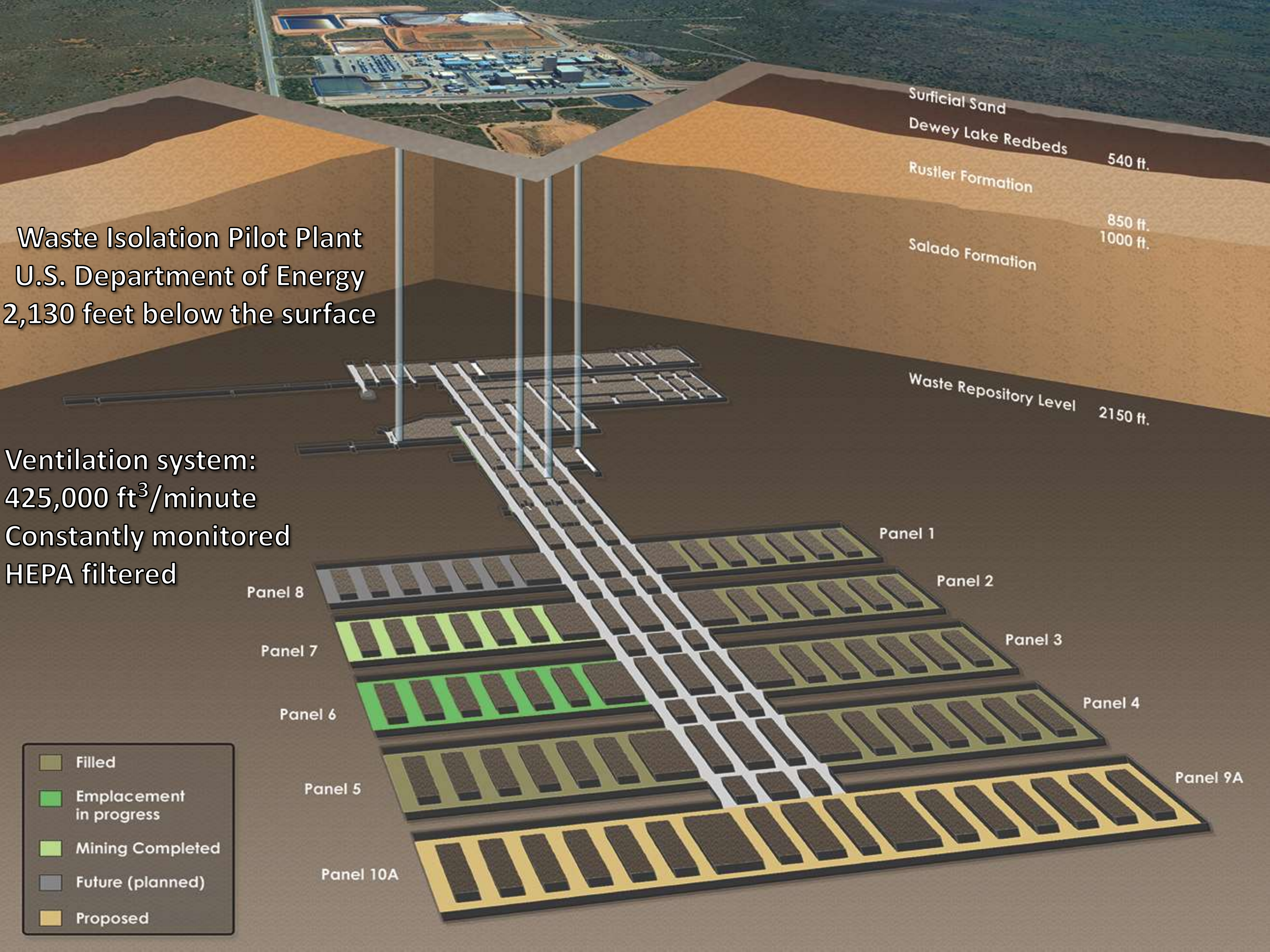
WIPP has shown that geologic disposal of nuclear waste is safe and cost-effective

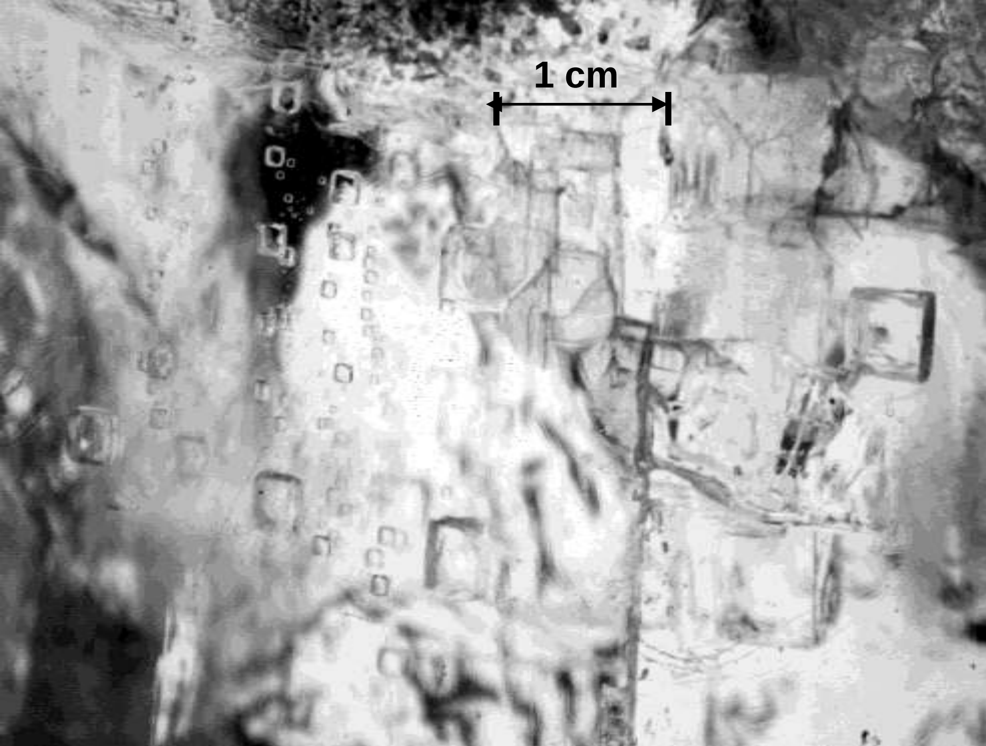
Only Defense-generated TRU waste presently permitted between 100 nCi/g and 23 Ci/L of alpha-emitting ^{239}Pu equivalents

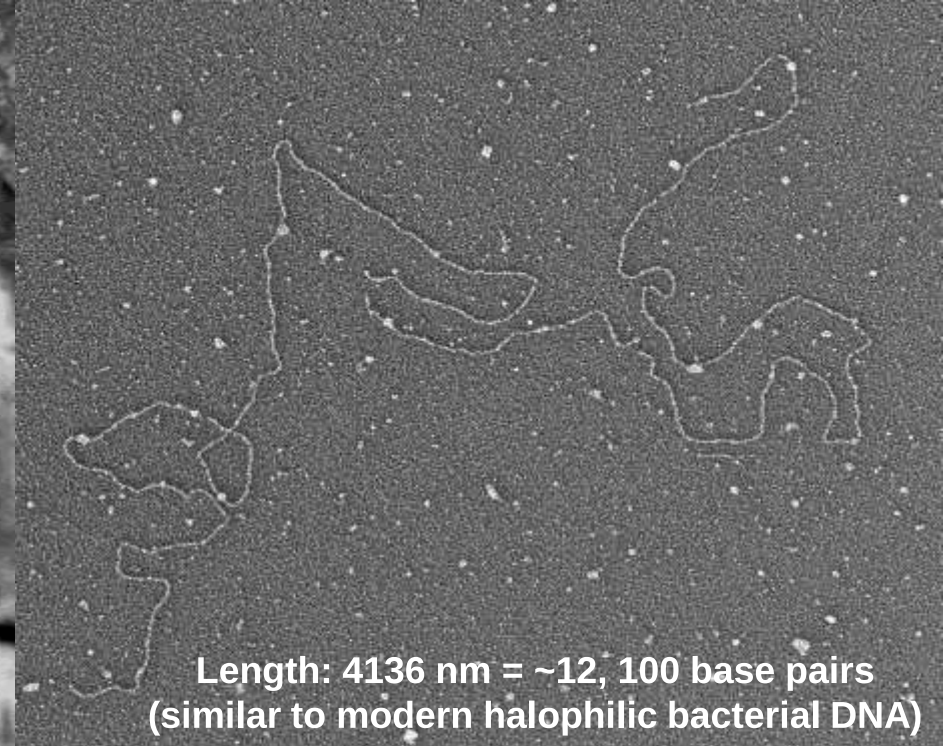
16 miles^2 set aside in the 1992 Land Withdrawal Act
- when WIPP is full, only 1/2 mile^2 will have been used

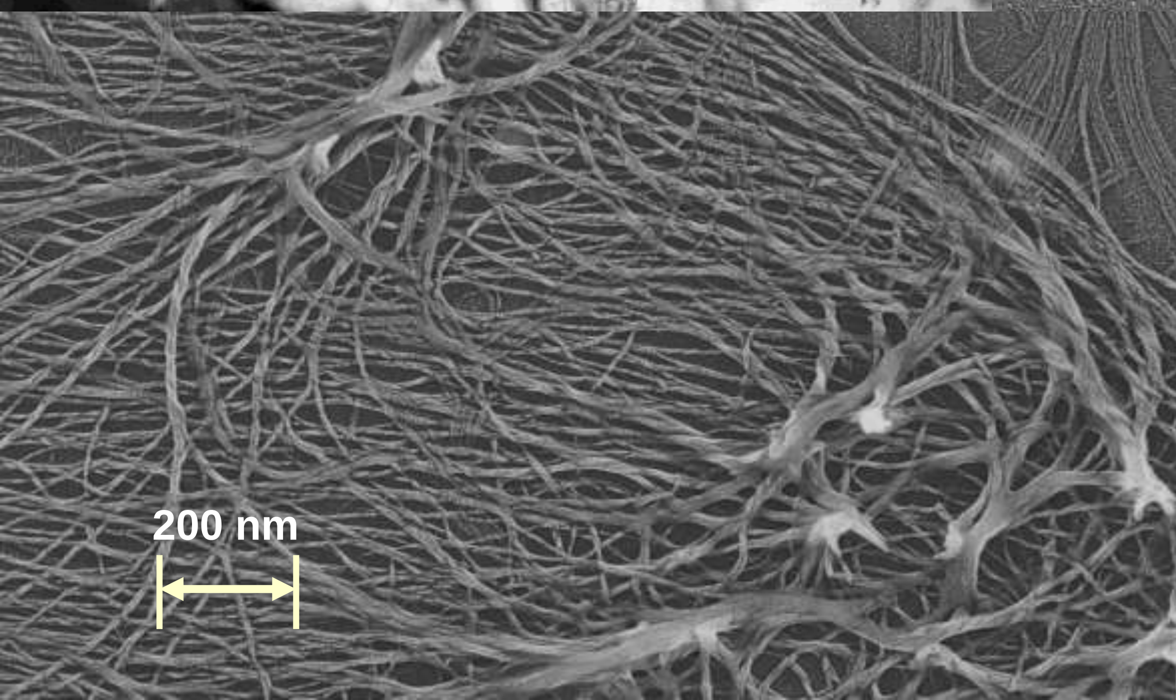
Waste Isolation Pilot Plant
U.S. Department of Energy
2,130 feet below the surface

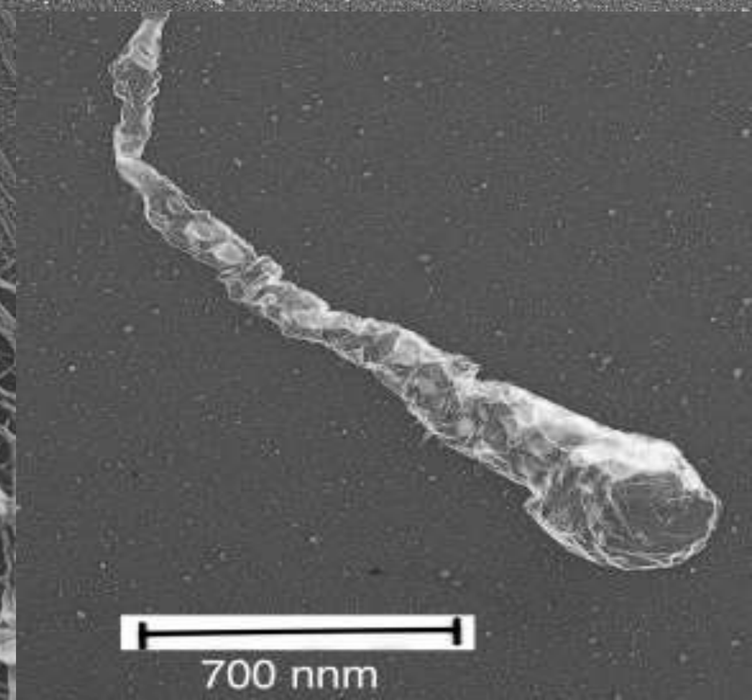
Ventilation system:
425,000 ft^3/minute
Constantly monitored
HEPA filtered




1 cm


Length: 4136 nm = ~12, 100 base pairs
(similar to modern halophilic bacterial DNA)


200 nm

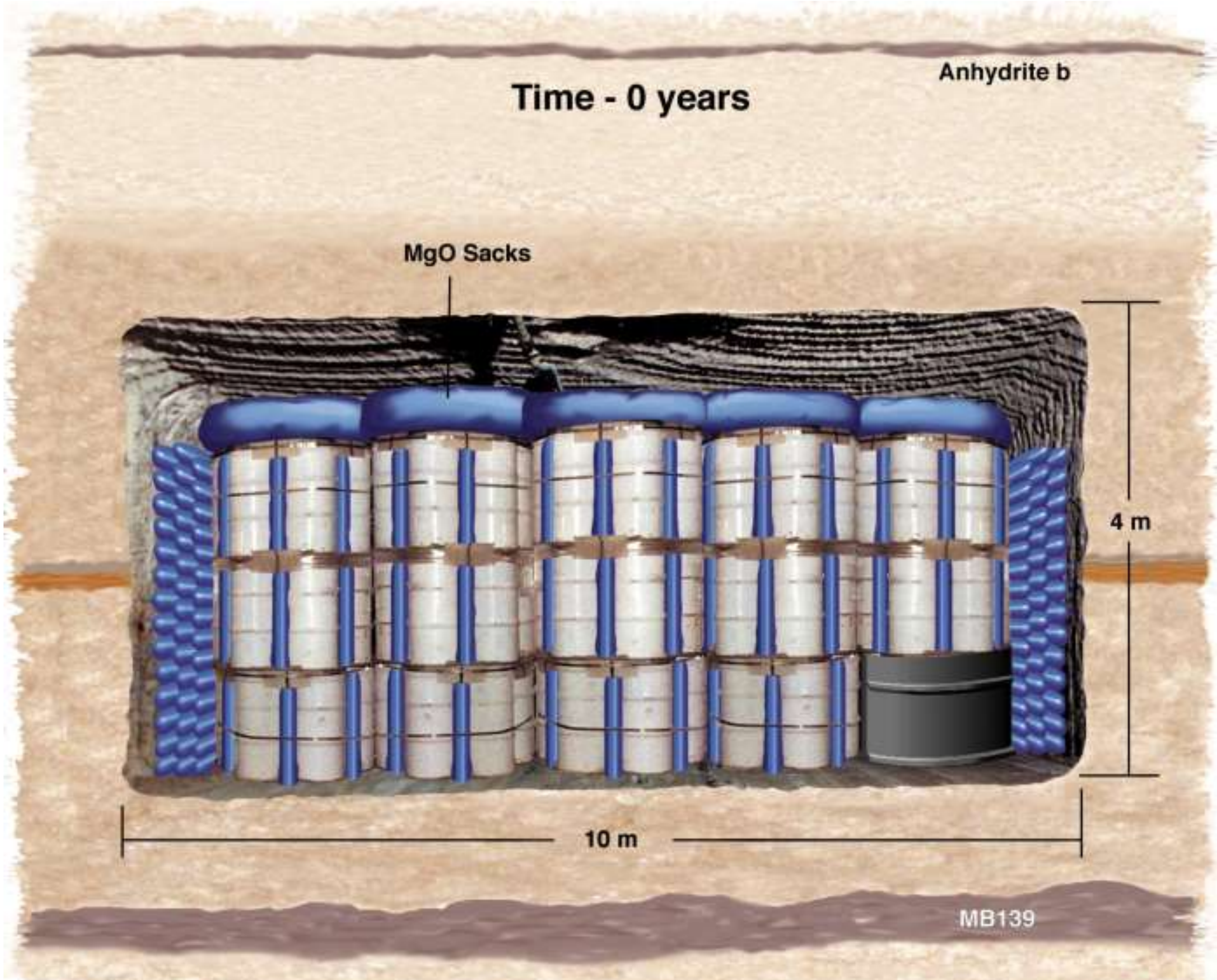

700 nnm

Mining the Salado is the easiest and safest mining operation in the world

January 2007, high activity waste began shipping to WIPP; up to 1000 R/hr surface and 23 Curies/liter (87 Curies/gallon)

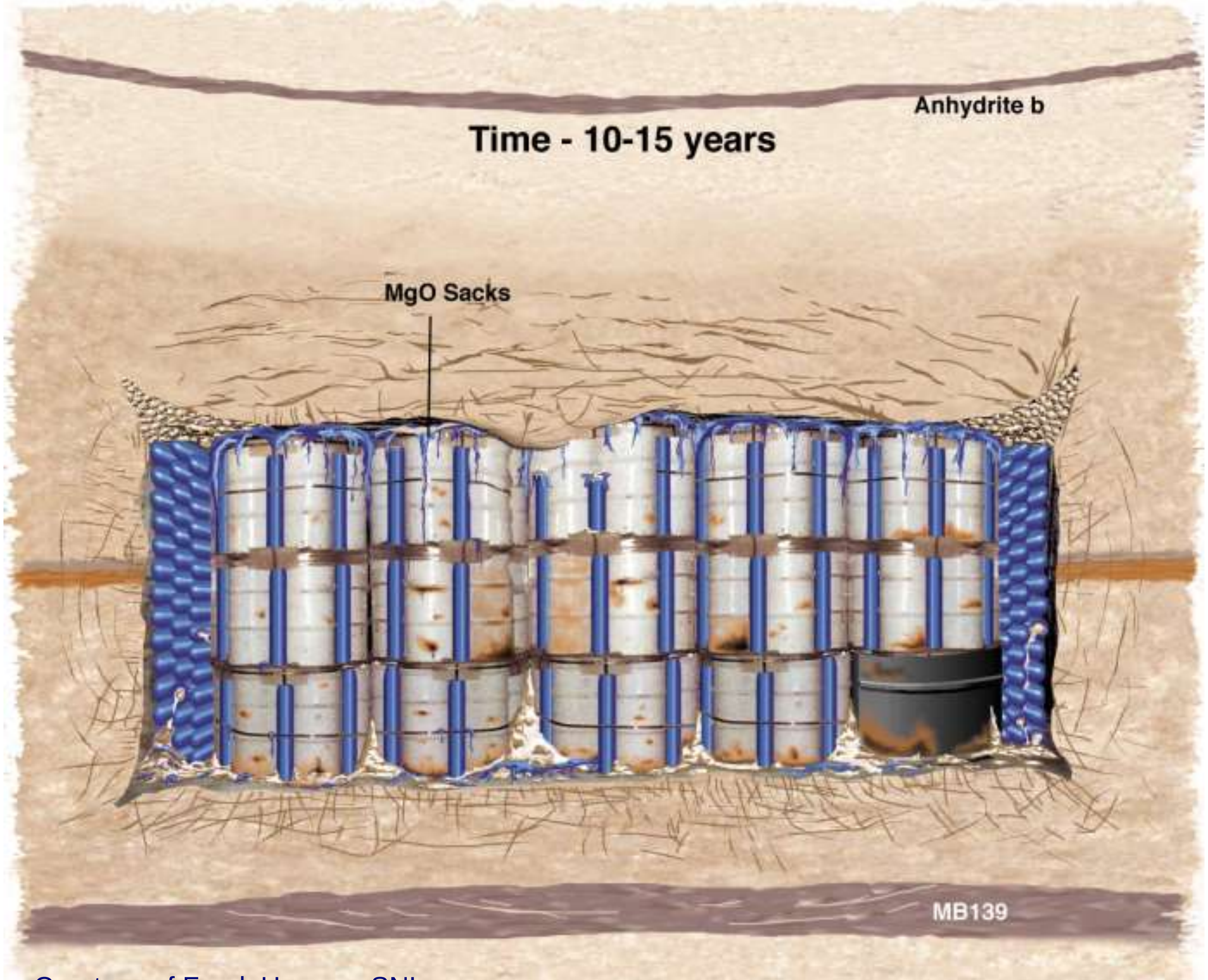
At the 2000 lbs/inch^2 pressure at this depth, the salt exhibits significant creep closure, i.e., the salt completely closes all fractures and openings, even micropores, making the salt extremely tight, such that water cannot move even an inch in a billion years

