The Basis of a Long-Term Strategic Energy Plan

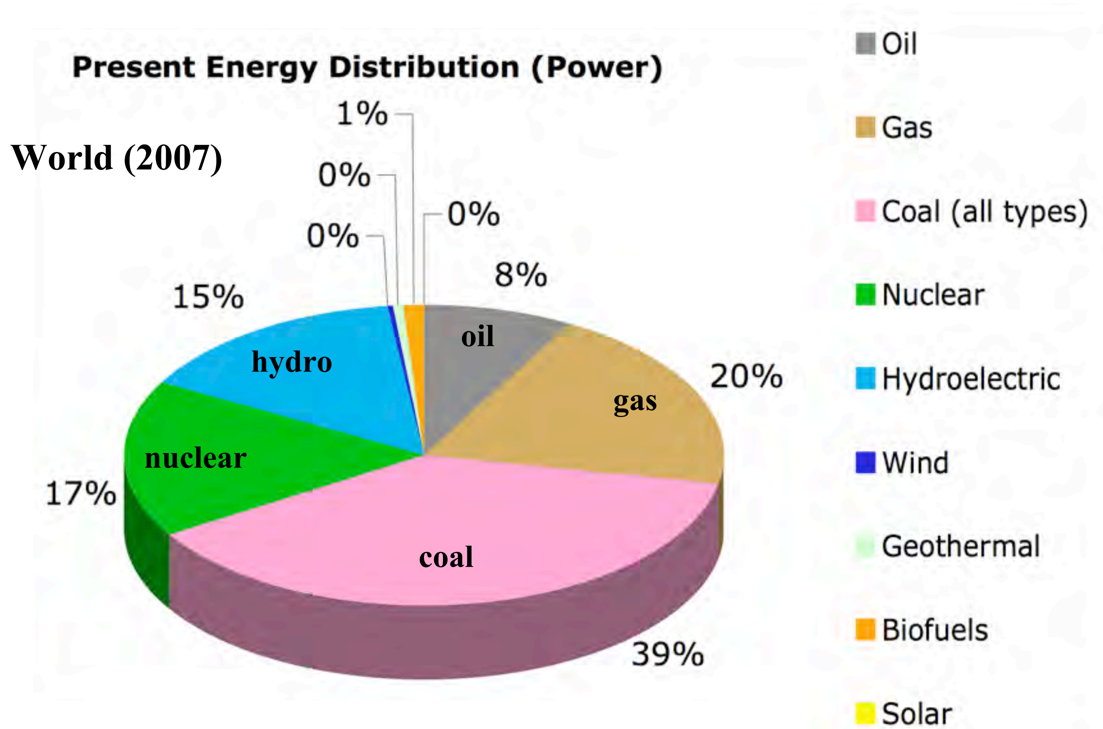
must address all security issues:

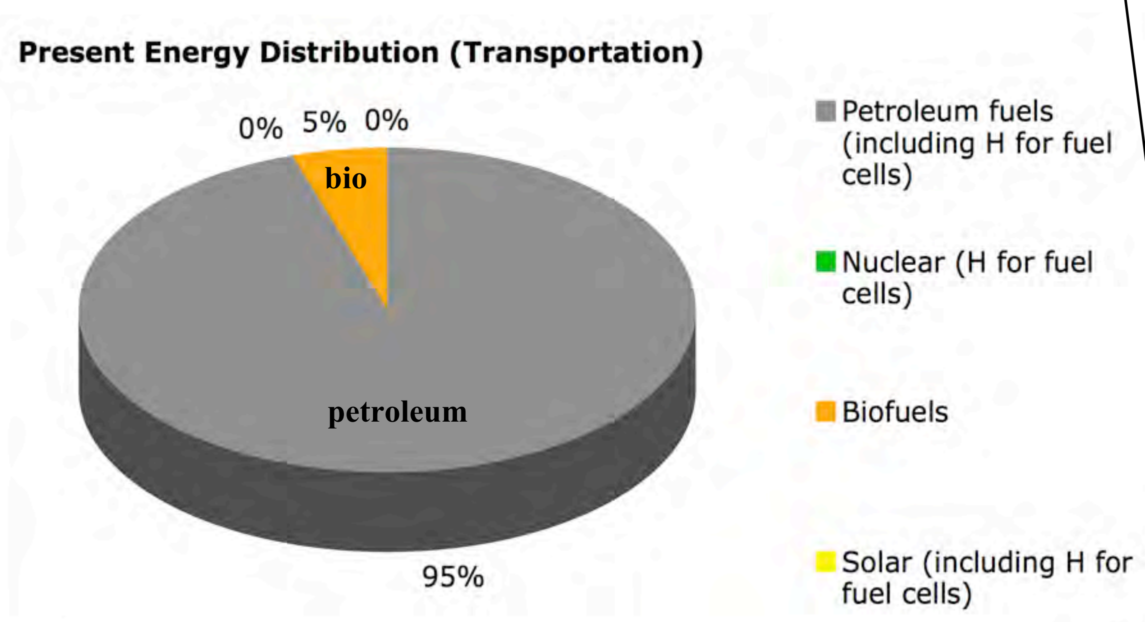
Environmental Security
Energy Security
Economic Security
National Security
Nuclear Non-Proliferation

Only a correct energy mix will approach total security

James Conca, Director
Carlsbad Environmental Monitoring and Research Center
New Mexico State University

Nuclear Energy Summit
October 8, 2008
Washington, D.C.



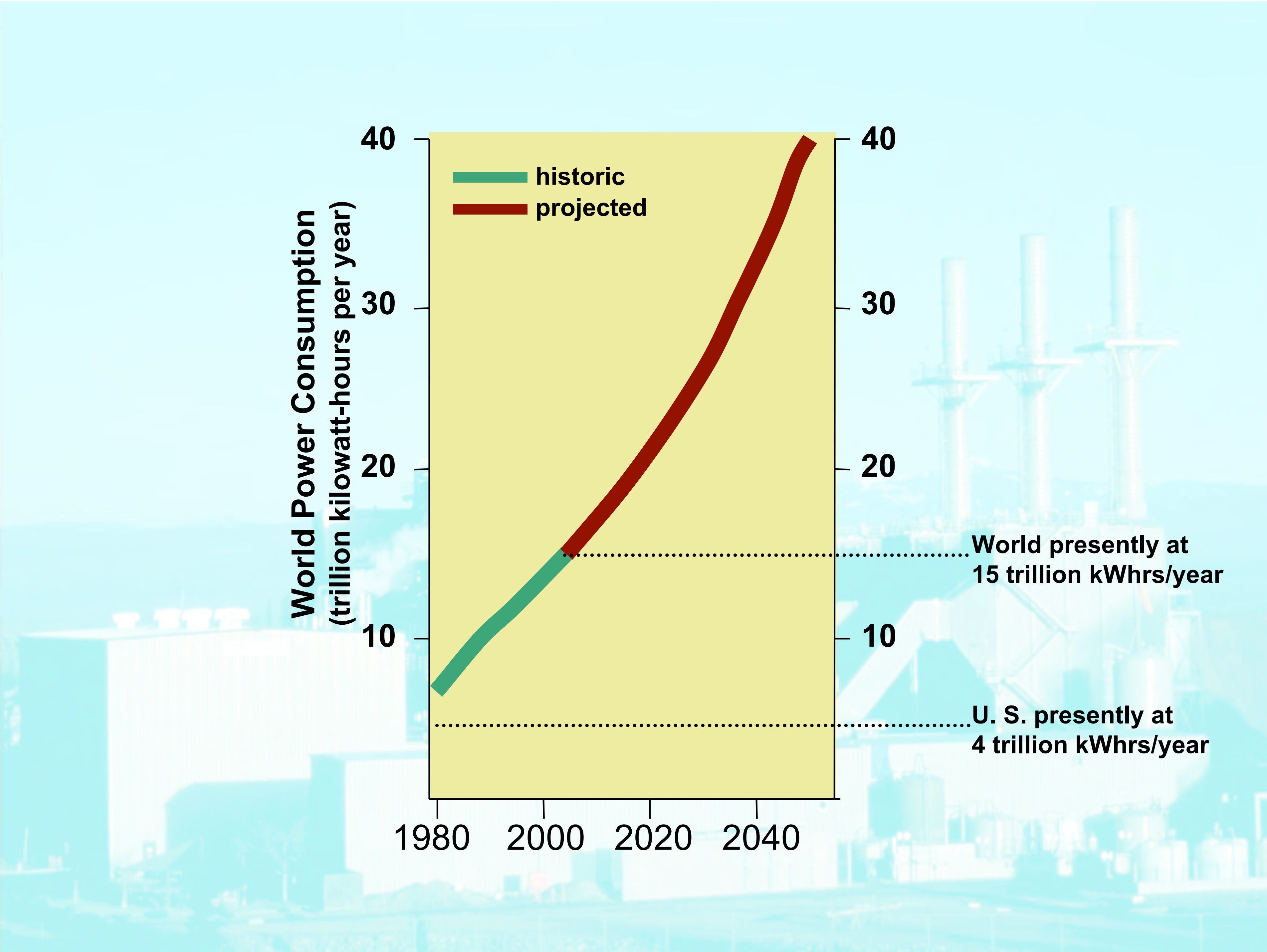


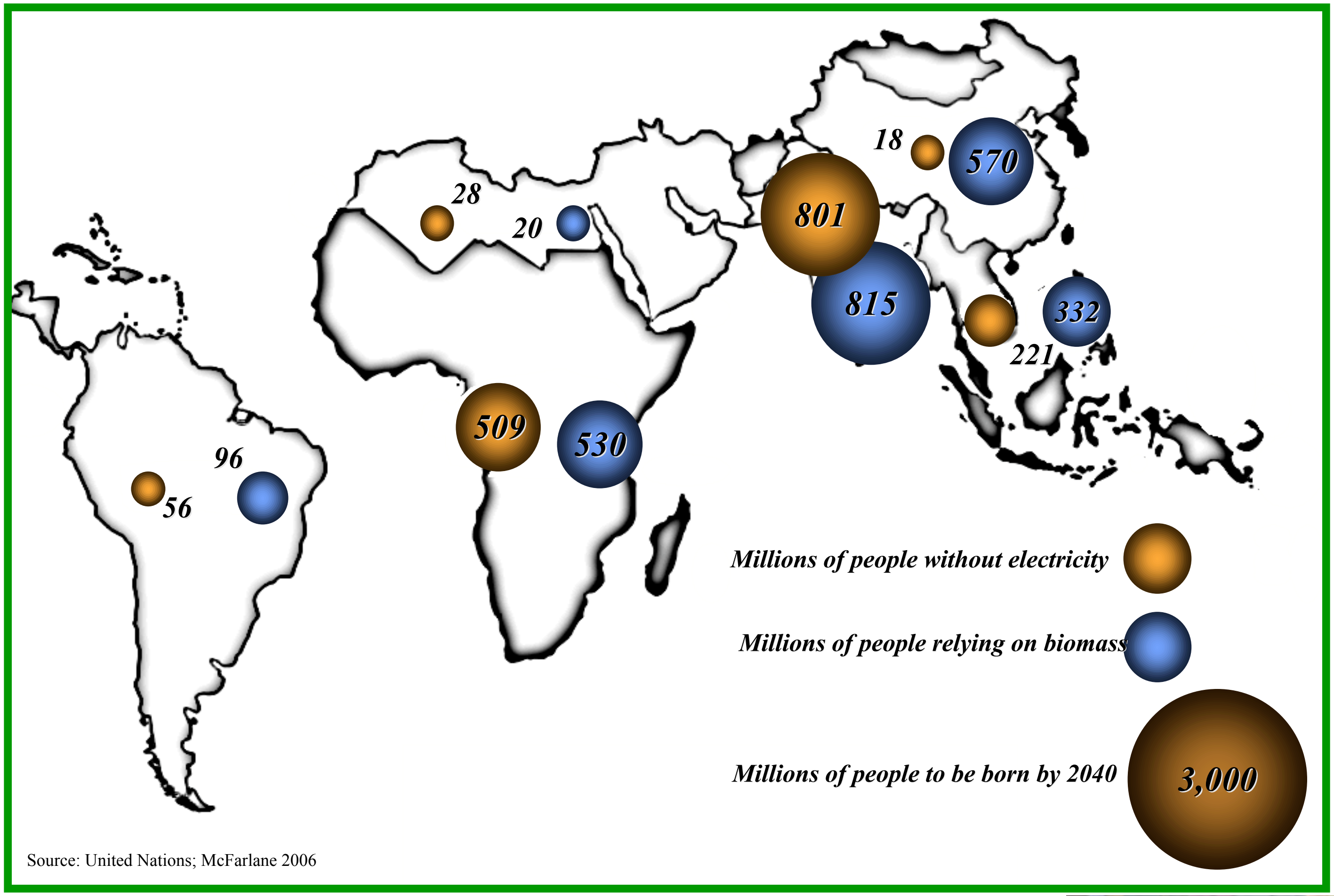
United States
50% coal
19% gas
19% nuclear
6% hydroelectric
6% other

California	**New Mexico**
21% coal	88% coal
41% gas	10% gas
13% nuclear	2% other
17% hydroelectric	
8% other	

