SAND2009-4062C

Nuclear Power as Part of Our Energy Surety & Economic Security Future

Health Physic Society PEP
7/2009

Mark Miller, Certified Health Physicist

mmiller@sandia.gov

N U C L

E A R P O W

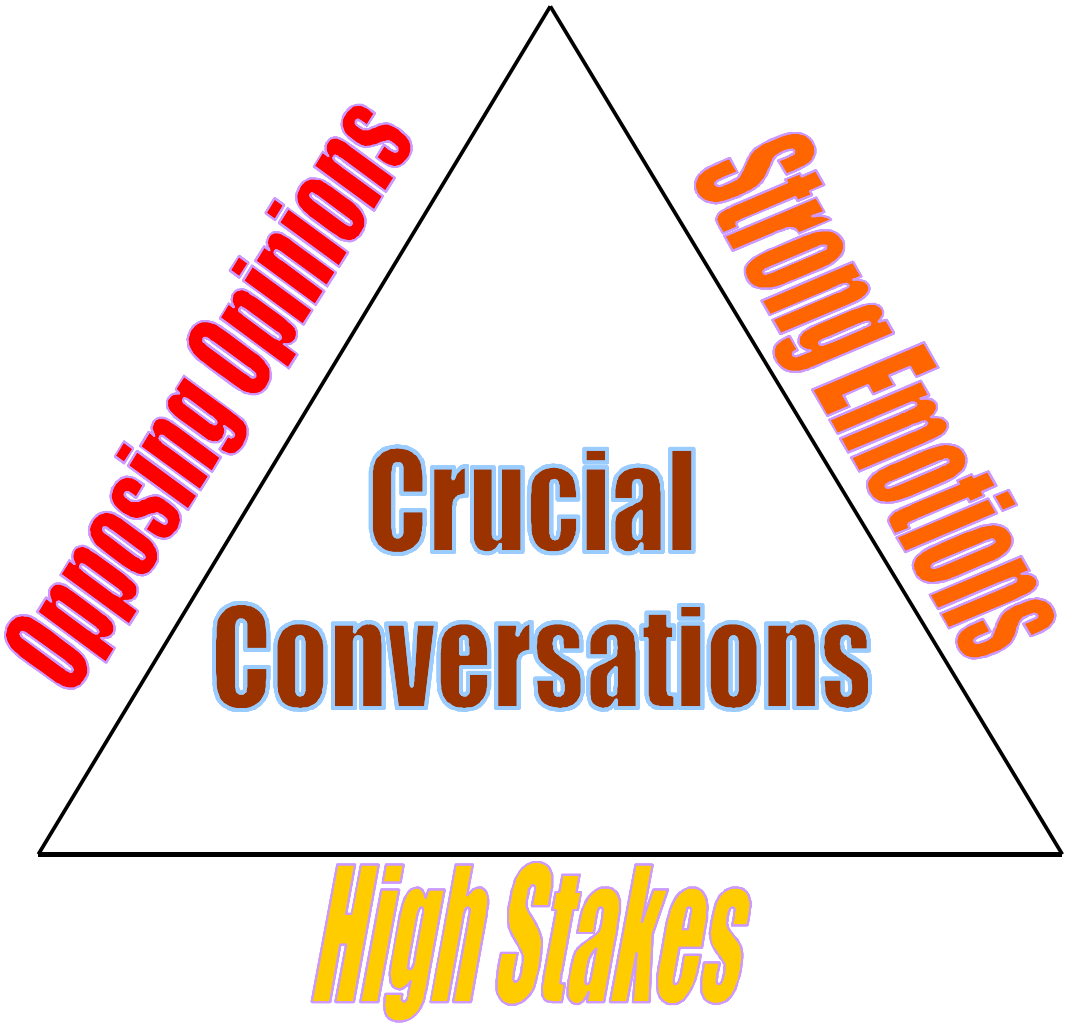
E R N U C L E A R

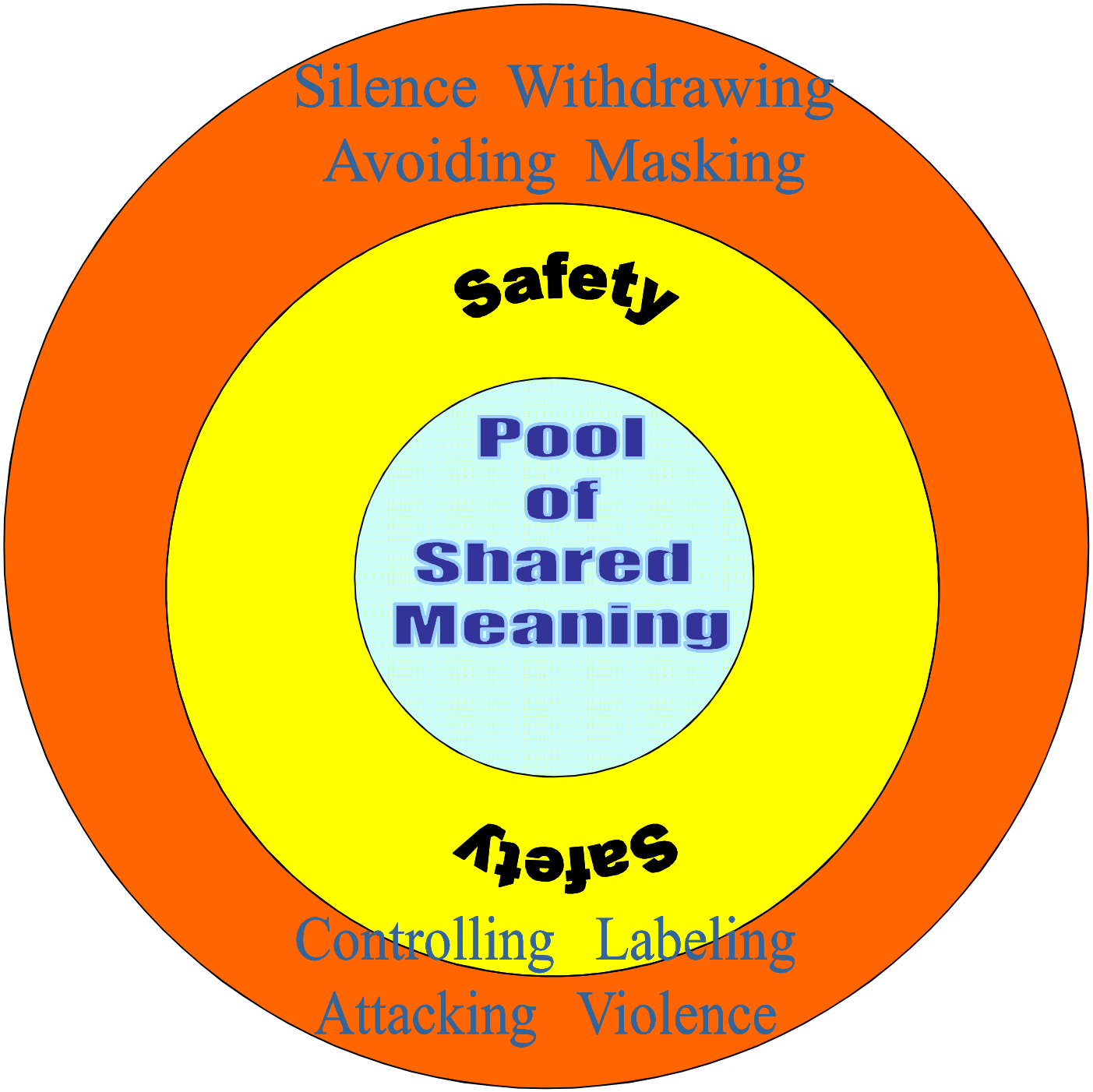
P O W E R as part of our

EnergySuretyandEconomic

SecurityFuture

What is YOUR Vision for the Future?


Opposing Opinions
Strong Emotions
Crucial Conversations
High Stakes


Silence Withdrawing
Avoiding Masking
Safety
Pool
of
Shared
Meaning
Safety
Controlling Labeling
Attacking Violence

Cognitive Misers

- People aren't well enough informed to weigh competing scientific arguments

- Faced with the torrent of news, citizens use their value predispositions as a filter

Nisbet and Mooney, 2006

Framing

"Frames organize central ideas, defining a controversy to resonate with core values and assumptions. Frames pare down complex issues by giving some aspects greater emphasis. They allow citizens to rapidly identify why an issue matters, who might be responsible, and what should be done."

Nisbet and Mooney, Science, 2007


MORE
POWER!
CHEAP
POWER!
CLEAN
POWER!
SAFE
POWER!

432 U.S. Coal Mining Fatalities Since 1996

5,900 fatalities annually worldwide (80% in China)

Topics

- What is Nuclear Power?
- Why should it be part of our energy portfolio?
- What concerns/challenges MUST be addressed?

Concerns?

- Energy Sources / Cost–Benefit / Availability
- CO_2 Emissions
- **Waste Disposal**
- Global Warming
- Long-Term / Short-Term / Sustainability
- Others?

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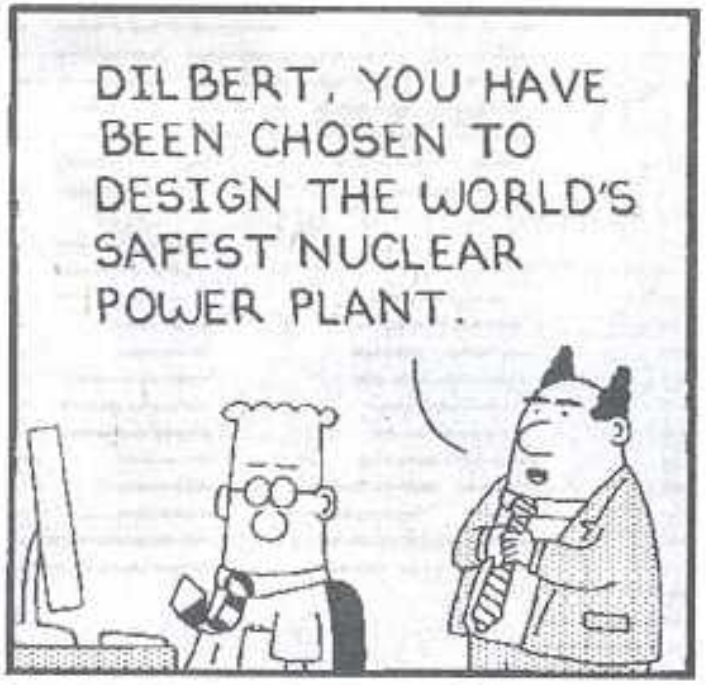


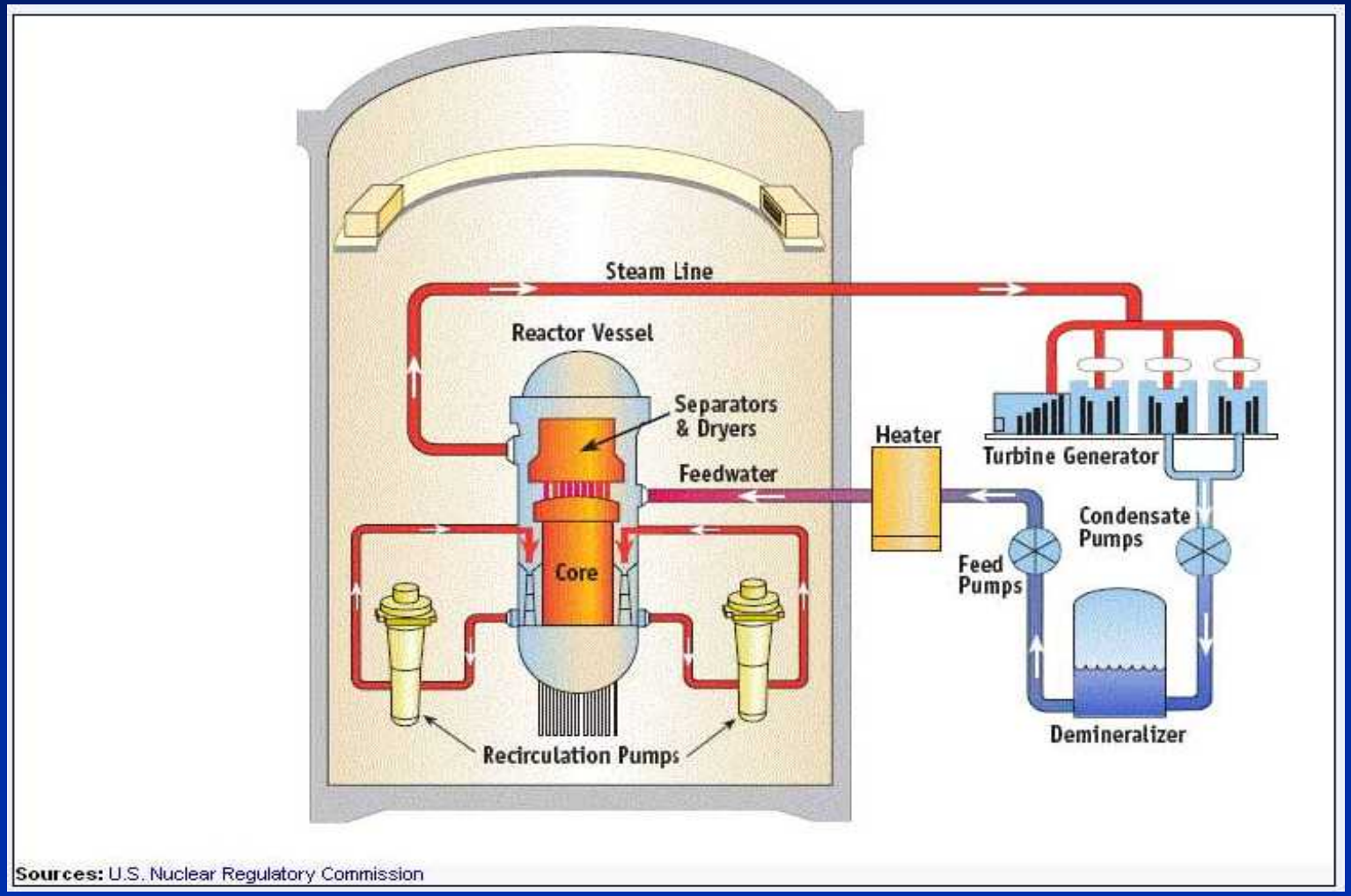
2-18-02 © 2002 United Feature Syndicate, Inc.

Topic

- What is Nuclear Power?

MM1

Typical Nuclear Reactor

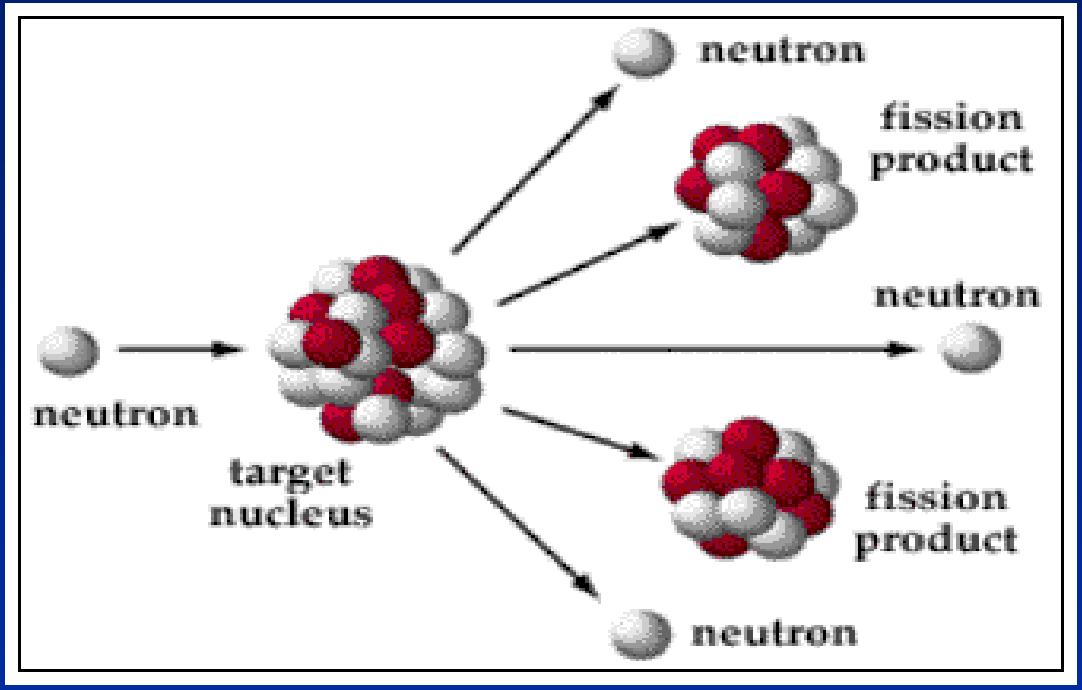


- Any heat source can be used to boil water (nuclear, coal, oil, gas)
- Core, fission, heat
- Waste volume per consumer

Slide 13

MM1 Mark Miller, 7/30/2008

Fission Process

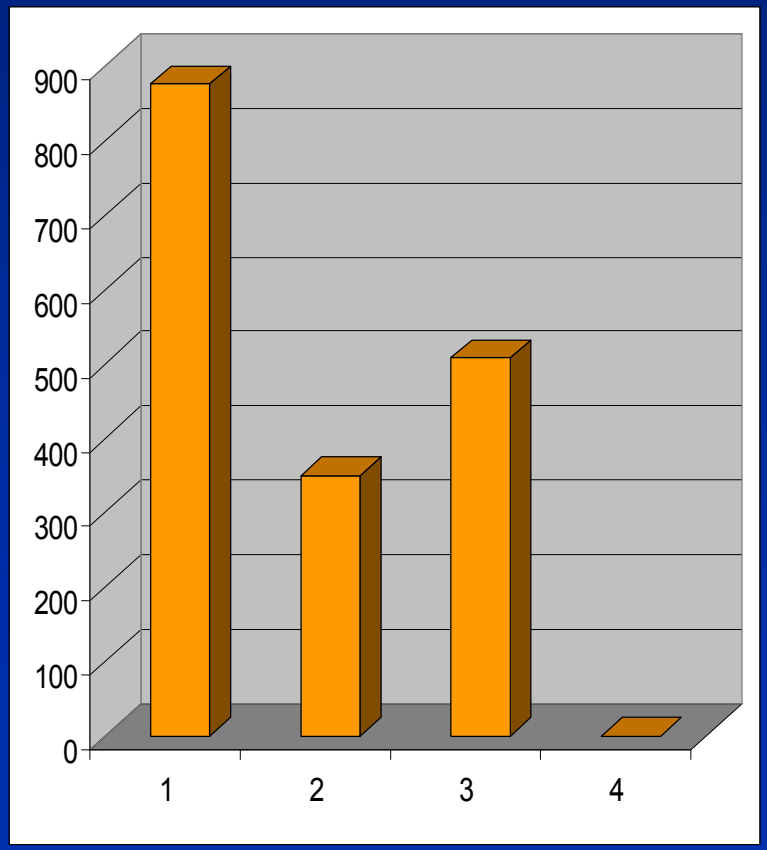


Plus…ENERGY !!!