Evolution of the WIPP Disposal Rooms (t = 0 yrs)



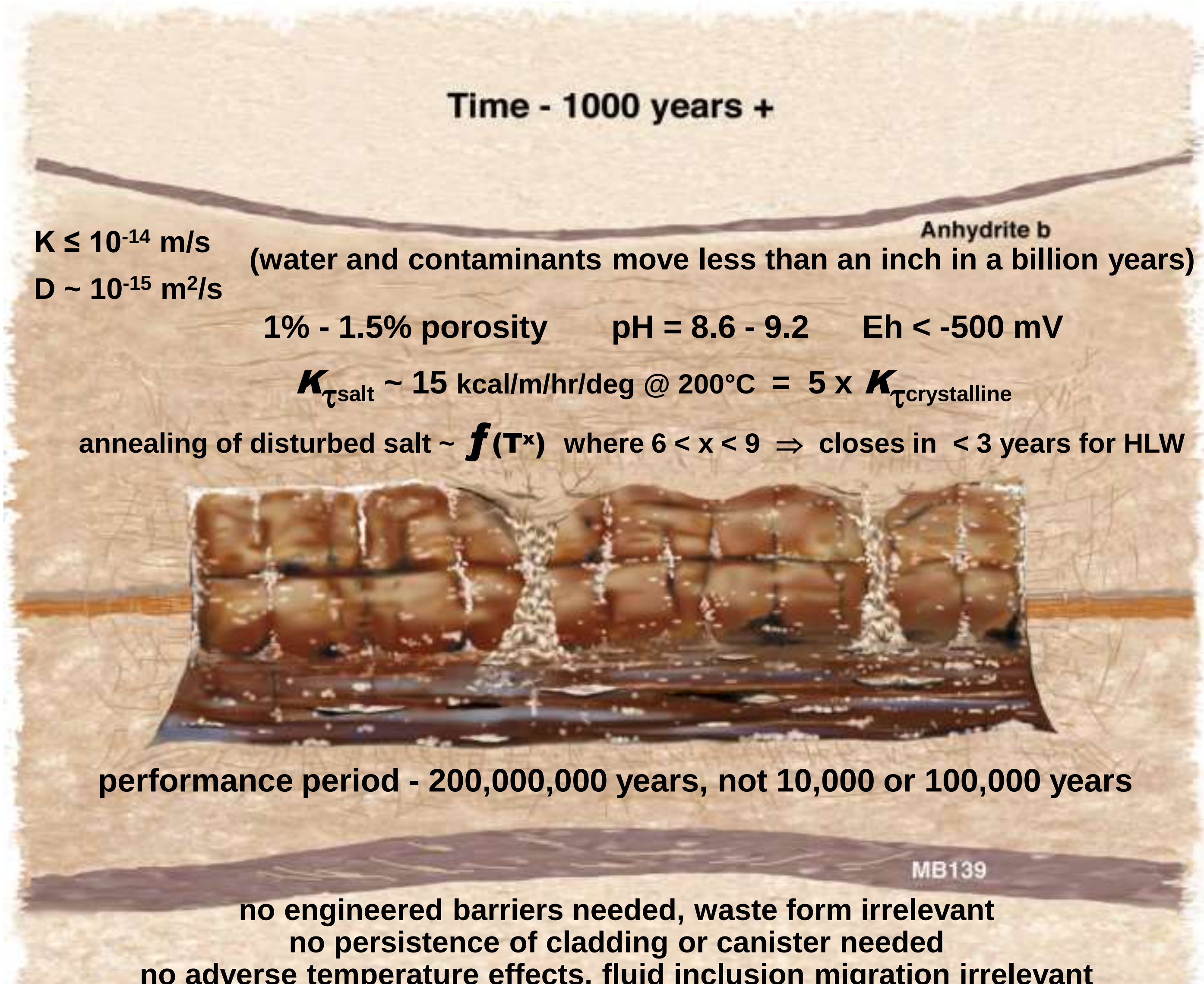
Courtesy of Frank Hansen, SNL

Evolution of the WIPP Disposal Rooms (10-15 yrs)



Courtesy of Frank Hansen, SNL

Evolution of the WIPP Disposal Rooms (1000 yrs)



$K \leq 10^{-14}$ m/s

$D \sim 10^{-15}$ m^2/s

(water and contaminants move less than an inch in a billion years)

1% - 1.5% porosity   pH = 8.6 - 9.2   Eh < -500 mV

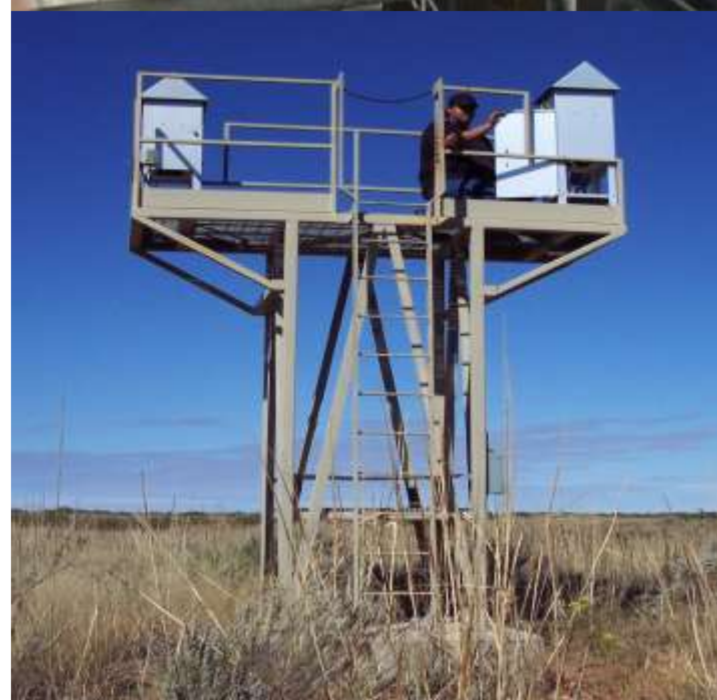
$\kappa_{\tau salt}$ ~ 15 kcal/m/hr/deg @ 200°C = 5 x $\kappa_{\tau crystalline}$

annealing of disturbed salt ~ $f(T^x)$ where 6 < x < 9 ⇒ closes in < 3 years for HLW

performance period - 200,000,000 years, not 10,000 or 100,000 years

no engineered barriers needed, waste form irrelevant
no persistence of cladding or canister needed
no adverse temperature effects, fluid inclusion migration irrelevant

On Valentine's Day 2014, a puff of airborne radioactivity was detected in the WIPP underground. Immediately, ventilation went to HEPA. The amount released was 1.8 Bq/m^3 of air (not even reportable as per EPA) that quickly dropped to hundredths of a Bq/m^3, measureable but a thousand times less than background doses. 21 Workers had measureable amounts that quickly disappeared, also well below background.



The nitrate waste drums

1970s-80s – metal-nitrate salts in nitric acid generated from experiments to remove Am from older weapons

1970s - experiments to remove Am from weapons materials; generated metal-nitrate salt waste

2011 - retrieved for packaging for WIPP, absorbents and neutralizers added, some incompatible with waste

2013 - advised to add inorganic cat litter, someone switched to organic “green” litter, and shipped to WIPP

2014 - drums heat up, pop top, release rad, WIPP closed
May 19 NMED issues two Admin Orders
- corral drums not in WIPP, make secure
- seal WIPP Panel 6 and Panel 7 room 7

The President's Blue Ribbon Commission on America's Nuclear future

Can not pick HLW site but can pick a strategy

Re-iterated that deep geologic disposal is best for nuclear waste disposal

Recommends interim storage for spent nuclear fuel

Recommends a quasi-government entity to execute disposal and storage program - with control of the NWF

Senate Energy and Water Appropriations Subcommittee

April 24 – directs DOE to find an interim storage site based on concensus

Recommends resumption of the site selection process for one or more repositories, i.e., a second repository

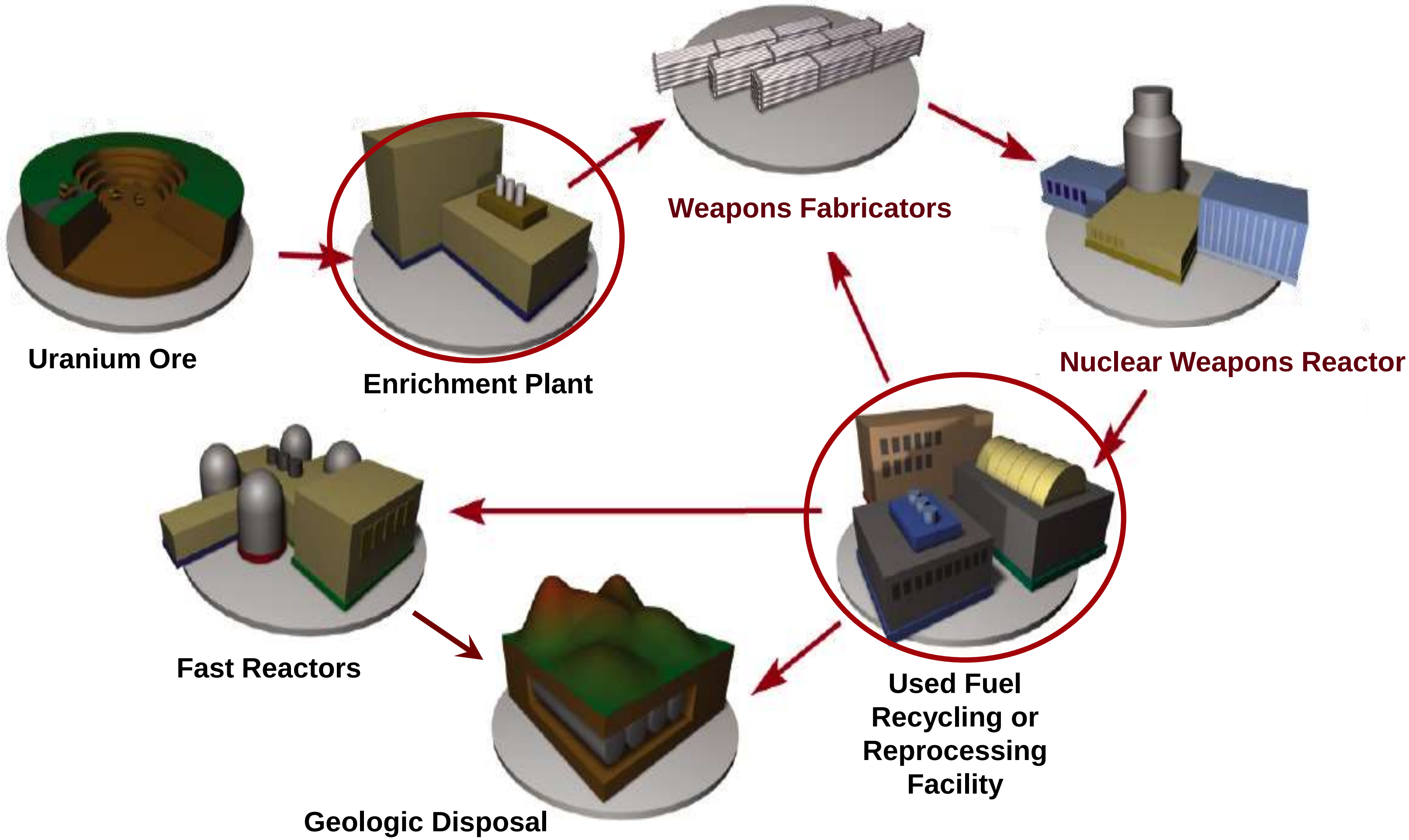
Senate Energy and Water Appropriations Subcommittee

April 2013 – Wyden proposes creating a new Nuclear Waste Administration (not quite the quasi-government entity).

WHAT IS DEFENSE HIGH-LEVEL NUCLEAR WASTE

- **33 USCS § 1402 (j) and 10 CFR 60.2 (1) define high-level radioactive waste as liquid wastes resulting from the operation of the first cycle solvent extraction system, and the concentrated wastes from subsequent extraction cycles, in a facility for reprocessing irradiated reactor fuel, and any solids into which such liquid wastes have been converted.**

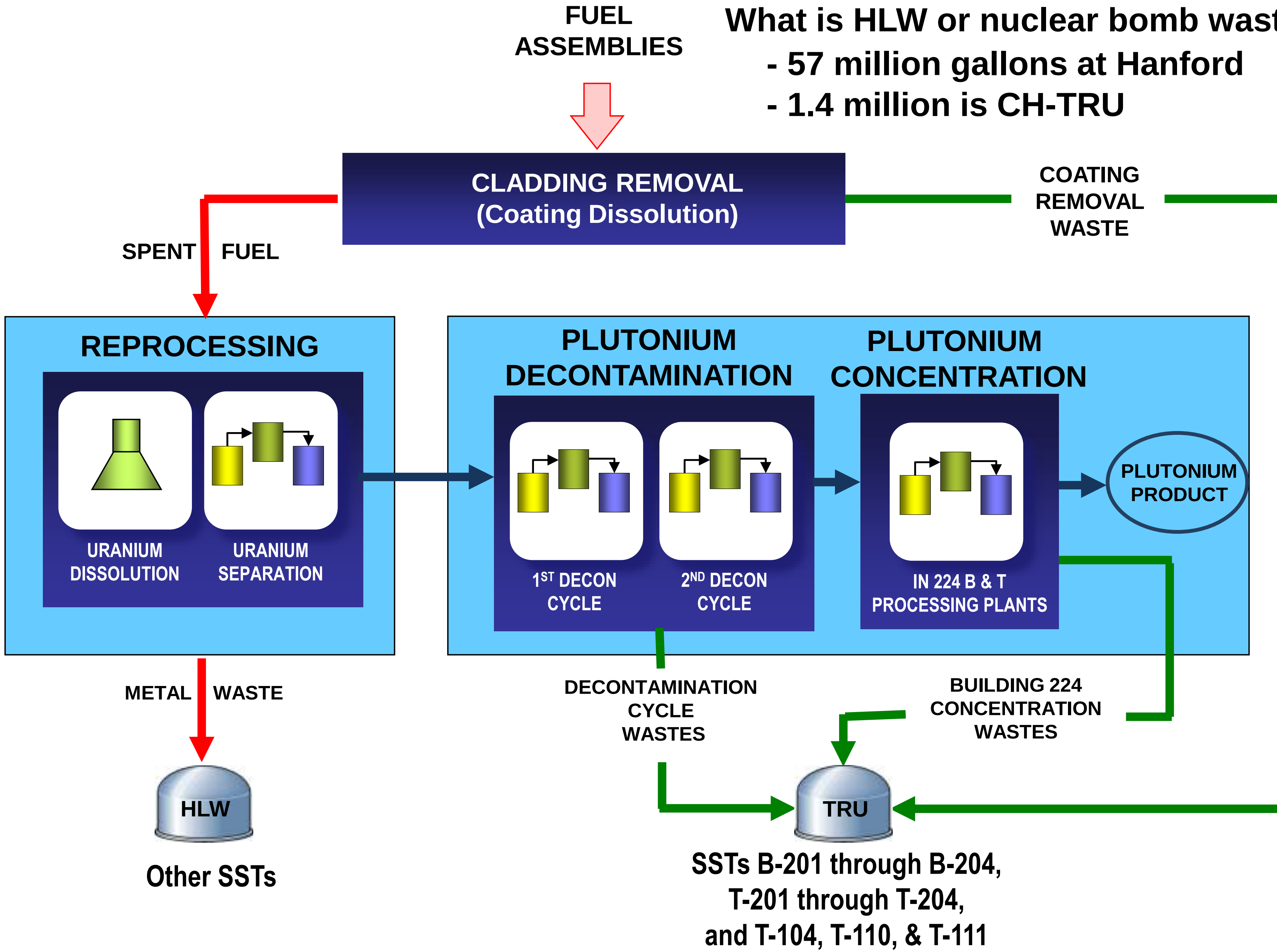
The Nuclear Fuel Cycle



Nuclear weapons are focused on two of these steps

What is HLW or nuclear bomb waste?

- 57 million gallons at Hanford
- 1.4 million is CH-TRU

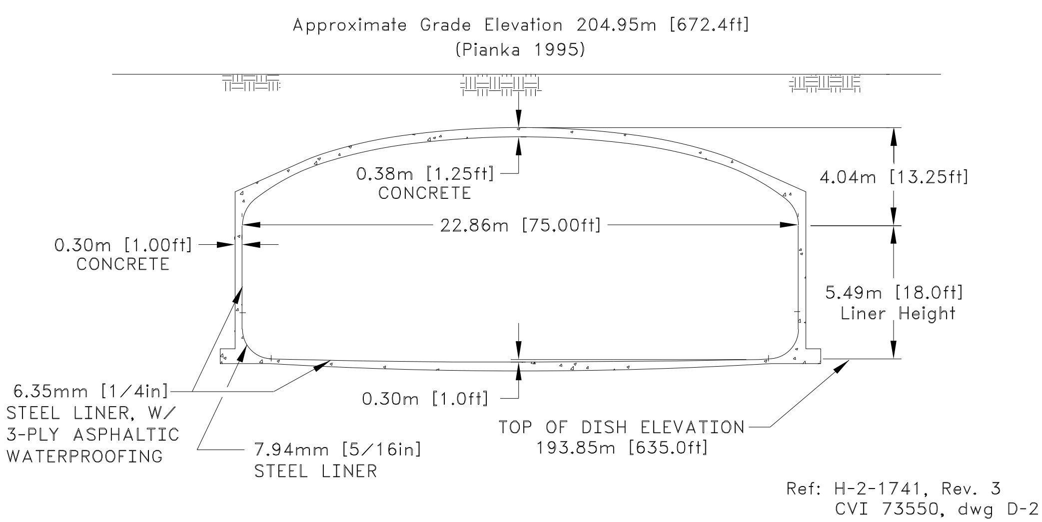


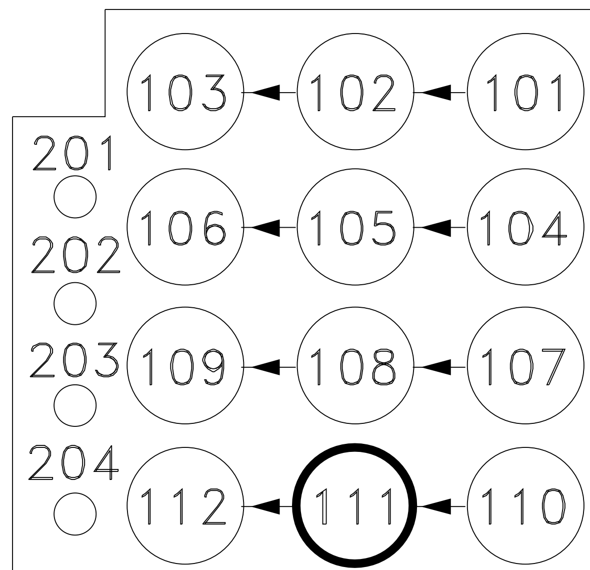
241-T-111

The leaking tanks were never HLW, most were already designated as TRU

TANK RISER LOCATION

T TANK FARM CASCADE





THE NATURE OF DEFENSE HIGH-LEVEL NUCLEAR WASTE

HLW must be:

- **highly radioactive,**
- **result from reprocessing spent nuclear fuel, and**
- **if a solid waste that was derived from liquid waste produced directly in reprocessing, it must contain fission products in sufficient concentrations to require permanent isolation.**

The House Armed Services Committee provided the following rationale for changing the HLW definition from the prior source-based definition to a source plus hazard-based definition:

"The recommended definition takes into consideration both the source and the hazard of the waste and permits the regulatory agency responsible under law for setting standards for radioactivity (EPA) to determine the concentration of fission products and transuranic elements that require permanent isolation." [H.R. Report.97-491, Part II, at 2 and 4 (July 16, 1982)].

In other words, it should matter what's in the waste.

THE NATURE OF DEFENSE HIGH-LEVEL NUCLEAR WASTE

Under current policy, wastes emanating from the reprocessing of irradiated and/or spent nuclear fuel are presumed to be HLW unless formally demonstrated to not be HLW using either:

- **Section 3116 of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA), or**

- **One of the DOE Order 435.1 Waste Incidental to Reprocessing (WIR) processes (evaluation or citation)**

Both Section 3116 and the WIR Evaluation Process require expensive treatment and extensive analyses to demonstrate that radionuclides have been removed from the subject waste stream to the maximum extent practical along with extensive performance assessments and consultation with NRC.

Each waste determination made using Section 3116 or the WIR Evaluation Process can take three to five years to complete and can cost several million dollars.

THE NATURE OF DEFENSE HIGH-LEVEL NUCLEAR WASTE

Congress provided better language to DOE when it defined high-level radioactive waste (HLW) in the Nuclear Waste Policy Act of 1982 (NWPA).

That definition directed government agencies to consider both the source and the hazard of wastes resulting from reprocessing spent nuclear fuel, such as is in most of the tanks at Hanford, before classifying the waste as HLW or otherwise.

NWPA defines HLW as the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in *sufficient concentrations*; and other highly radioactive material that is determined, consistent with existing law, to require permanent isolation.