European Union
30% coal
18% gas
32% nuclear
11% hydroelectric
6% oil 3% other

India
75% coal
2% nuclear
20% hydroelectric
3% other


World Power Consumption
(trillion kilowatt-hours per year)
historic
projected
40
30
20
10
1980
2000
2020
2040
World presently at
15 trillion kWhrs/year
U. S. presently at
4 trillion kWhrs/year



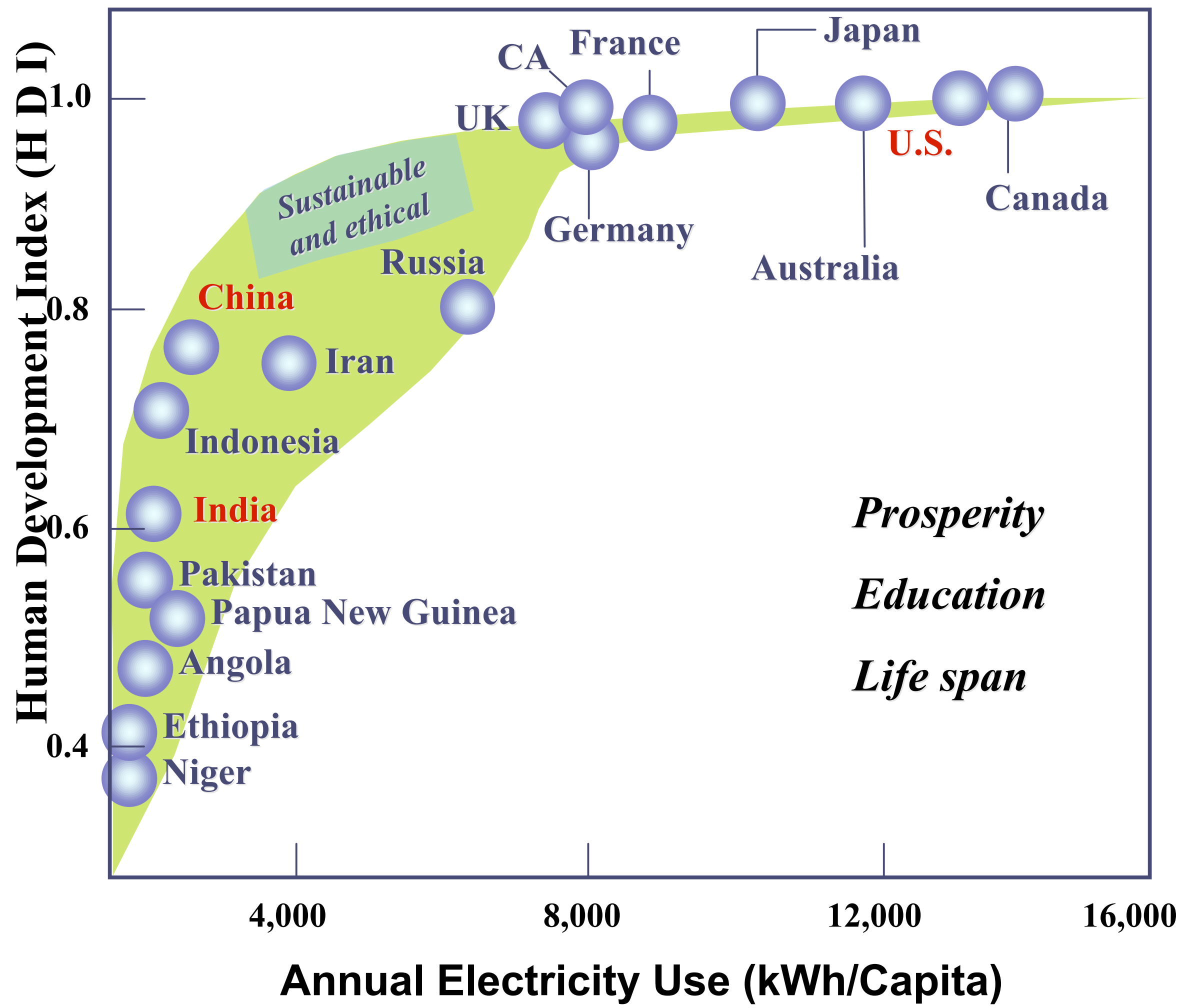
Map of Global Energy Poverty

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

Access to energy is essential to quality of life

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



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

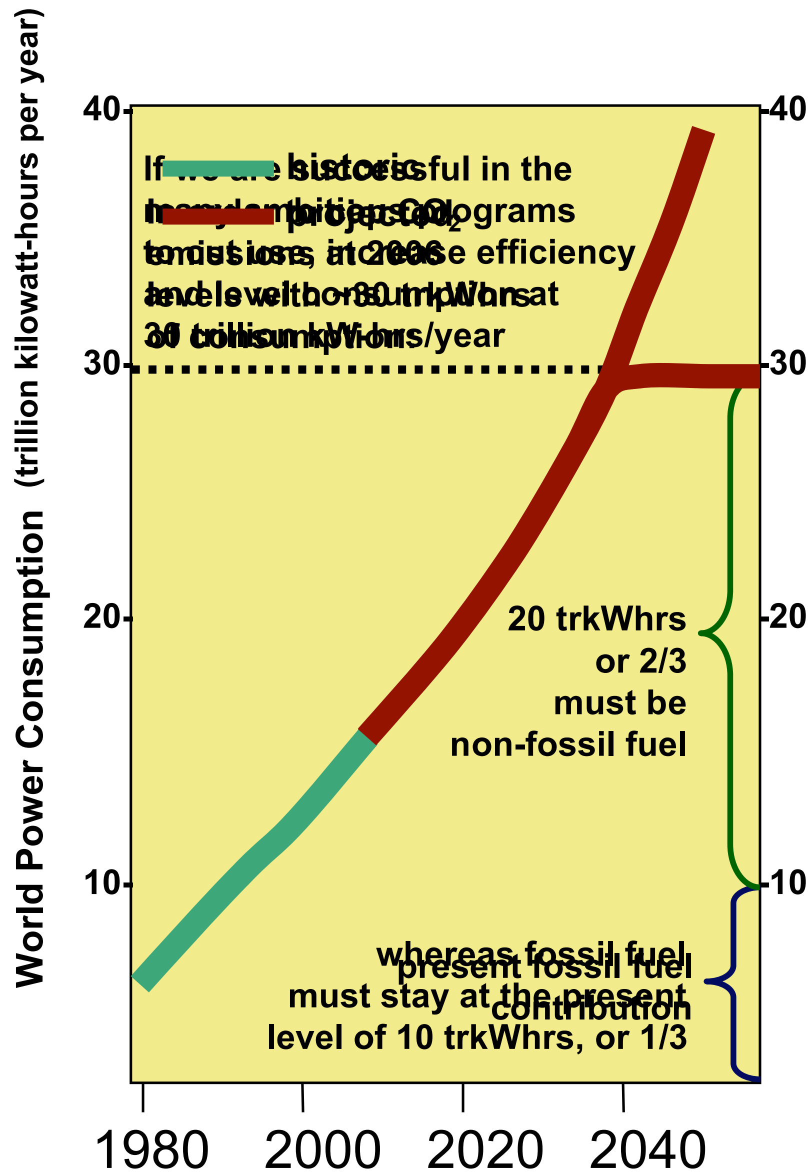
Source: United Nations Development Program; McFarlane 2006

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**

Out of the 15 trillion (tr) kWhrs of energy presently used in the world per year, fossil fuels provide about 10 trkWhrs, or two-thirds of the total energy consumed, while hydroelectric and nuclear split the rest.

In order to prevent increases in atmospheric CO_2 and other effects such as drops in oceanic pH, fossil fuel production cannot increase significantly to fill this gap. Instead, renewables and nuclear must provide 20 trkWhrs of electricity by 2040, which is twice what all fossil fuel produces today.

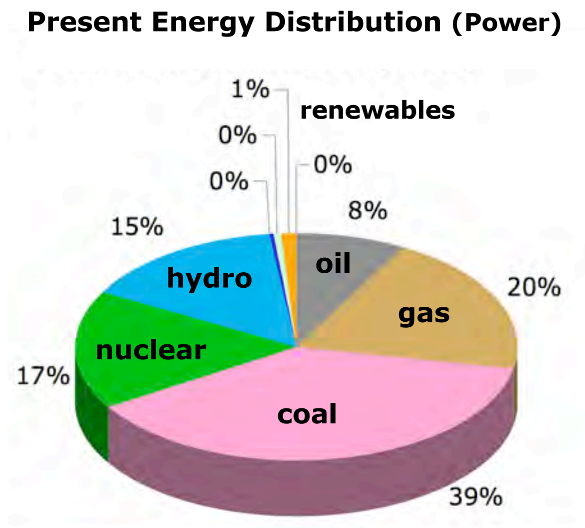


The Target → a Third, a Third and a Third - 1/3 fossil fuel, 1/3 renewables and 1/3 nuclear

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

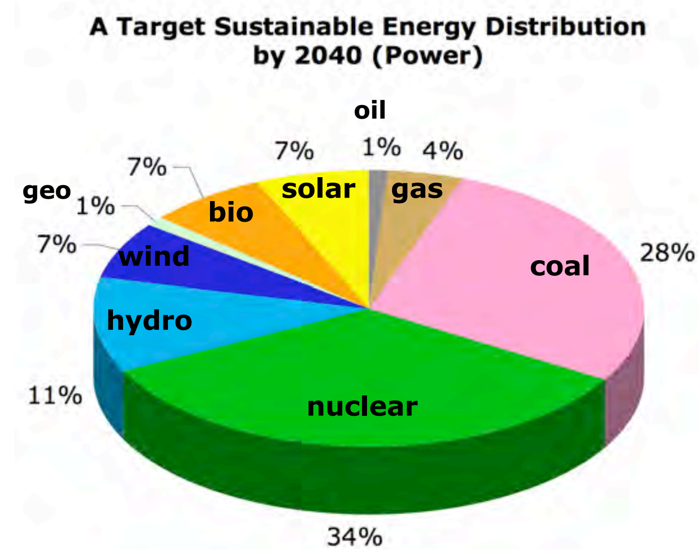
World (2007)

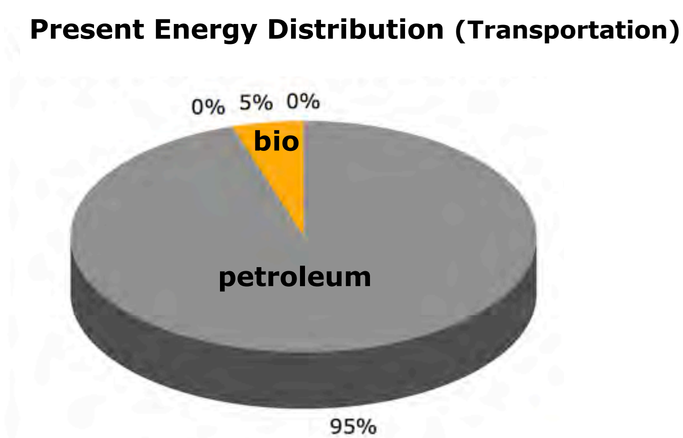
15 tkWhrs/yr

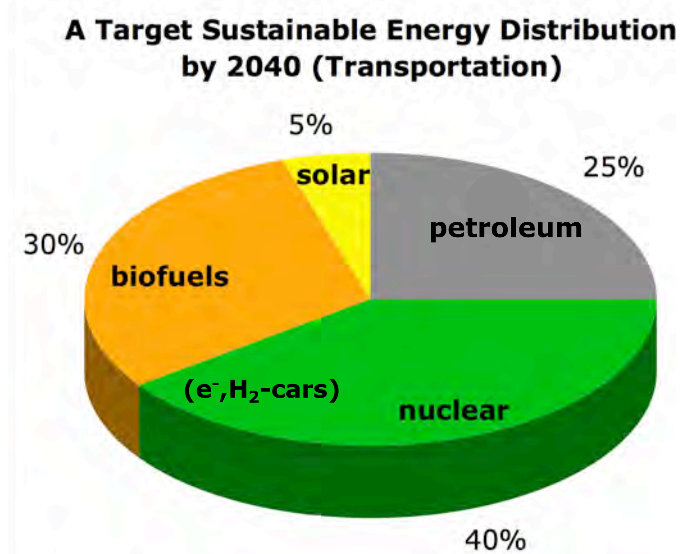


World (2040)