To make enough electricity to run a 100-watt light bulb for a year, you could:

1) Burn *876* pounds of coal,
2) Burn 350 pounds of natural gas,
3) Burn 508 pounds of oil, or
4) Use 0.0007 pounds of uranium (enriched to 4%)

From Cravens, 2007



Existing Commercial Nuclear Power Plants

- 104 operating light water reactors in U.S.
- Built 1960s through 1980s
- Life expectancy from 2020s to 2040s with license renewal (49 approved so far, more expected)
- ~20% of U.S. electricity
- 90^{+} % availability factor!
- Capital costs paid off, 1.5¢ to 2¢ kWh production costs
- Uranium fuel readily available, largely foreign purchased
- Acceptable on-site spent fuel storage today, Yucca Mountain in future(?)
- Robust Safety & Security
- Avoid ~ <u>180 million tons</u> CO_x, SO_x, NO_x emissions per year

New Plants in the Future

- 26 Reactors
- 17 Const. & Oper. Lic. (COL) applications (number of sites)

13 to be collocated at existing sites

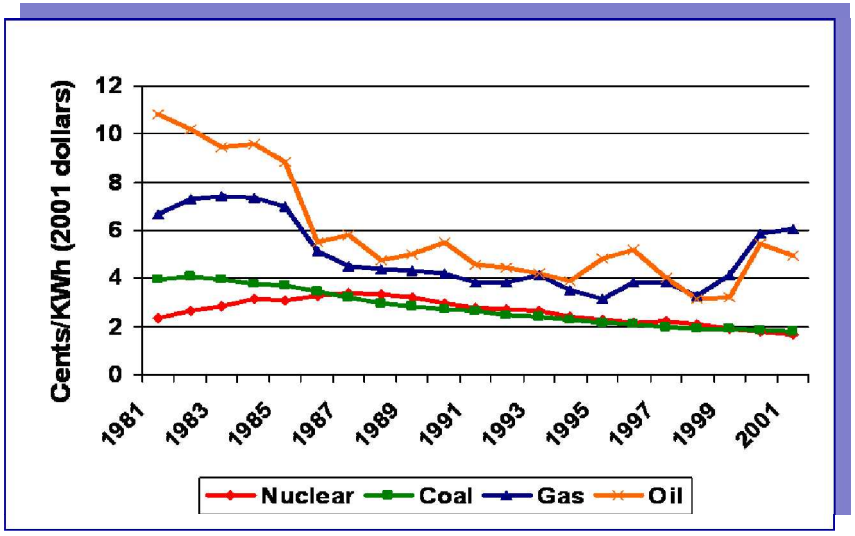
- 4 to be at new sites
- **None** will be started soon, given the current climate (IMHO)

Nuclear Energy in the U.S. Has Performed Very Well

- 104 commercial nuclear power plants produce electricity in the United States today

Nuclear Power Costs Continue to Decrease

United States



- They are, on average, 24 years old and licensed to operate for 40 years (with an option to renew for an additional 20)
- Costs continue to decline
- Gas and oil generation costs are increasing

News Flash … 7/2009

- Uganda (and all of the Third World!) is looking into nuclear power to address challenges of disease, poverty, hunger and shortages of drinking water.
- Poland has approved construction of 2 new nuclear plants.
- Italy plans to build a new nuclear plant to tap into the nuclear revival (reversal of its current policy).
- France has 56 nuclear plants which generate **76%** of its electricity needs!
- Britain has 24 reactors which generate 20% of its electricity needs, plans 8 more!
- Japan has 55 reactors which generate 30% of its electricity needs, more planned.
- (2/2009) Sweden has reversed its 30-year “no-nuclear-power” stance.
- (2/2009) United Arab Emirates is pursuing Nuclear Energy as power demand soars.
- Germany ???

Time Frame

- Compile & license application 1 Year
- NRC Licensing Process 3-4 Years
- Construction 4 Years

So, even if we start today:

– 1st Plant on line in 2018!

World-Wide Growth in Energy Demand Will Require ALL Available Energy Technology Options

- A **complete** portfolio of supply options: renewables, fossil, nuclear
- Highly efficient and environmentally benign technologies
- Fault-tolerant, self-healing infrastructures
- Enhanced physical and cyber security and safety

Why It Matters

- The U.S. Energy Information Administration's (EIA) extended forecast of electricity consumption requirements—as shaped by demographic trends, migration patterns, and population growth—suggests a 40% increase from current levels by 2030.

- To put this in perspective, that's the equivalent of approximately 292,000 MW of new generating capacity. (A typical power plant is ~ 1000 MW.)

- Today, carbon-free fuels account for only a third of global power generation.

Topic

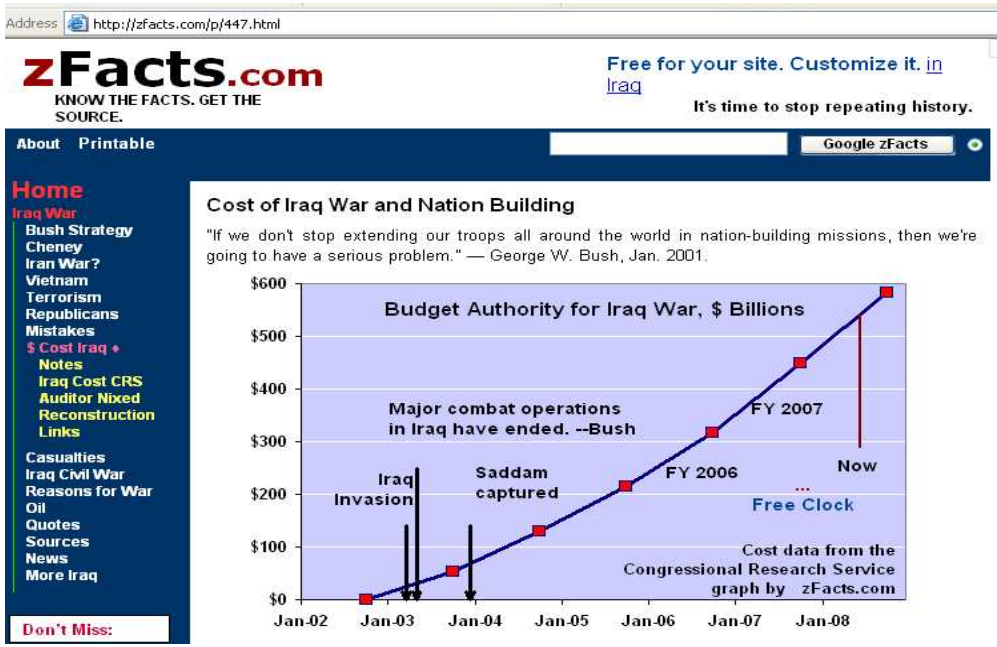
- **Why** should Nuclear Energy be part of our energy portfolio?

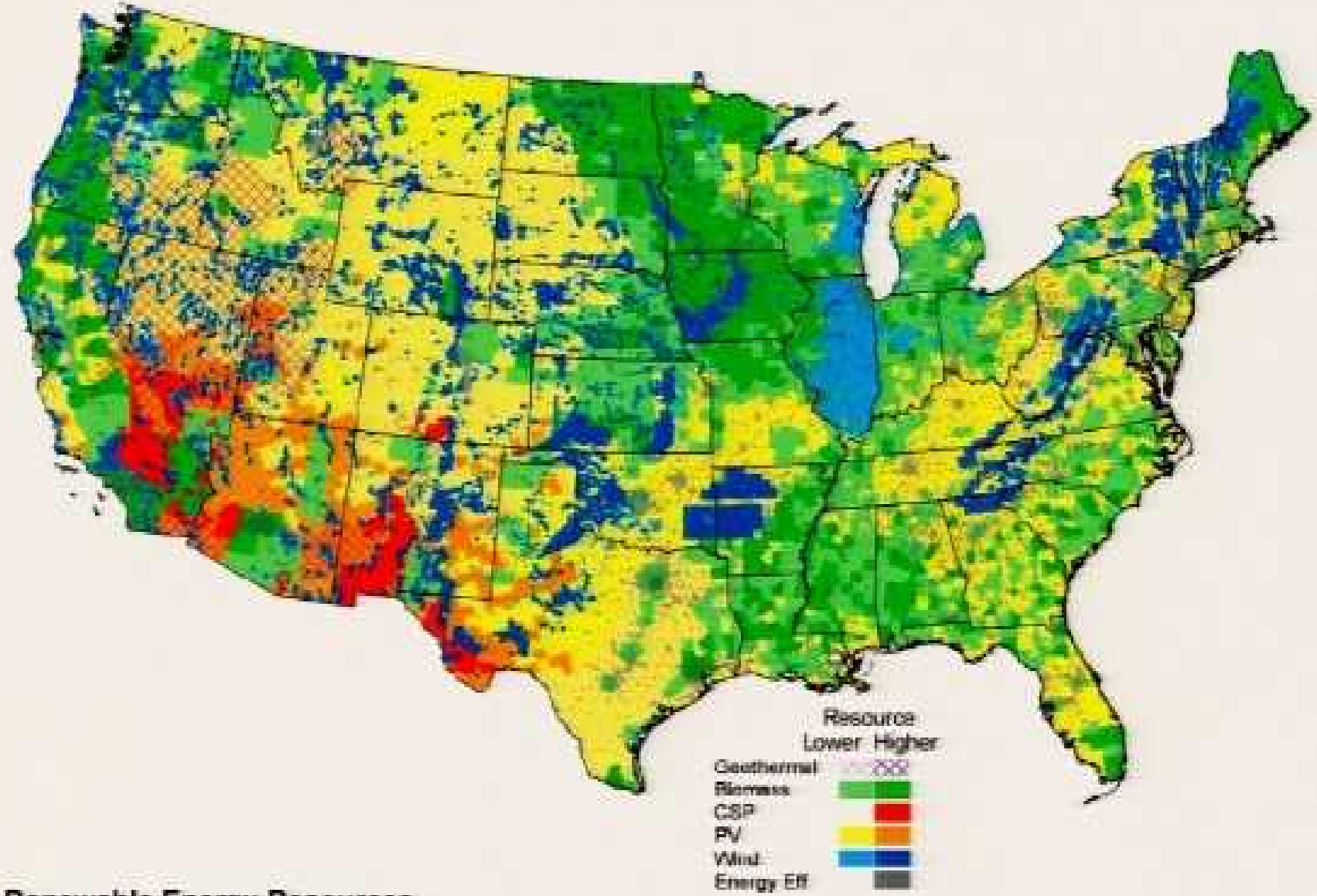
Options

- Photovoltaic
- Increasing Transmission Efficiency
- Hydrogen
- Hydro
- Ocean Tidal Energy
- Biomass
- Distributed Generation
- Oil, gas, LNG
- Coal
- Nuclear
- Wind
- Solar
- Geothermal
- Transportation Paradigm Changes!
- Conservation!

Nuclear Power Plant Construction vs. Cost/Benefit of War

- $526 billion in 5+ years
- $526/~65 months = $8B/month
- 1 Nuclear Plant = ~ $8B
- Therefore, U.S. could have “invested” in **65** Nuclear Plants vs. War !





Renewable Energy Resources
American Solar Energy Society

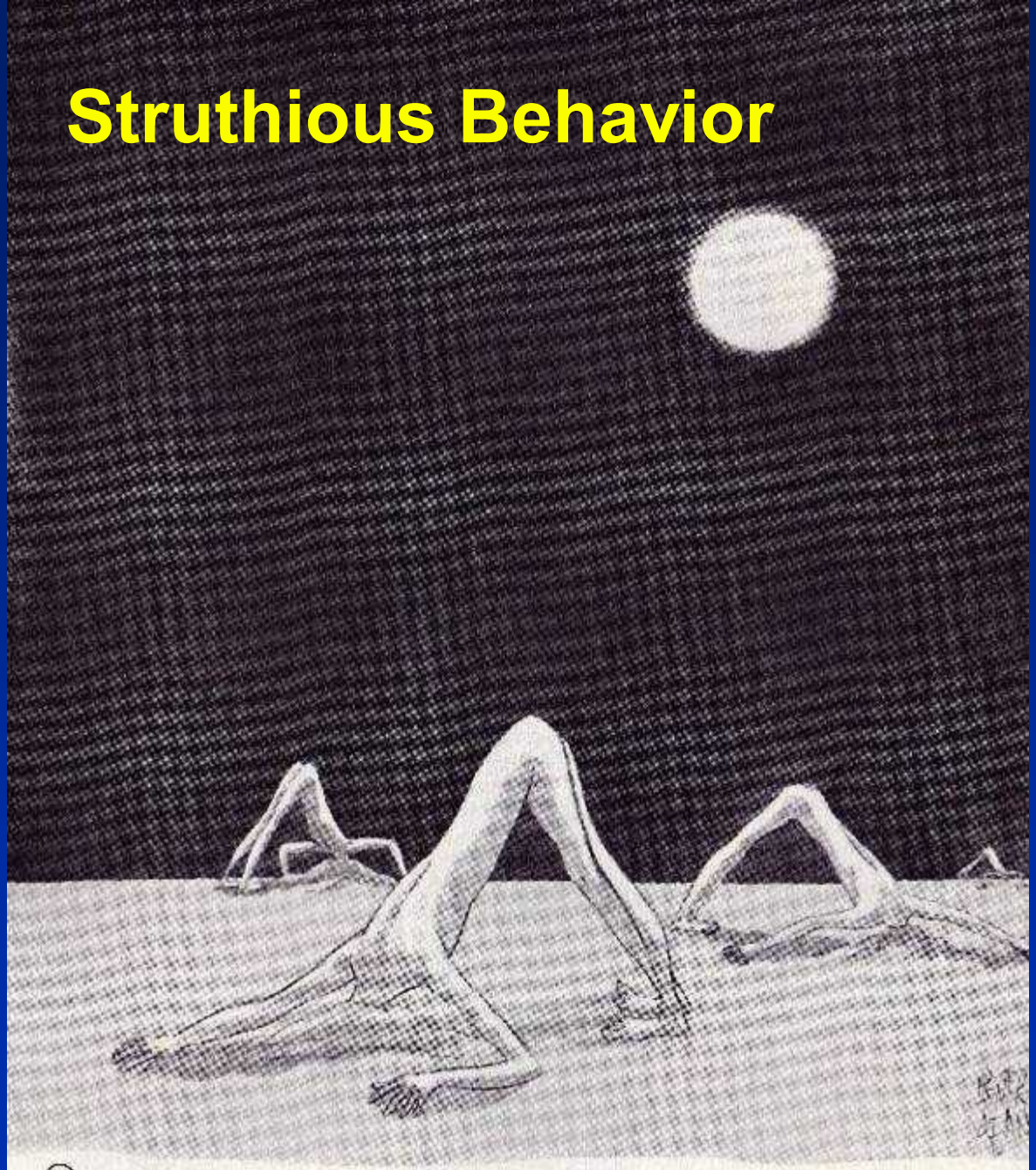
Nuclear Energy is One Option to a Sustainable and Secure Energy Future

- Nuclear plants are safe, reliable and economic.
- Nuclear energy reduces carbon emissions.
- World nuclear fuel supplies can last many hundreds of years.