Unfortunately, at the time NRC refused to define the word *sufficient*, believing that *"the principles of waste classification were well known"*

THE NATURE OF DEFENSE HIGH-LEVEL NUCLEAR WASTE

To find a conservative interpretation of *sufficient*, the best and only reasonable place is:

- **10 CFR 61.55 defines these *sufficient* limits as 7 Ci/liter for ^{90}Sr and 4.6 Ci/liter for ^{137}Cs, below which the waste can go into a shallow landfill**

This is an extremely important distinction at sites like Hanford, where tank wastes are the product of multiple early reprocessing approaches as well as multiple campaigns that removed almost half of the fission products from Hanford tank wastes for use in research and commercial enterprises. Cesium and strontium capsules, and casks containing cesium ion exchange resin, were routinely transferred to Oak Ridge from Hanford to provide cesium-137 for sealed sources and research. The result is that most of the fission products in Hanford tank wastes today are contained in only a few of the 177 underground storage tanks.

THE NATURE OF DEFENSE HIGH-LEVEL NUCLEAR WASTE

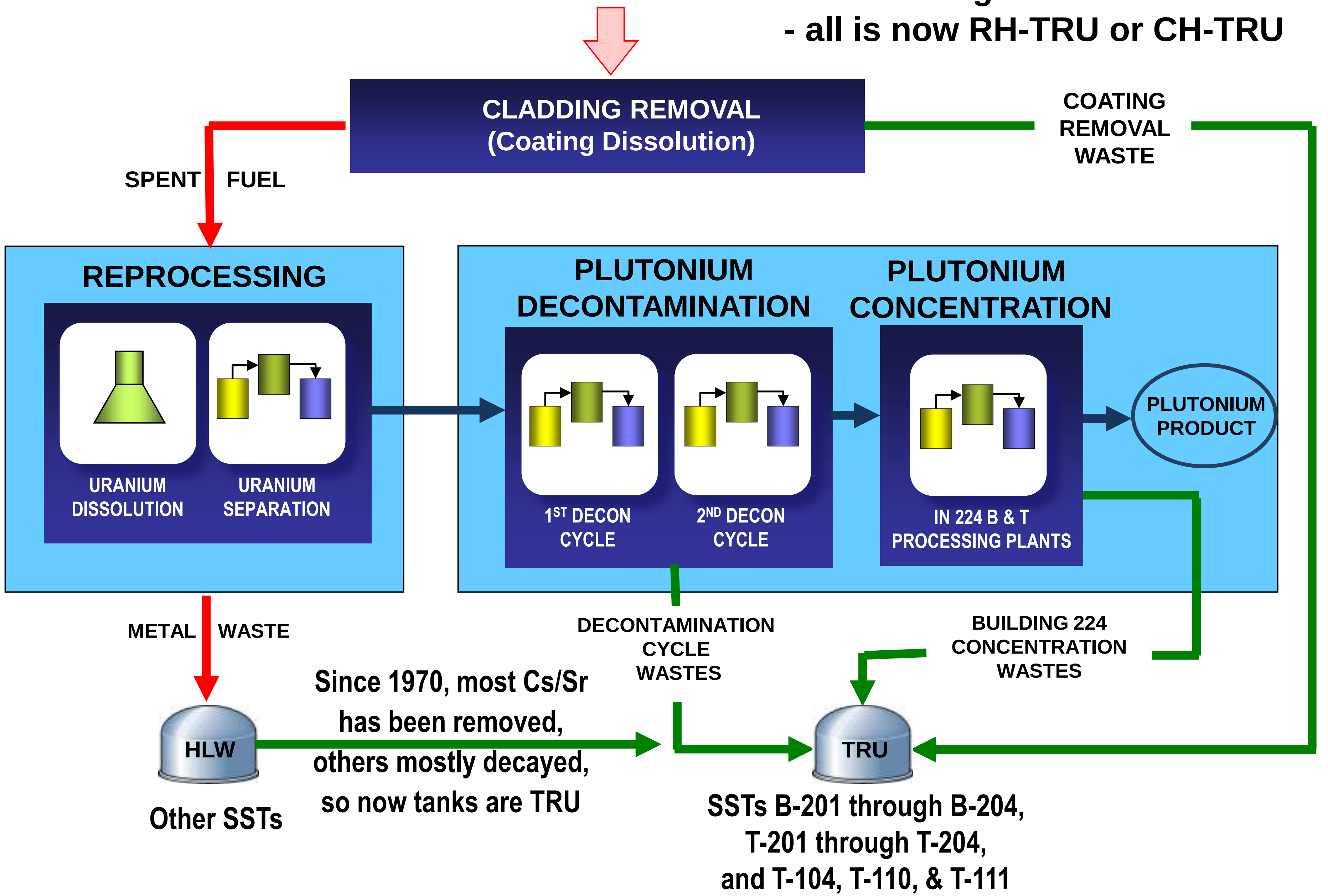
- **10 CFR 61.55 defines these *sufficient* limits as 7 Ci/liter for ^{90}Sr and 4.6 Ci/liter for ^{137}Cs.**

All Hanford HLW tanks now have less than 1 Ci/liter of either ^{90}Sr or ^{137}Cs

- **most Cs/Sr removed for use in research and to control heat in the tanks, and the rest has gone through about 2 decay lives**
- **The average amount of alpha-emitting radionuclides exceed 100 nanoCi/g of ^{239}Pu equivalent (lower limit for TRU)**

What is HLW or nuclear bomb waste?

- 57 million gallons at Hanford
- all is now RH-TRU or CH-TRU



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Therefore, Hanford HLW tank waste is no longer HLW except in name, but does meet the material definition of RH-TRU waste

Is it possible to incorporate this observation into our long-term disposal program?

What would an alternative plan look like for Hanford Tank waste?

Scenarios – 1) vitrify all 2) vitrify a little 3) no need to vitrify any

- **Waste Sludge (11 million gallons)**
  - **1.4 million gallons is contact-handled transuranic waste (CH) that could be retrieved, dried, packaged, and disposed of at WIPP following a Class 3 Permit Modification approved by the State of New Mexico -- much of this is in the leaking tanks**
  - **9.6 million, presently intended for pretreatment in the WTP to remove soluble chemicals and leach aluminum, is planned to be vitrified in the WTP as HLW. This would produce over 11,000 canisters of HLW glass over > 40 years.**
  - **a Drying and Packaging Facility that would be about a fourth of the cost of the WTP. Drying and packaging of this waste would result in about 3.5 million gallons of packaged waste acceptable to WIPP in < 20 years.**
  - **Rail transport using dedicated containers and trains - rail spurs already in place at Hanford and WIPP**
  - **< $10 billion total**

Description	Number	Unit Cost	Total
Waste Container	11,000	$20K	$ 220M
Type B cask	100	$2M	$ 200M
Shipment	200	$1M	$ 200M
Added WIPP Years of Operation	10	$200M	$2,000M
Total			$2,620M

What would an alternative plan look like for Hanford HLW?

- **Saltcake and Supernatant Waste (45 million gallons)**
  - supernatant, mixed with water, used to dissolve tank saltcake wastes
  - could be pretreated in the WTP as a liquid, removing the heavy particle issues
  - if Tc-99 is removed from the pretreated liquid, waste immobilized as LAW for disposal at Hanford using a combination of drying and cast-stoning
  - cost less than 20% of present baseline, or about $12 billion

- **If this is not acceptable to WA State, liquid could be dried down to about 35 million gallons of solid, and disposed in WIPP**
  - additional 15 years of operations at WIPP, totaling < $8 billion

Description	Number	Unit Cost	Total
WIPP facility upgrade	1	3,000	$3,000M
Waste Container	35,000	$20K	$ 700M
Shipment	600	$1M	$ 600M
Added WIPP Years of Operation	15	$200M	$3,000M
Total			$7,300M

Baseline (as HLW) **> $60 billion, > 40 years**
Alternative (as TRU) **< $30 billion, < 30 years**

This alternative is likely the only path to satisfy the anticipated cost and schedule deadlines of the Tri-Party Agreement

Required Changes to the WIPP Land Withdrawal Act (LWA P.L. 102-579)

LWA provides EPA regulatory authority through 40 CFR Part 191

- LWA limits the total capacity of TRU waste to 6.2 million ft^3 (175,570 m^3)
- LWA limits the total radioactivity of RH waste to 5.1 million curies
- Consultation and Cooperative Agreement with the State of New Mexico (1981)
  - total Remote Handled (RH) TRU capacity of 250,000 ft^3 (7,080 m^3)
  - total Contact Handled (CH) TRU capacity of 5.95 million ft^3 (168,490 m^3)

Regulatory changes needed

- Repeal 2004 Category 3 Permit Mod prohibiting tank waste of any sort
- Increase above limits to handle increased defense waste volumes
- Modify LWA to acceptance of non-TRU waste or re-categorize defense HLW waste as TRU
- Modify RCRA permit with the New Mexico Environment Department
- Modify Compliance Certification with the EPA
- Changes to the Low-Level Radioactive Waste Policy Amendment Act (LLRWPAA) to authorize EPA to regulate other waste at WIPP
- DOE Order 435.1, NWPA 1982, Tri-Party Agreement, NEPA, etc.

WDoE would rather change LWA; NM would rather designate HLW as TRU

Waste Disposal Footprint in Salt

What's possible?

Final footprint of WIPP will be only 1 $mile^2$ out of 16 set aside for nuclear waste disposal by the the 1992 Land Withdrawal Act

Waste Disposal Footprint in Salt

New footprint of an expanded WIPP to include HLW as RH-TRU, with interim storage for SNF, would be less than 3 mile^2 out of the 16 set aside for nuclear waste disposal by the the 1992 Land Withdrawal Act

Some specific policy actions needed to implement BRC recs:

New Mexico, Washington, South Carolina, ID, TN and NY should form a multi-state compact on their own

Support the formation of a quasi-government entity to execute disposal and storage program as recommended

- give it full control of the Nuclear Waste Fund

Support interim storage for spent nuclear fuel

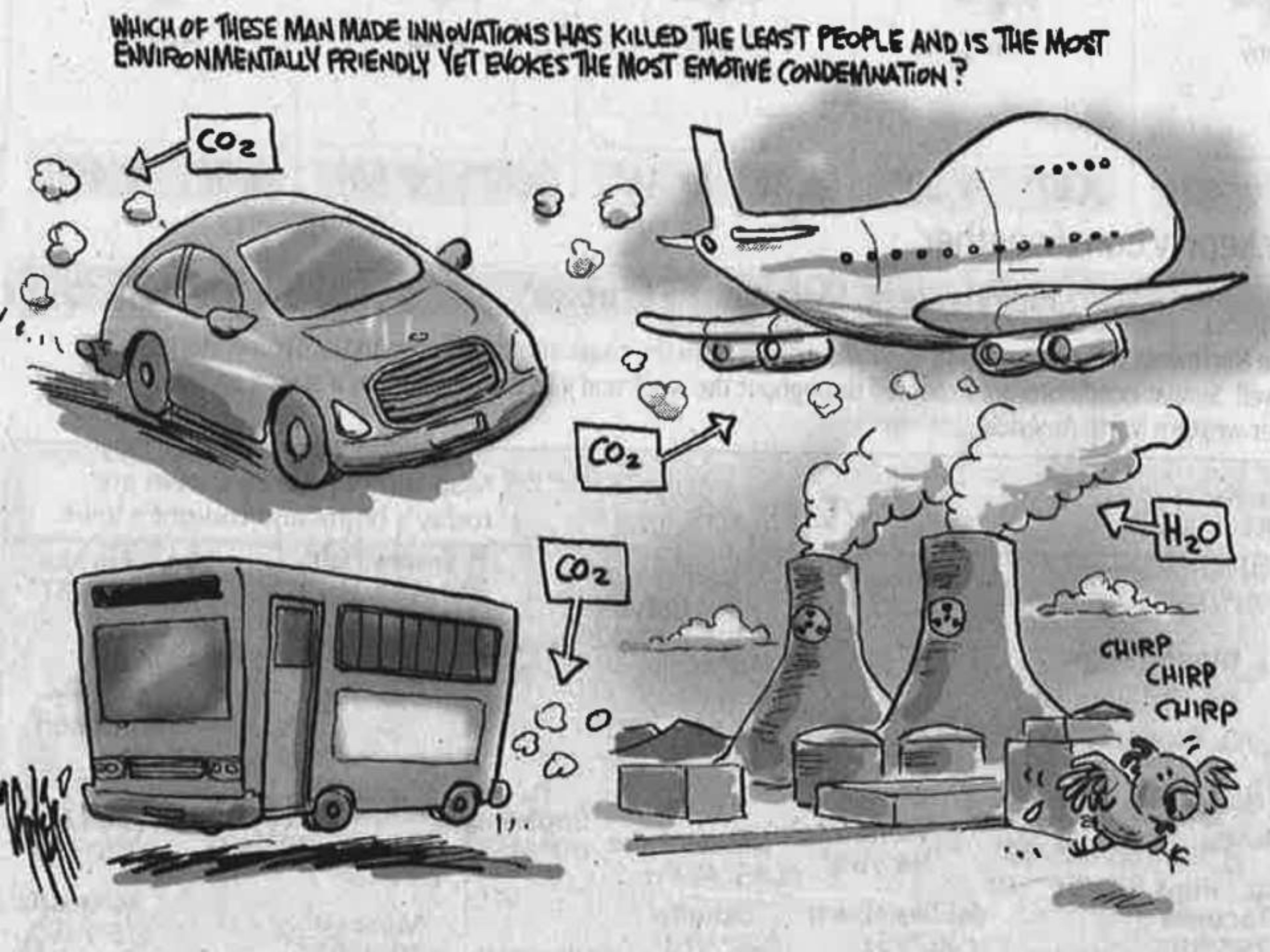
Support resumption of the site selection process for a second repository

Support the completion of the Yucca Mt. license review

Make the minor changes necessary to the NWPAct of 1982 and the LWAct of 1992 that will make all of this happen

Begin with defense HLW in salt

- co-mingle HLW with SNF *in space but not time*


WHICH OF THESE MAN MADE INNOVATIONS HAS KILLED THE LEAST PEOPLE AND IS THE MOST ENVIRONMENTALLY FRIENDLY YET EVOKES THE MOST EMOTIVE CONDEMNATION?
CO2
CO2
CO2
H2O
CHIRP
CHIRP
CHIRP

The New EPA Carbon Rules

To reduce carbon emissions from American power plants by 30% over 2005 levels between now and 2030

(http://www.epa.gov/cleanpowerplan).

Rules allow States flexibility to meet these goals with any mix of

conservation
efficiency
renewables
retrofitting coal plants with gas
building new-design nuclear

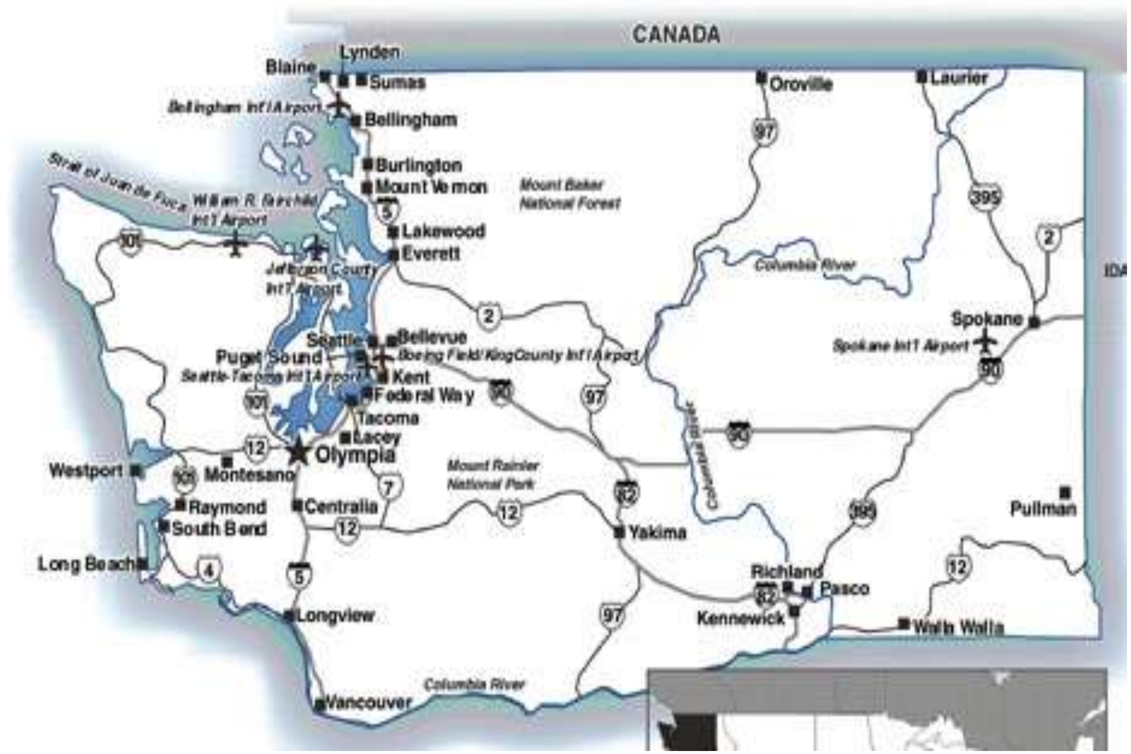
- With respect to nuclear power, the EPA Plan allows states, e.g., Georgia, South Carolina and Tennessee, to take credit for the carbon savings gained by new nuclear reactors under construction and for any future nuclear plant construction
- EPA has stated that premature closure of existing nuclear plants will make it difficult for the U.S. to meet its climate goals.
- Two-thirds of Americans support a new federal rule cutting carbon emissions from the nation’s power plants

How Do We Achieve a Low-Carbon Future for Washington State?

- WA State emissions have decreased since 1990, because of lower emissions in the agriculture and the industrial sectors.

- Our only coal plant is closing in 2025 and will eliminate almost half of our emissions from power sources.

- Electric vehicles are the most effective way in Washington State to address the petroleum fuel issue because the majority of electricity generated in WA State is from non-fossil fuel.