30 tkWhrs/yr





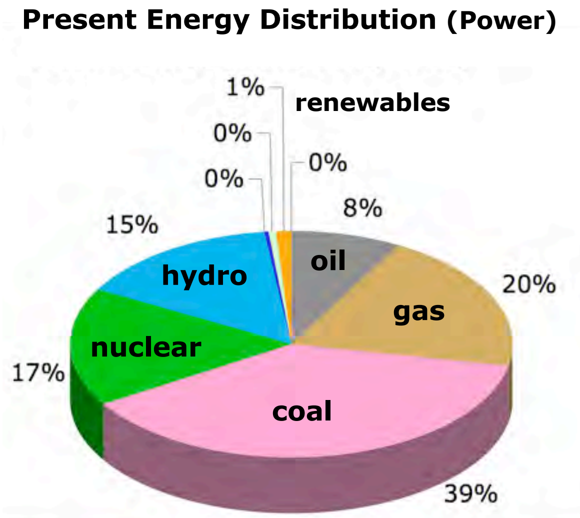


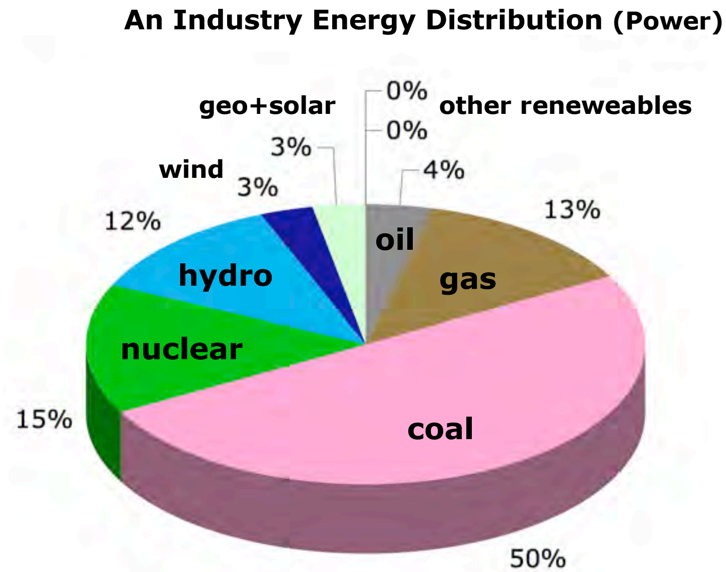
The most likely scenario given the direction of present investment and development

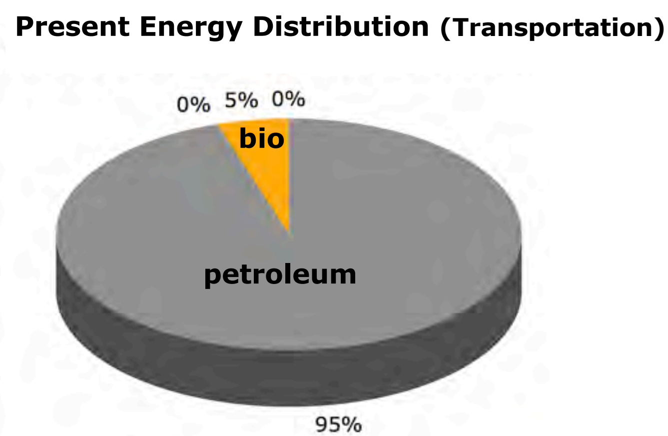
Dramatic increase in coal and development of unconventional fossil fuels