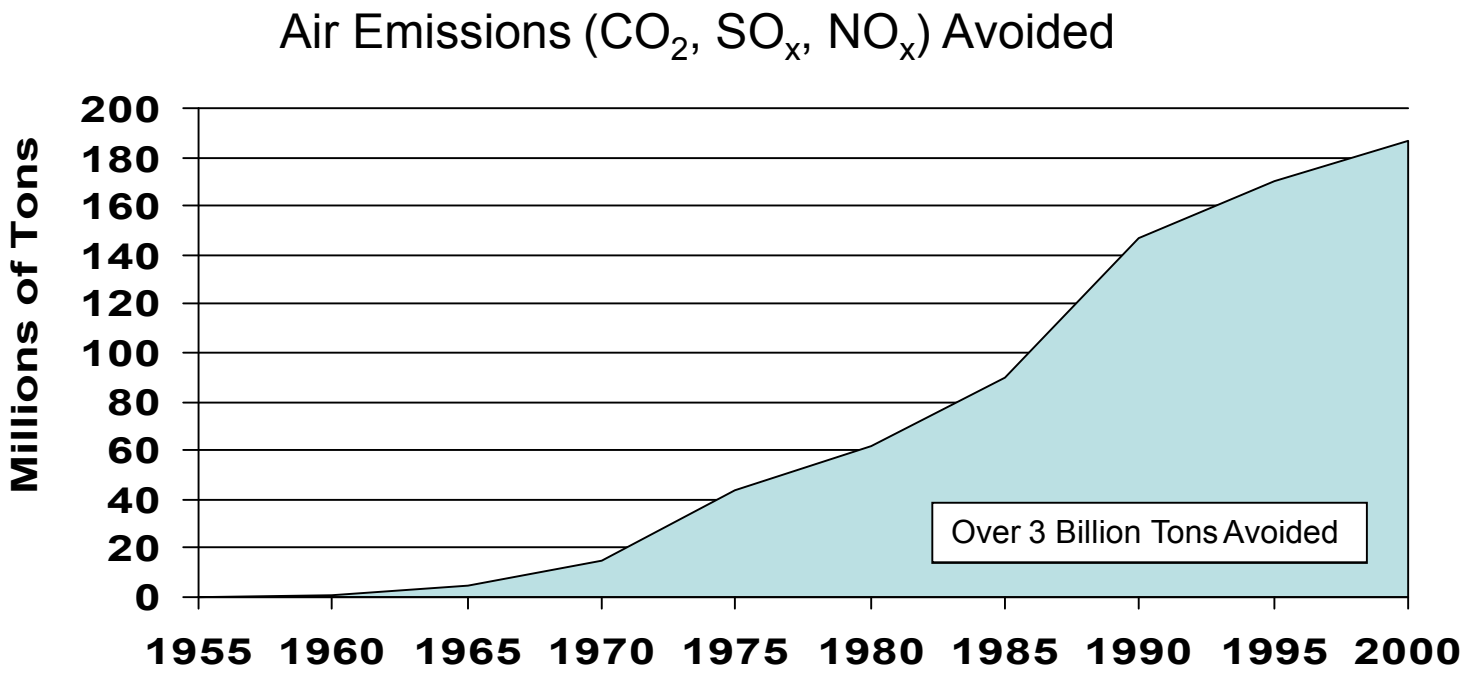
But Challenges Remain

- Highest levels of safety, security and reliability must be achieved - everywhere.
- Nuclear materials and technology must be controlled to prevent weapons proliferation.
- A solution to the nuclear "waste" management issue must be achieved.

Struthious Behavior



Nuclear Power Does Not Emit Harmful Gases



Source: Nuclear Energy Institute

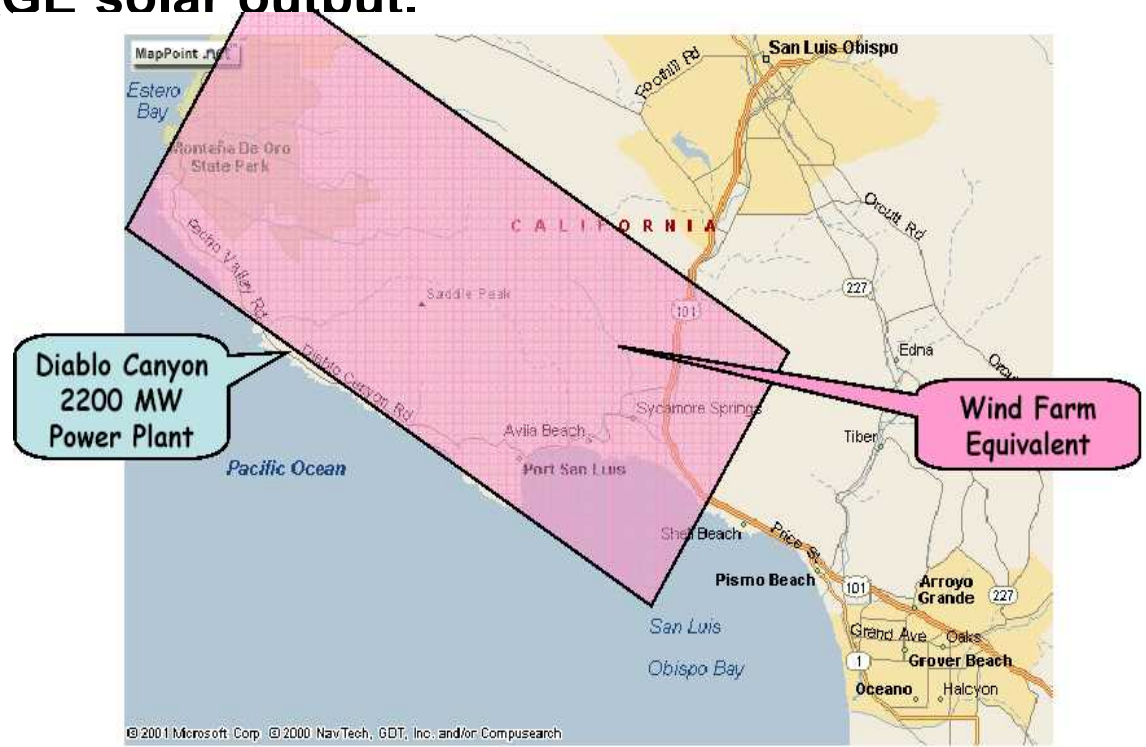
Lifecycle Emissions for Electricity Generation in Germany Grams per MWh

Generation type	SO2	NOx	Particulates	CO2
Nuclear	32	70	7	19,700
Coal	326	560	182	815,000
Gas	3	277	18	362,000
Oil	1,611	985	67	935,000
Wind	15	20	4.6	6,460
PV (Home Application)	104	99	6.1	53,300

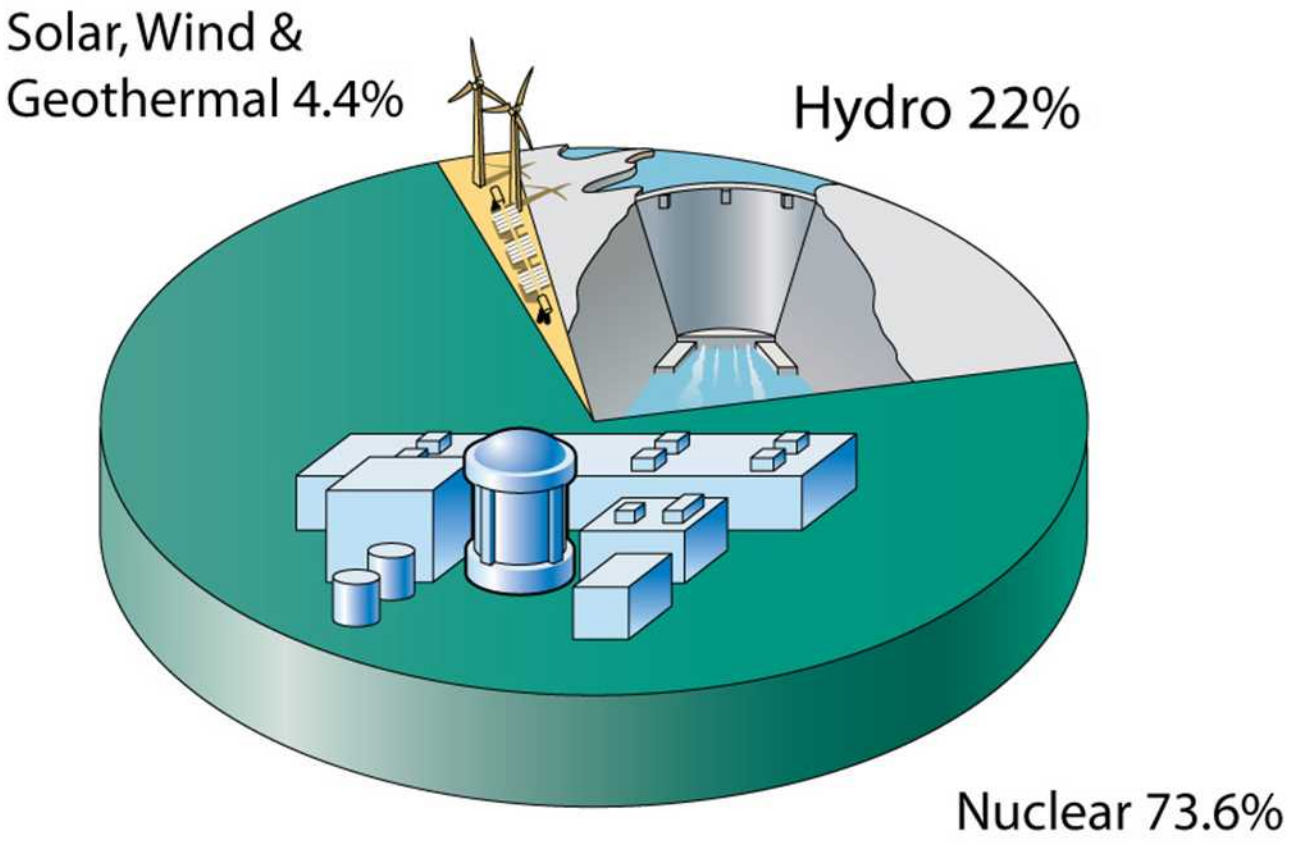
Source: "*ExternE - Externalities of Energy. National Implementation in Germany*", W. Krewitt, P. Mayerhofer, R. Friedrich, A. Trukenmüller, T. Heck, A. Greßmann, F. Raptis, F. Kaspar, J. Sachau, K. Rennings, J. Diekmann, B. Praetorius; IER, Stuttgart;

Nuclear Power is High Energy Density

- ¾ square mile for nuclear plant
- 440 square miles for equivalent power wind farm
- 220 square miles for equivalent solar farm
- 500,000 PV systems (like on my house…at MAX solar output, when the sun shines), or 3.1 million systems, based on AVERAGE solar output.



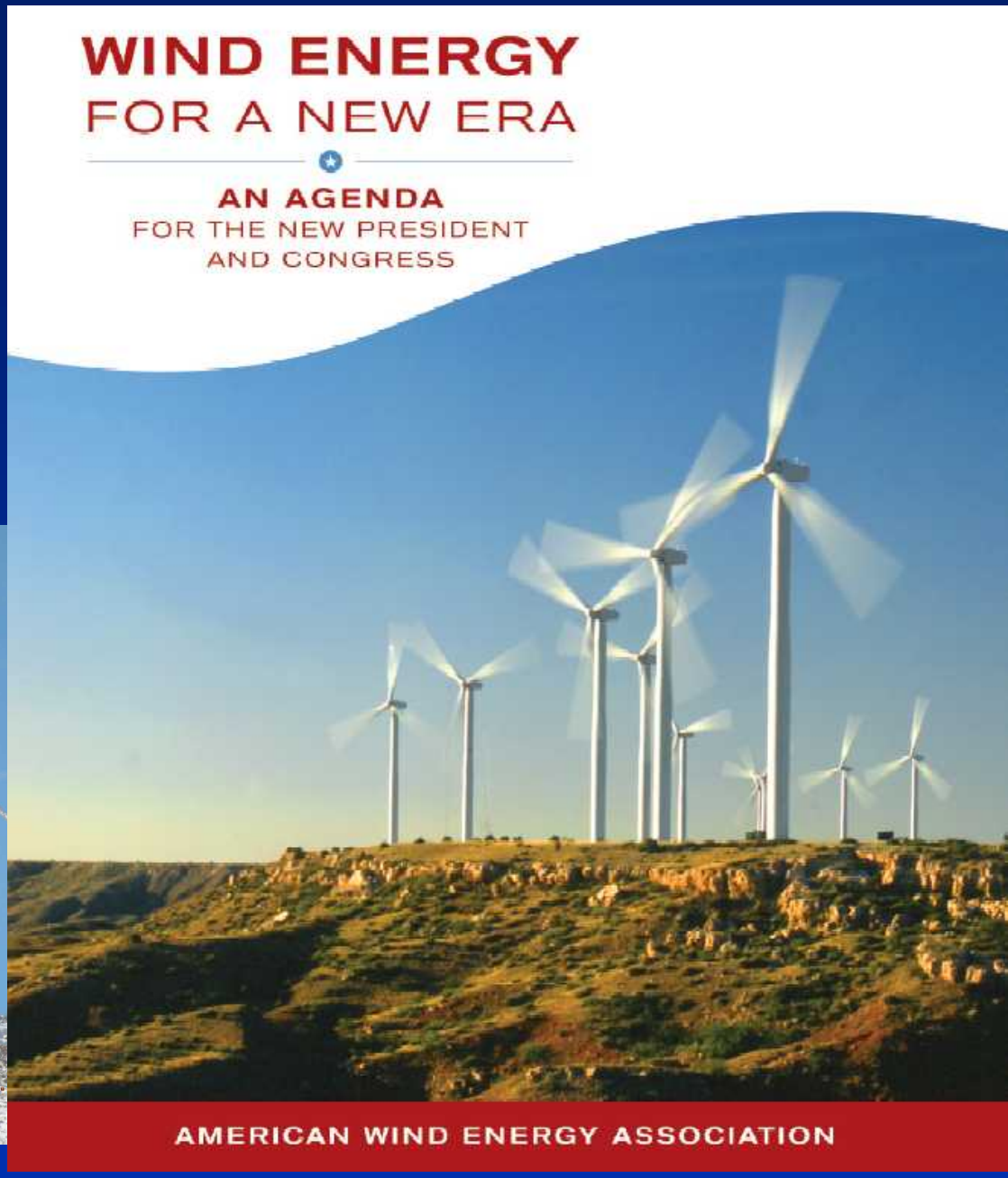
Sources of Emission-Free Electricity 2007



http://www.nei.org/keyissues/protectingtheenvironment/

12 “Evergreen” PV Panels ~ 2000 watts (max)

Wind Farm
Near Bakersfield, CA

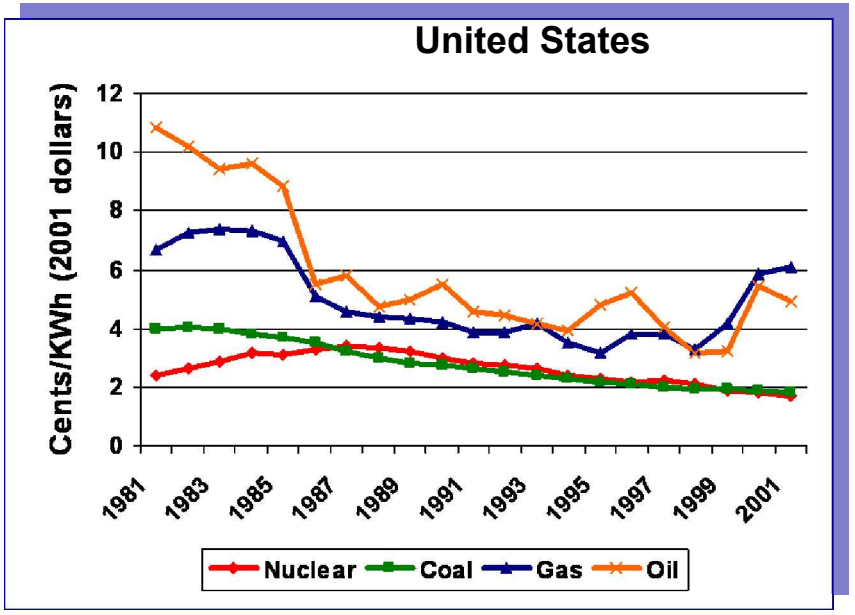


Nuclear Energy in the U.S. Has Performed Very Well

Source: NEI

- 104 commercial nuclear power plants produce electricity in the United States today

Nuclear Power Costs Continue to Decrease



- They are, on average, 24 years old and licensed to operate for 40 years (with an option to renew for an additional 20)
- Costs continue to decline
- Gas and oil generation costs are increasing

What will be the role of nuclear power? Momentum is swinging nuclear's way ...(or is it?)

- Climate change legislation
- Environmentalists' changing attitude toward nuclear
- Continued growth in demand for electricity
- Rising energy costs for fossil fuel generation
- 2005 Energy Policy Act tax credits & loan guarantees
- Streamlined regulatory processes
- Economic Distress?
- Waste Disposal (Arrrgghhh!)
- Political Gridlock (Arrrgghhh!)

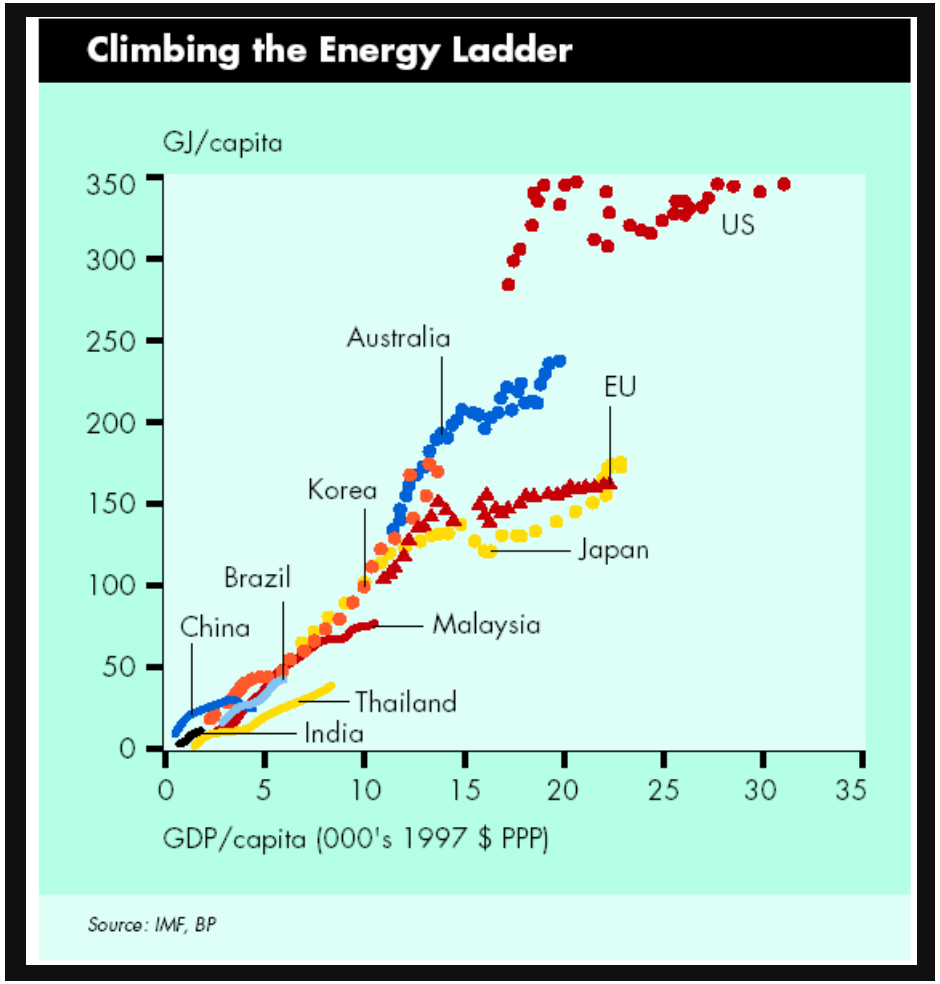
Public opinion has shifted and so has the policy landscape.