President Obama's *Climate Action Plan*

New carbon rules are EPA's first step under last June's Climate Action Plan

Cutting carbon - 30% by 2030 (new EPA rules)

Increasing renewables - to 20% by 2020 (presently 11% if hydro is included)

Get smarter – use scientific data to make decisions

Fuel efficiency – eventually 40 mpg for all vehicles

Efficient housing, appliance, buildings and rural communities – factor energy into mortgages, building, loans to rural utilities and farmers,

Super pollutant and methane cuts – eliminate HFCs and other super GHGs, reduce fugitive methane releases

Reduce deforestation – the single worst action for the planet

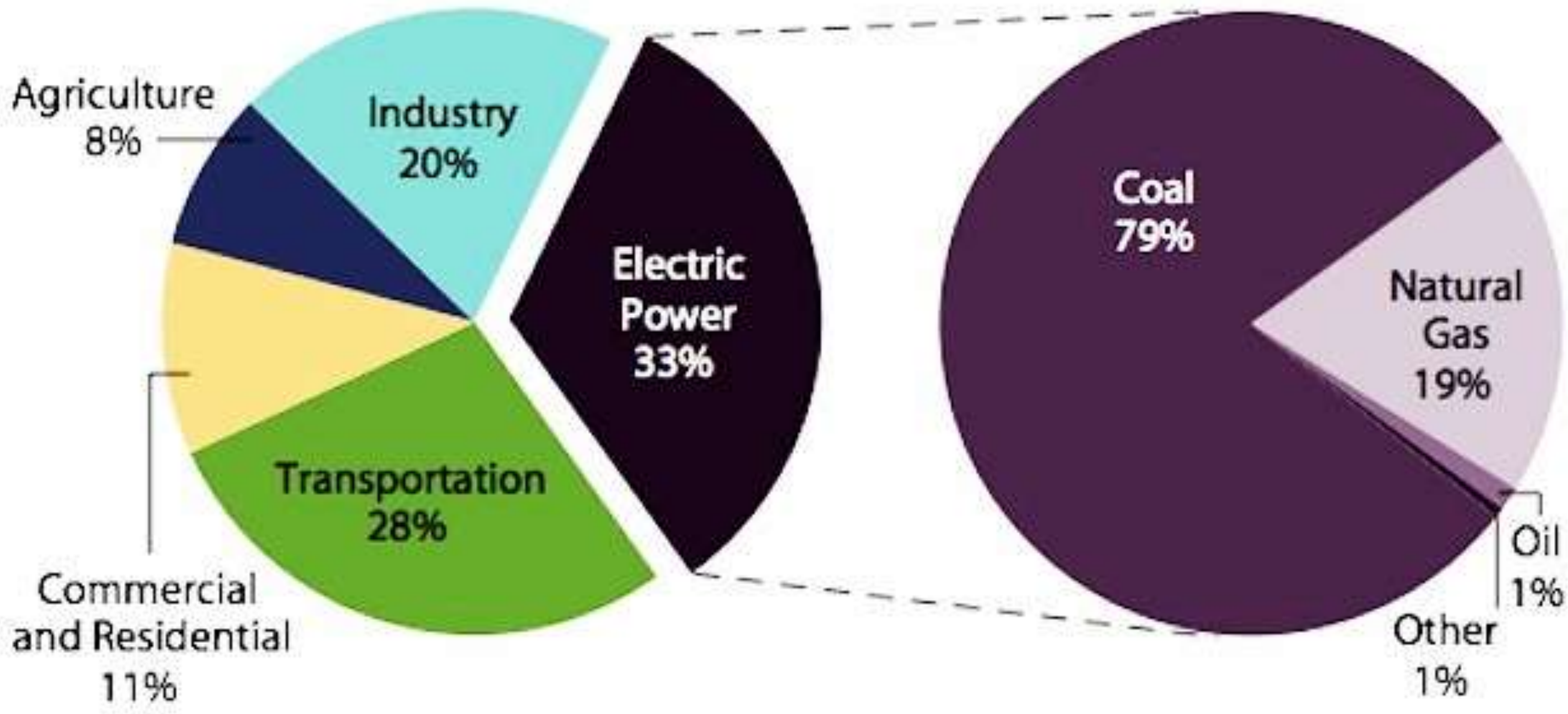
Climate resilience – promote and invest in infrastructure, planning and programs that resist the impacts of climate changes including sea level rise, extreme weather, disease and pests, adaptive agriculture, drought, fires and flooding

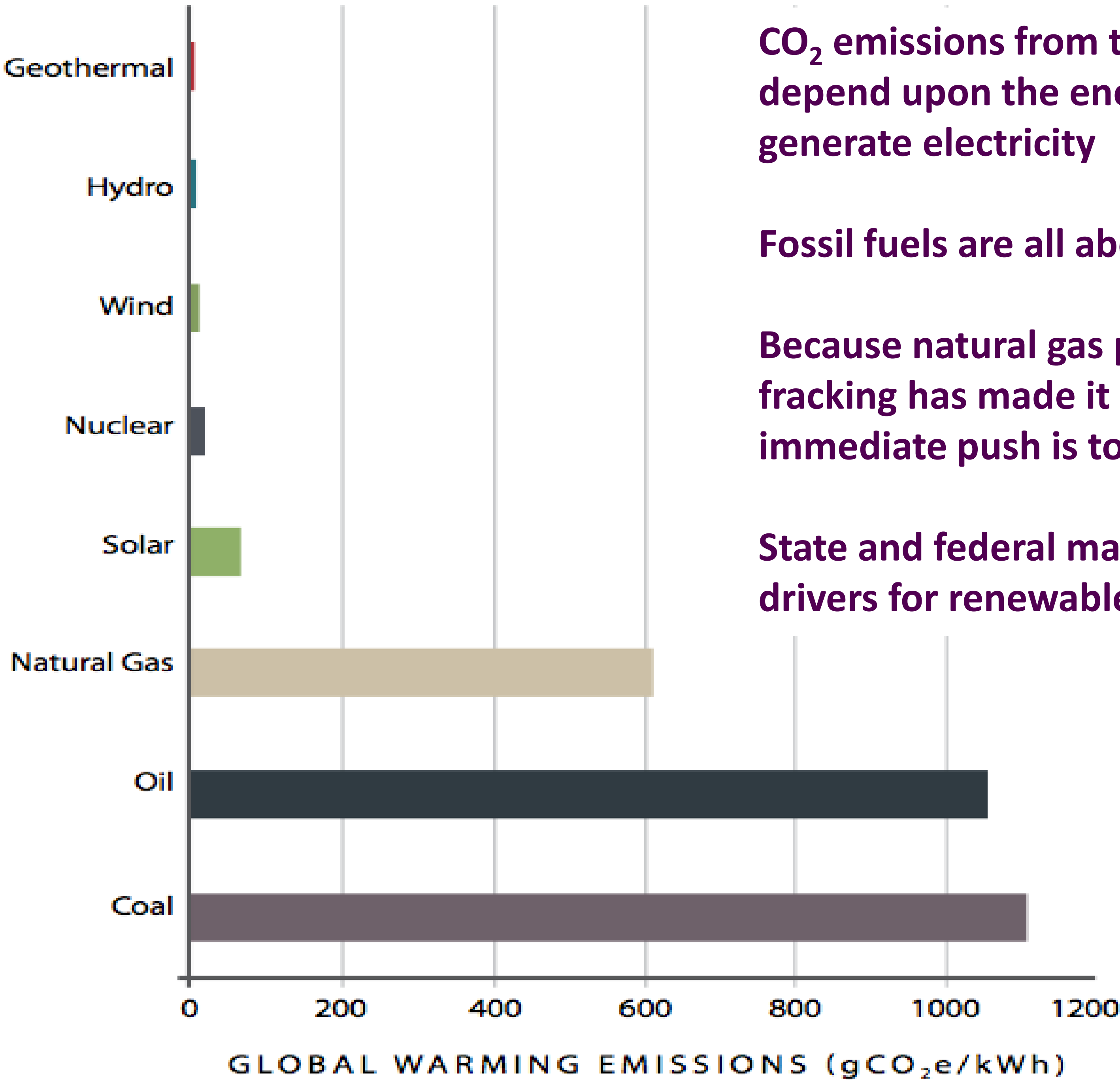
Seek a solution with specific countries and a United Nations global treaty on climate

The Electric Power Sector is the largest source of carbon emissions in America and coal accounts for most of the share (EIA 2013)

Total U.S. Carbon Emissions by Economic Sector in 2011

Total U.S. Electric Power Carbon Emissions by Fuel in 2011





CO_2 emissions from the power sector depend upon the energy source used to generate electricity

Fossil fuels are all about carbon

Because natural gas prices are so low, and fracking has made it so abundant, the immediate push is to replace coal with gas

State and federal mandates are the main drivers for renewables

The Issues with Emissions – not just about climate, and not just about carbon

> "We all know this is not just about melting glaciers. This is one of the most significant public health threats of our time." - Gina McCarthy, EPA Chief

Long-term effects:

Climate Change - effects planet as a whole - agriculture, sea level, droughts, disease
- will occur whether it's human induced or not – need to be ready – EP and EM

Short-term effects:

Human Health Effects - >1,000,000 people die each year from coal particulates, 20,000 in the U.S., >200,000 in China alone. The use of coal increases our health care costs by 10%, or $300 billion each year in the U.S.

Direct Environmental Harm – spills, pipeline breaks, coal impoundment failures, drilling and mining effects

Ocean Acidification – pH dropping through simple CO_2 dissolving in seawater to form carbonic acid.

- 4 days for upper layer of seawater to equilibrate with CO_2 in atmosphere
- 1000 years for entire ocean to equilibrate with atmosphere and carbonate rocks

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Energy Source	Mortality Rate (deaths per trillion kWh)	
Coal – global average	100,000	(50% of global electricity)
Coal – China	170,000	(75% of China's electricity)
Coal – U.S.	10,000	(44% of U.S. electricity)
Oil	36,000	(36% of global energy, 8% of global electricity)
Natural Gas	4,000	(20% of global electricity)
Biofuel/Biomass	24,000	(21% of global energy)
Solar (rooftop)	440	(< 1% of global electricity)
Wind	150	(~ 1% of global electricity)
Hydro – global average	1,400	(15% of global electricity, 171,000 Banqiao dead)
Nuclear – global average	40	(17% of global electricity w/Chernobyl&Fukushima
Nuclear – U.S.	0.01	(20% of U.S. electricity)

Sources –World Health Organization; CDC; 1970 - 2011

The Issues with Emissions – not just about climate, and not just about carbon

> "We all know this is not just about melting glaciers. This is one of the most significant public health threats of our time." - Gina McCarthy, EPA Chief

Long-term effects:

Climate Change - effects planet as a whole - agriculture, sea level, droughts, disease
- will occur whether it's human induced or not – need to be ready – EP and EM

Short-term effects:

Human Health Effects - >1,000,000 people die each year from coal particulates, 20,000 in the U.S., >200,000 in China alone. The use of coal increases our health care costs by 10%, or $300 billion each year in the U.S.

Direct Environmental Harm – spills, pipeline breaks, coal impoundment failures, drilling and mining effects

Ocean Acidification – pH dropping through simple CO_2 dissolving in seawater to form carbonic acid.

- 4 days for upper layer of seawater to equilibrate with CO_2 in atmosphere
- 1000 years for entire ocean to equilibrate with atmosphere and carbonate rocks

The Issues with Emissions – not just about climate, and not just about carbon

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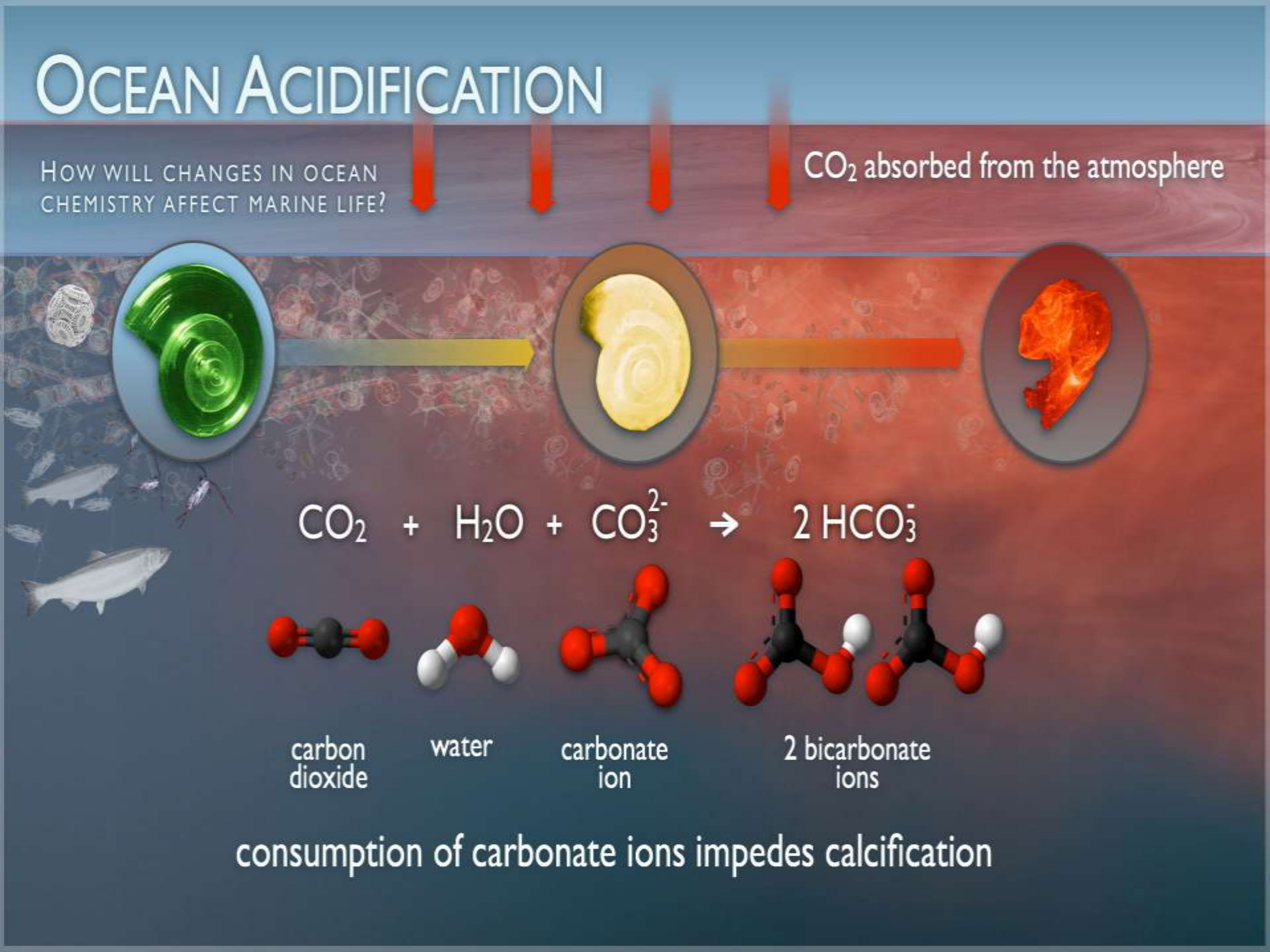
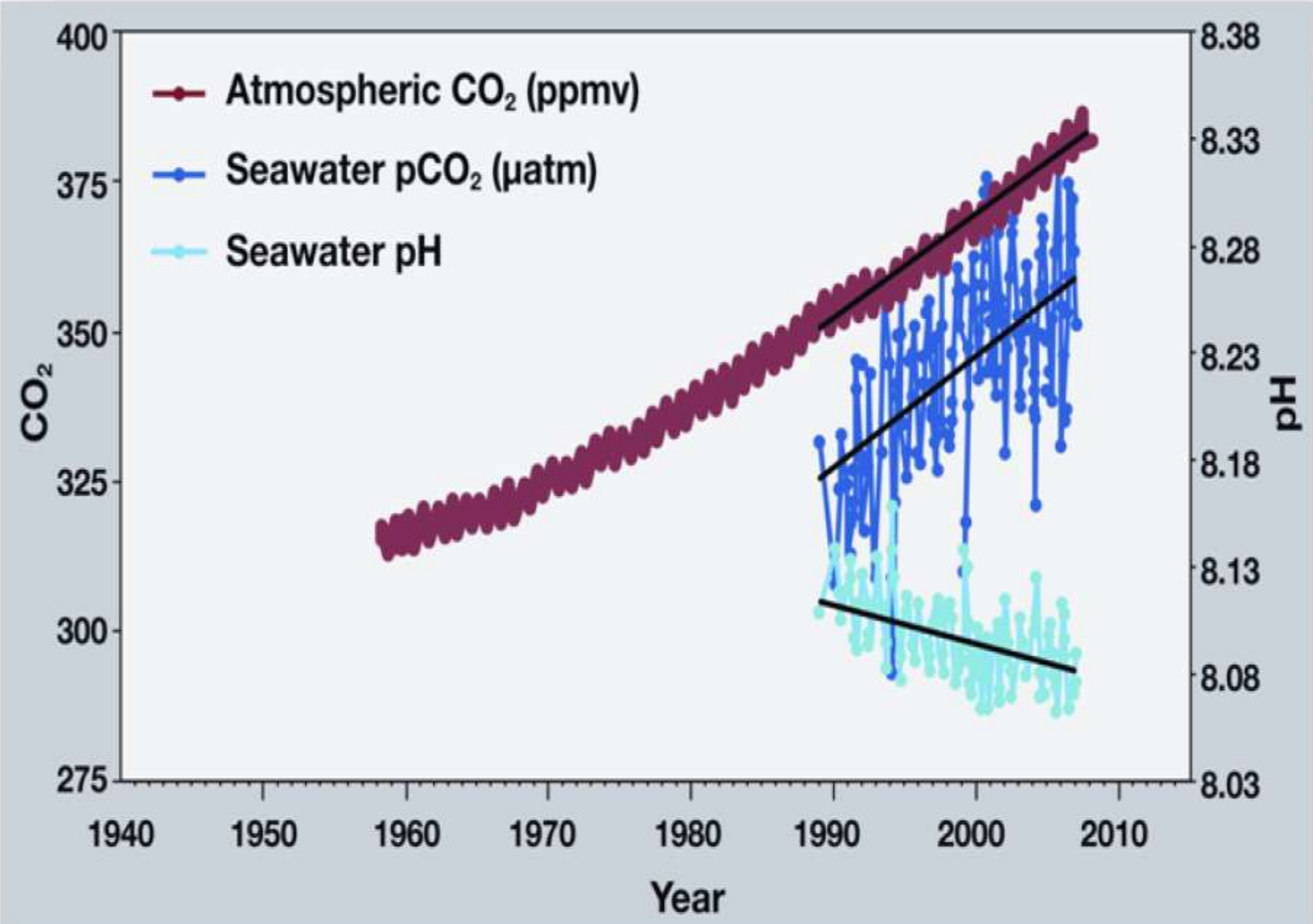
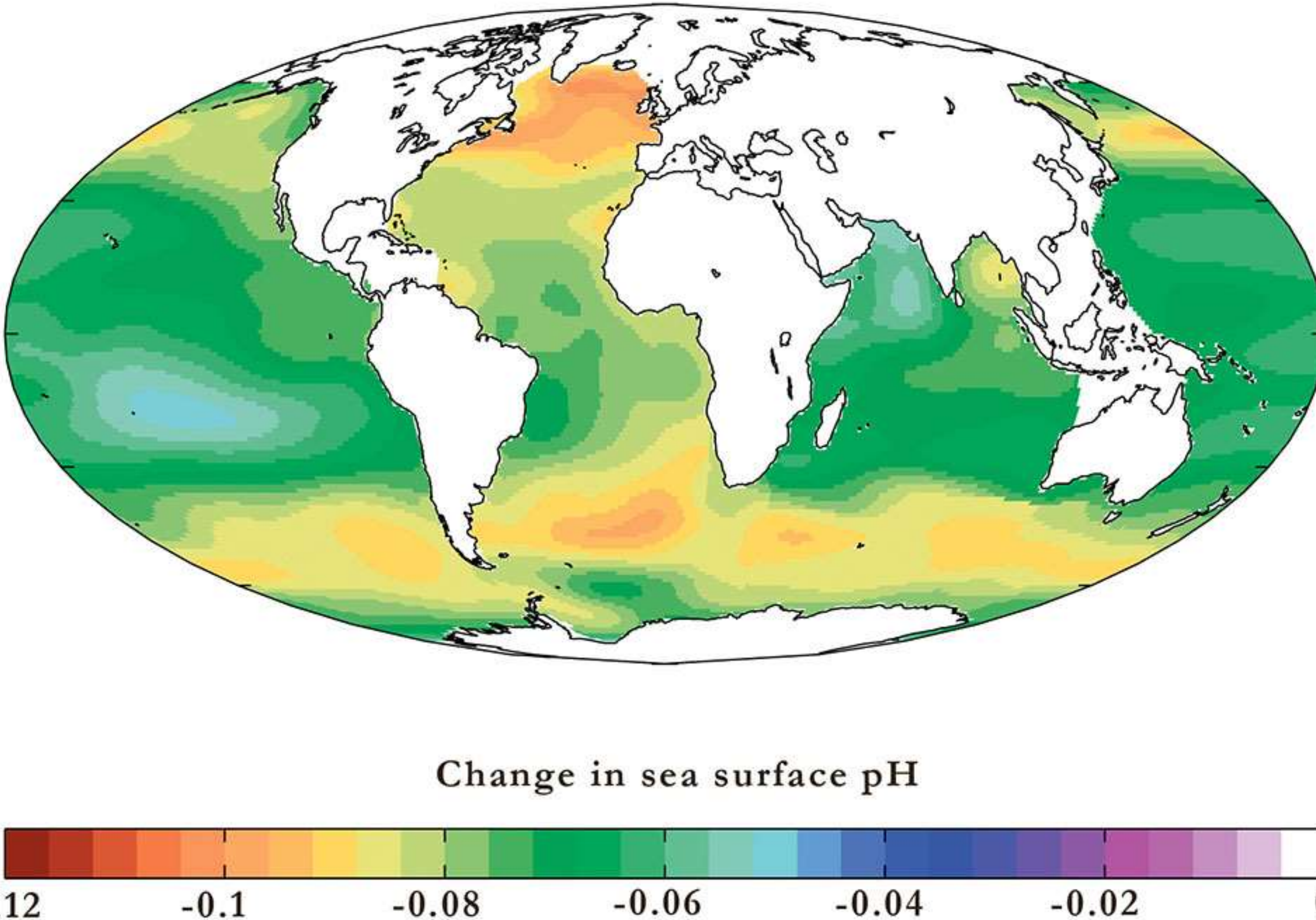

Ocean Acidification
How will changes in ocean chemistry affect marine life?
CO_2 absorbed from the atmosphere
$CO_2 + H_2O + CO_3^{2-} \rightarrow 2\ HCO_3^-$
carbon dioxide
water
carbonate ion
2 bicarbonate ions
consumption of carbonate ions impedes calcification



Atmospheric CO_2 (ppmv)
Seawater pCO_2 (µatm)
Seawater pH
CO_2
400
375
350
325
300
275
pH
8.38
8.33
8.28
8.23
8.18
8.13
8.08
8.03
1940
1950
1960
1970
1980
1990
2000
2010
Year



The colder the water, the more CO_2 dissolves in it, oceans closer to the poles are affected more

What are the EPA Carbon Rules supposed to accomplish?

To benefit the economy, public health and the environment

- A recent Harvard study on the total effects of coal use in America concluded that coal costs us about $500 billion annually and any decrease in coal use has a direct benefit to the economy, public health and the environment.

- This summer, EPA Chief Gina McCarthy flatly stated:

“The primary aim in implementation of moderately increased carbon cutback requirements is to kick-start the U.S. nuclear power industry”

This was echoed by previous EPA Chiefs

- Christine Todd Whitman, EPA Chief under Bush

- Carol Browner, EPA Chief under Clinton, and Director of Obama’s Office of Energy and Climate Change Policy.

What are the EPA Carbon Rules supposed to accomplish?

For overall carbon emissions from the U.S. power sector

- Replace all existing coal with natural gas ➔ 20% reduction
- Replace all existing coal with new nuclear ➔ 60% reduction
- Replace coal with a 60/40 mix of gas and nuclear ➔ 30% reduction
- Replace existing coal plants as they die to minimize the disruption in jobs and supply

Support for nuclear is the smart choice

What About Our Existing Nuclear Fleet?