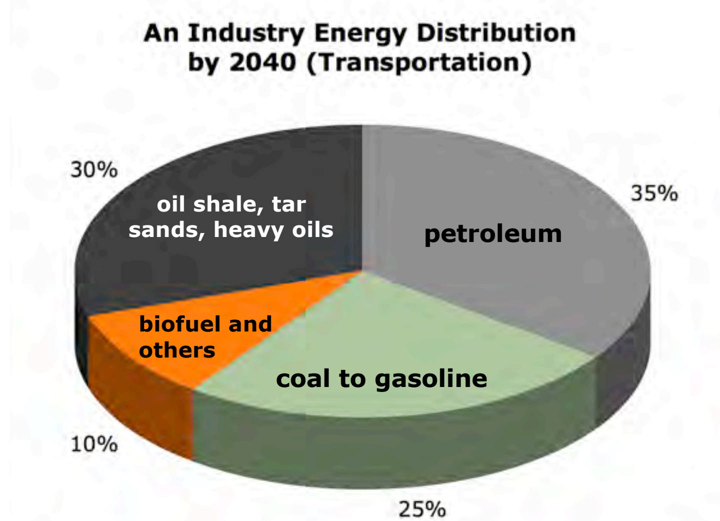
World (2007)
15 tkWhrs/yr

World (2040)
30 tkWhrs/yr

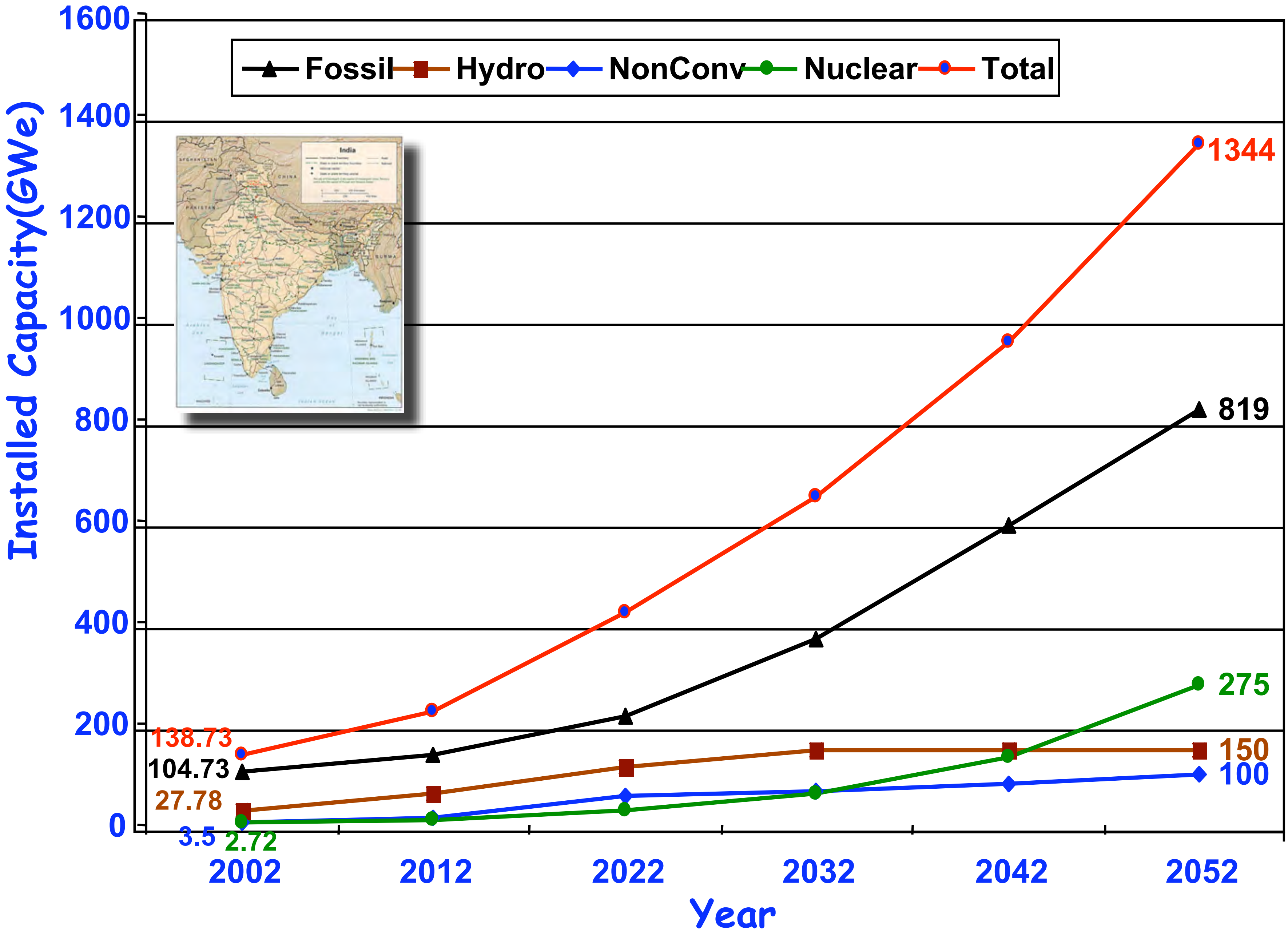






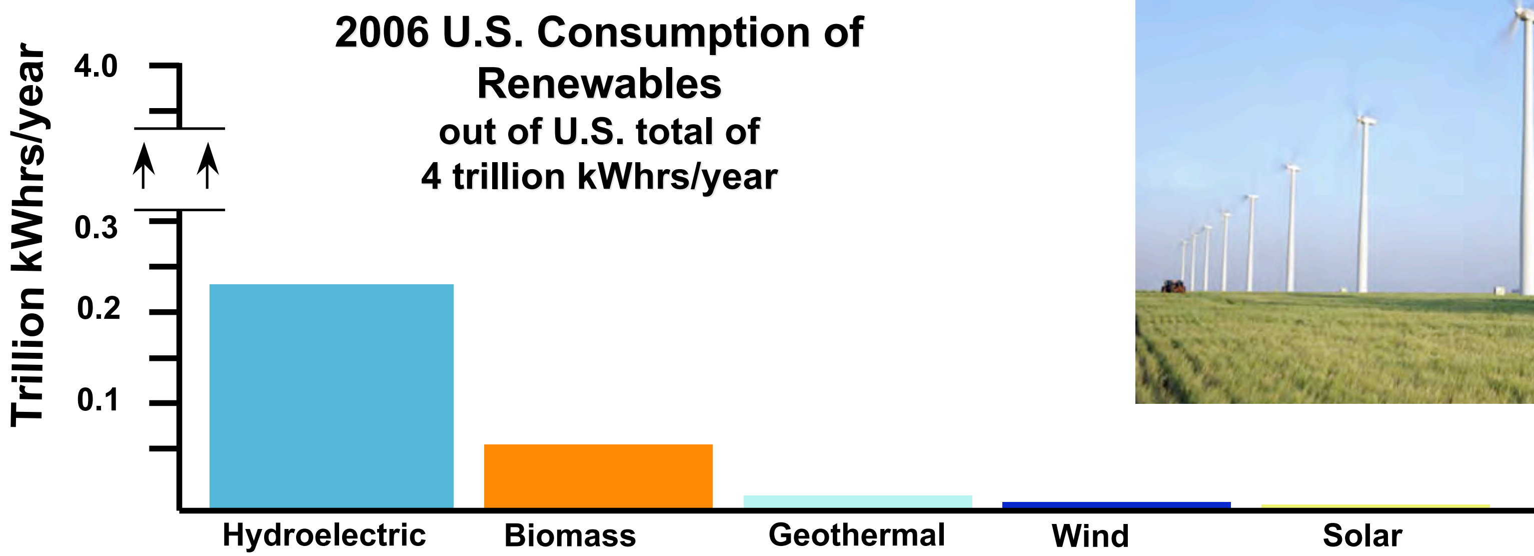


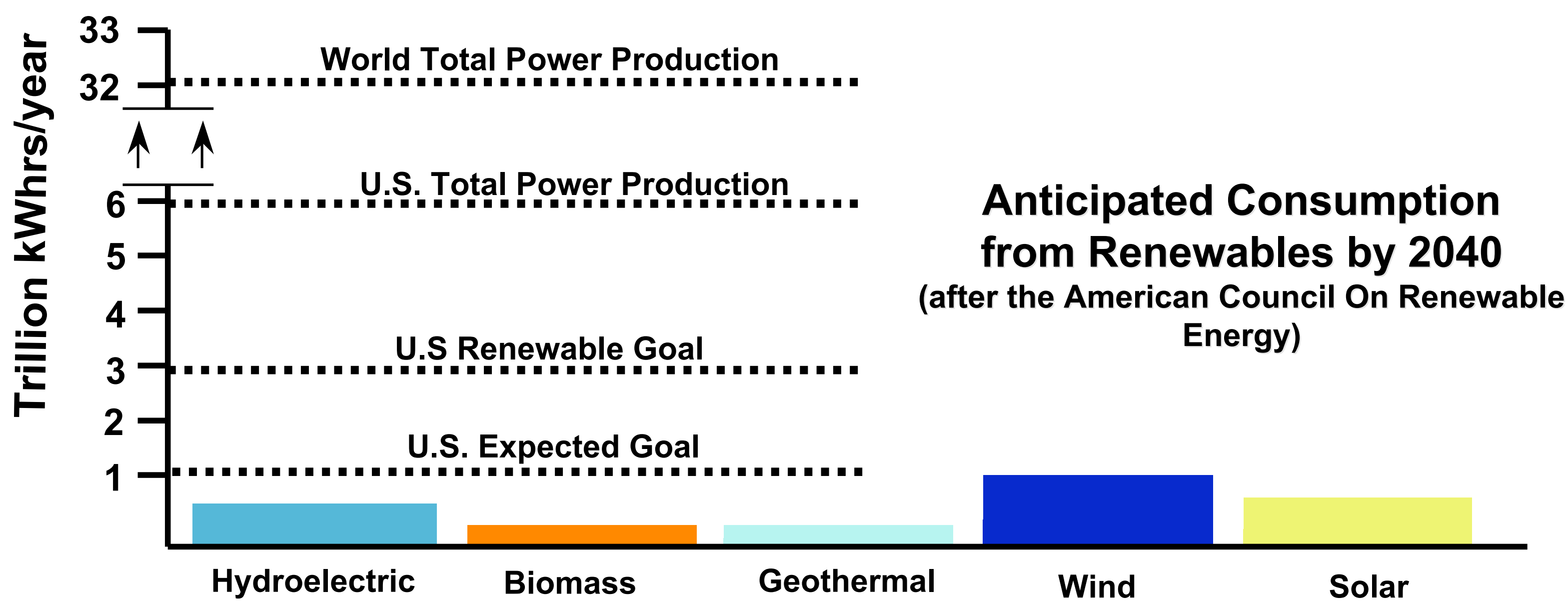
India's planned power capacity

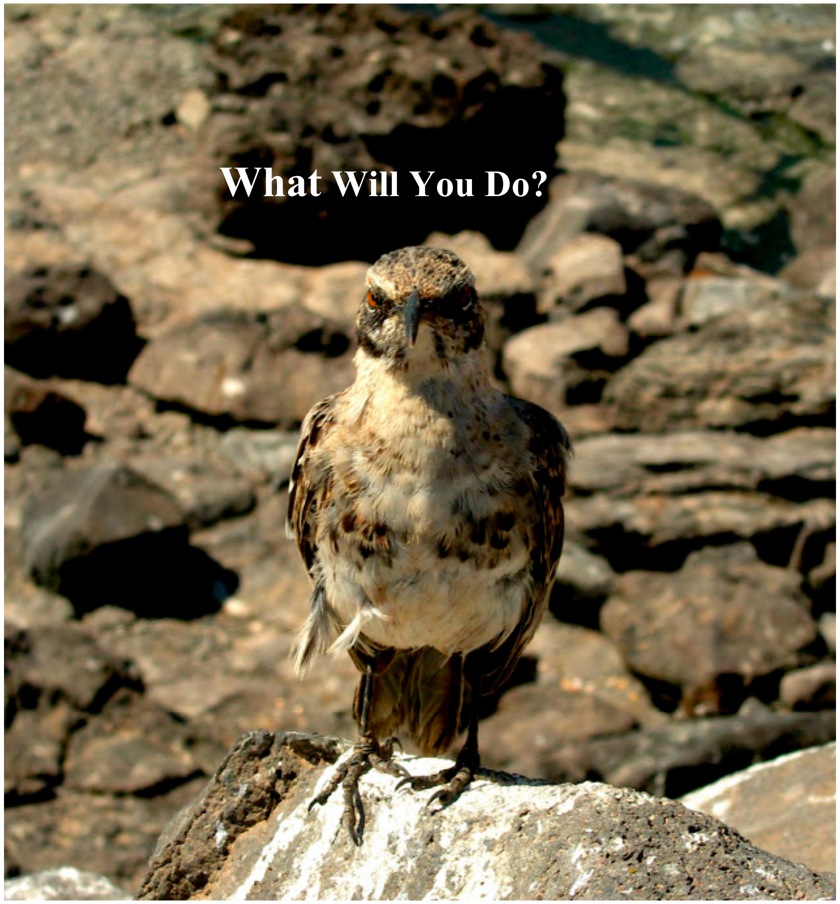


Renewables for 10 trillion kW-hrs

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


2006 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


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

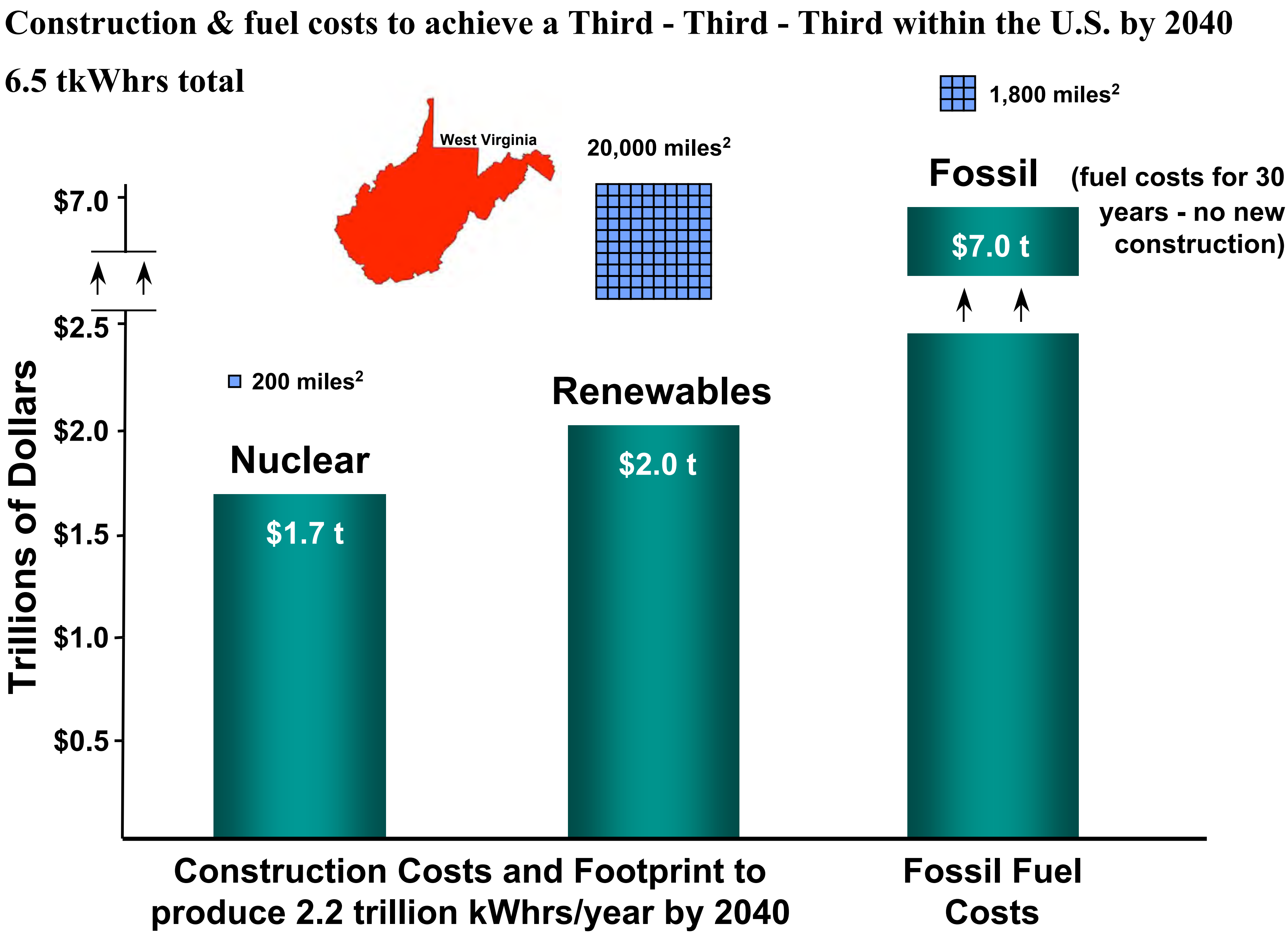


In the United States

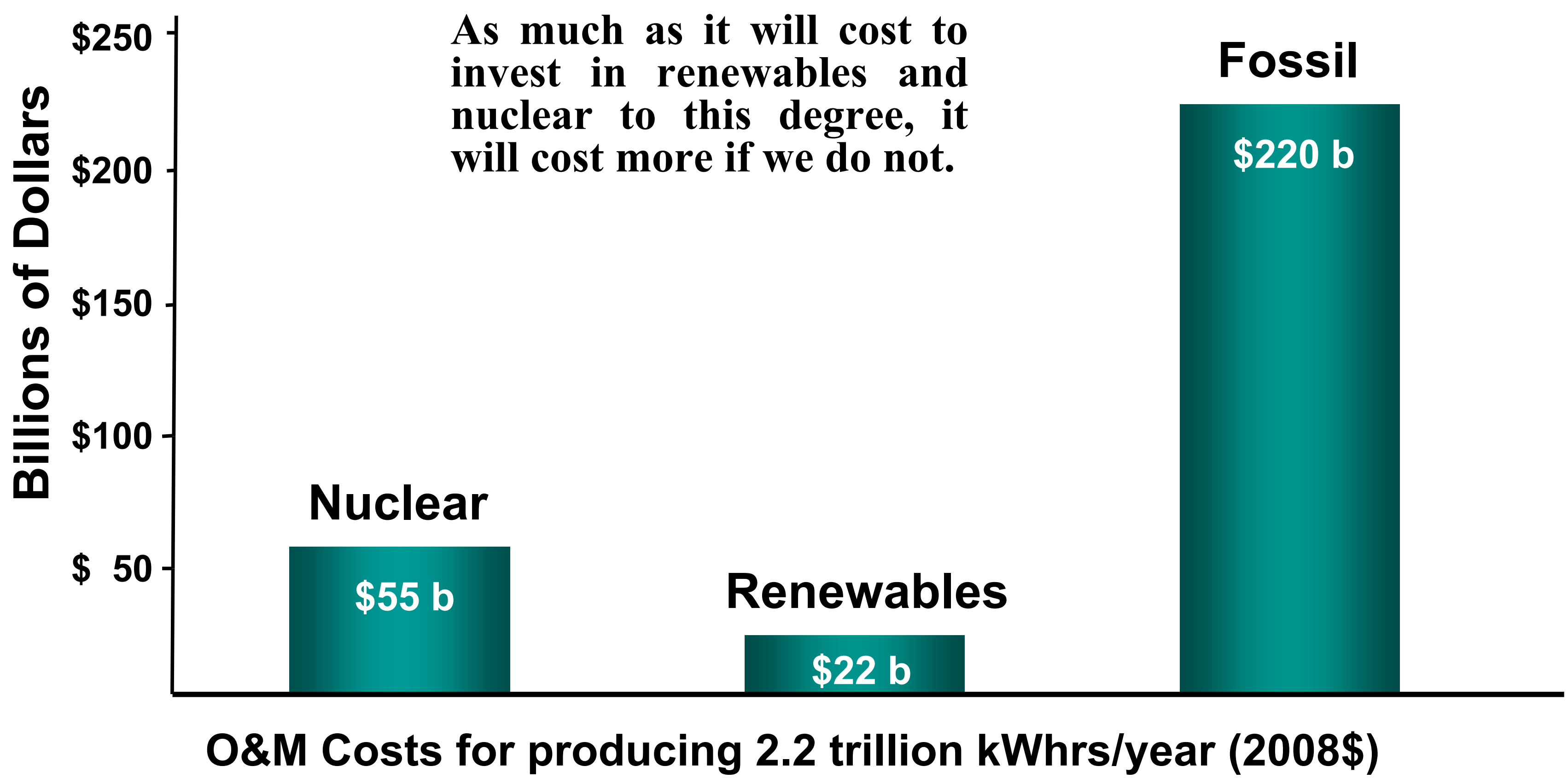
- Increase efficiency and conservation - 1 tkWhrs by 2020
- Increase CAFE to 50 mpg by 2015 - not 35 mpg by 2020
- develop plug-in capabilities - fully-electric cars
- Embrace green building practices and new urbanization strategies that localize essential production, and reduce energy use and transportation - culture change
- Dramatically increase electric grid and distribution development - new transmission infrastructure
- Plan resource stockpiling, e.g., steel, copper

by 2040, for energy security and economic stability, we need:

- 100,000 3+ MW wind turbines totaling 0.8 trillion kWhrs/year
- Concentrated and ordinary solar arrays totaling 0.5 trillion kWhrs/year
- 200 GenIII+ nuclear reactors, depending upon plug-in vehicle demand (~ 2 trillion kWhrs/year)
- 10 bbl/yr of biofuels from algae, cellulosics and high-efficiency biomass
- 0.8 trillion kWhrs/year from other geothermal, wave, tidal and biogas
- no new coal- or gas-fired power plants


Construction & fuel costs to achieve a Third - Third - Third within the U.S. by 2040
6.5 tkWhrs total
West Virginia
20,000 miles²
1,800 miles²
Fossil
(fuel costs for 30 years - no new construction)
$7.0 t
$7.0
$2.5
$2.0
$1.5
$1.0
$0.5
Trillions of Dollars
200 miles²
Renewables
Nuclear
$2.0 t
$1.7 t
Construction Costs and Footprint to produce 2.2 trillion kWhrs/year by 2040
Fossil Fuel Costs

Once a Third - Third - Third is achieved, O&M costs per year for 2.2 trillion kWhrs will be quite different for each source:



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
2. operational risks - nuclear industry safety record - best of any industry in the world
3. proliferation/terrorism - use non-proliferable fuel and strategies/ nuclear reactors are one of the most terrorist-proof targets
4. waste disposal - the WIPP site in New Mexico has shown that deep-geologic disposal of any nuclear waste is safe and cost-effective; the License Application for Yucca Mt has been docketed
5. public perception - this can only be addressed by education and the media

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)	30,000
construction	5,000
hunting	4,100
police work	800
contraception	750
mining	359
nuclear industry (~20% of U.S. power)	0

*actuals, estimates

Energy Equivalence of Uranium

A 1,000 MW coal-fired power plant on average

- **produces 4.8 billion kWhrs of electricity per year**
- **uses 3,500,000 tons of coal per year**
- **produces 8,000,000 tons of CO_2 per year**
- **produces 440,000 tons of haz waste per year**

Energy Equivalence of Uranium

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- produces 440,000 tons of haz waste per year

A 1,000 MW nuclear power plant on average

- produces 8.1 billion kWhrs of electricity per year
- uses 29 tons of fuel (4% enriched) per year which can be recycled
- produces less than 1 ton of CO_2 per year
- produces less than 10 tons of haz waste per year
- produces about 5 tons of nuclear waste per year

Burning 1 ounce of uranium is equal to burning over 75 tons of coal

What about the waste?