- Climate change is a prominent topic in the mainstream media
- 2007 IPCC report concludes human-caused GHG emissions are causing climate change
- The issue has reached a critical mass with the public…
- 2008 U.S. poll shows 63% favor nuclear energy

Diversity = Surety

- No single energy source is viable, nor secure
- Government / Laboratory Leadership Critical
- Incentivizing individuals and businesses to diversify to ensure increasing momentum

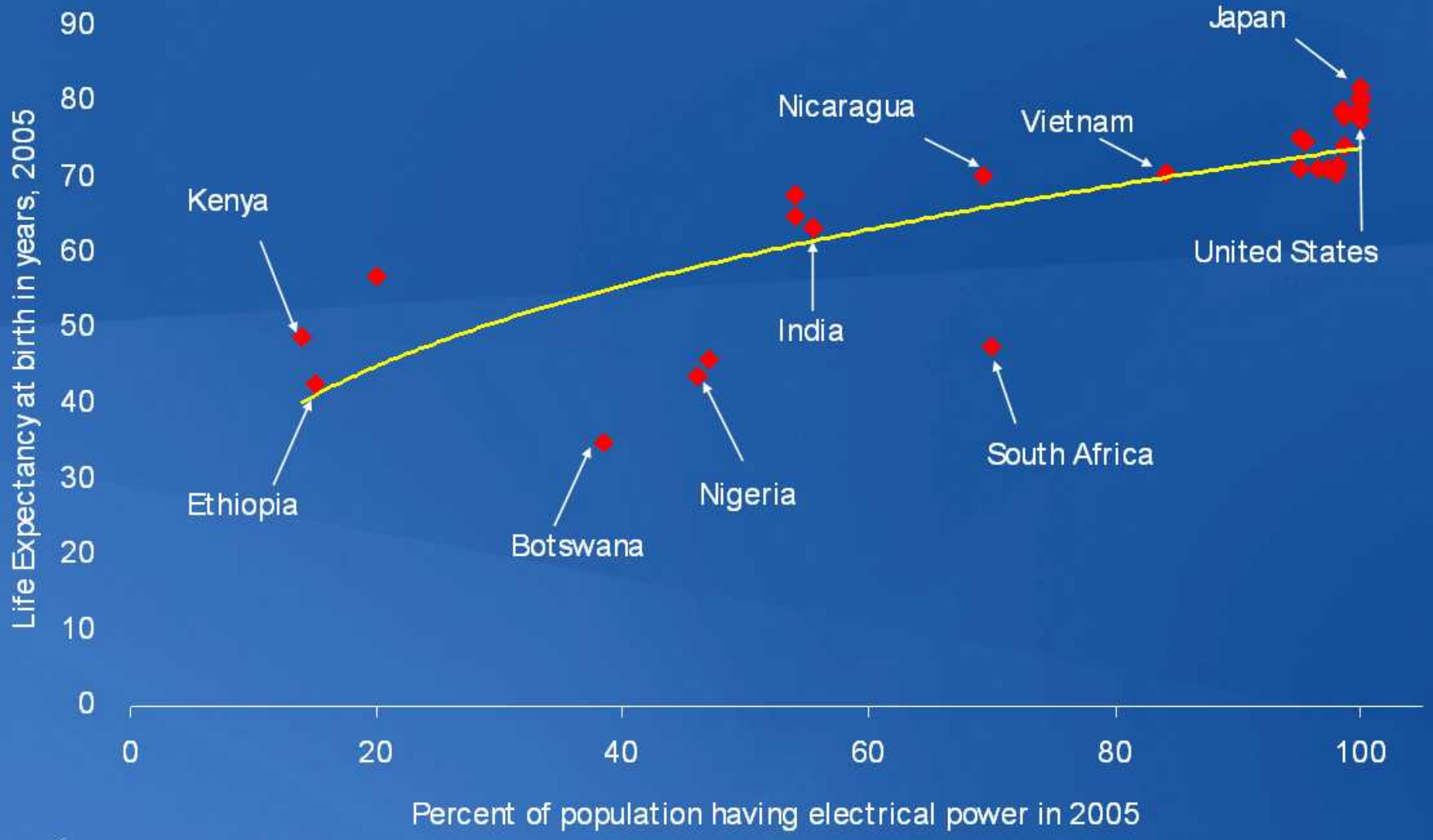
Economic Prosperity and Stability Require Access to Reliable and Affordable Energy



- Energy consumption is **directly** tied to national economic prosperity
- Increasing potential for regional and global conflict over access to conventional energy resources

Source: Royal Dutch Shell, "Exploring the Future–Energy Needs, Choices and Possibilities"

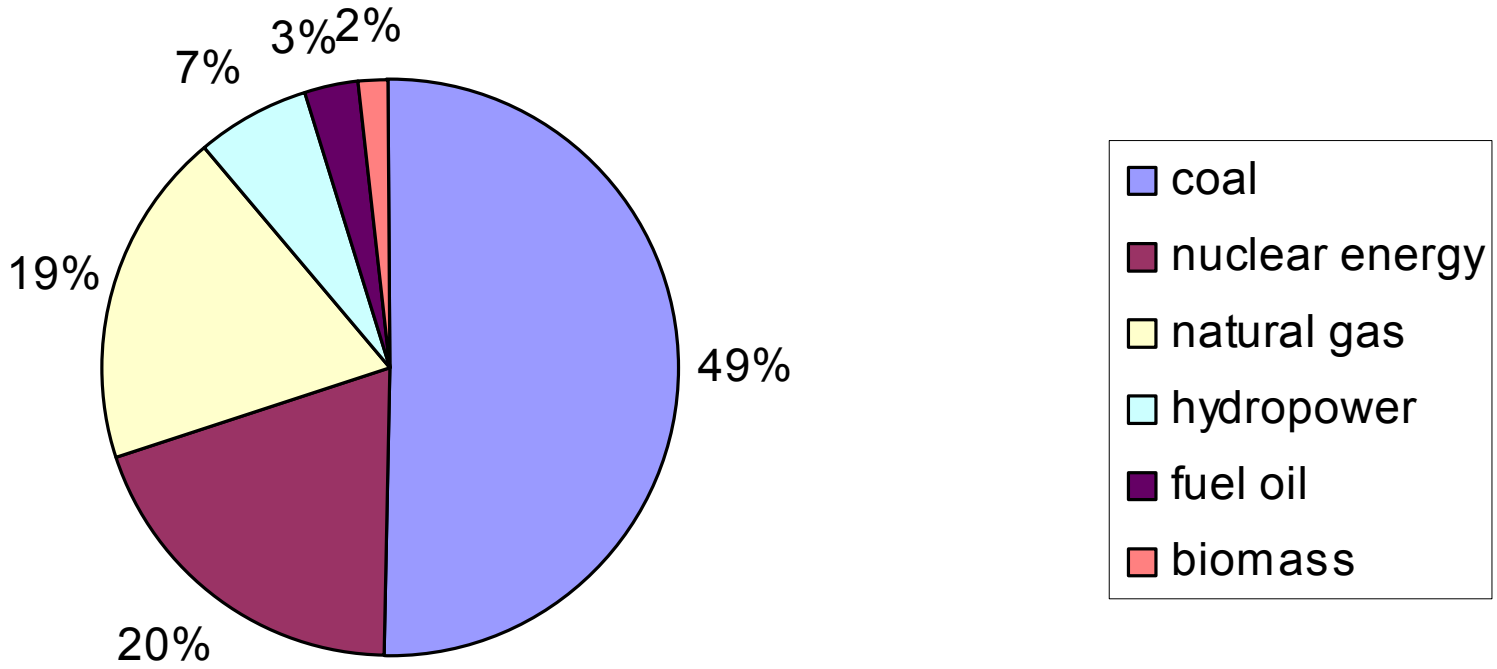
Cross Country Comparisons of Life Expectancy and Electrification



Source: International Energy Agency & World Bank

UNITED STATES ELECTRICITY SUPPLY

49%+19%+3%+2% = *73%* of U.S. Energy is CO_2-producing!



*Information provided by Edison Electric Institute

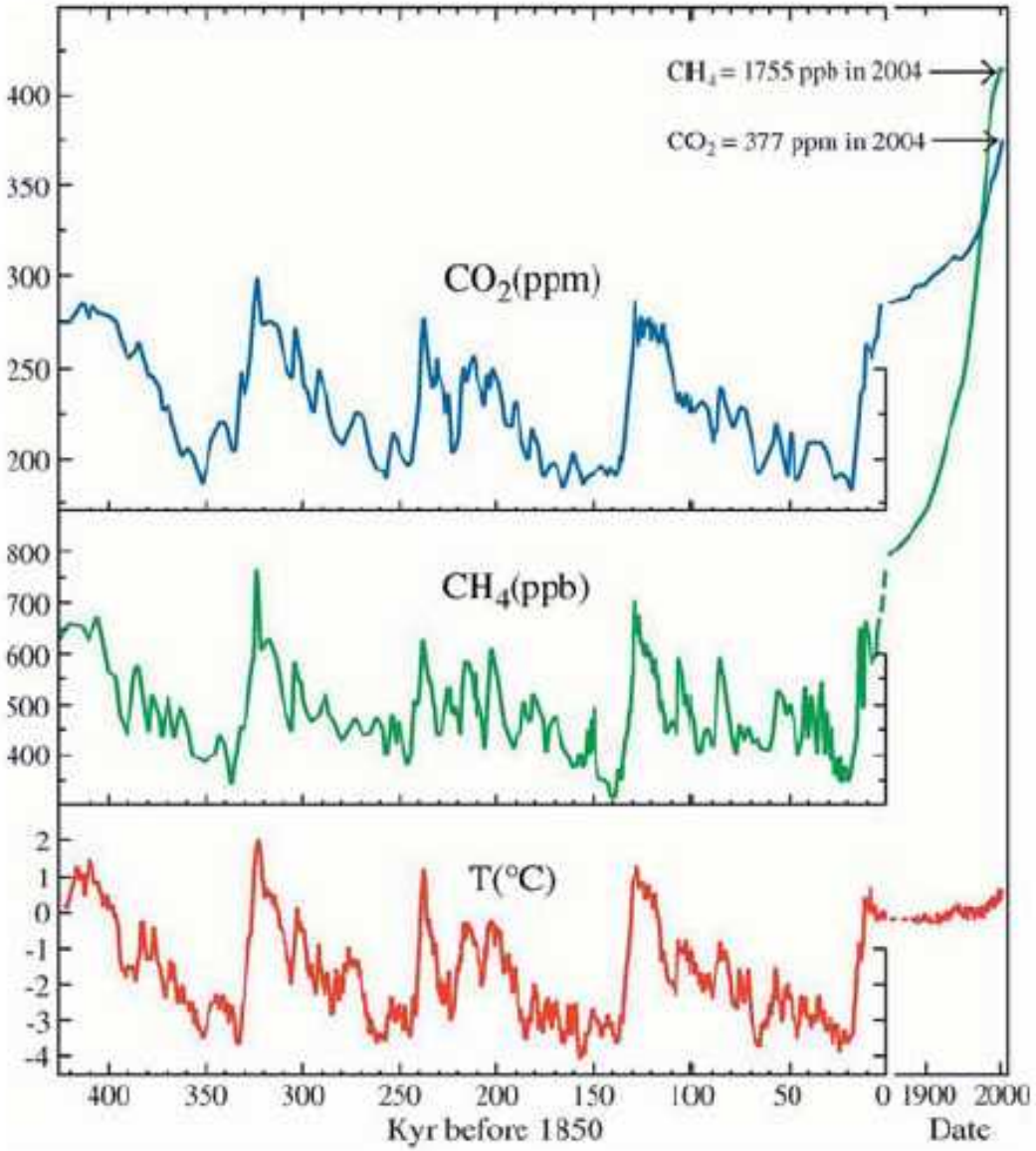
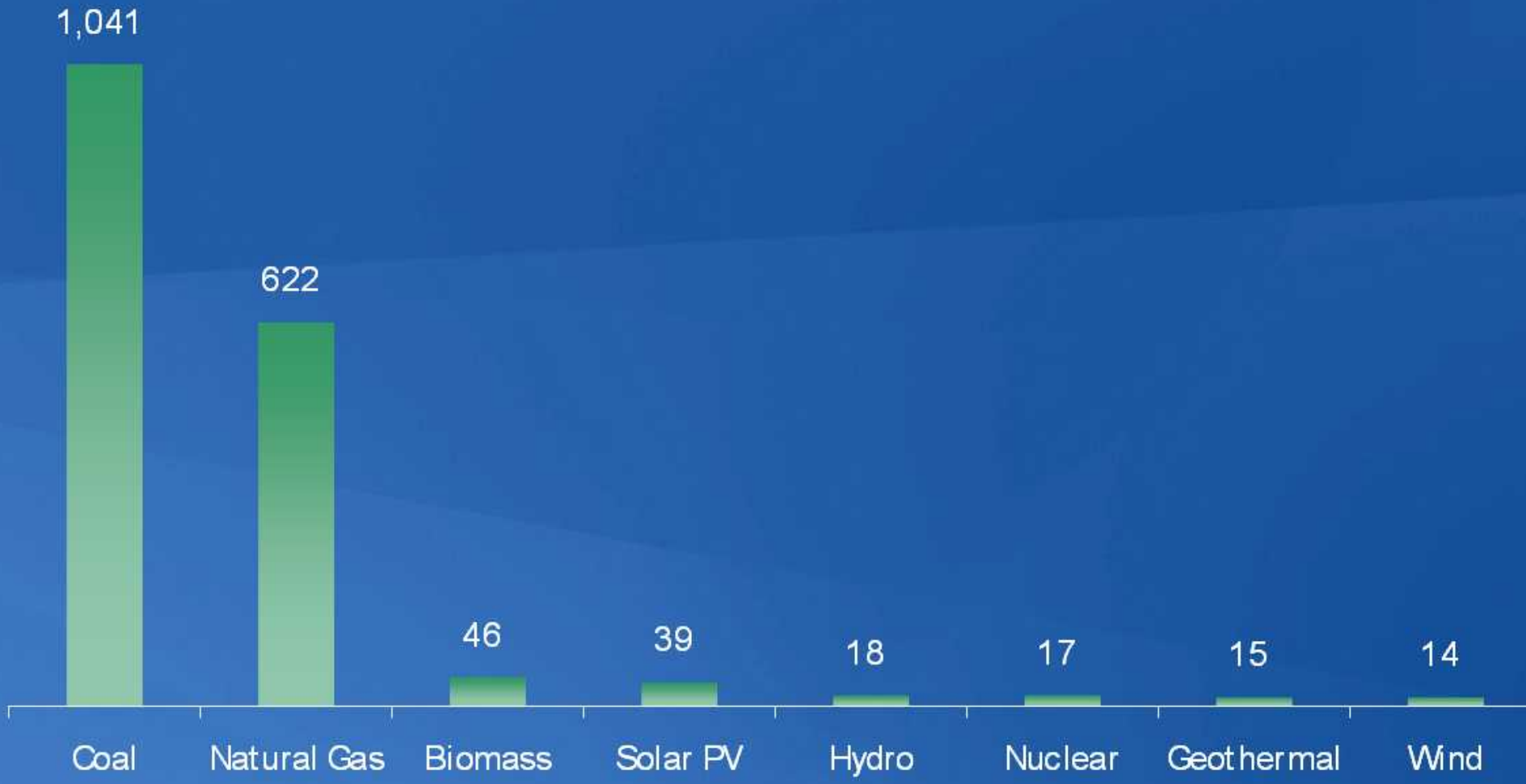


Figure 2. Paleoclimatic data from ice cores. Note the unprecedented recent increases in carbon dioxide and methane. The temperature, though increasing, has not yet reached record levels but will likely do so by mid-century. (Source: Hansen, Clim. Change, 68, 269, 2005.)

Comparison of Life-Cycle Emissions

Tons of Carbon Dioxide Equivalent per Gigawatt-Hour



Source: "Life-Cycle Assessment of Electricity Generation Systems and Applications for Climate Change Policy Analysis," Paul J. Meier, University of Wisconsin-Madison, August 2002.

Liquid Fuels Are the Lifeblood (but unsustainable!) of World Economies

- **97%** of U.S. Transportation uses **Oil** (train, truck, car, agriculture)
- **70+%** of this **Oil** is Imported!
- U.S. Economy is Critically Dependant on **Oil**
- Continued Energy Surety / Economic Security is not Possible Without **Change**
- Gasoline is currently $9/gallon in Germany and Italy (at this price it would cost **$450** to fill up the 50-gallon tank on your gas guzzler or RV)!

Scientific Notation Soon?

"C'mon, c'mon—it's either one or the other."