Our nuclear fleet offsets significant CO_2 emissions each year:

- 700 million tons if coal were used to produce the amount of energy
- 500 million tons if natural gas were used to produce that energy
- 350 million tons if new combined cycle gas turbine were used

There is no viable way to replace our nuclear fleet with any other mix of sources and maintain this level of carbon offsets. Even a 50/50 mix of CCGT and renewables, which would boost renewables beyond the levels imagined at present, would still result in an increase of about 250 million tons CO_2 emissions each year, which represents a 5% increase in total emissions.

This is why McCarthy and others are generally alarmed at the prospect of losing our fleet, the most recent symptom being the closing of Vermont Yankee and Kewaunee.

The Business Model for a Low-Carbon Future

A recent Brookings Institute Report investigated the benefits of replacing coal and old-style natural gas plants with various low-carbon alternatives.

The ranking from most cost-effective to least cost-effective is:

- combined cycle gas turbine (CCGT)
- nuclear
- hydro
- wind
- solar

The Business Model for a Low-Carbon Future

Other conclusions were:

CCGT, hydro and nuclear have strong net benefits in cost and emissions.

CCGT is highly dependent on the price of natural gas

Wind and solar have much lower net benefits:

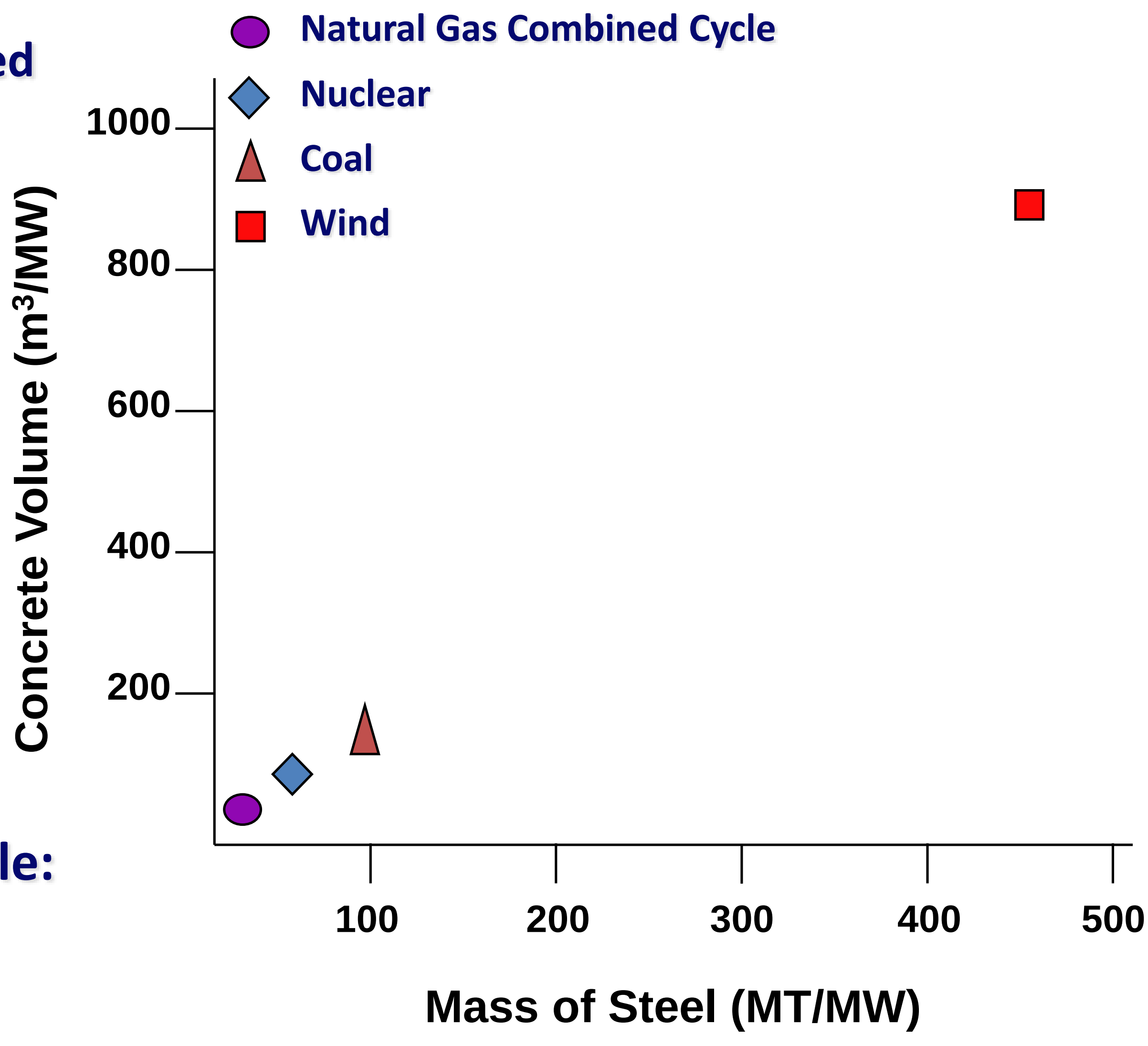
- *low capacity factor, requiring back-up sources*
- *high per-MW construction costs*
- *high intermittency*
- *high frequency variability*

A price on carbon is more effective than Cap&Trade, mandates or other incentives. The price on carbon must exceed \$50/tonCO_2emitted to be effective in targeting coal.

Materials, Resource and Capital Needs

Concrete + steel + copper are > 98% of construction inputs, and become more expensive in a carbon-constrained economy

- **Wind: 6.4 m/s avg wind speed 25% cap. factor**
  - 460 MT steel/MW
  - 870 m^3 concrete/MW
- **Coal: 78% cap. factor**
  - 98 MT steel/MW
  - 160 m^3 concrete/MW
- **Nuclear (LWR): 90% capacity factor**
  - 40 MT steel/MW
  - 90 m^3 concrete/MW
- **Natural Gas Combined Cycle: 75% cap. factor**
  - 3.3 MT steel / MW
  - 27 m^3 concrete / MW



Do We Need A Carbon Tax Or A Cap&Trade Plan? Or Neither?

REMI Report for WA State

- Tax better than Cap&Trade for all sectors and fiscal results
  - jobs (+30,000)
  - GDP (+$700 million)
  - emissions (-50% by 2050)

Governor Inslee's Carbon Plan

- Cap&Trade (link to California)
- end coal generation (on track for 2025)
- ***reduction in vehicle emissions***
- increased funding for clean energy and ***energy efficiency***
- reduction in government carbon footprint

WA State Goals

- By 2020, reduce overall emissions of GHGs in the State to 1990 levels
- By 2035, reduce overall emissions of GHGs to 25% below 1990 levels
- By 2050, reduce overall emissions to 50% below 1990 levels

The Governor's office investigated, among other things, the effects of a straight carbon tax at two magnitudes:

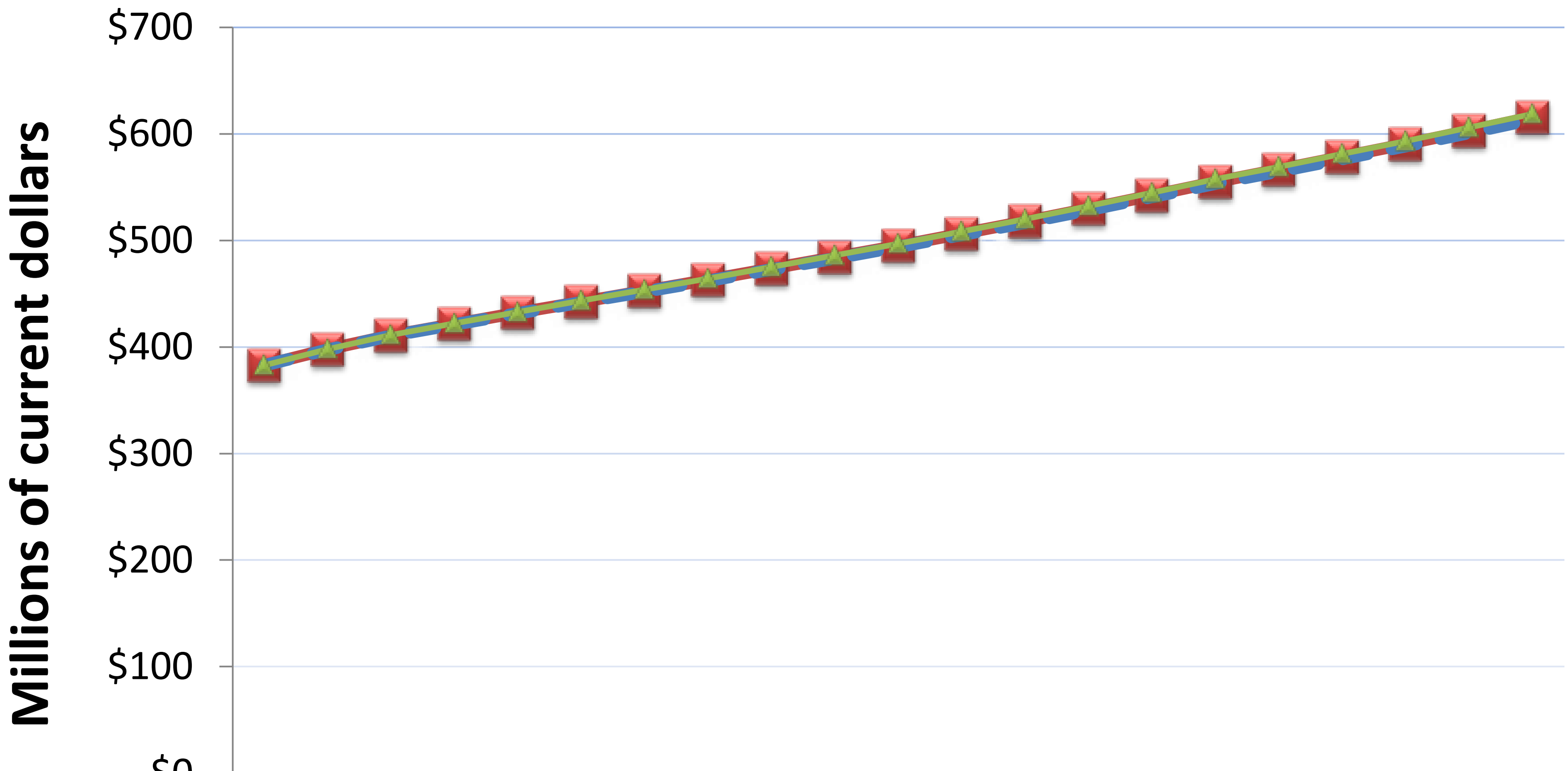
- a low carbon-price scenario of $12/metric tonCO2 in 2016
  - 60-cent-per-metric ton increase each year until 2020
  - increase by $2/metric ton each year thereafter.

- a high carbon-price scenario with the same $12/metric tonCO2 in 2016, but with an
  - $8/metric-ton increase each year thereafter.

This carbon tax would be on energy producers, not consumers, and the revenues would be spent as follows:

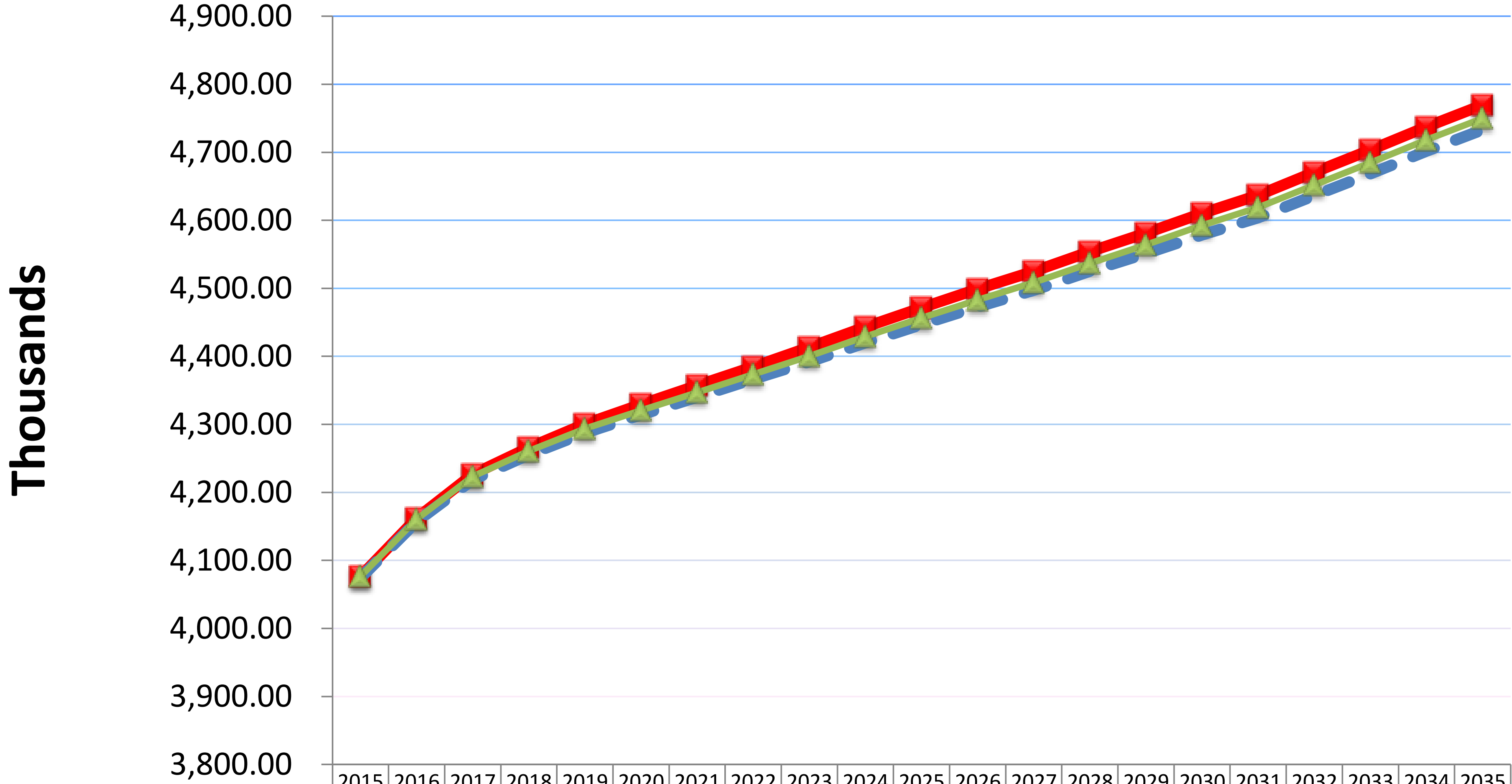
- 30% on lower income populations (the ones who need it the most)
- 15% on trade-exposed industries (highly impacted by the tax)
- 40% on transportation construction (this is the really good one)
- 10% on renewable electricity
- 5% on administration

Gross Domestic Product: No Effect
High & Low Price Scenarios



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
GDP Blnded Low Pr	382.	397.	410.	421.	432.	442.	452.	462.	473.	484.	495.	506.	517.	529.	542.	554.	566.	578.	590.	602.	615.
Baseline	382.	397.	410.	421.	431.	441.	452.	462.	472.	483.	494.	505.	516.	528.	540.	553.	564.	576.	588.	600.	613.
GDP High Pr	382.	398.	411.	422.	432.	443.	453.	464.	475.	485.	496.	508.	520.	532.	544.	557.	569.	581.	593.	605.	618.

Employment: No Effect
High & Low Price Scenarios



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Tot Emp High Pr	4,07	4,16	4,22	4,26	4,30	4,32	4,35	4,38	4,41	4,44	4,47	4,49	4,52	4,55	4,58	4,61	4,63	4,67	4,70	4,73	4,76
Baseline	4,07	4,15	4,21	4,25	4,28	4,31	4,34	4,36	4,39	4,42	4,44	4,47	4,49	4,52	4,55	4,57	4,60	4,63	4,66	4,70	4,73
Employment Blnded Low Pr	4,07	4,16	4,22	4,26	4,29	4,32	4,34	4,37	4,40	4,42	4,45	4,48	4,50	4,53	4,56	4,59	4,61	4,65	4,68	4,71	4,75

High Price Scenario:
Job Gains and Losses for Four Industries
Overwhelmingly Positive

Construction – 7,630 jobs gained

Chemical Industry – 289 jobs gained

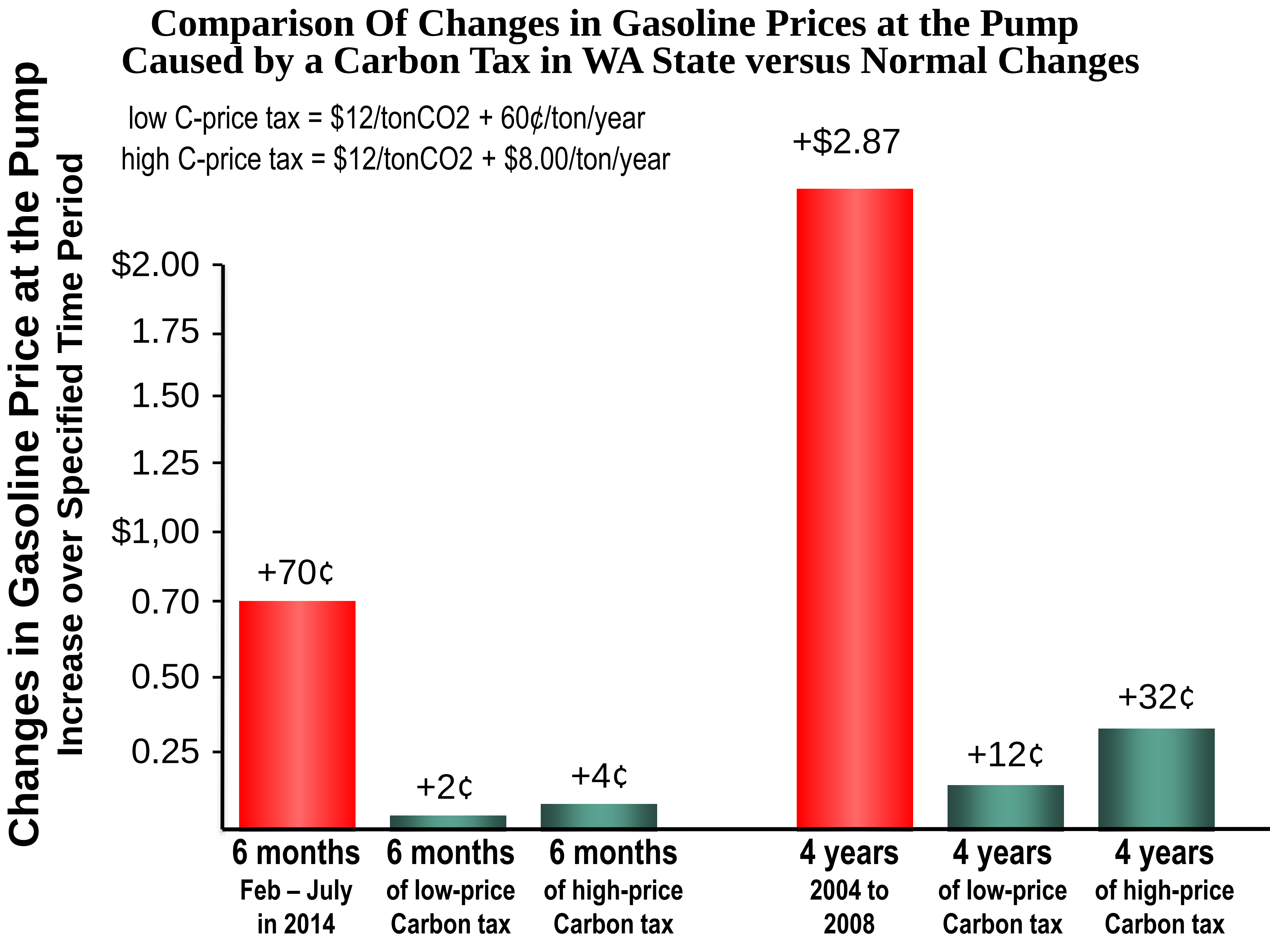
Natural Gas Industry – 19 jobs lost

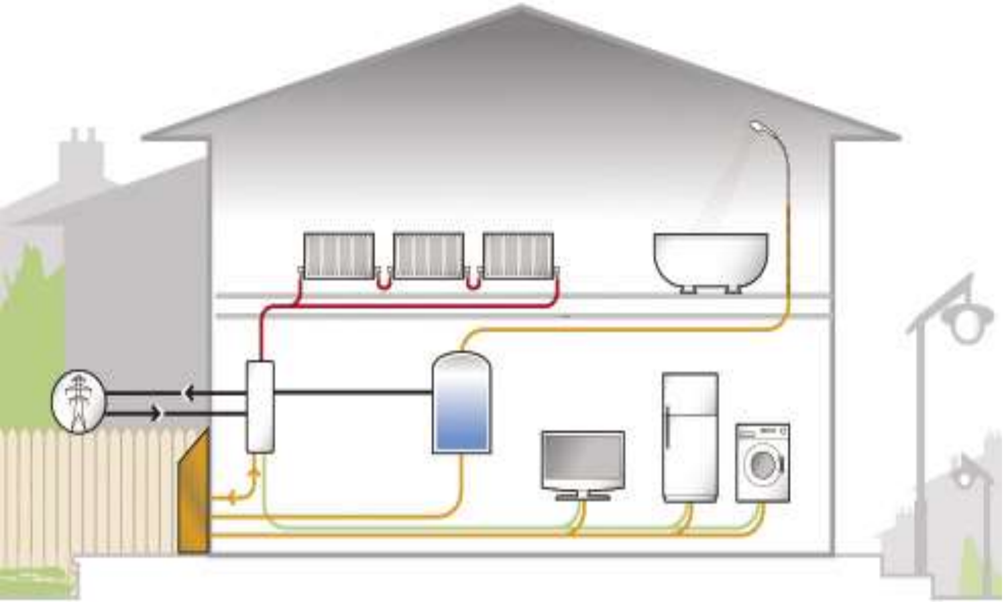
Textile Mills – 30 jobs lost

The Greatest Impact for Washington Citizens is the Effect of Each Tax on Gasoline Prices

Baseline* (gas production costs don't rise)	2020: $3.25/gal 2035: $3.89/gal Net: $0.76/gal
Low Carbon Price	2020: +$0.13/gal 2035: +$0.38/gal
High Carbon Price	2020: +$0.44/gal 2035: +$1.46/gal

(*EIA Pacific Region, 2012 dollars, taxes included)


Comparison Of Changes in Gasoline Prices at the Pump
Caused by a Carbon Tax in WA State versus Normal Changes
low C-price tax = $12/tonCO2 + 60¢/ton/year
high C-price tax = $12/tonCO2 + $8.00/ton/year
Changes in Gasoline Price at the Pump
Increase over Specified Time Period
$2.00
1.75
1.50
1.25
$1,00
0.70
0.50
0.25
+70¢
+2¢
+4¢
+$2.87
+12¢
+32¢
6 months
Feb – July
in 2014
6 months
of low-price
Carbon tax
6 months
of high-price
Carbon tax
4 years
2004 to
2008
4 years
of low-price
Carbon tax
4 years
of high-price
Carbon tax



How Do We Achieve a Low-Carbon Future for Washington State?