First, there is not much of it.

All the nuclear waste in the world would fit into any high school football stadium.

In the United States:

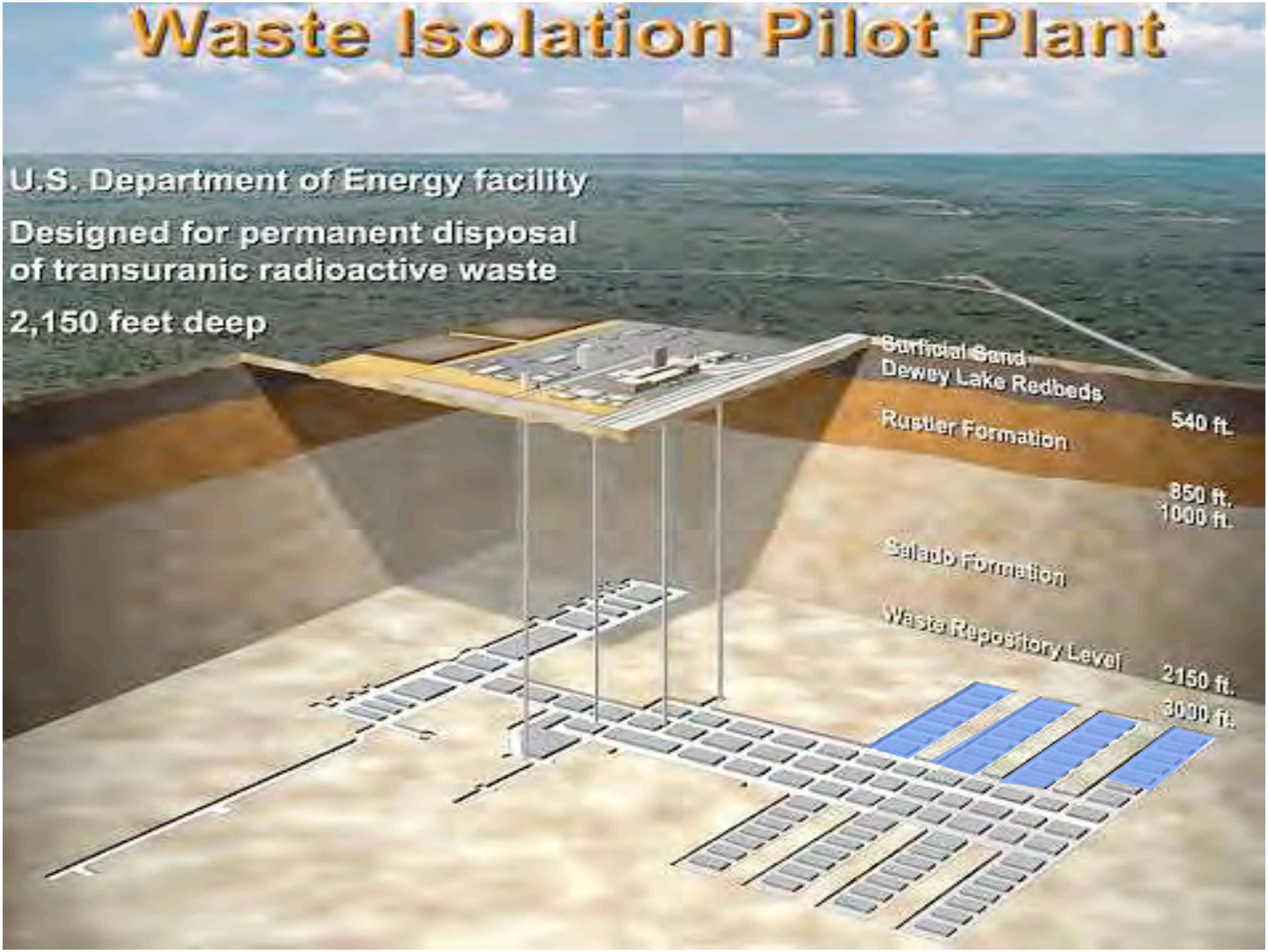
waste from all nuclear power (20% of U.S. power supply)	~ 2,000 tons solids generated each year
waste from all coal fired power plants (50% of U.S. power supply) generated each year	~ 400,000,000 tons solids ~ 2,000,000,000 tons CO_2 25,000 tons of radwaste (emitted)

Second, 95% of spent fuel can be recycled. This greatly reduces the amount of waste and increases the amount of fuel.

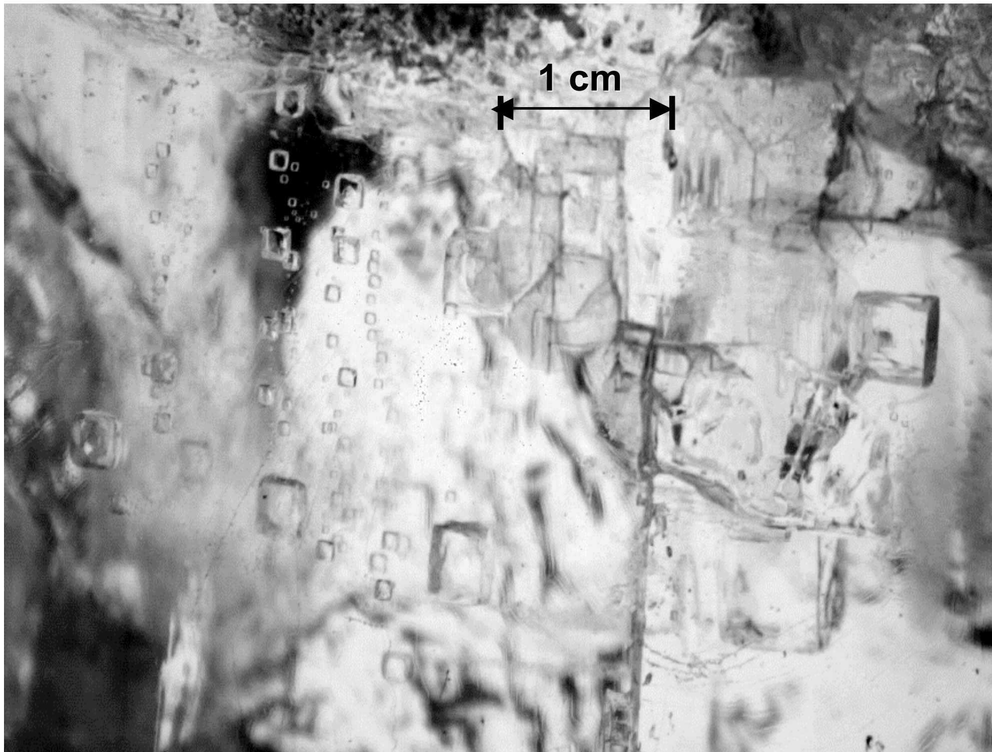
Third, nuclear waste is the easiest hazardous material to measure and detect, and is easy to manage. No incidents have ever occurred during the transportation and disposal of nuclear waste, unlike that for *any other* hazardous material.

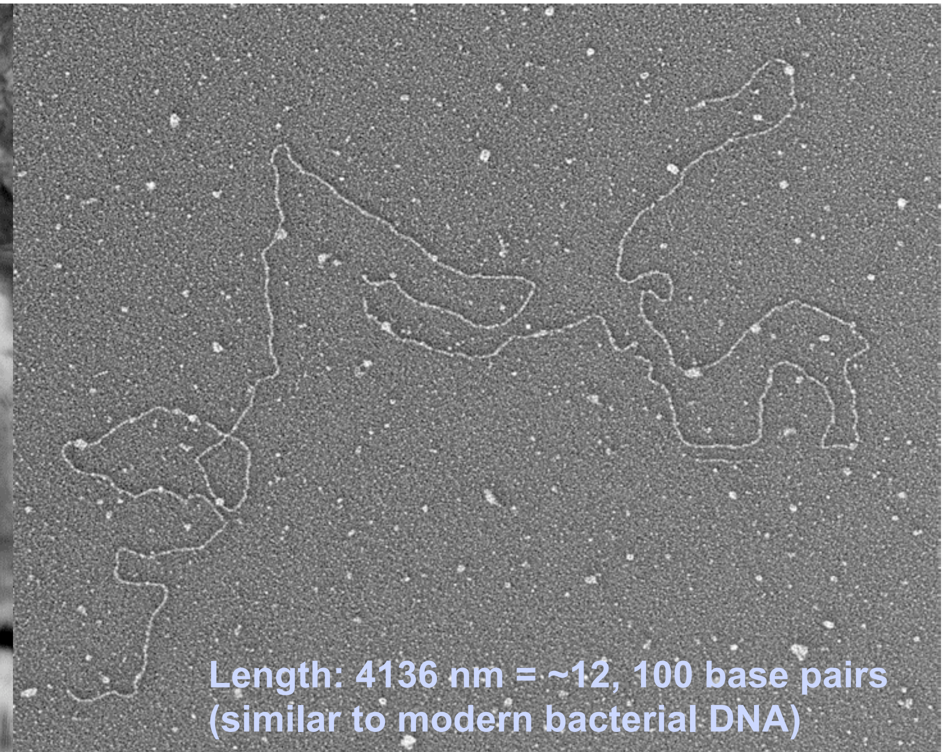
Fourth, the Waste Isolation Pilot Plant has shown that deep geologic disposal of nuclear waste is safe and cost-effective.

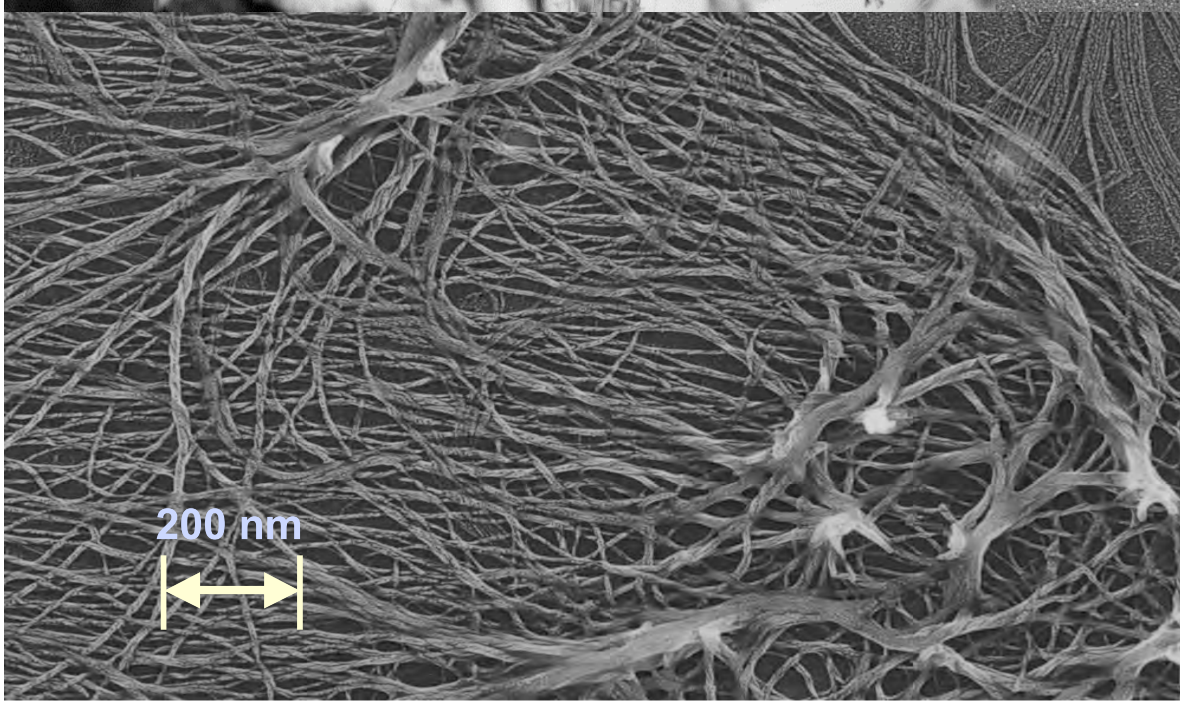
The Salado salt formation can accept as much nuclear waste as the world can generate in the next 10,000 yrs.