Thoughts:
"Nuclear Energy Futures"

- Energy demand will continue to grow and nuclear power is poised for growth world-wide – energy security without greenhouse gas emission

- The U.S. must help shape a global nuclear fuel services supply system that provides the benefits of nuclear energy to all nations while discouraging production of materials having nuclear proliferation concern – addresses the national security imperative

- Create partnerships among nuclear supply states to improve the safety, reliability and security of these systems

Eisenhower's "Atoms for Peace" (12/1953)

- Recognition that U.S. could control risks by "calling the shots"
- Reduced risk of proliferation
- Not only national, but global economic improvement
- 53 years later ….GNEP

Global Nuclear Energy Partnership

U.S. Announces New Measures to Expand the Use of Nuclear Power While Reducing the Threat of Nuclear Proliferation

"So tonight I announce the Advanced Energy Initiative… **We will invest more in…clean, safe nuclear energy."**

President Bush, January 2006

GNEP's Primary Goal - Enable the sustained use of nuclear energy worldwide, while addressing three fundamental issues:

- **Reduce Proliferation Threat**
- **Minimize Nuclear Waste**
- **Reduce Carbon Emissions**

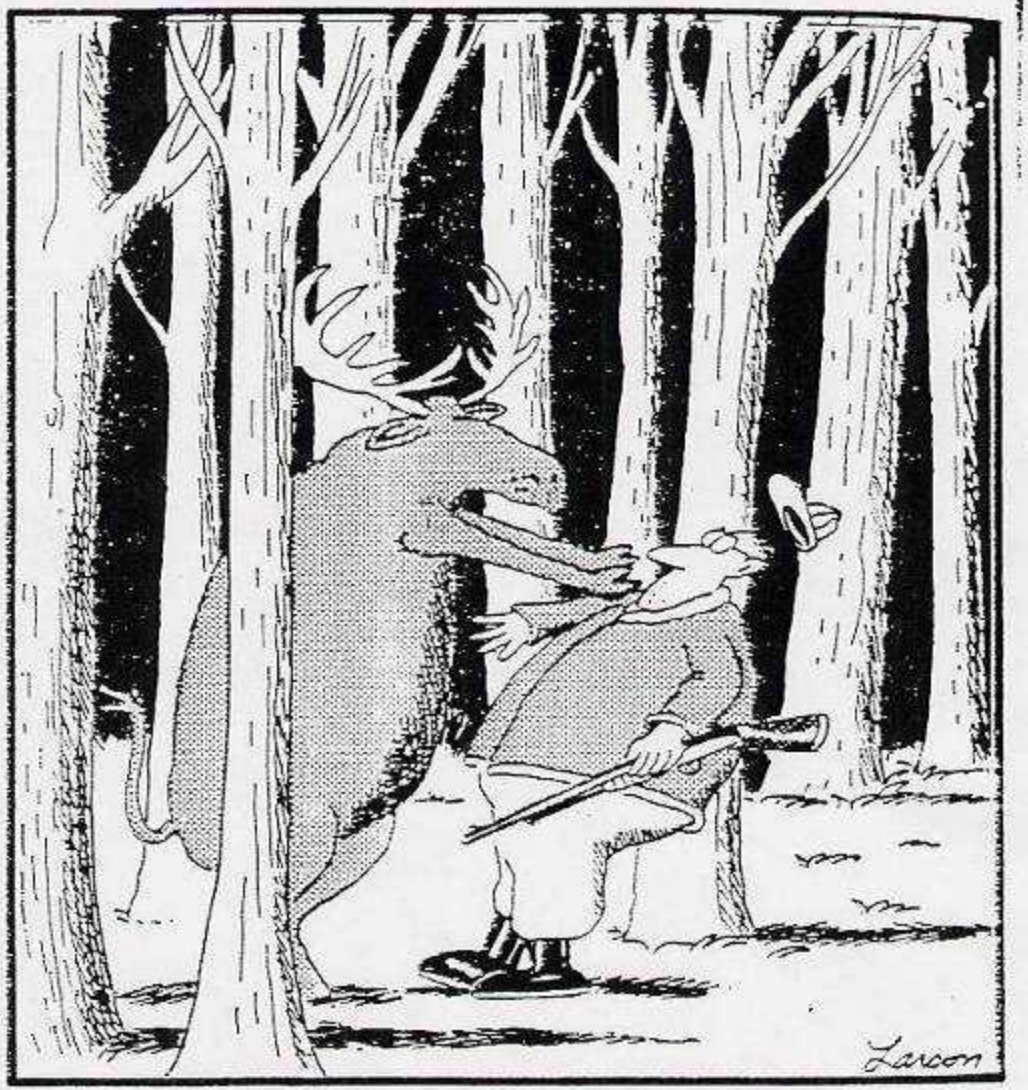
KEY PROGRAM ELEMENTS

- **Expand use of nuclear power – U.S. and Global**
- **Address nuclear waste challenges**
- **Enhance nuclear safeguards technology**
- **Establish reliable fuel services - "supply and return"**
- **Demonstrate recycle technology**
- **Demonstrate advanced burner reactors**
- **Demonstrate small, exportable reactors**

Costs of GNEP Failure

- Until GNEP becomes a reality or the Yucca Mountain repository begins accepting used nuclear fuel, nuclear-powered utilities are expected to continue using interim storage for the next 10 to 20 years.
- If history serves as a guide to the future, failing to follow through with a comprehensive program offered by GNEP will likely produce the same results witnessed in 1977. Since then, the "indefinite deferral" of reprocessing commercial UNF, and the absence of a viable alternative, has cost billions of dollars—many of them paid into the Nuclear Waste Fund—while producing few, if any, positive accomplishments.
- Nuclear power plants have diverted resources for the storage of UNF to avoid plant closure while waiting for a licensed geologic repository to open.
- If GNEP fails, expect these scenarios to be repeated over the next 30 years.

When conflicts are not managed effectively, there are social, legal, environmental, and institutional costs.



Carl shoves Roger, Roger shoves Carl, and tempers rise.

Topic

- What concerns/challenges MUST be addressed?

Concerns?

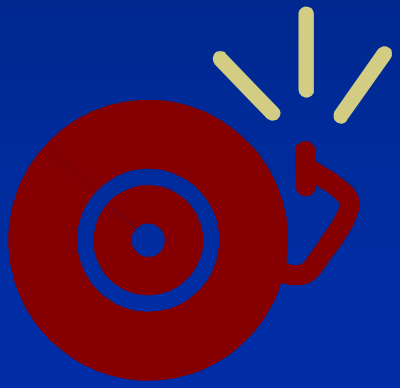
- "Waste" Disposal
- Energy Sources / Cost–Benefit / Availability
- CO_2 Emissions
- Global Warming
- Long-Term / Short-Term / Sustainability
- Current intervener process (only allowed in the U.S.) is a major economic and political roadblock to effectively using nuclear power
- Others?

Challenges

- High – Controlling cost & schedule
- High – “Big Iron” – Reactor Vessels
- High – “Waste”/ Political
- Medium – “Waste” / Technical
- Medium – Skilled Labor
- Low – Fuel

Safety?

No member of the public has ever died due to radiation released from a U.S. nuclear power plant.



Name another industry with a similar record……

(There have been 41 fatalities from work on wind turbines!)

Spent Fuel "Waste" Disposition

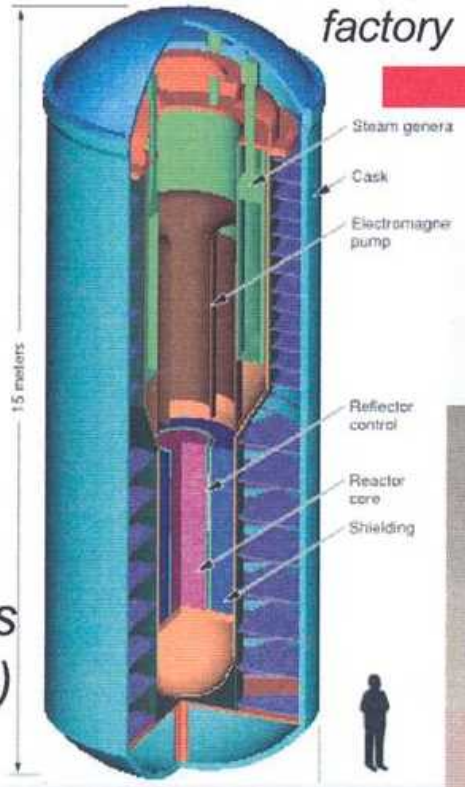
- Very large impediment to resurgence of nuclear power option
- "Open" cycle versus "closed" cycle
- "Closed" cycle involves reprocessing – threat of proliferation
- High challenge, politically
- Medium challenge, technically
- "Closed" cycle enables us to extract the remaining 90+% of the energy remaining in spent fuel!
- Completely avoided if a "fast reactor" design is used!

The U.S. Has Lost It's Leadership Position in Nuclear Power

- PWR and BWR reactors are now PURCHASED from France or Japan, we no longer SELL to anyone.
- U.S. has lost the industrial capacity to manufacture key reactor components (especially the large ones).
- U.S. must introduce a major paradigm shift in order to regain credibility the worldwide nuclear debate.
- "Right-sized" fast reactors may be the answer.
- More versatile, proliferation resistant, modular, etc.

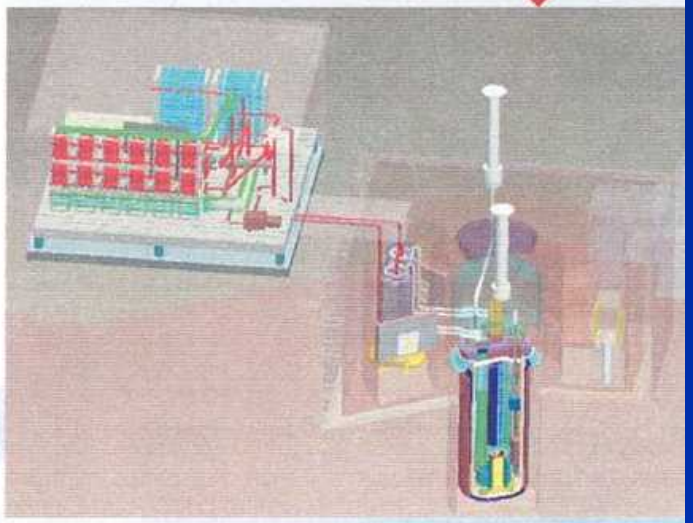
Right-sized "Fast" Reactor

- ***Factory produced, fueled, sealed***
- ***Long fuel lifetime*** *(up to 30 years, no need for on-site fueling)*
- ***Inherently safe***
- ***High efficiency***
- ***Transportable*** *(components shipped to site for assembly)*
- ***Remotely monitored***
- ***Capacity - 100 to 300 MW_E***



Shipped from factory

Major components Assembled on site



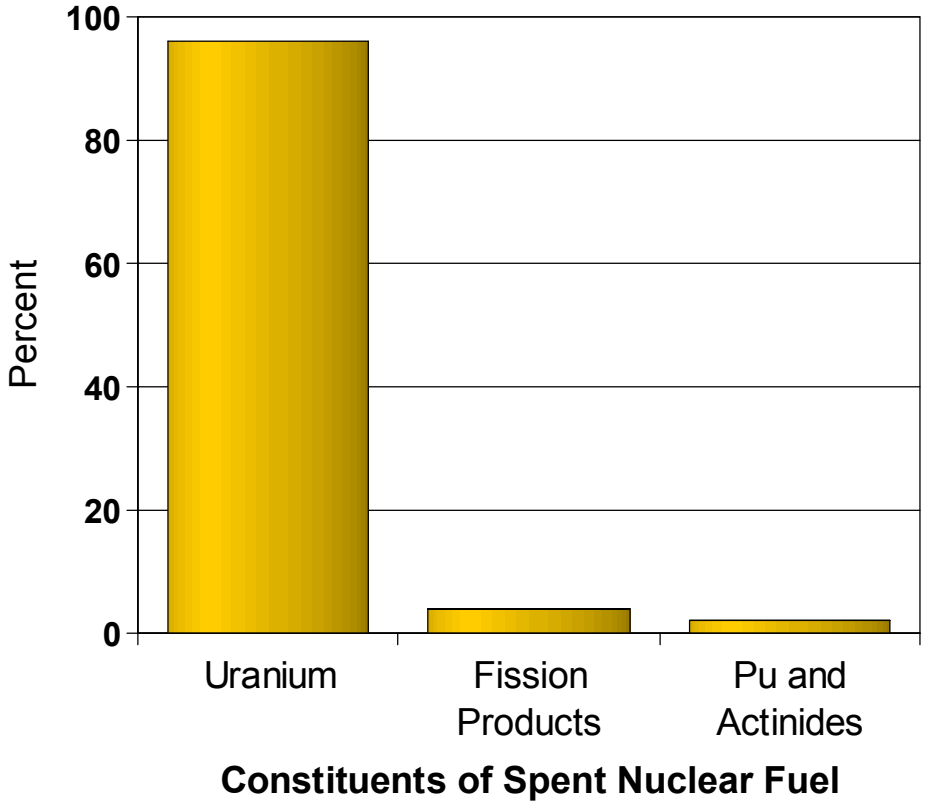
Un-intended consequences of the "decision to defer"

- During the 1976 presidential election campaign, critics raised concerns over the acquisition of plutonium from civilian nuclear power programs, the proliferation of nuclear weapons, and controls over exporting nuclear technology. In response to these concerns, and just prior to the 1976 election, President Ford announced a major decision by the U.S. government calling for a temporary halt to reprocessing that was aimed at stopping the proliferation of nuclear weapons capability.
- In 1977, the Carter Administration extended the moratorium into a long-term policy to defer indefinitely the commercial reprocessing and recycling of plutonium produced in U.S. nuclear power plants. As a result of this decision, approximately 97% of the recoverable uranium and plutonium from UNF became non-recoverable waste products.
- Although the goal in principle was laudable, it ultimately eliminated all U.S. commercial reprocessing. In spite of the U.S. position, reprocessing continued elsewhere in the world, causing the U.S. to lose much of its influence in international nonproliferation efforts.

Reprocessing Facts

- Currently, reprocessing and recycling is conducted in France, the United Kingdom, Japan, Russia, India, and China; Germany and Belgium have conducted pilot activities.
- Approximately 97% of the used fuel is recyclable when it leaves the reactor—96% as uranium and 1% as plutonium—while 3% is non-reusable waste materials and fission products.

Composition of Spent (Used) Nuclear Fuel



Constituents of Spent Nuclear Fuel

- **95.6% uranium**; possibly disposition as Class C low-level waste or recycled
- 3% stable or short-lived fission products; do not pose major disposal challenges
- 0.3% **cesium and strontium**; decay in a few centuries (primary near-term HLW heat source)
- 0.1% long-lived iodine and technetium; transmute or store
- 0.9% plutonium; burn as fuel
- 0.1% long-lived actinides; fission in fast spectrum reactors or accelerator-driven systems (ADS)

Waste Volumes

1) Consider 3 logs in your fireplace:

- 1 night's fire . . .
- 1 Bucket of Ashes . . .

2) Consider 3 Nuclear Fuel "Logs":

- ~900 days/nights of heat . . .
- 3 "Logs" of waste
- 90+% of original energy still recoverable via reprocessing!
- Fast reactors would enable this without reprocessing!

Radioactive Waste Types

There are roughly five categories of radioactive waste: low level, high level, mixed, transuranic, and uranium mining and milling tailings. How a waste is categorized is not necessarily based on the amount of radioactivity, but instead on where the waste is generated.

- Low-Level Waste
- High-Level Waste
- Mixed Waste
- Transuranic Waste
- Uranium Mining & Mill Waste
- Processed Radioactive Materials
- Radioactive Waste Transport

Concerns?

- Energy Sources / Cost–Benefit / Availability
- CO_2 Emissions
- “Waste” Disposal
- Global Warming
- Long-Term / Short-Term / Sustainability
- Others?

Right-sized "Fast" Reactor

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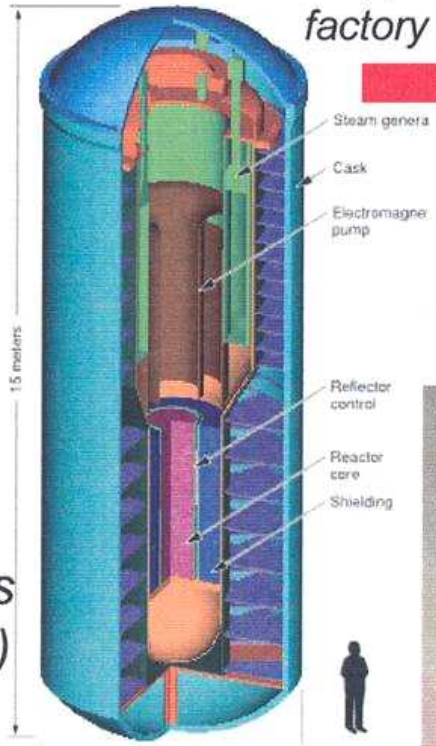
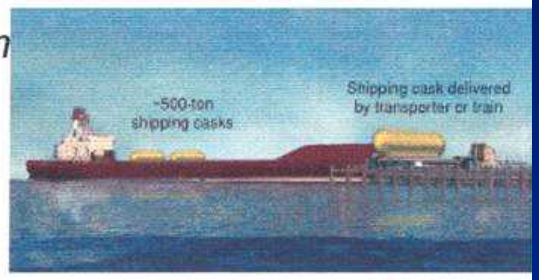
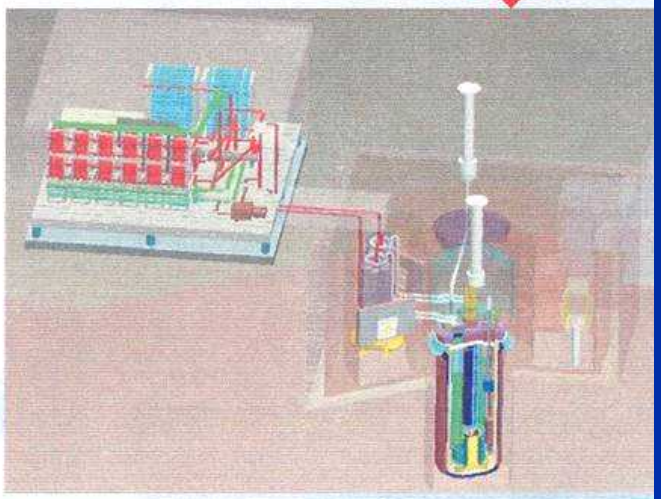
- ***Remotely monitored***
- ***Capacity - 100 to 300 MW_E***