The biggest sources of carbon emissions in Washington State are from:

- **residential/commercial/industrial uses of fossil fuel**
- **gasoline and diesel fuels in vehicles**

How Do We Achieve a Low-Carbon Future for Washington State?

- WA State emissions have decreased since 1990, from lower emissions in the agriculture and the industrial sectors.
- Our only coal plant is closing in 2025 and will eliminate almost half of our emissions from power sources.
- Electric vehicles are the most effective way in Washington State to address the petroleum fuel issue because the majority of electricity generated in WA State is from non-fossil fuel.

The Energy Source You Use to Charge Your Electric Vehicle (EV) Is Critical

A fully-electric vehicle in Washington State gets the equivalent of over 100 miles/gallon

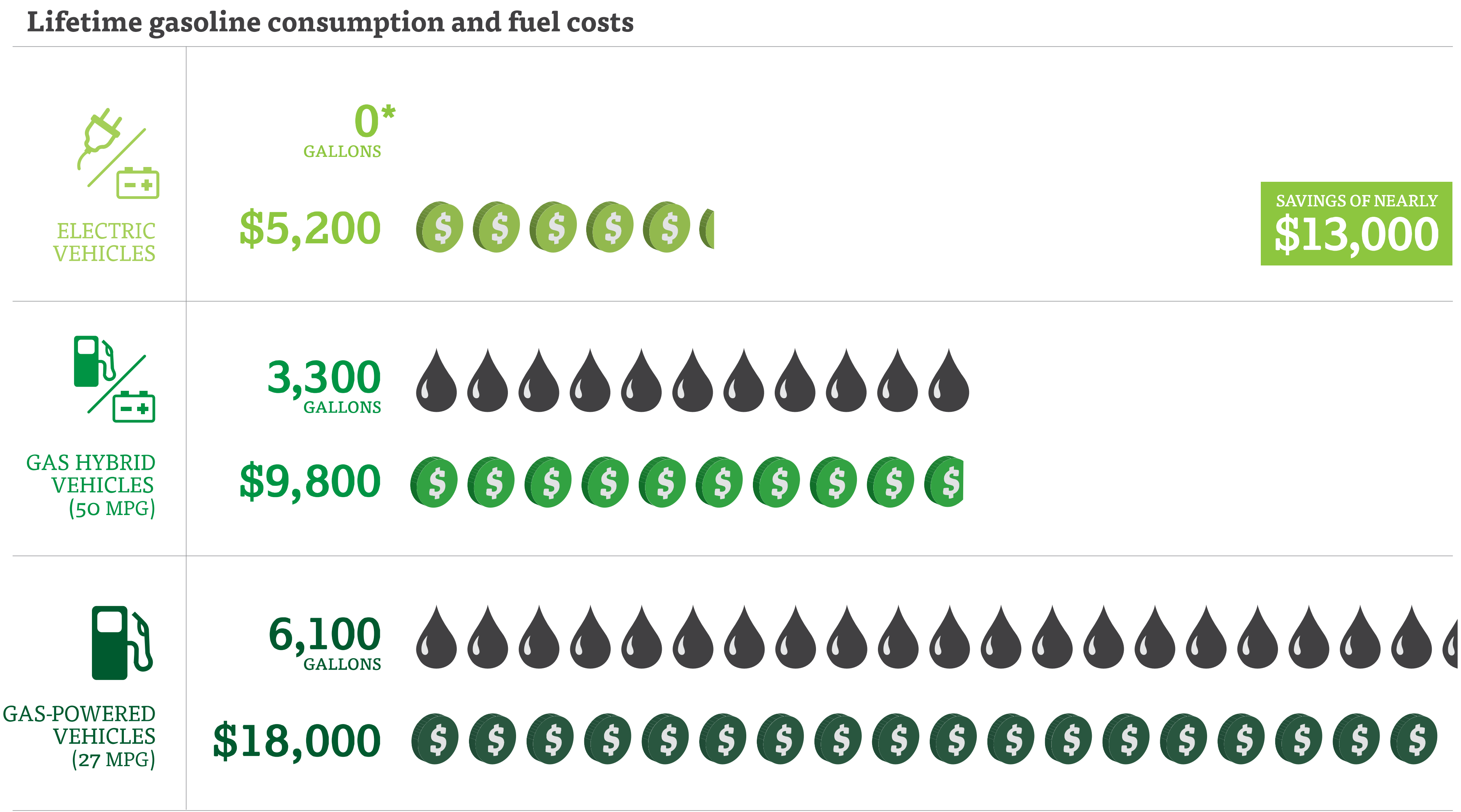
Electricity generation in WA State is over 80% non-fossil fuel because of hydro, nuclear and wind. Electric vehicles in WA are *green,* equivalent to getting over 100 mpg.

Electric vehicles charged in Indiana are no greener then ordinary cars using gasoline and getting 30 mpg because over 90% of their electricity is generated from coal.

If Washington State replaces 80% of our cars with electric vehicles by 2050 we would cut CO_2 emissions from our transportation sector by 75%

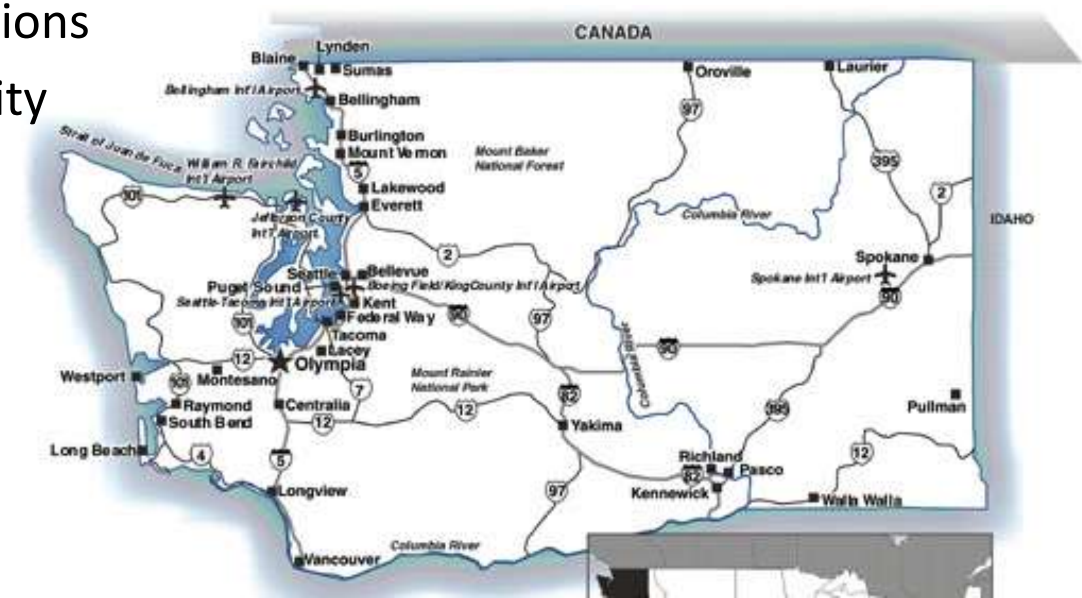
WA state consumer's would save $13,000 on average

Figure 2.1. COMPARISON OF LIFETIME VEHICLE FUEL/CHARGING COSTS AND GASOLINE CONSUMPTION



Conclusions

- The United States can easily meet EPA's Carbon Reduction Goals of a 30% reduction in CO_2 emissions by 2030 by replacing old coal plants, *as they die,* with gas, nuclear and renewables
- Washington State has already met these goals. WA should amend I-937 to make hydro a *clean* energy applicable to fossil fuel offsets, carbon and renewable goals
- We need long-term planning on what happens when nuclear and large hydro approach the end of their life expectancy
- Washington State could cut emissions over 40% just by going to a majority of electric vehicles by 2050
- Invest in charging stations every 70 miles along Routes 5, 90, 82, 395, 12, 97, 2, 101 and 14



Washington State's Low-Carbon Future

ENW is an example of a system that more than meets the new EPA rules

- *a diverse mix of non-fossil fuel generating systems*
- *exceeds 10 billion kWhrs/year, enough to power Seattle*
- *total capacity of 1,300 MW with an average combined capacity factor of >90%*
- *emits less than 20 gCO2/kWhr at 4.7 - 5.2 ¢/kWh now and for the next 30 years*

CGS set a record 9.7 billion kilowatt hours of electricity for the 2014 fiscal year

CGS Capacity Factor

1170 MW x 1000 kW/MW x 8766 hrs/year = 10.3 billion kWhrs possible/year

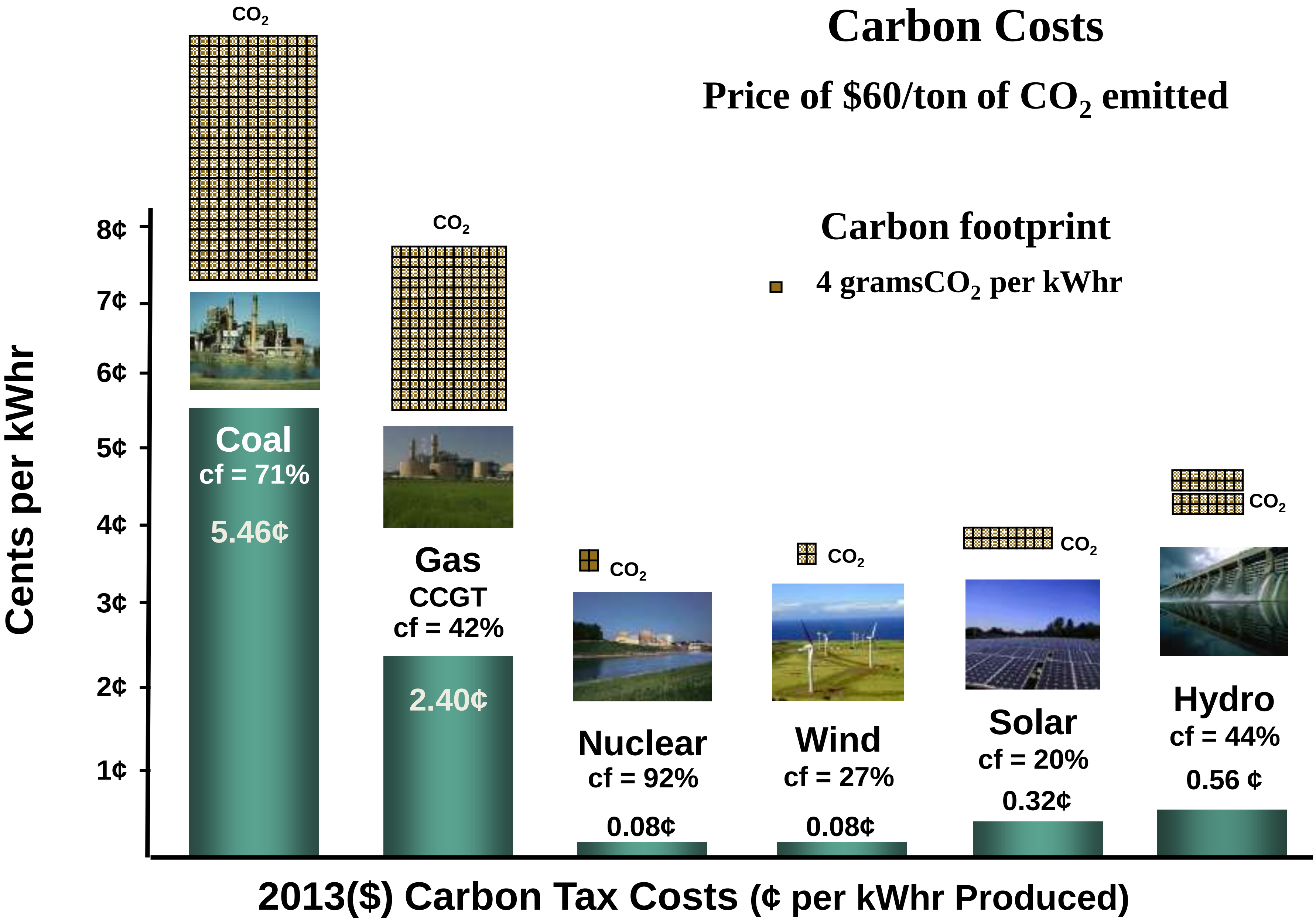
9.7 billion kWhrs ÷ 10.3 billion kWhrs = 0.95 or cf = 95%

White Bluffs Solar Station (38.7 kW with a cf = 15%)

Packwood Lake Hydroelectric Project (27.5 MW with a cf = 38%)

Nine Canyon Wind Project (96 MW with a cf = 31%)

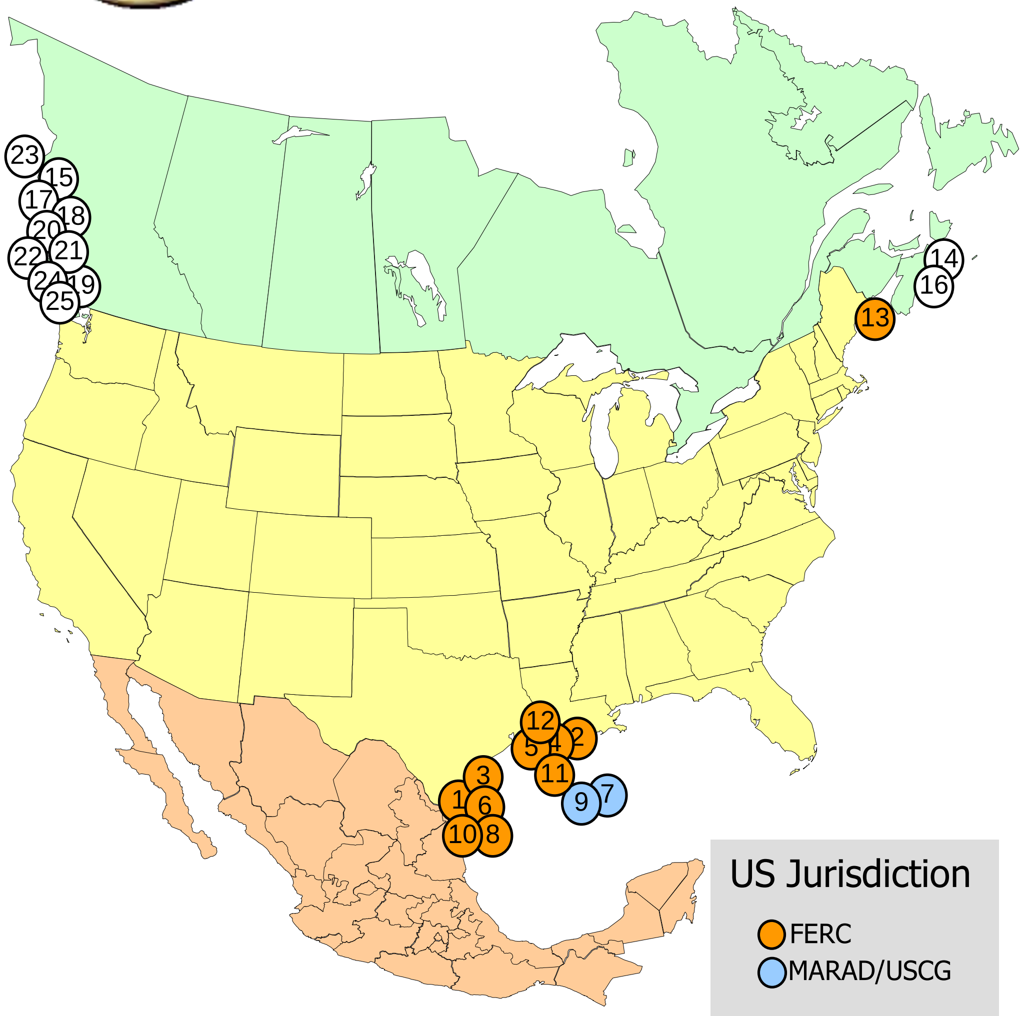
Tieton Dam Hydroelectric Project (15.6 MW- seasonal)



Carbon Costs
Price of $60/ton of CO_2 emitted
Carbon footprint
4 gramsCO_2 per kWhr
Cents per kWhr
8¢
7¢
6¢
5¢
4¢
3¢
2¢
1¢
CO_2
Coal
cf = 71%
5.46¢
Gas
CCGT
cf = 42%
2.40¢
Nuclear
cf = 92%
0.08¢
Wind
cf = 27%
0.08¢
Solar
cf = 20%
0.32¢
Hydro
cf = 44%
0.56 ¢
2013($) Carbon Tax Costs (¢ per kWhr Produced)

What about Natural Gas?

North American LNG Export Terminals
Potential



Export Terminal

POTENTIAL U.S. SITES IDENTIFIED BY PROJECT SPONSORS

1. **Brownsville, TX:** 2.8 Bcfd (Gulf Coast LNG Export)
2. **Cameron Parish, LA:** 0.16 Bcfd (Waller LNG Services)
3. **Ingleside, TX:** 1.09 Bcfd (Pangea LNG (North America))
4. **Cameron Parish, LA:** 0.20 Bcfd (Gasfin Development)
5. **Cameron Parish, LA:** 0.67 Bcfd (Venture Global)
6. **Brownsville, TX:** 3.2 Bcfd (Eos LNG & Barca LNG)
7. **Gulf of Mexico:** 3.22 Bcfd (Main Pass - Freeport-McMoRan)
8. **Brownsville, TX:** 0.94 Bcfd (Annova LNG)
9. **Gulf of Mexico:** 1.8 Bcfd (Delfin LNG)
10. **Brownsville, TX:** 0.27 Bcfd (Texas LNG)
11. **Cameron Parish, LA:** 0.54 Bcfd (SCT&E LNG)
12. **Port Arthur, TX:** 0.2 Bcfd (WesPac/Gulfgate Terminal)
13. **Robbinston, ME:** 0.27 Bcfd (Kestrel Energy - Downeast LNG)

POTENTIAL CANADIAN SITES IDENTIFIED BY PROJECT SPONSORS

14. **Goldboro, NS:** 1.4 Bcfd (Pieridae Energy Canada)
15. **Prince Rupert Island, BC:** 2.91 Bcfd (BG Group)
16. **Melford, NS:** 1.8 Bcfd (H-Energy)
17. **Prince Rupert Island, BC:** 2.74 Bcfd (Pacific Northwest LNG)
18. **Prince Rupert Island, BC:** 4.0 Bcfd (ExxonMobil – Imperial)
19. **Squamish, BC:** 0.29 Bcfd (Woodfibre LNG Export)
20. **Kitimat/Prince Rupert, BC:** 0.32 Bcfd (Triton LNG)
21. **Prince Rupert, BC:** 3.12 Bcfd (Aurora LNG)
22. **Kitsault, BC:** 2.7 Bcfd (Kitsault Energy)
23. **Stewart, BC:** 4.1 Bcfd (Canada Stewart Energy Group)
24. **Delta, BC:** 0.4 Bcfd (WesPac Midstream Vancouver)
25. **Vancouver Island, BC:** 0.11 Bcfd (Steelhead LNG)

Do We Need A Carbon Tax Or Cap&Trade?