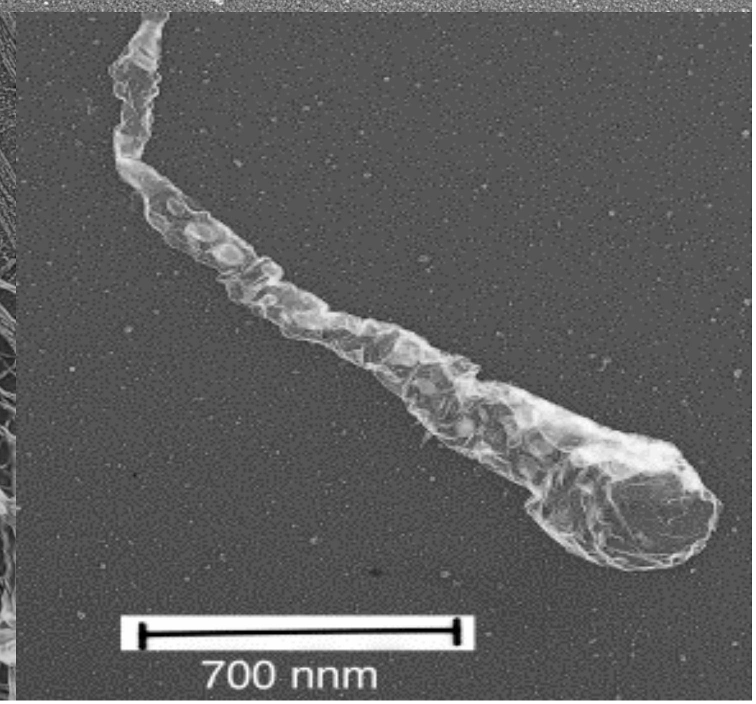


Waste Isolation Pilot Plant
U.S. Department of Energy facility
Designed for permanent disposal of transuranic radioactive waste
2,150 feet deep
Surficial Sand
Dewey Lake Redbeds
540 ft.
Rustler Formation
850 ft.
1000 ft.
Salado Formation
Waste Repository Level
2150 ft.
3000 ft.


1 cm


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


200 nm

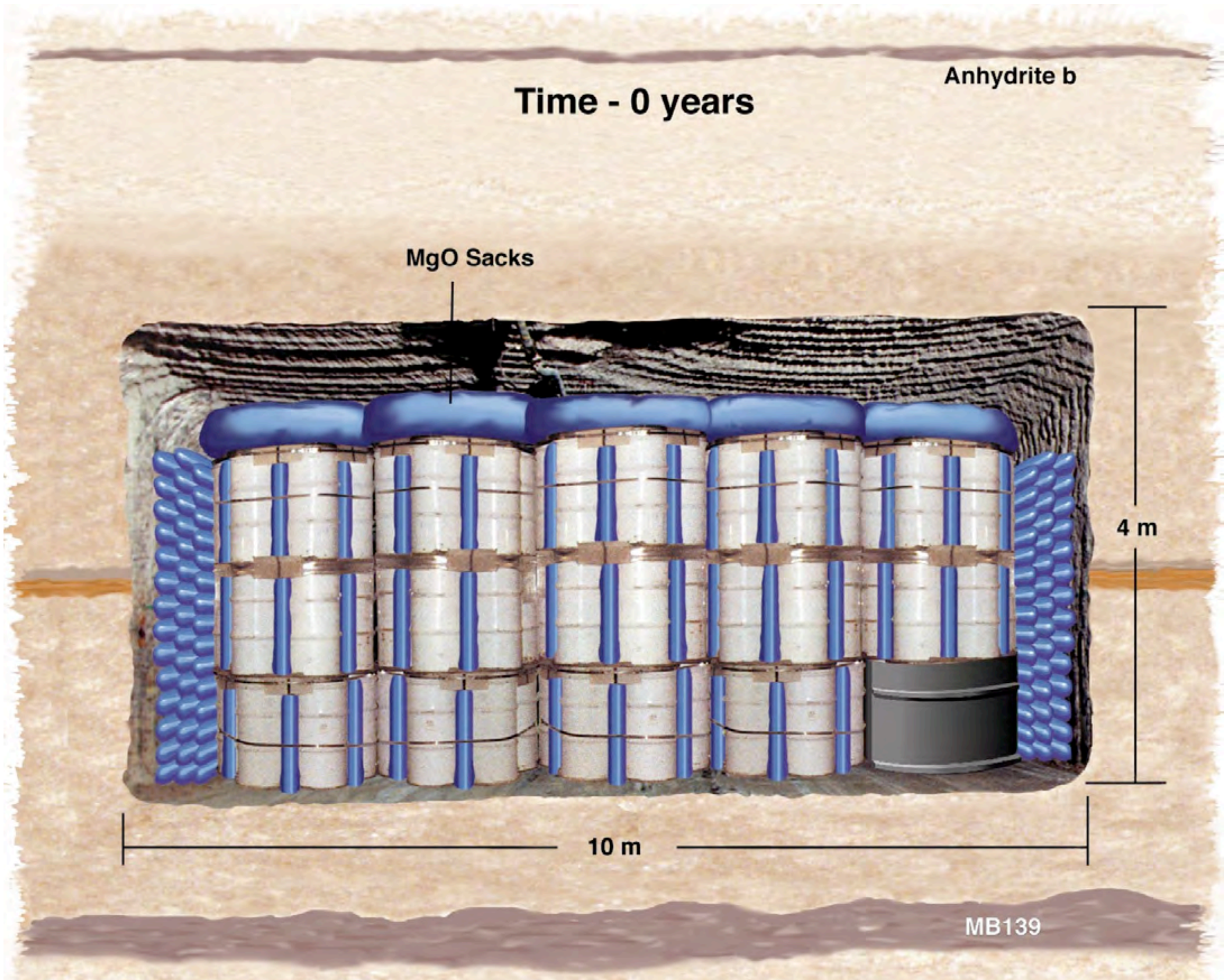

700 nnm

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

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

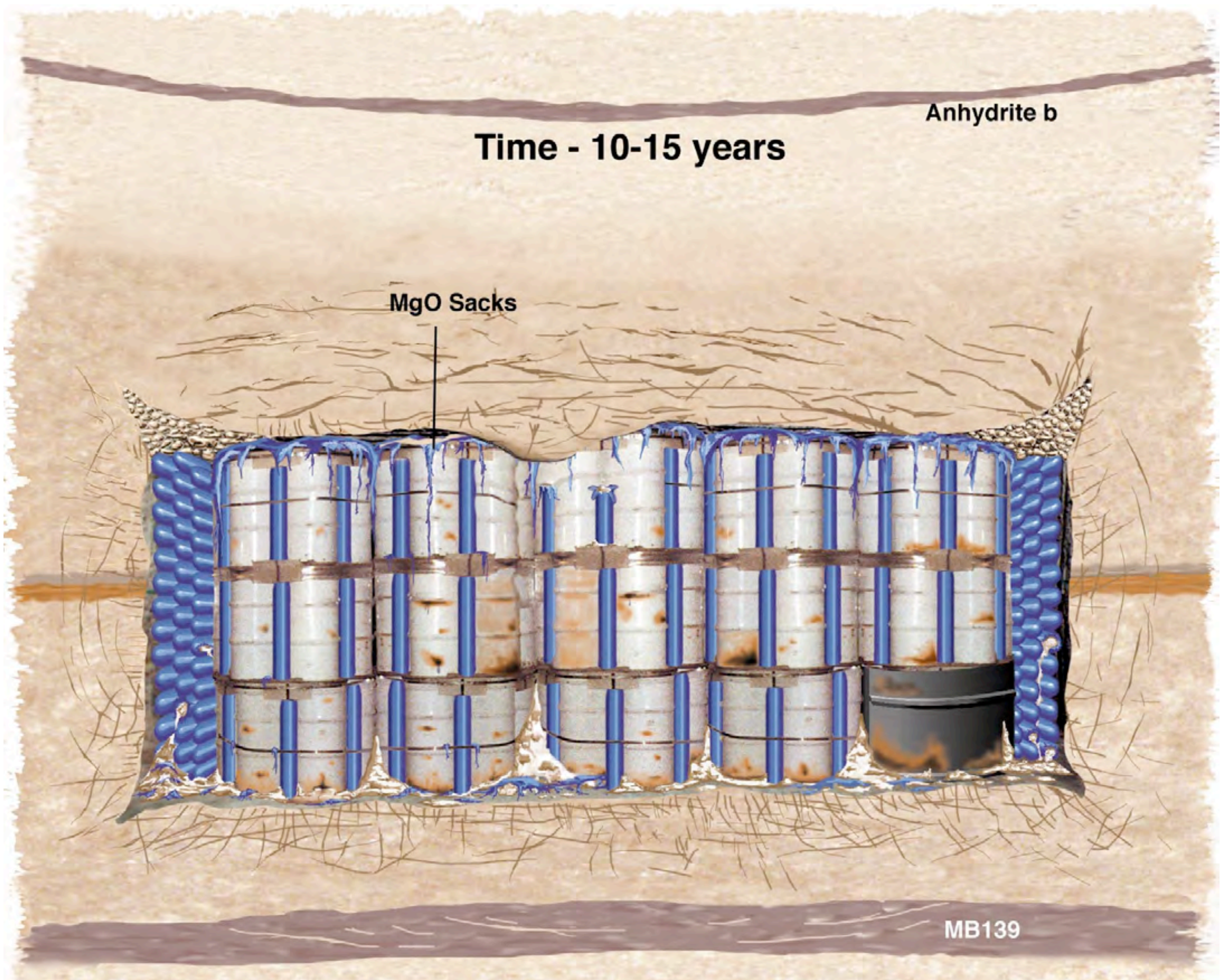
Shown are 10,000 nuclear waste drums and standard waste boxes filling one of 56 rooms. As of June 2008, over 250,000 have been disposed. The performance period for this repository is over 200 million years.

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



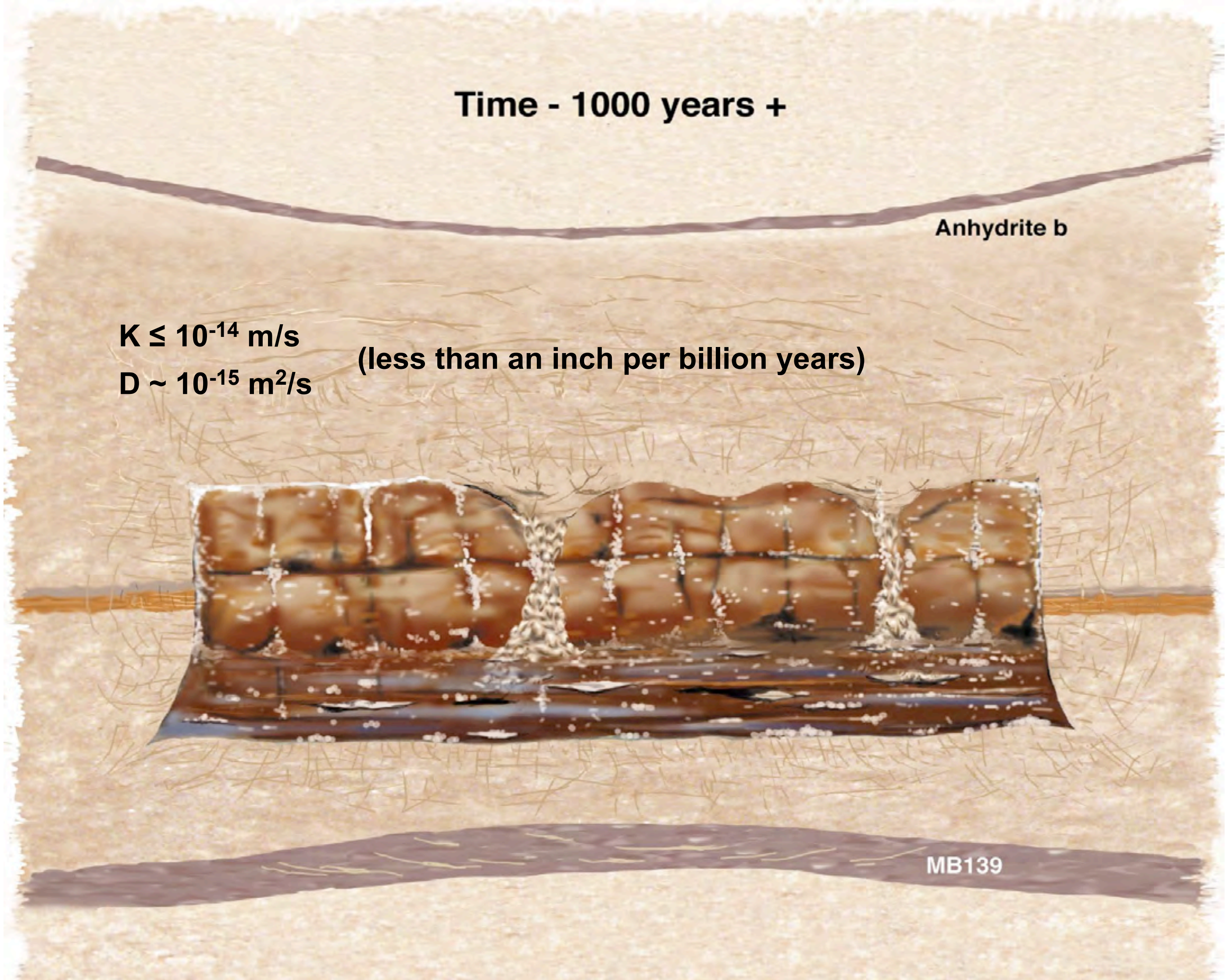
Courtesy of Frank Hansen, SNL

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



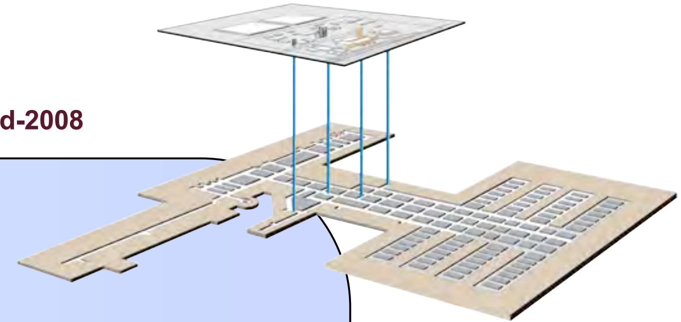
Courtesy of Frank Hansen, SNL

Evolution of the WIPP Disposal Rooms (1000 yrs)



Courtesy of Frank Hansen, SNL

9-Year Snapshot of WIPP mid-2008



Source: DOE CBFO

- 9 years of operation
- 95,000 loaded waste containers disposed
- 55,000 cubic meters of TRU waste disposed
- 275,000 fifty-five gallon drum equivalents
- 5 waste panels mined out of 8 planned
- 7 million miles driven on highways/roads (loaded)
- 13 DOE sites cleaned of legacy TRU waste
- 0 releases to the environment
- 0 contaminated personnel
- 21 consecutive years as NM *Mine Operator of the Year*

Sufficient capacity in the Salado for >10,000 years of nuclear waste disposal

Nuclear waste drums to WIPP, mostly contaminated debris.