Shipped from factory

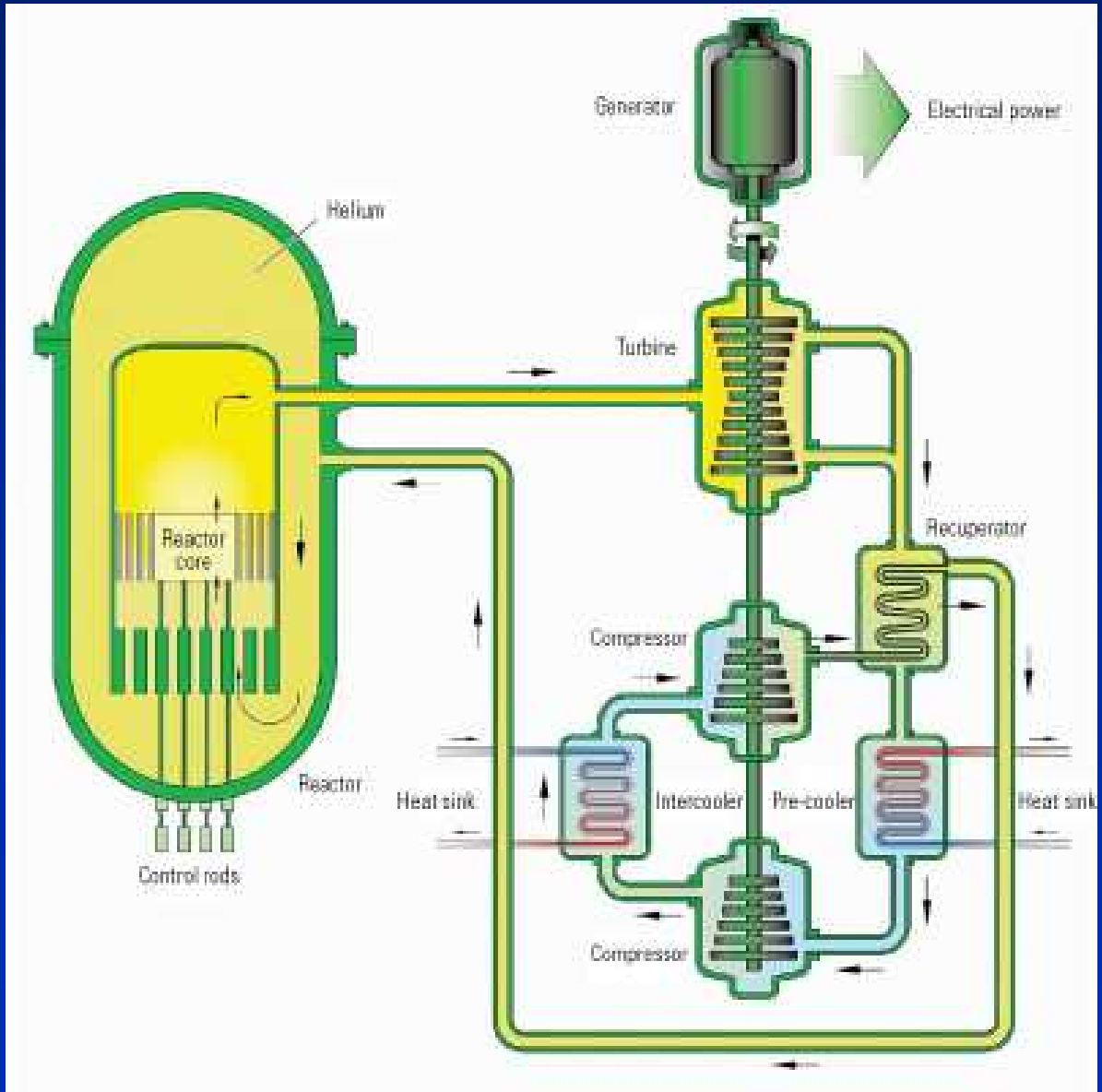


Major components Assembled on site



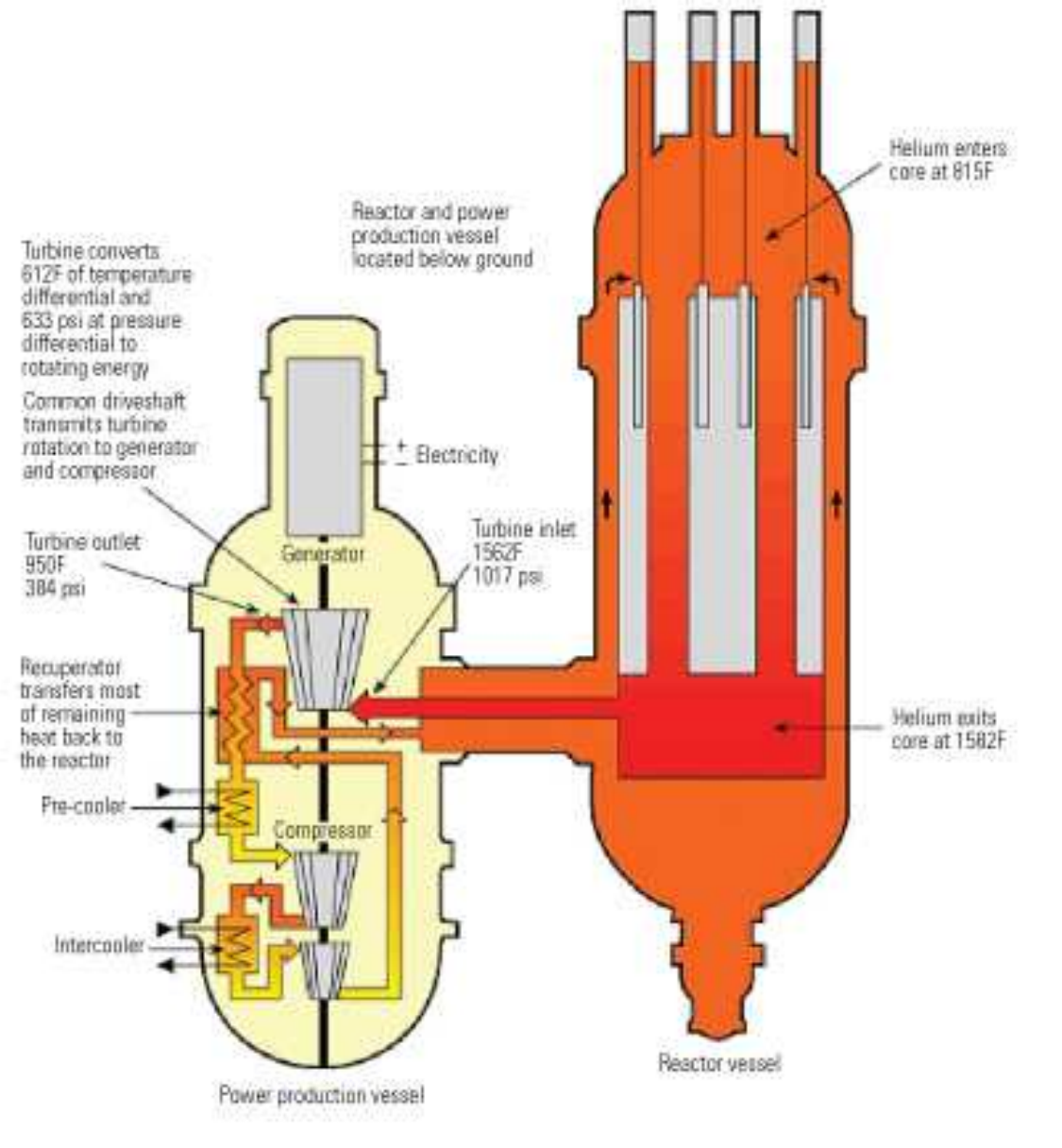
The gas-cooled fast reactor

Source: DOE



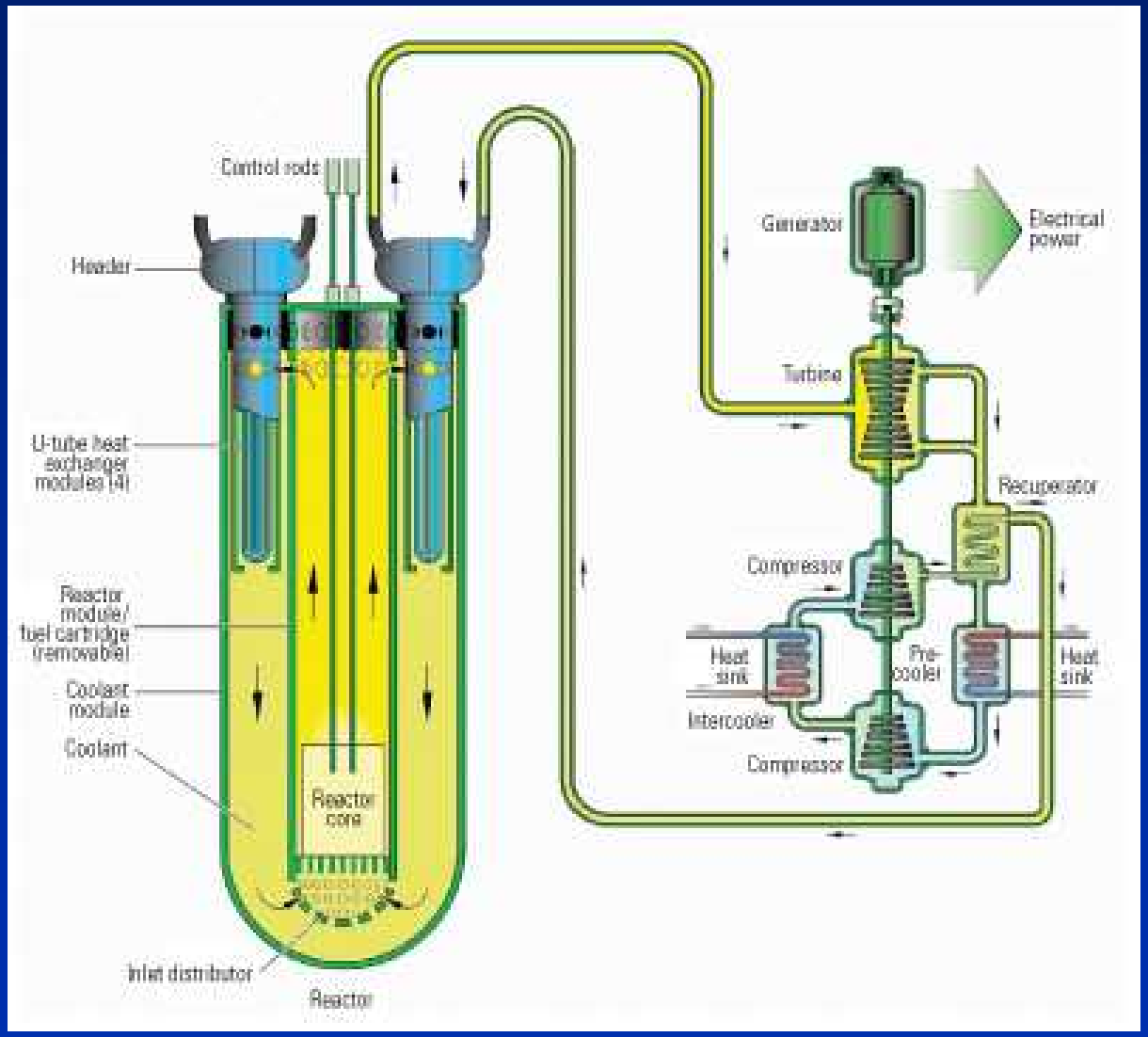
Gas turbine-modular helium reactor

Source: General Atomics



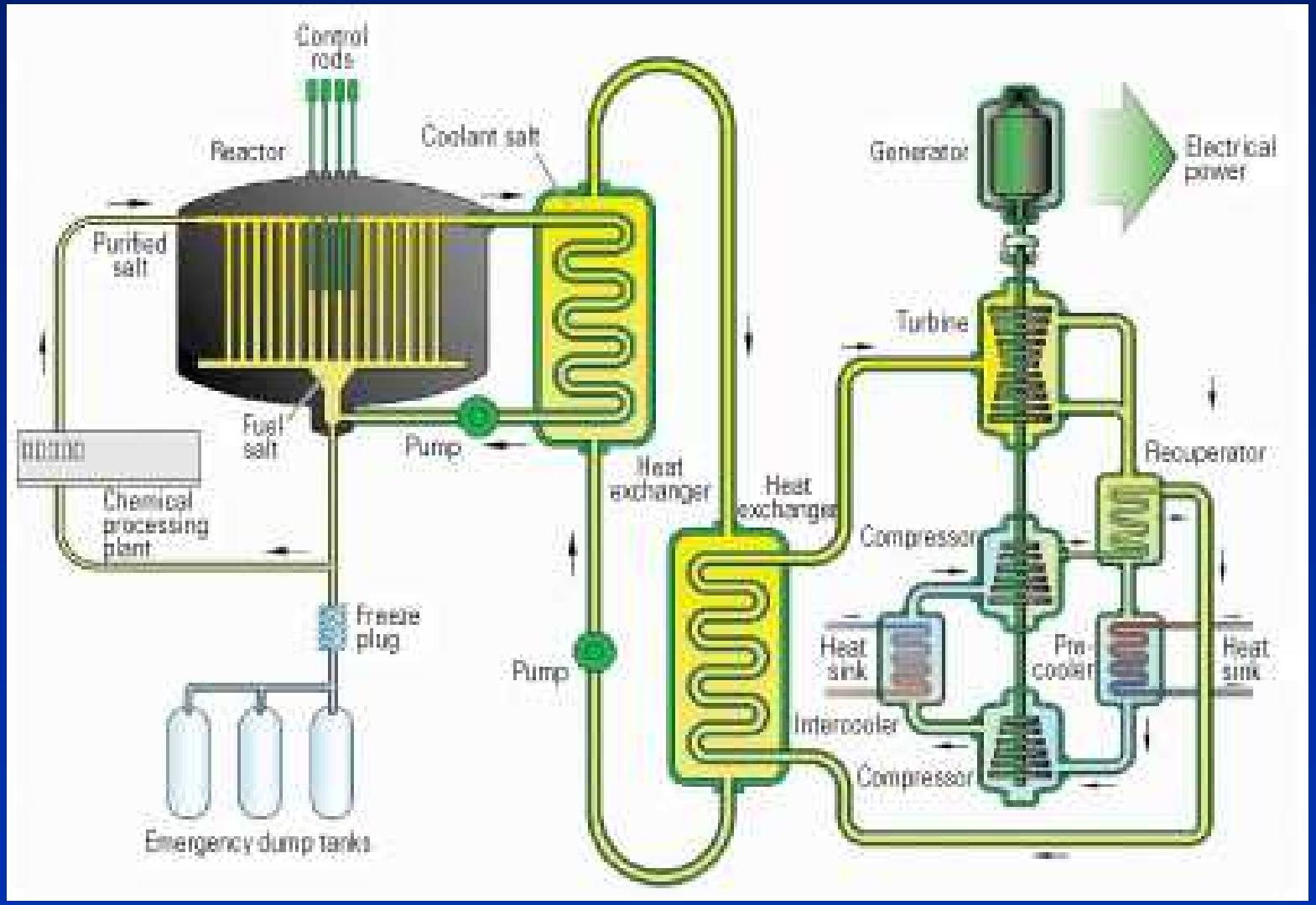
Lead-cooled fast reactor

Source: DOE



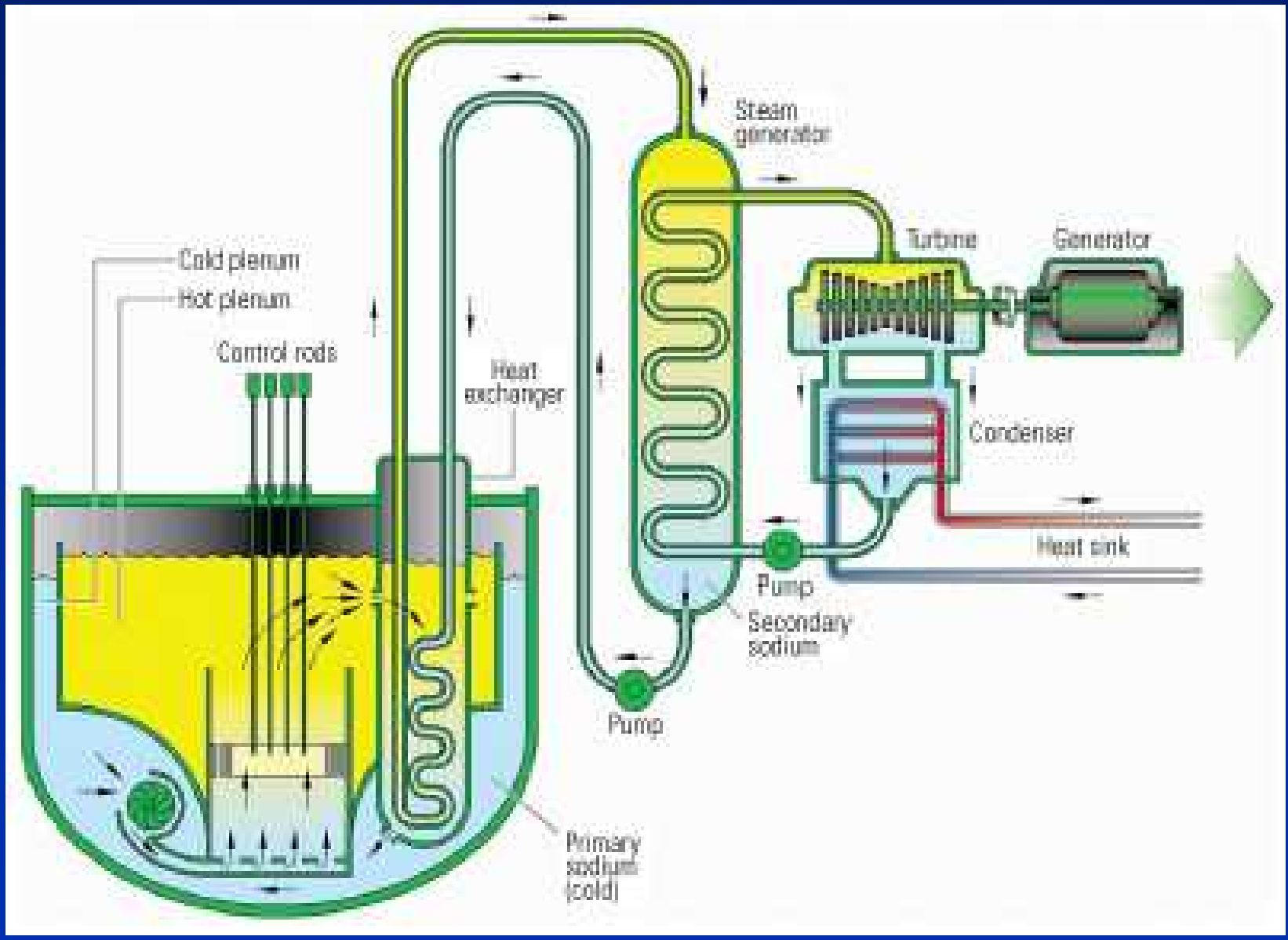
The molten salt reactor

Source: DOE



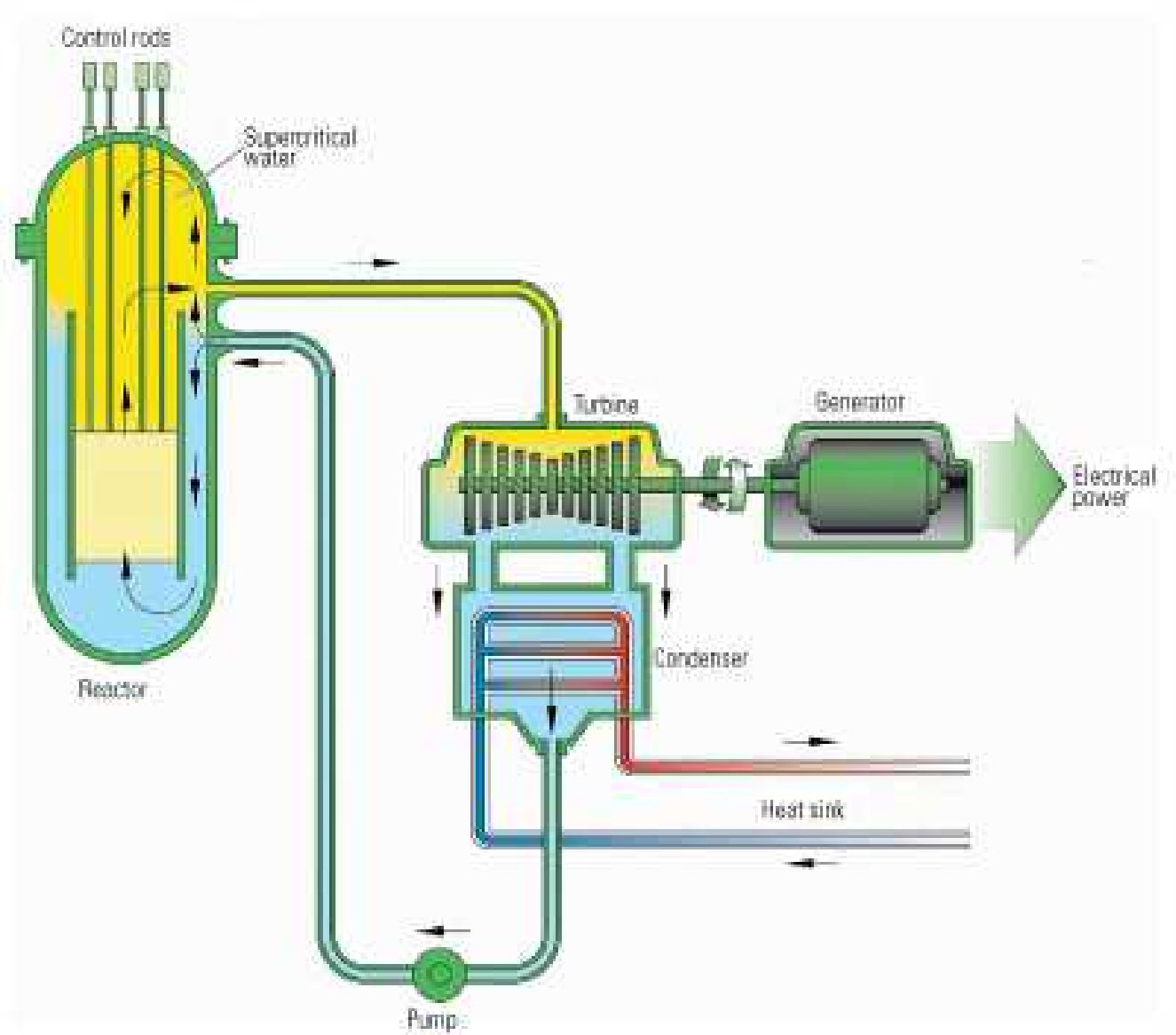
Sodium-cooled fast reactor

Source: DOE

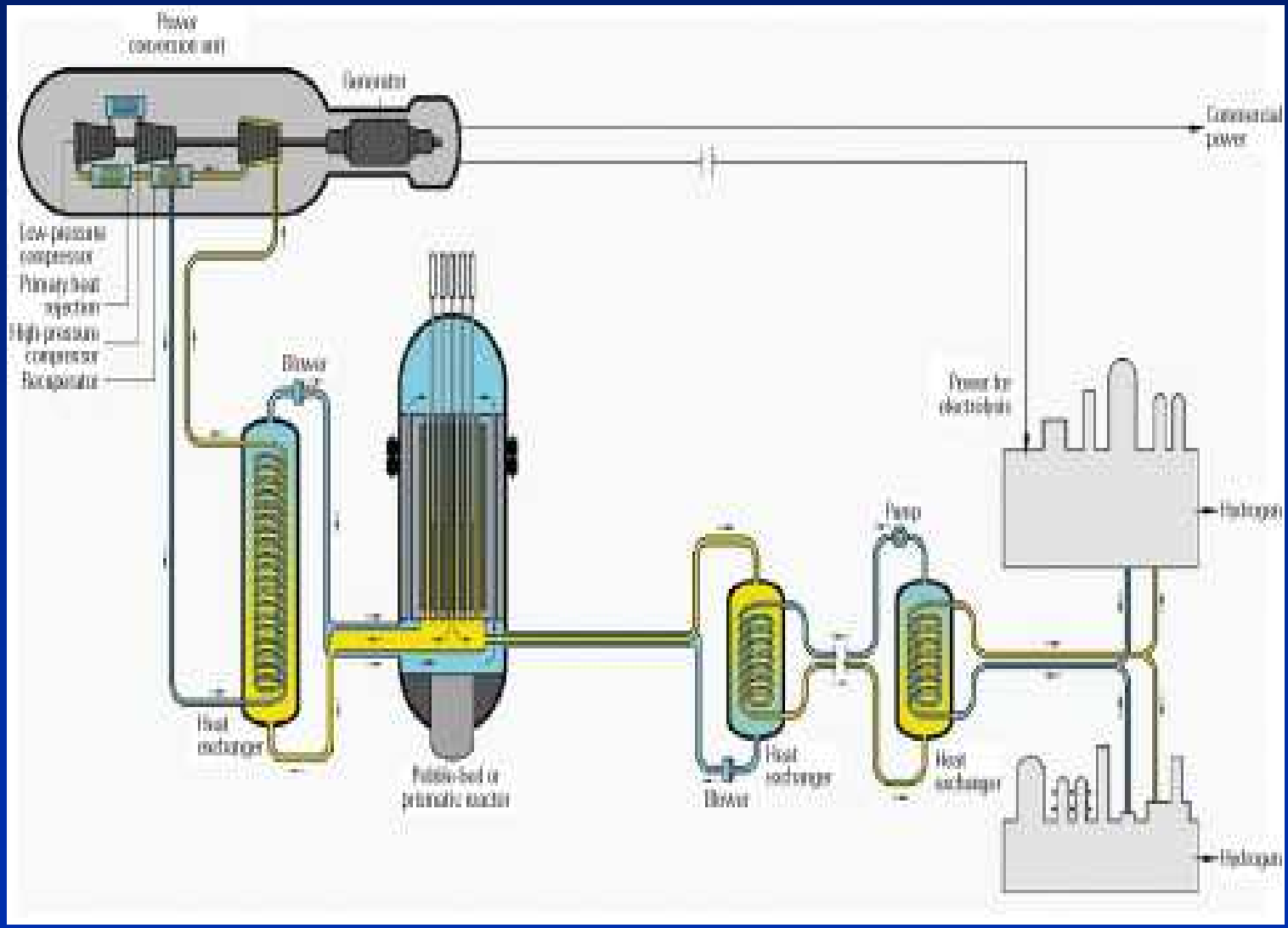


Supercritical water-cooled reactor

Source: DOE



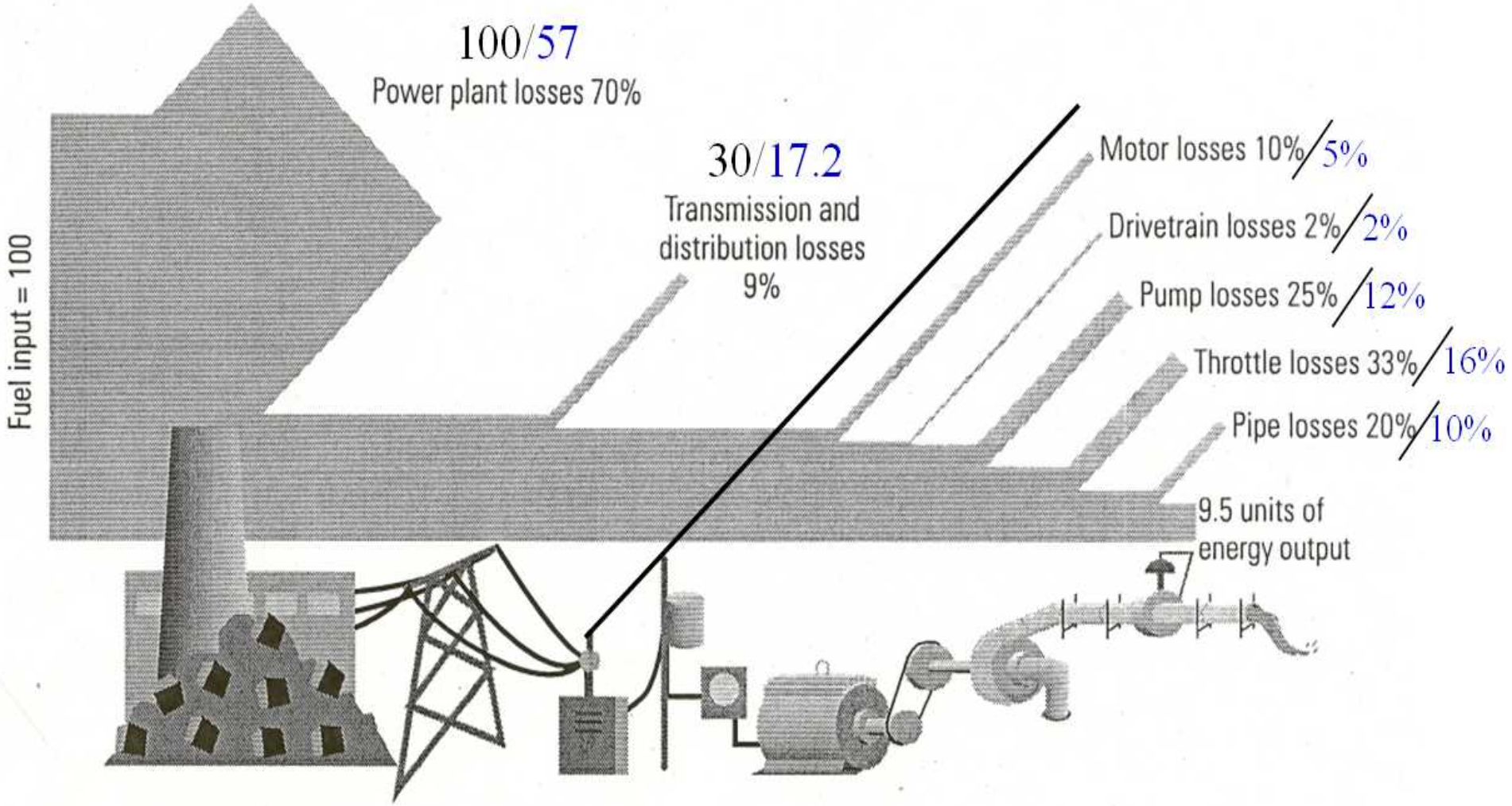
Very high temperature reactor Source: DOE



Switching Gears

- **Increasing Transmission Efficiency**
- **Conservation!**
- **Transportation Paradigm Changes!**
- Photovoltaic
- Hydrogen
- Hydro
- Ocean Tidal Energy
- Biomass
- Distributed Generation
- Oil, gas, LNG
- Coal
- Nuclear
- Wind
- Solar
- Geothermal

Leveraging Efficiency



E Source Drivepower Technology Atlas, 1992

Architecture 2030 Challenge

- Concerned about the impact of buildings on climate change
- Reports that EIA projects U.S. will need another 34 Q of energy by 2030
- Business As Usual (BAU) scenario: 1 Quad equivalent to another 40 1000-MW power plants
- Re-bundling of 2003 EIA statistics by Mazria et al revealed that Buildings use almost 50% of total U.S. energy use (globally, it's higher)
  - 8% for construction, 40% for operations
  - 76% of all electricity
- Building stock in U.S.: 275B SF
  - In next 30 years, over ¾ of building stock will be new or renovated.
  - Need to start now

www.architecture2030.org

Architecture 2030 Challenge

Challenge is to the Global building design community

- Now – 50% reduction of average for that building type in that country