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***+%&%, $+)**

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Implementation of the Carbon Rules

The U.S. is already halfway to achieving the rule's 30%

- CO_2 emissions from the energy sector have fallen 16%
  - 2.4 billion tons in 2005 to 2.0 billion in 2013
- if moderate new nuclear were pursued ➔ a 40% reduction by 2030

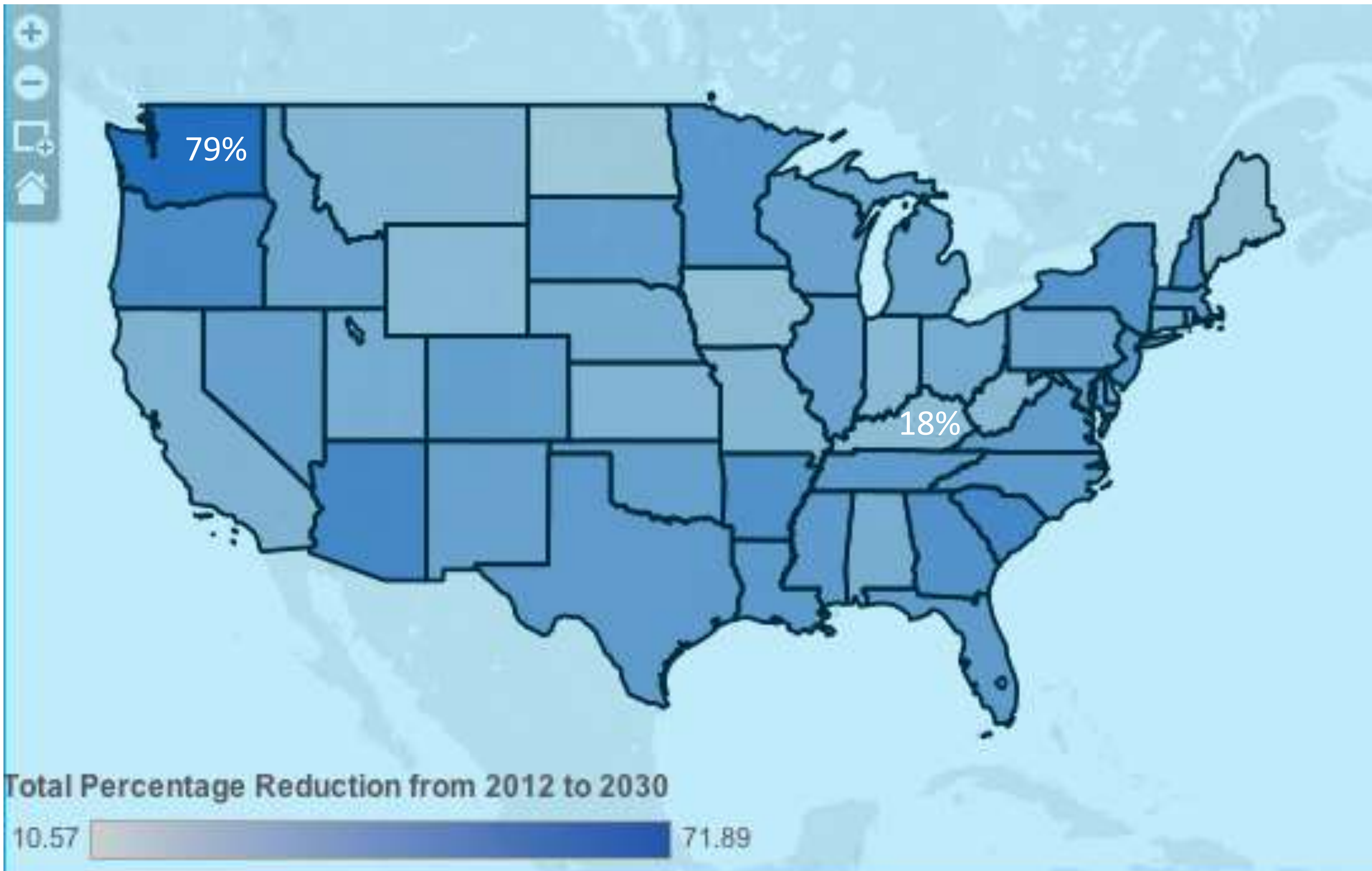


Table 1.1. WELL-TO-WHEELS EV MILES PER GALLON EQUIVALENT (MPG_{ghg}) BY ELECTRICITY SOURCE

Coal	30
Oil	32
Natural Gas	54
Solar	500
Nuclear	2,000
Wind	3,900
Hydro	5,800
Geothermal	7,600

Table 1.2. ELECTRIC VEHICLE EFFICIENCY RATINGS

2012 MODELS	MITSUBISHI "i"	FORD FOCUS EV	NISSAN LEAF	CHEVY VOLT
ELECTRIC EFFICIENCY (kWh/MILE)	0.3	0.32	0.34	0.36
ENERGY EFFICIENCY RATING (MILES PER GALLON OF GASOLINE EQUIVALENT)	112	105	99	94

Source: *www.fueleconomy.gov*.

If Washington State gets to 80% electric vehicles by 2040, we would cut CO_2 emissions from our transportation sector by 75%

For America as a whole, the target of 100,000,000 electric cars by 2040 will drive a trillion miles a year, requiring 250 billion kWhrs

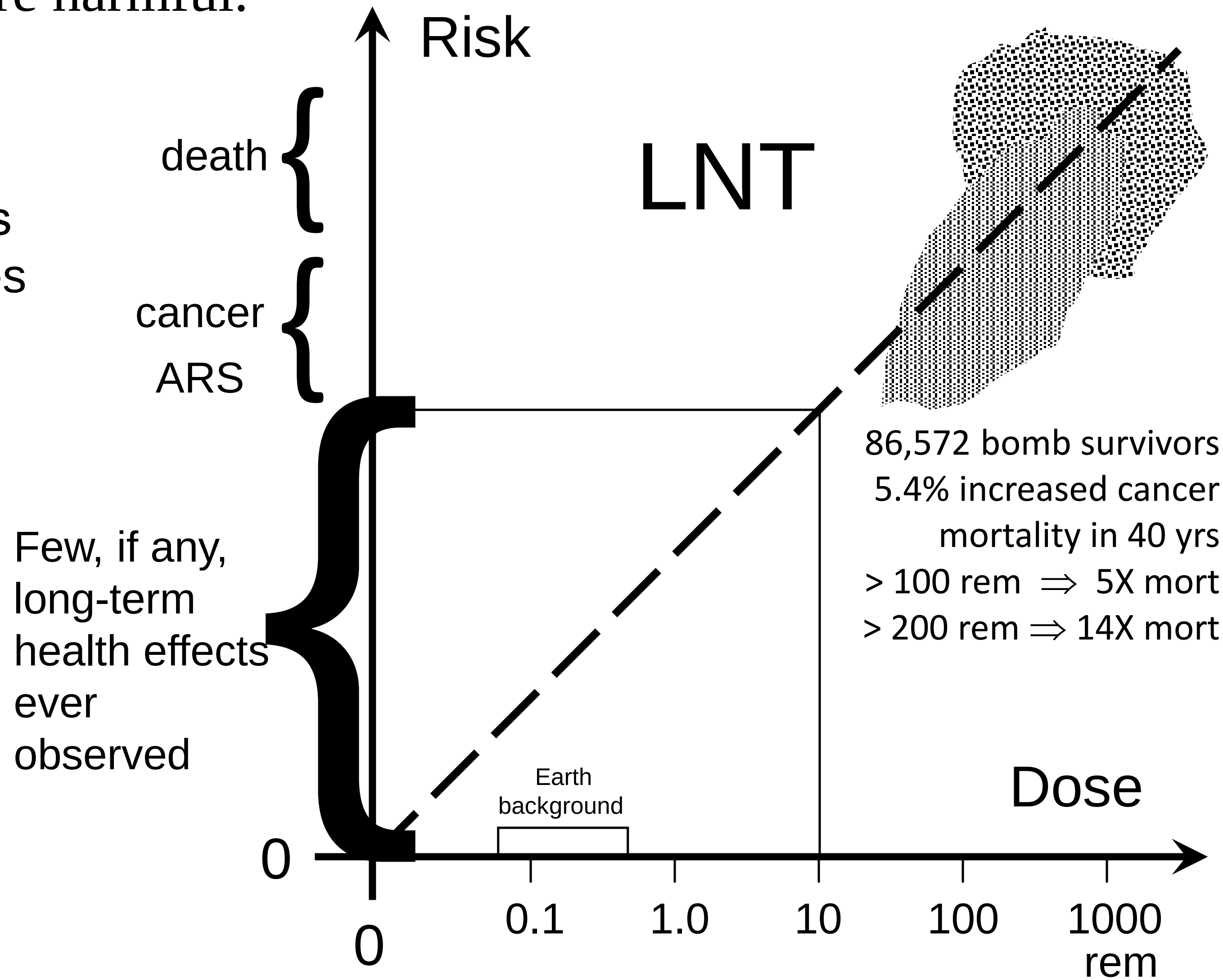
- 30 GenIII nuclear reactors
- 150 CCGT gas plants
- 250,000 MW wind turbines.

That is a lot of energy, but still only about 6% of the total electricity production in the U.S., and powering that many electric vehicles from nuclear, hydro or renewables alone would eliminate about 10% of our carbon emissions.

Linear-no-threshold hypothesis: even the smallest amounts of radiation are harmful.

Chernobyl fireman and workers died from > 100 rem in 48 hrs, and other industrial accidents

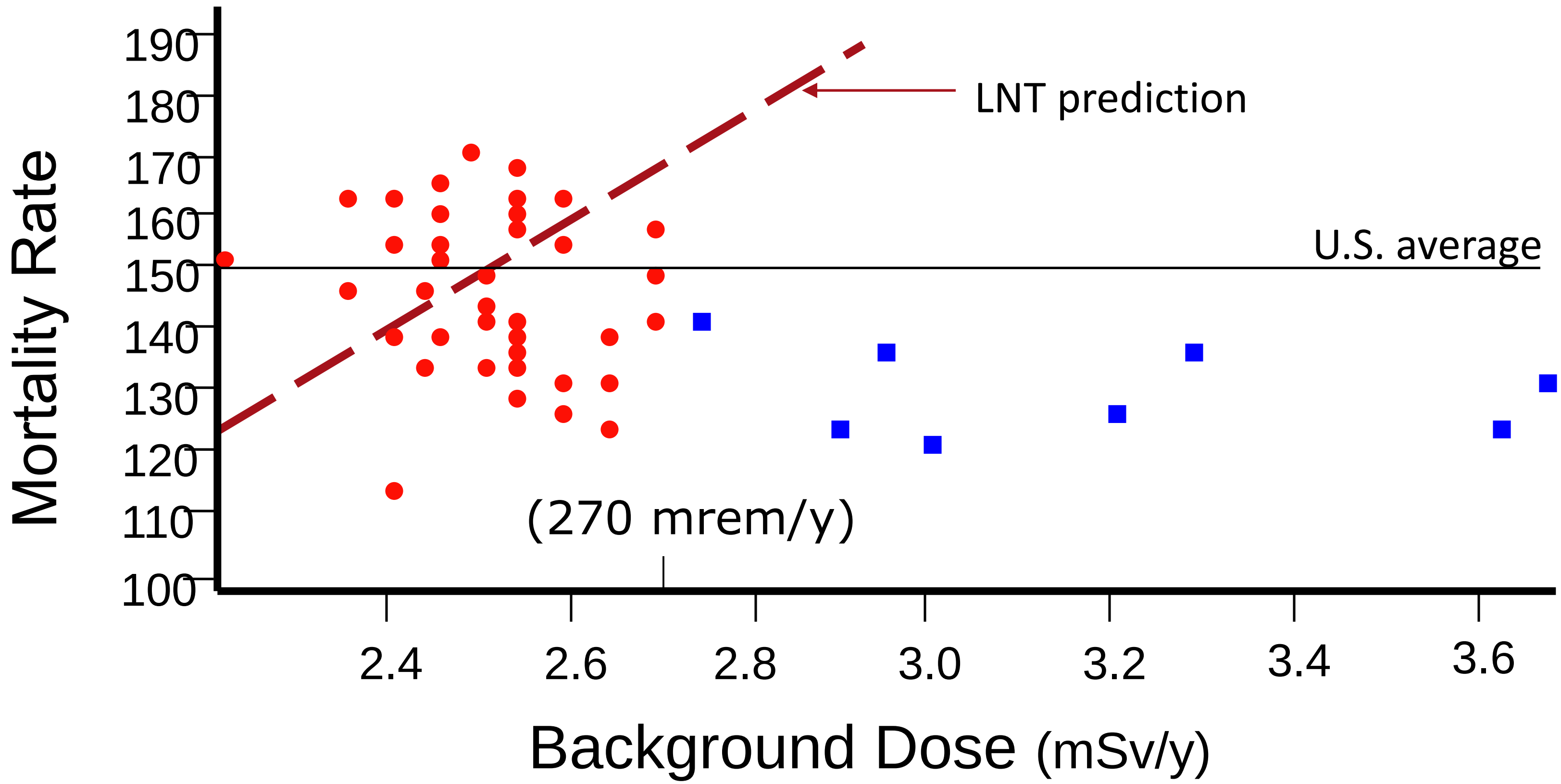
- cancer risk doubles when dose doubles
- it triples when dose triples
- it halves when dose halves



“The committee finds the linear no-threshold (LNT) model to be a computationally convenient starting point.” - BEIR VII Report (NAS 2005)

BACKGROUND RADIATION DIFFERENCES

ANNUAL CANCER MORTALITY/100,000 FOR EACH U.S. STATE OVER A 17-YEAR PERIOD (Frigerio and Stowe, 1976)

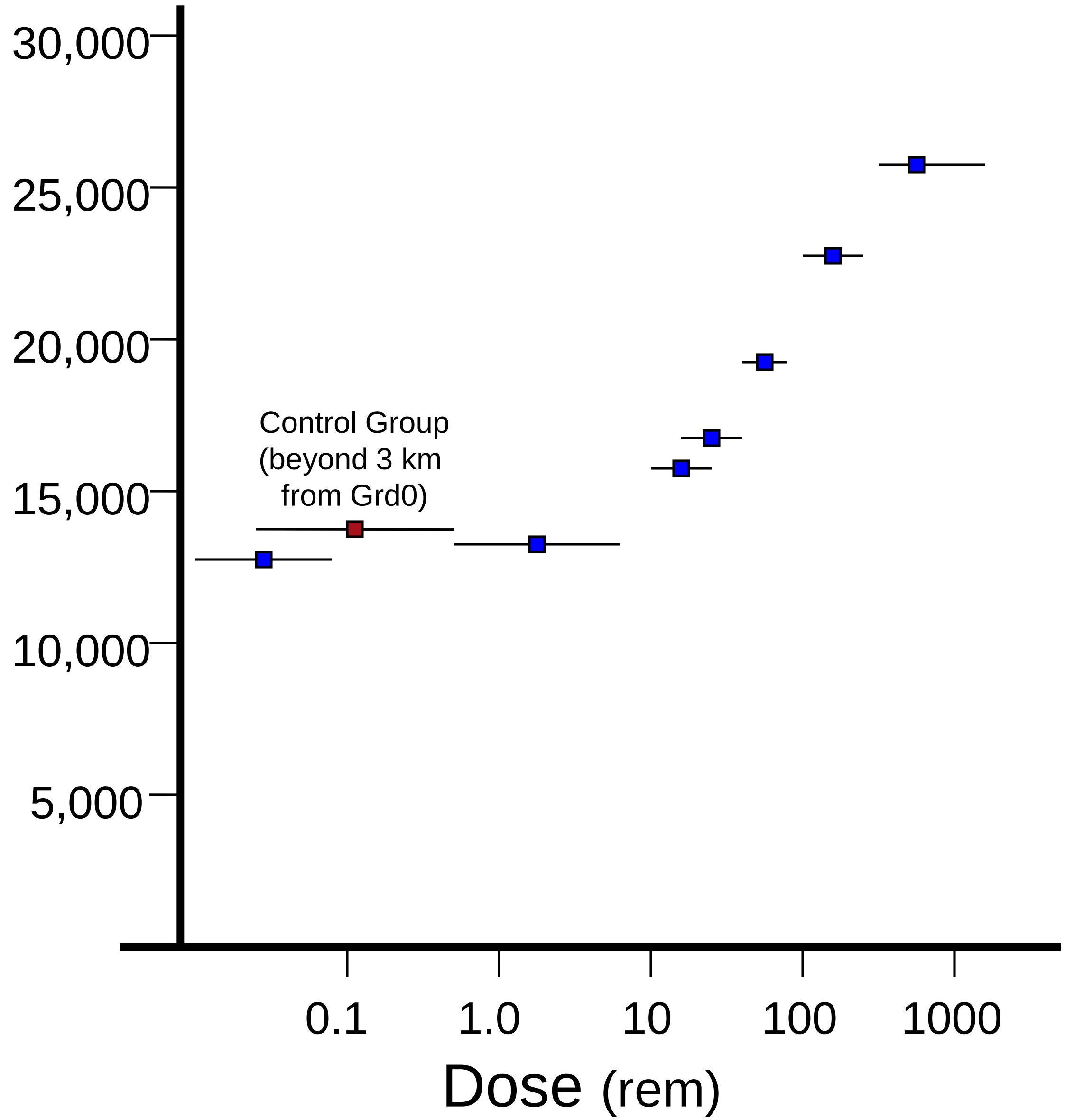


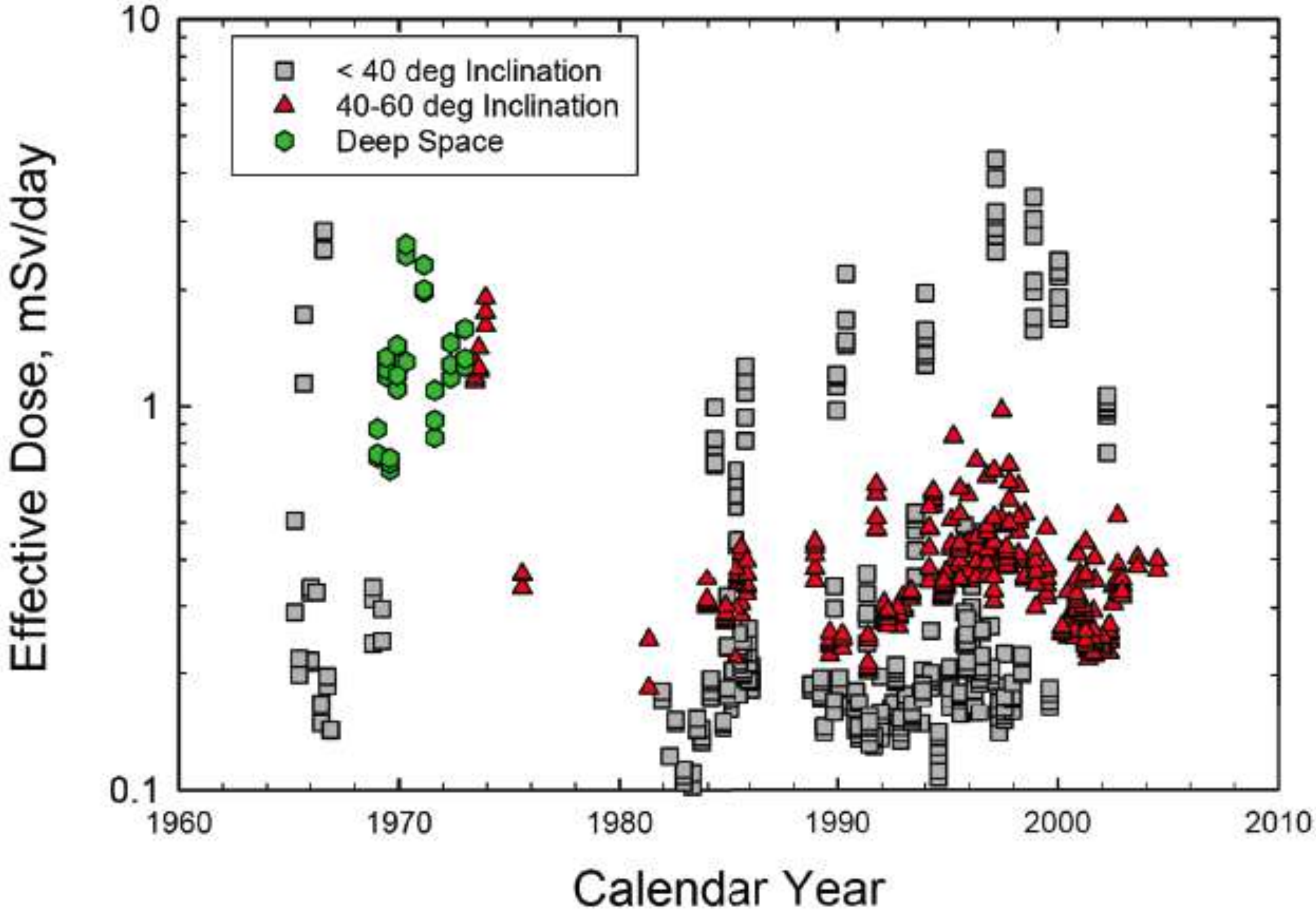
Solid Cancers per 100,000 population in the Atomic Bomb Survivor Cohort of 79,901 subjects (data from 1994 ICRP).