Nuclear waste generated by defense activities.

Nuclear waste stored at many sites awaiting disposal at WIPP.

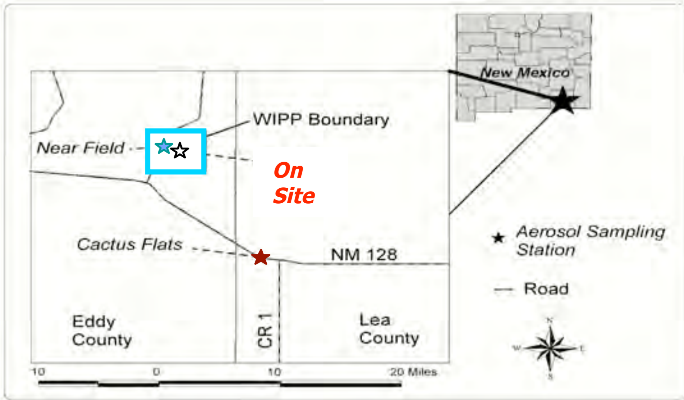
Environmental Monitoring of WIPP

26,000 ft^2 NMSU radiochemistry facility

- Environmental, radiochemistry and separations laboratories: perchloric acid hoods, IC, ICP-MS/OES, GC-MS, VOCs
- a plutonium-uranium lab and counting labs: over 100 α-specs, germanium γ-specs, gas proportional counters and liquid scintillation counters, UV-Vis spectroscopy, Nd–YAG laser, XRD, UFA
- bioassay facility with whole body dosimetry`

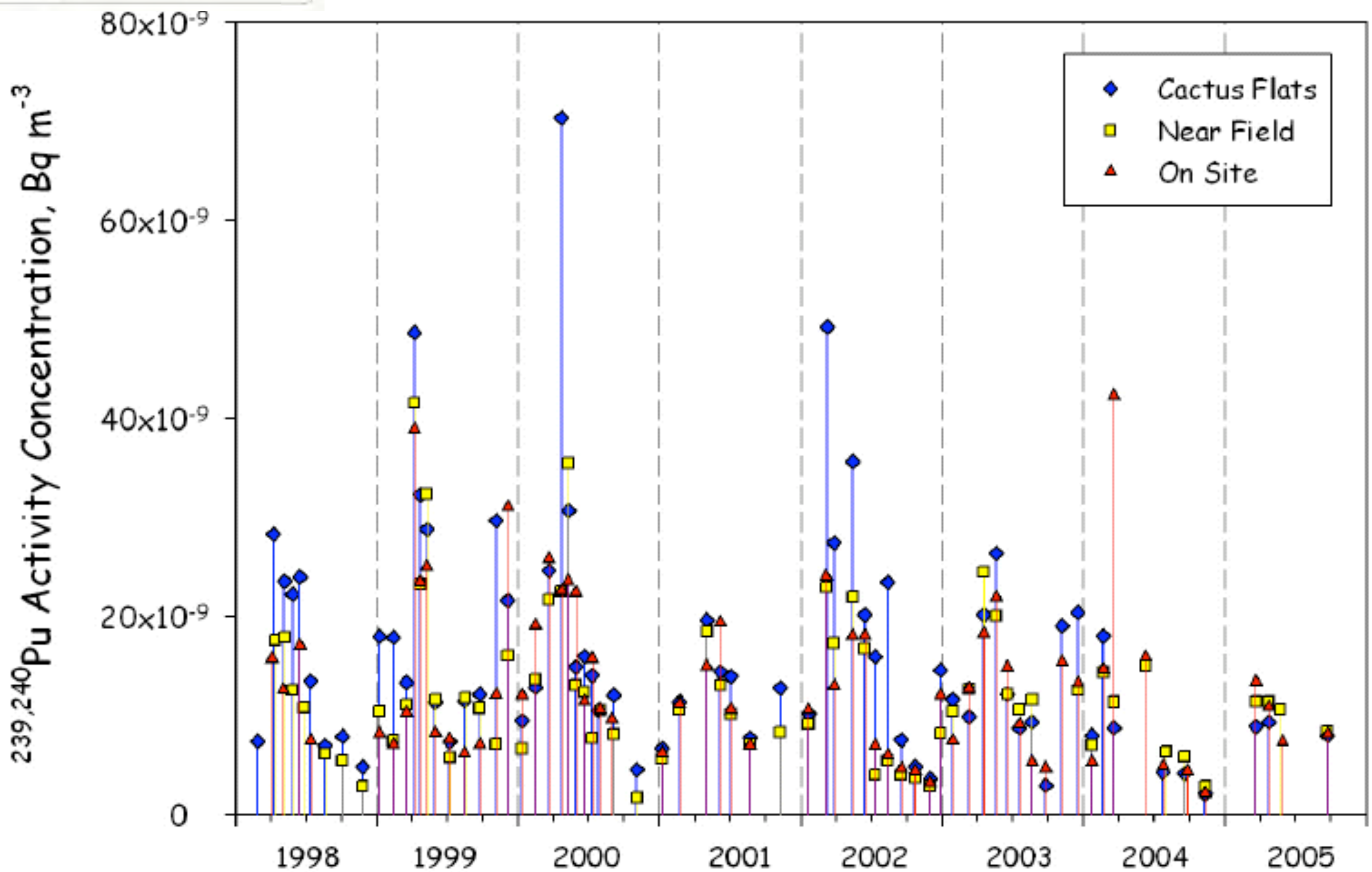
Routine Analyses

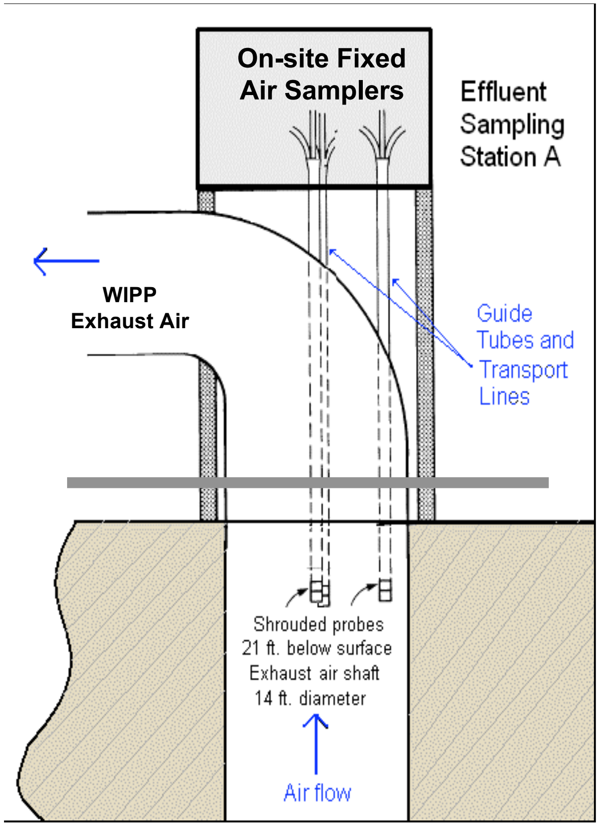
- **Radionuclides** (generally to femtoCurie levels)
  - ^{228}Ac,^{241}Am,^{7}Be,^{212}Bi,^{213}Bi,^{214}Bi,^{144}Ce,^{249}Cf,^{60}Co,^{134}Cs, ^{137}Cs,^{152}Eu,^{154}Eu,^{40}K,^{234m}Pa,^{233}Pa,^{210}Pb,^{212}Pb,^{214}Pb,^{106}Ru, ^{125}Sb, ^{90}Sr, ^{208}Tl,^{235}U,^{241}Am,^{238}Pu,^{239,240}Pu,^{228}Th,^{230}Th ^{232}Th, ^{234}U,^{235}U,^{238}U (and enrichment factors, HAT)
- **Inorganics**
  - As, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hg, K, La, Li, Mg, Mn, Mo, Na, Nd, Ni, Pb, Pr, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, U, V, Zn
  - Chloride, Fluoride, Nitrate, Nitrite, Phosphate, Sulfate
- **Organics**
  - VOCs, head space gases, flammables
- **17 radionuclides monitored in lung and whole body** (MDE < 6 keV)
- **Other material properties** (K, θ, G, D, κ, n, etc.)



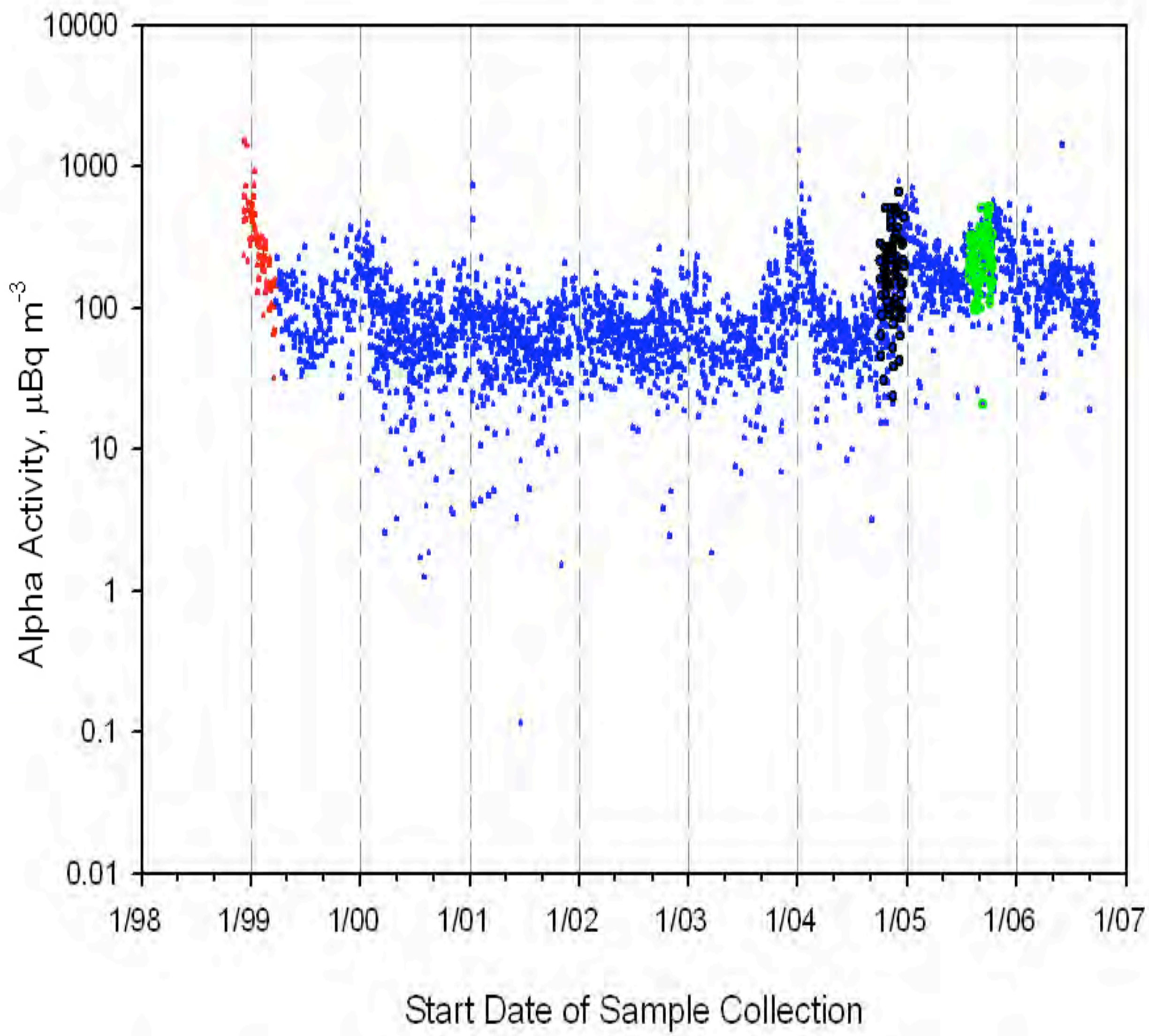
Ambient Aerosol Studies

- ^{239,240}Pu variability tied to seasonal dust cycle (coupled to [Al]); same for ^{241}Am