  - All new construction and major renovation
  - Commit to same for retrofits to equivalent amount of existing buildings
- 2010 – 60%
- 2015 – 70%
- 2020 – 80%
- 2025 – 90%
- 2030 - Carbon neutral
- Aligned with 2006 DOE Climate Change Technology Program Strategic Plan and supported by ASHRAE

Some Definitions

- **Energy Efficiency**
  - The ability to produce more energy services (e.g., lighting, heating, cooling, transportation) from a fixed amount of energy.
- **Energy Intensity**
  - "…the ratio of energy consumption to some measure of demand for energy services"
  - Energy/capita
  - Energy/GDP
- **Energy Productivity**
  - The ability to create more economic value (e.g., GDP, worker productivity and air quality) from a fixed amount of energy
- **Exergy**
  - The maximum beneficial use of an energy source, given its surroundings

Source: *SAND Report – Toward an Energy Surety Future*

Energy Security

- As most of you know, the largest source of immediately available cost-effective “new” energy is the energy we waste every day. Indeed, it is the cheapest, most abundant, cleanest, most readily available source of energy we can access. It is our duty to maximize this resource for the federal government and for the nation.
  - Samuel Bodman, Secretary of Energy, GovEnergy conference, August 7, 2007

- Energy efficiency → Energy Productivity → Exergy maximum
- Improving Energy Security

Residential energy use

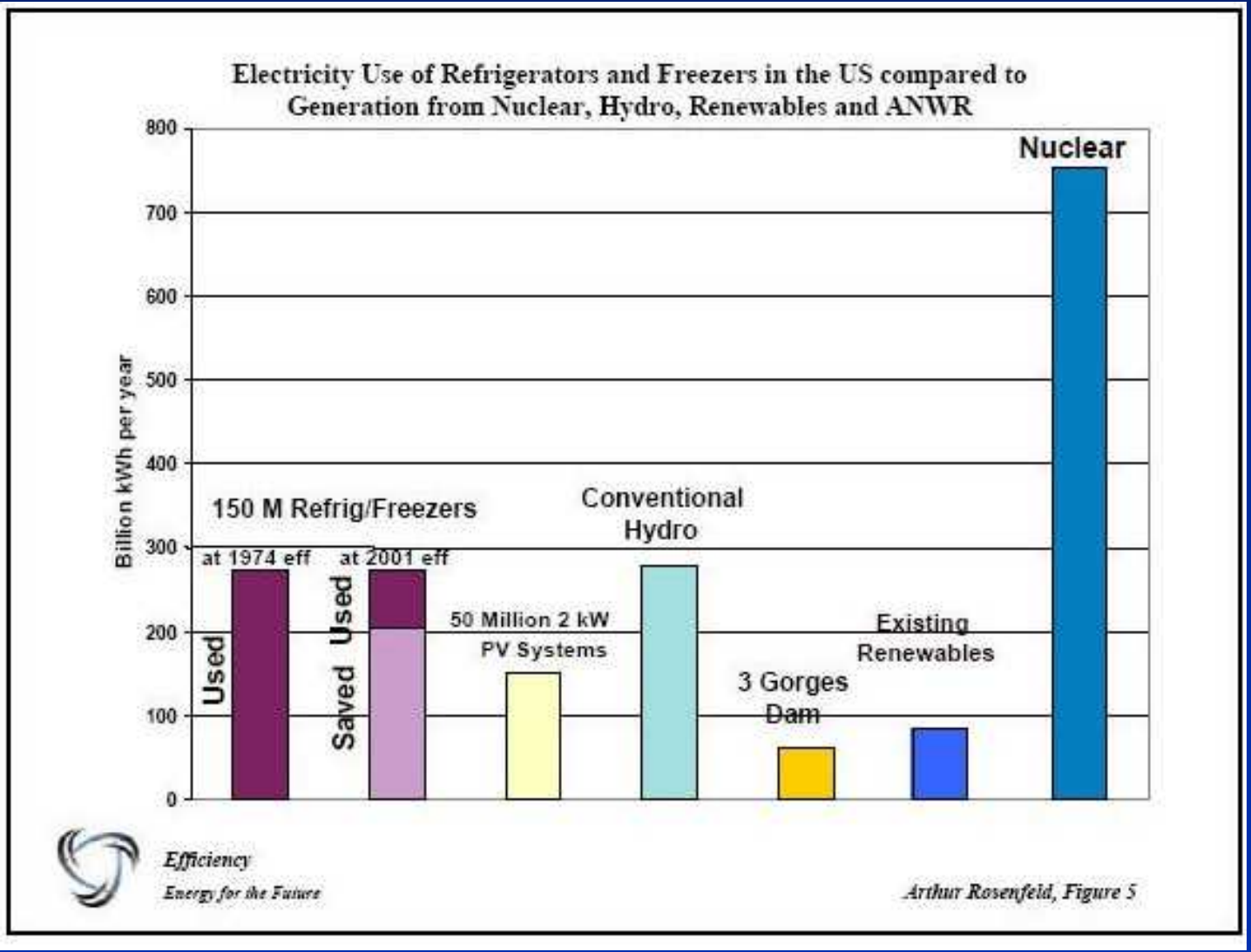
Table 2. Site Energy Use, 2001

End Use	Site Energy		
	QBtu	QBtu Share	Exajoules
Space Heating	4.62	46.9%	4.47
Water Heating	1.68	17.1%	1.65
Refrigerators	0.53	5.4%	0.56
Lighting	0.34	3.5%	0.36
Air Conditioning	0.62	6.3%	0.65
Appliances & Misc	2.06	20.9%	2.17
Total	9.86	100%	9.84