Number of Solid Cancers over 40 years

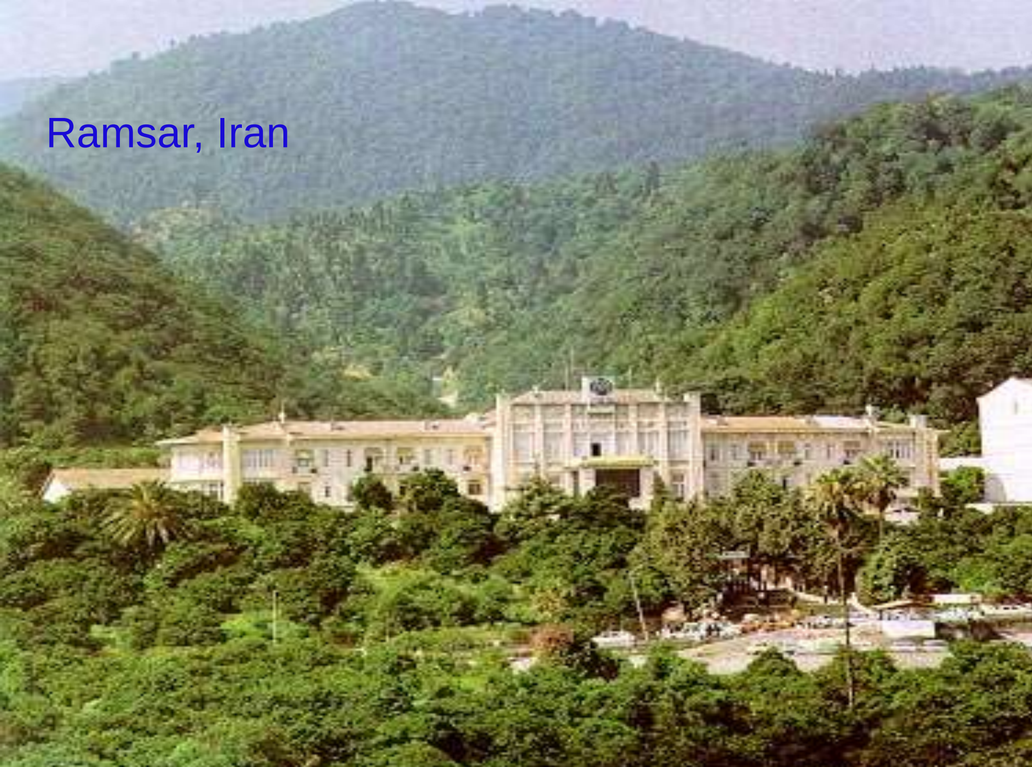
(per 100,000 population)

normalized per 100,000	dose range
13,748	> 3 km from Grd0
12,806	< 0.1 rem
13,494	0.5-10 rem
15,476	10-20 rem
16,752	20-50 rem
19,094	50-100rem
23,949	100-200 rem
26,808	> 200 rem





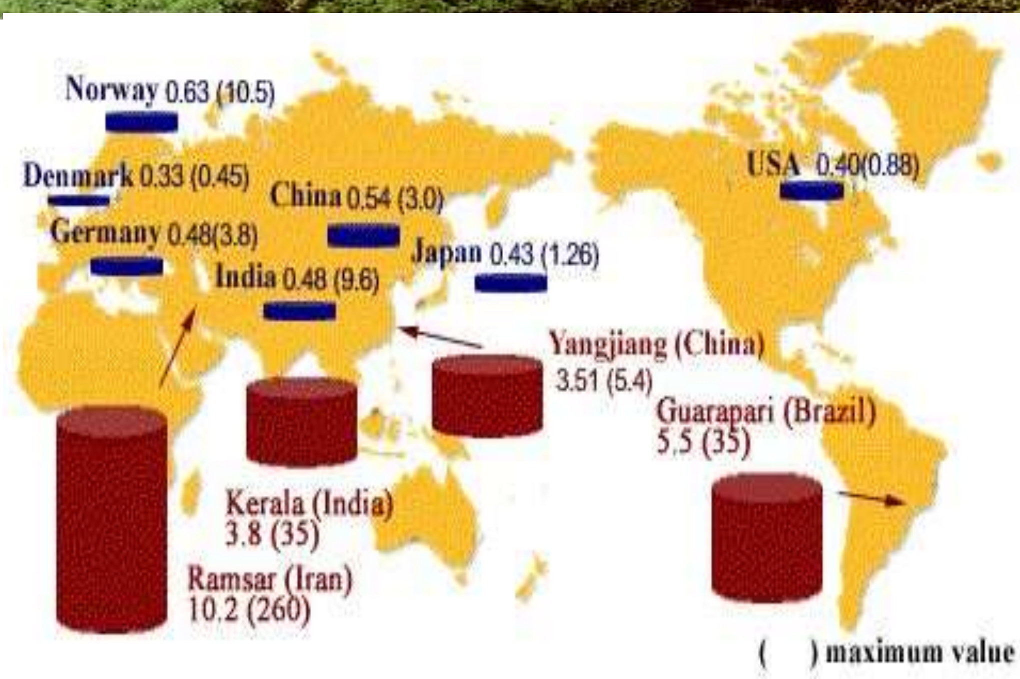
Astronaut radiation exposure history (United States) from 1962 to 2005 (Cucinotta 2007; NAS 2008). Scatter results from differences in altitude, orbital inclination, vehicle orientation and shielding, position within the vehicle, and position within the solar cycle and variations in solar activity.



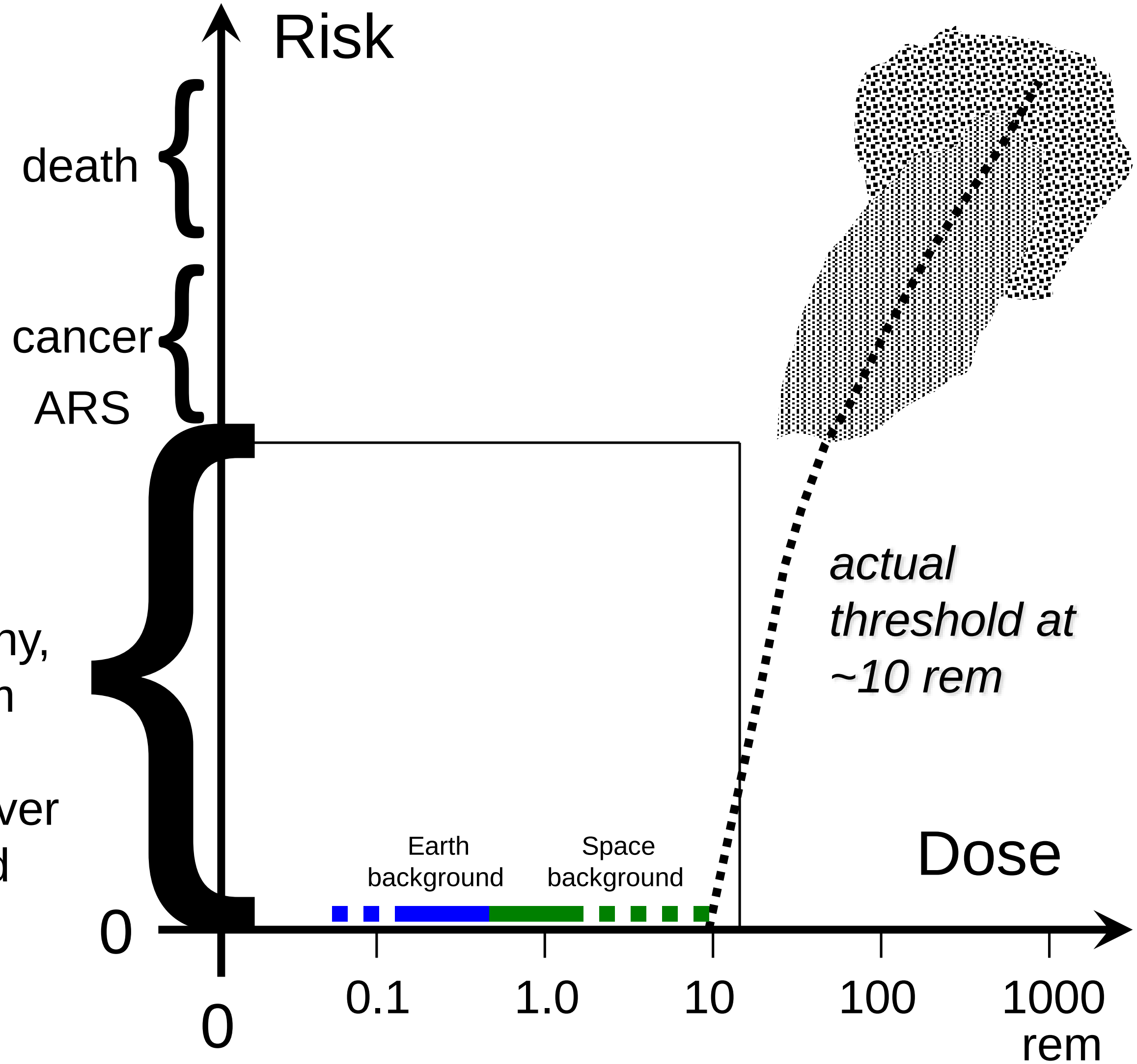
High Background Radiation Areas (HBRA) versus Normal Background Radiation Areas (NBRA)

Cancer mortality and life expectancy do not appear different in High Background Radiation Areas (HBRA) and near-by Normal Background Radiation Areas (NBRA).

In vitro exposure of lympocytes in people from both HBRA and NBRA to a "*challenge* dose of 1.5 Gy of γ-radiation showed the HBRA residents at only 56 % of the average number of induced chromosomal abnormalities relative the NBRA inhabitants, indicating an adaptive response in the HBRA residents.



Proposed threshold dose of about 10 rem/year: small amounts of radiation are not harmful.



32,915 bomb survivors < 10 rem ⇒ no increase in mortality

background across the Earth,
0.1 - 10 rem/yr ⇒ no affect on cancer or mortality rates

Fukushima Dai-ichi Nuclear Power Plant


Fukushima
Tohoku quake

Causes of Mortality From Japanese Tohoku Catastrophe

- Earthquake motion from initial Magnitude 9 Quake
  = 2,000 deaths
- Tsunami wave drowning and impact
  = estimated 21,000 deaths
- Earthquake aftershocks in one week duration
  = 50 deaths (from debris movement)
- Nine oil refineries damaged or destroyed, blamed for many deaths resulting from lack of fuel and medicine
- More loss of coal powered generation (1/3) and natural gas (2/3) than nuclear (1/5)
- Earthquake, Tsunami cleanup mortality
  = estimated 20 deaths from material motions during rescue
- Nuclear Power Plant Failures
  = 1 death from crane injury during quake
  = 2 missing after tsunami
  = 0 radiation deaths (three workers have received ~ 27 rem)

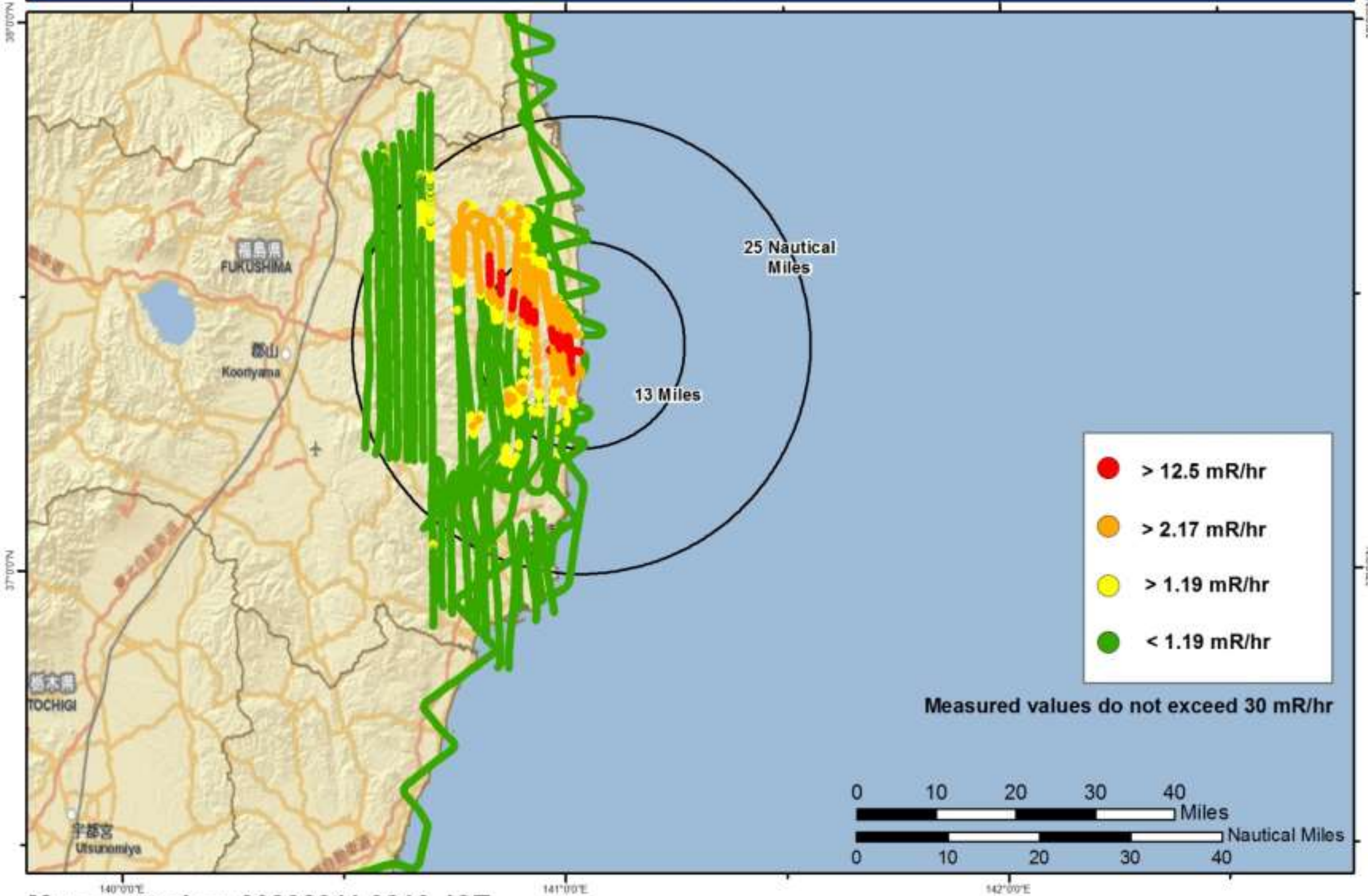
the above numbers are estimates, subject to confirmation with government reported data expected in one month
Office of The Prime Minister of Japan, Nuclear and Industrial Safety Agency (NISA), Tokyo Electric Power Company (TEPCO) Press Releases, Ministry of Education, Culture, Sports, Science and Technology (MEXT)

NNSA National Nuclear Security Administration

Aerial Monitoring Results - C-12

Survey Date - 17, 18, 19 March 2011

FUKUSHIMA DAIICHI JAPAN



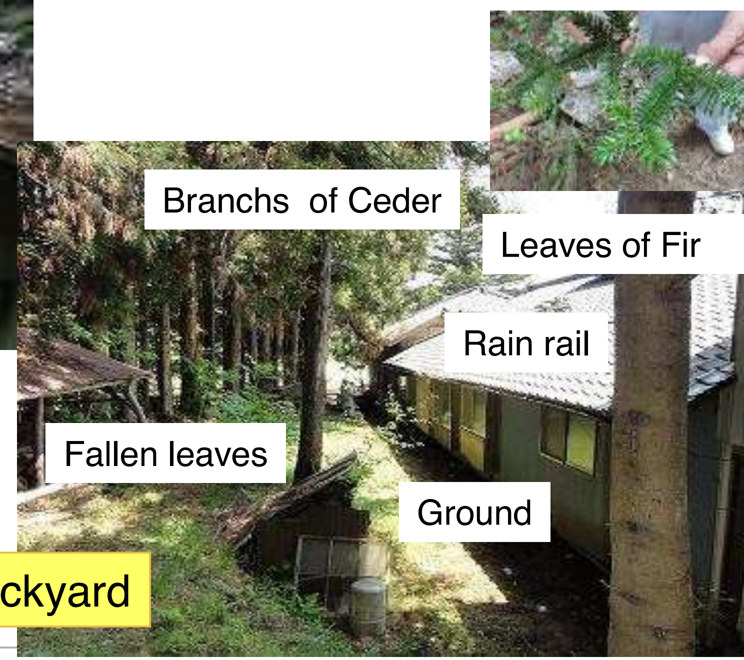
Map created on 03232011 0210 JST

Name: NIT_C-12 23Mar2011 v4

Nuclear Incident Team DOE NIT
Contact (202) 586 - 8100

Radiation Source around a house in Iitate Village

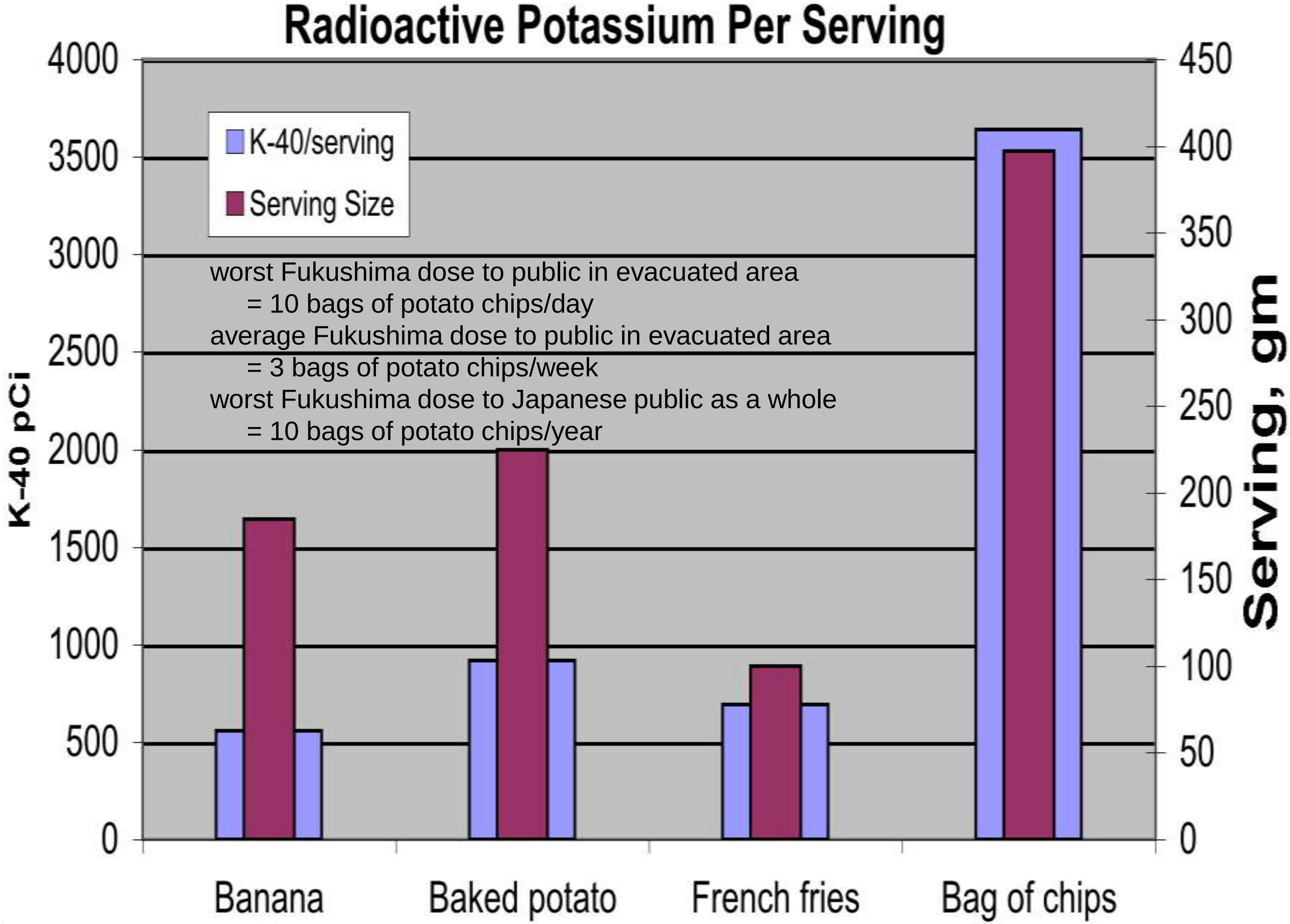
Front and Side



Backyard

Ambient dose rate：13～15 μ Sv/h
Surface dose rate：20～170 μ Sv/h

From Radiation Safety Forum[2011/June/4]



Source: Dan Yurman, 2011