Daily monitoring of WIPP Underground Air using On-Site Fixed Air Samplers



- **Activity variability from both alpha and beta follows seasonal cycles**

Putting zero into perspective

From the perspective of radiological effects, we cannot see

who works at WIPP
who lives near WIPP
that WIPP even exists

Putting zero into perspective

From the perspective of radiological effects, we <u>cannot</u> see

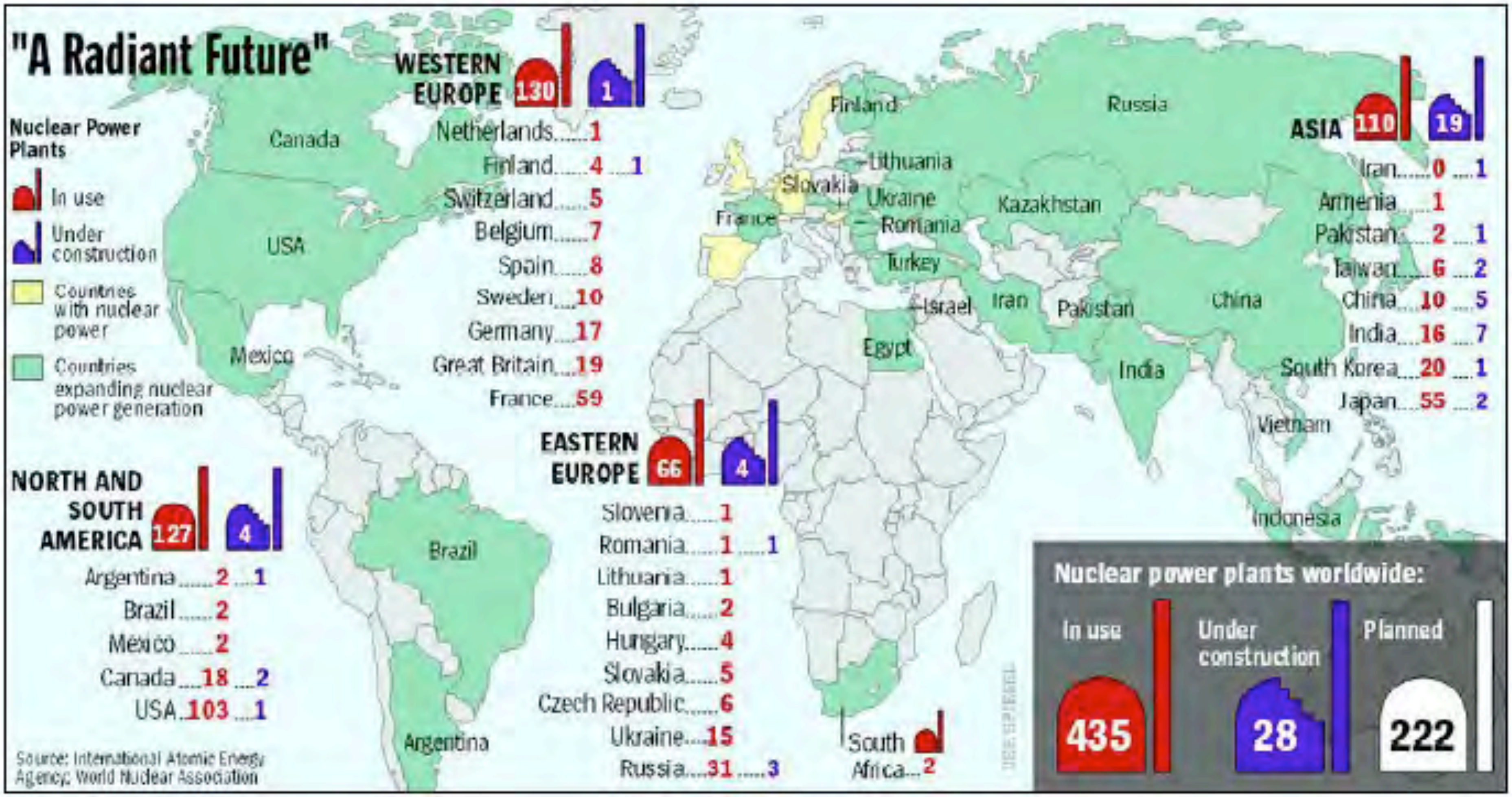
- **who works at WIPP**
- **who lives near WIPP**
- **that WIPP even exists**

But we <u>can</u> see:

- **smokers** (higher ^{137}Cs, U from tobacco seen in a statistical # of smokers)
- **who breathed in dust from Chernobyl** (^{137}Cs, ^{90}Sr)
- **when large dust storms occur in China** (inorganics)
- **who has big muscles** (^{40}K in muscle)

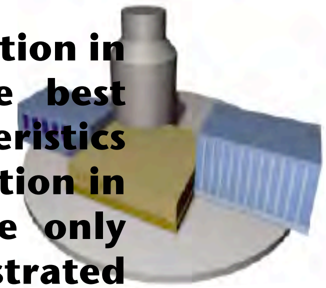
Global Nuclear Energy

Global Expansion of Nuclear Energy IS Happening



A Complete Nuclear Fuel Cycle is possible for Global Nuclear Energy having less than 5 reactors

The Salado Salt Formation in New Mexico has the best performance characteristics of any geologic formation in the world and is the only site having demonstrated operational success with high activity waste



Nuclear Power Plant

Geologic Disposal

Only the few supplier nations need to have, and can afford, a complete Nuclear Fuel Cycle -

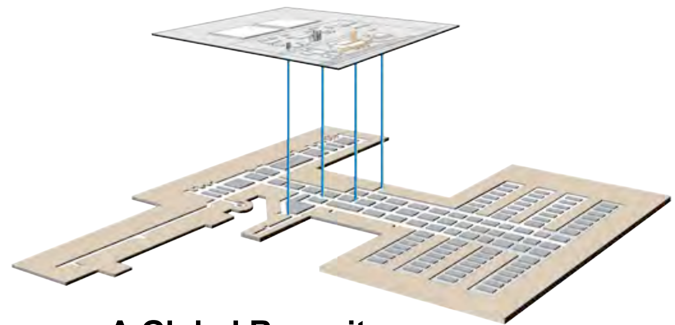
France, U.K., Japan, India, Canada, Russia, China, Korea, U.S.

But the United States could provide the final step in the Fuel Cycle, preventing nuclear materials from falling into the wrong hands, and saving the rest of the world $500 billion

User Nations need only have one or two steps in the Nuclear Fuel Cycle, saving billions of dollars

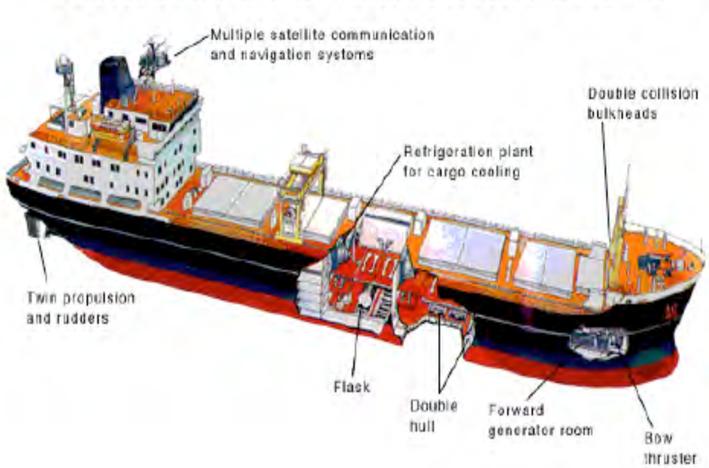
Advantages of a single global small-user repository

- **Ethical - Salado salt is best formation in world**
- **Small amount of nuclear waste worldwide (< 1 million meters^3)**
- **Japan and Israel already demonstrated oceanic SNF shipping**
- **Least costly - demonstrated operations and known costs**
  - **~ $100 billion over 50 years for all small-user countries (not France, Japan, Russia, U.K, China, India, S. Korea)**
  - **> $500 billion if these countries developed their own disposal programs**
- **No U.S. taxpayer dollars - funded by partner countries (even pays for our own program - NWFund can be used for R&D)**
  - **~ $2 billion per reactor for 50 years, > $200 billion income over 50 years**
  - **~$100 billion operating, $100 billion for R&D and Gen IV development**
- **Proliferation - only way to retain control of nuclear materials in a multi-user nuclear world without confrontation and the appearance of domination**



A Global Repository in the Salado Salt

Purpose-built vessel for transport of spent nuclear fuel



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(As of February 26, 2008)

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Switzerland
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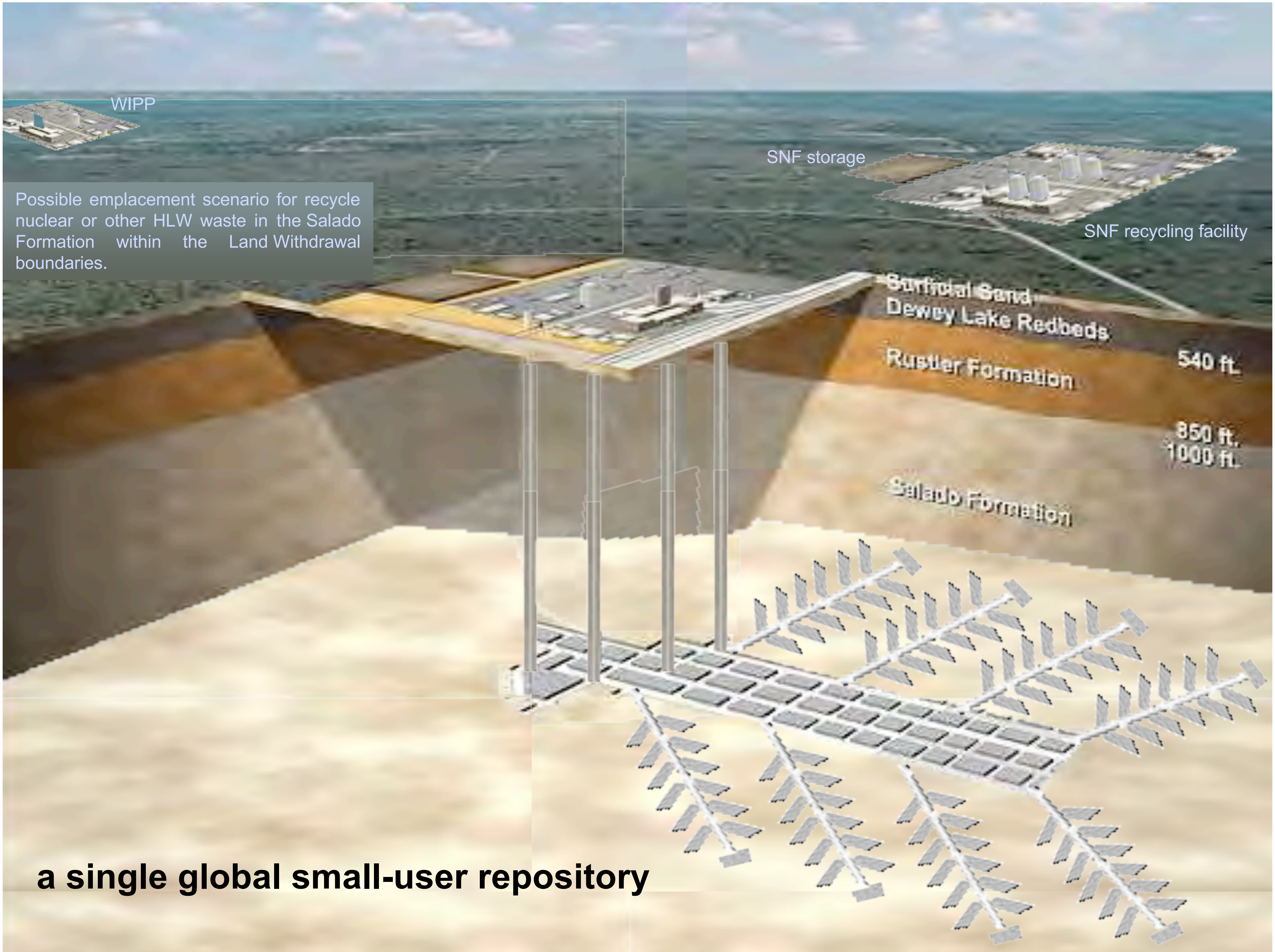
WIPP
SNF storage
SNF recycling facility
Possible emplacement scenario for recycle nuclear or other HLW waste in the Salado Formation within the Land Withdrawal boundaries.
Surficial Sand
Dewey Lake Redbeds
Rustler Formation
540 ft.
850 ft.
1000 ft.
Salado Formation
a single global small-user repository


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