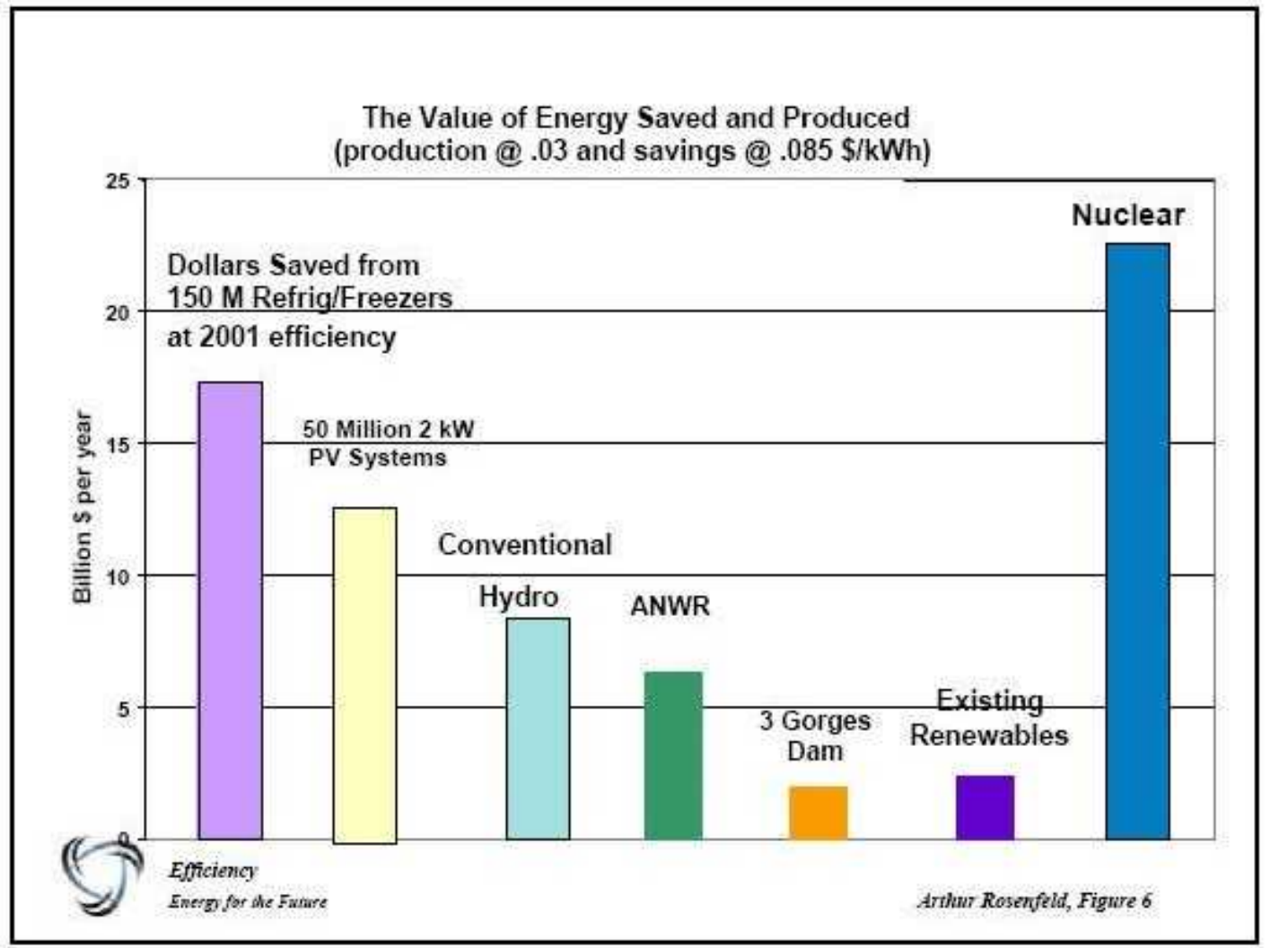
Sources: U.S. EIA, 2004a and U.S. EIA, 2005

- **Quantifying the Effect of the Principal-Agent Problem on US Residential Energy Use – August 2006**
  - Part of a five-nation study. Supported by DOE & EPA.

Energy Star: refrigerator efficiency as an example of impact



Energy Star Refrigerators: Economic impact

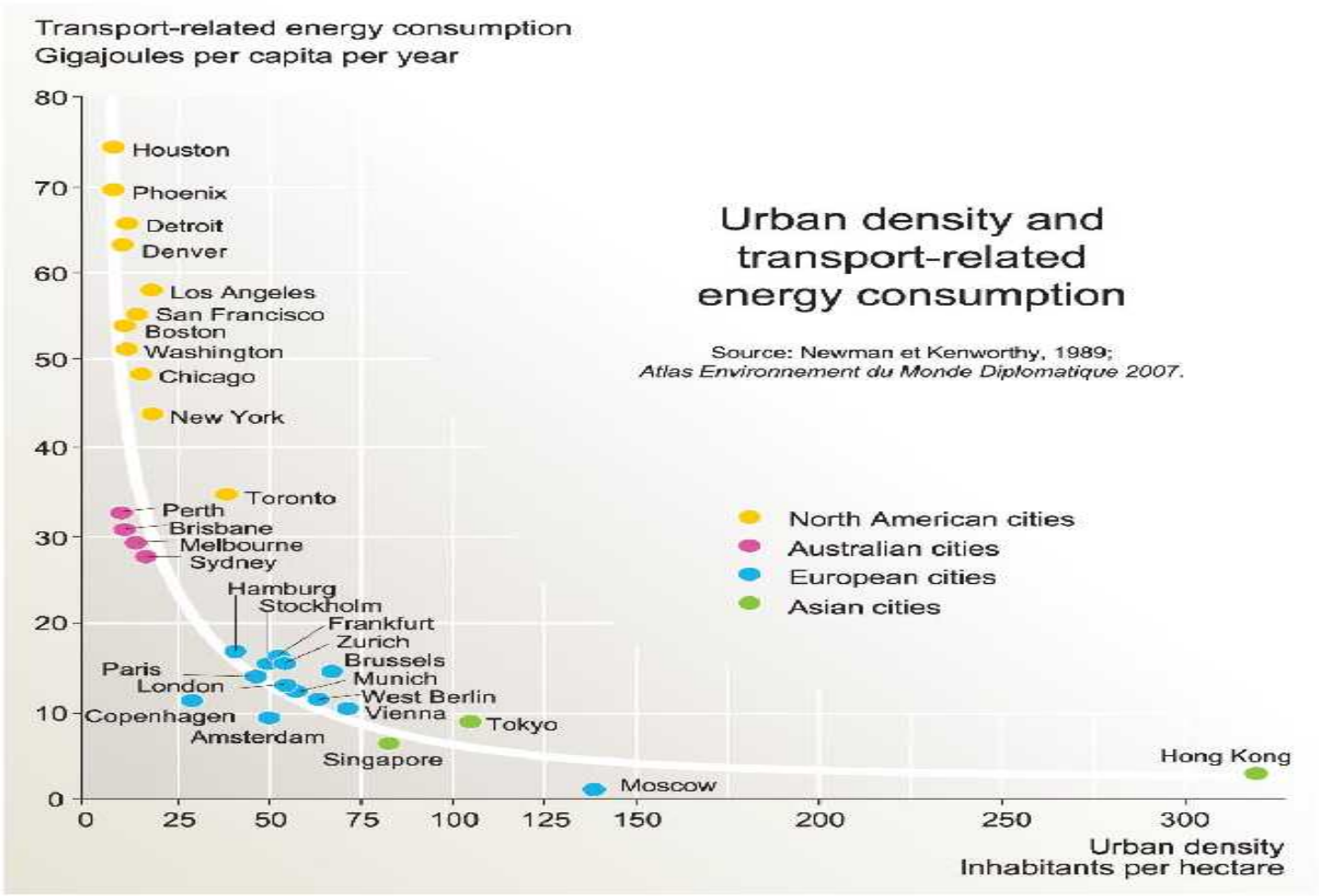


February 2009 National Geographic

- A utility near Austin Texas avoided the need to build a 650 MW power plant by appealing to customers in it's service area to buy ONLY Energy Star efficient appliances!
- Can we afford to ignore success stories like this?

DOE studies “show that 80% of the projected growth in electricity demand could be met by energy efficiency improvements alone”.

Transportation-related Energy Consumption



Similarly, any gains in environmental protection of wildlife habitat and more sustainable agricultural practices might be washed away by the extensive land use requirements necessary in any new waves of exurban development.

Rural land loss (sprawl) as related to each growth factor (1970-90)
(Source data: Census Bureau
100 largest U.S. Urbanized Areas)

We have exactly enough time …

starting NOW!

What is YOUR vision for our energy future?

What will YOU do?

What will your grandchildren think?

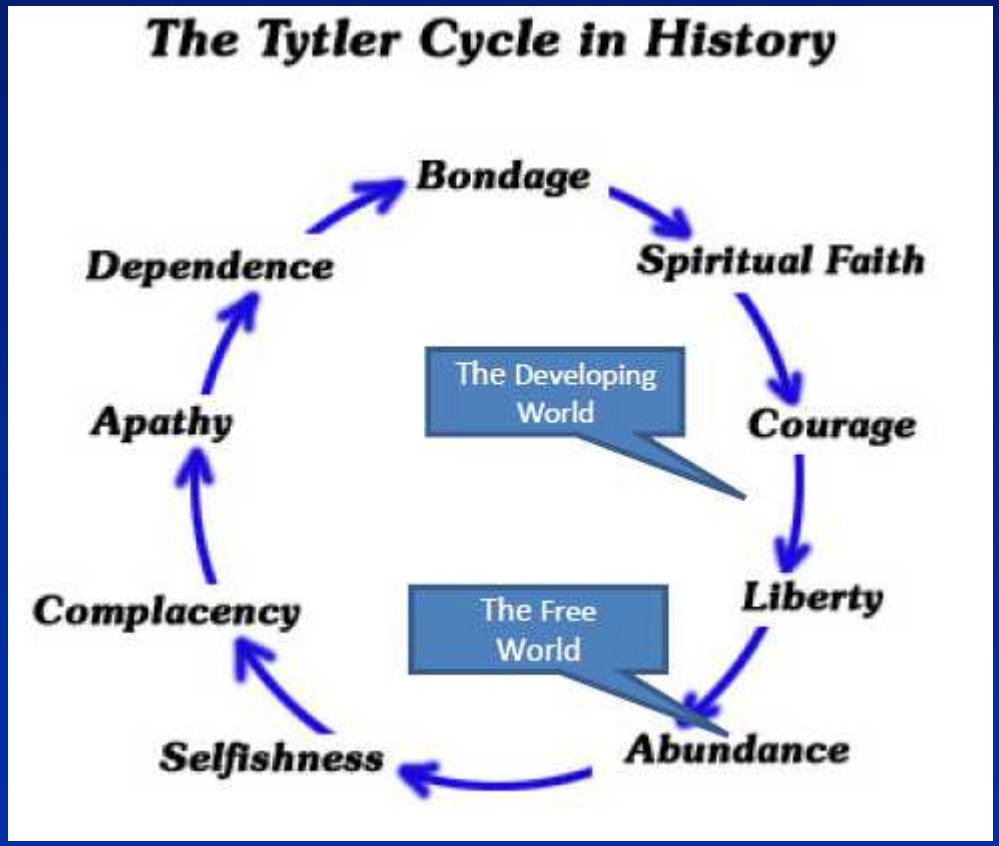
WWJD?

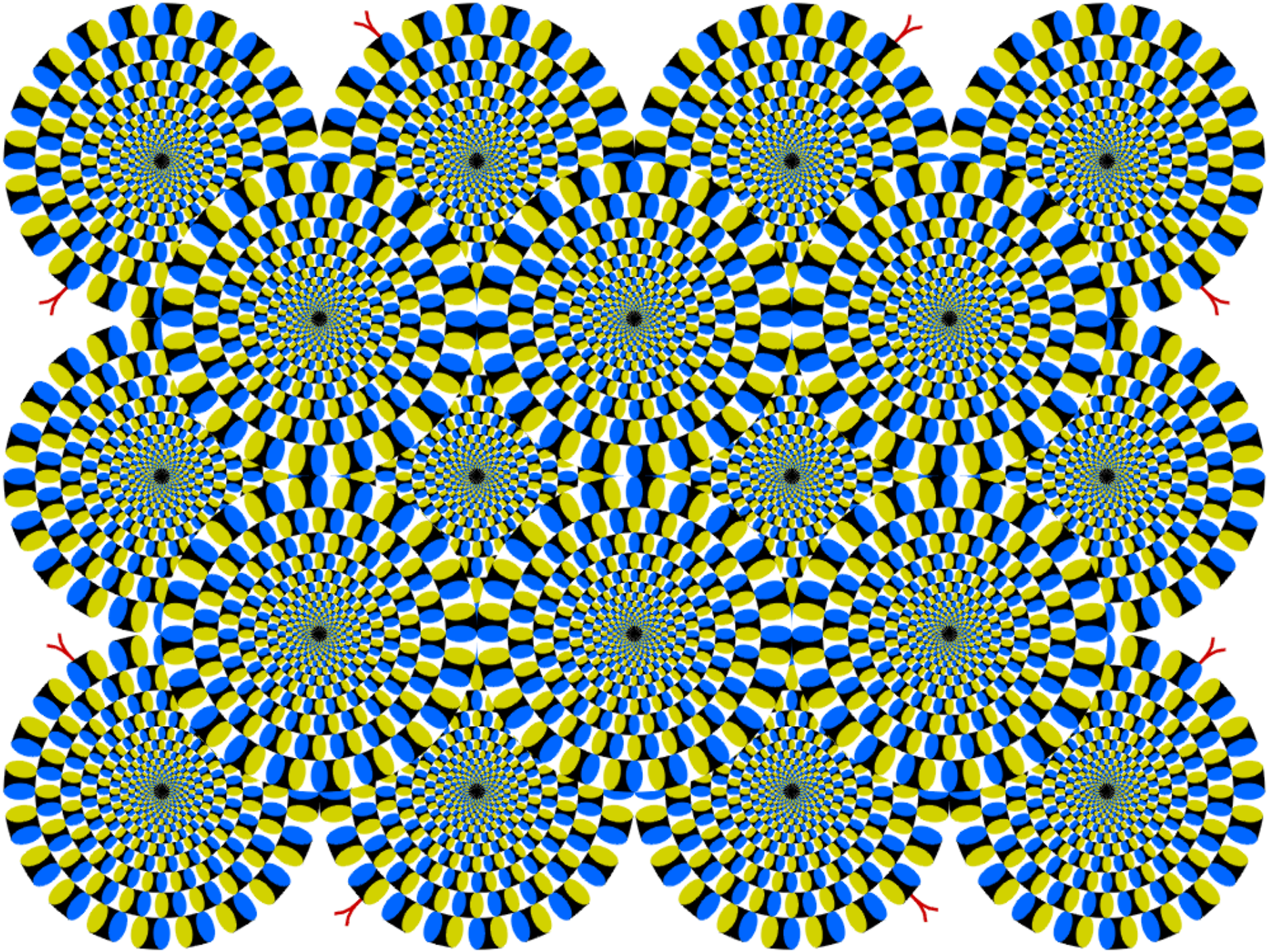
Questions?

"People and nations behave wisely —
once they have exhausted all other alternatives."
— Churchill

Suggested Reading

- Hot, Flat and Crowded by Thomas Friedman
- Collapse by Jared Diamond
- The Omnivore's Dilemma by Michael Poulan
- In Defense of Food by Michael Poulan
- Nukenomics by Ian Jackson
- Beyond Fossil Fools by Joe Shuster
- Power to Save the World: The Truth about Nuclear Energy by Gweneth Cravens
- America the Powerless by Alan Waltar
- Prescription to Save the Planet by Tom Blees


The Tytler Cycle in History
Bondage
Spiritual Faith
Courage
Liberty
Abundance
Selfishness
Complacency
Apathy
Dependence
The Developing World
The Free World



HYPERION
Power Generation

- Uranium hydrided fuel (negative thermal feedback is inherent)
- Thermal output of 70MW
- 1.5m diameter, 2m height
- Weight is within allowed parameters for shipping via truck over roads/rail
- Hyperion Power Modules can be ganged for greater power output
- Lifespan of a module is 5-7 years depending on power load
- For projects with a lifespan beyond that of one power module, two vaults are built and power modules are “leapfrogged” to ensure uninterrupted power
- Security is provided by local personnel, local monitoring, remote monitoring and surveillance