Nuclear Energy for Electricity

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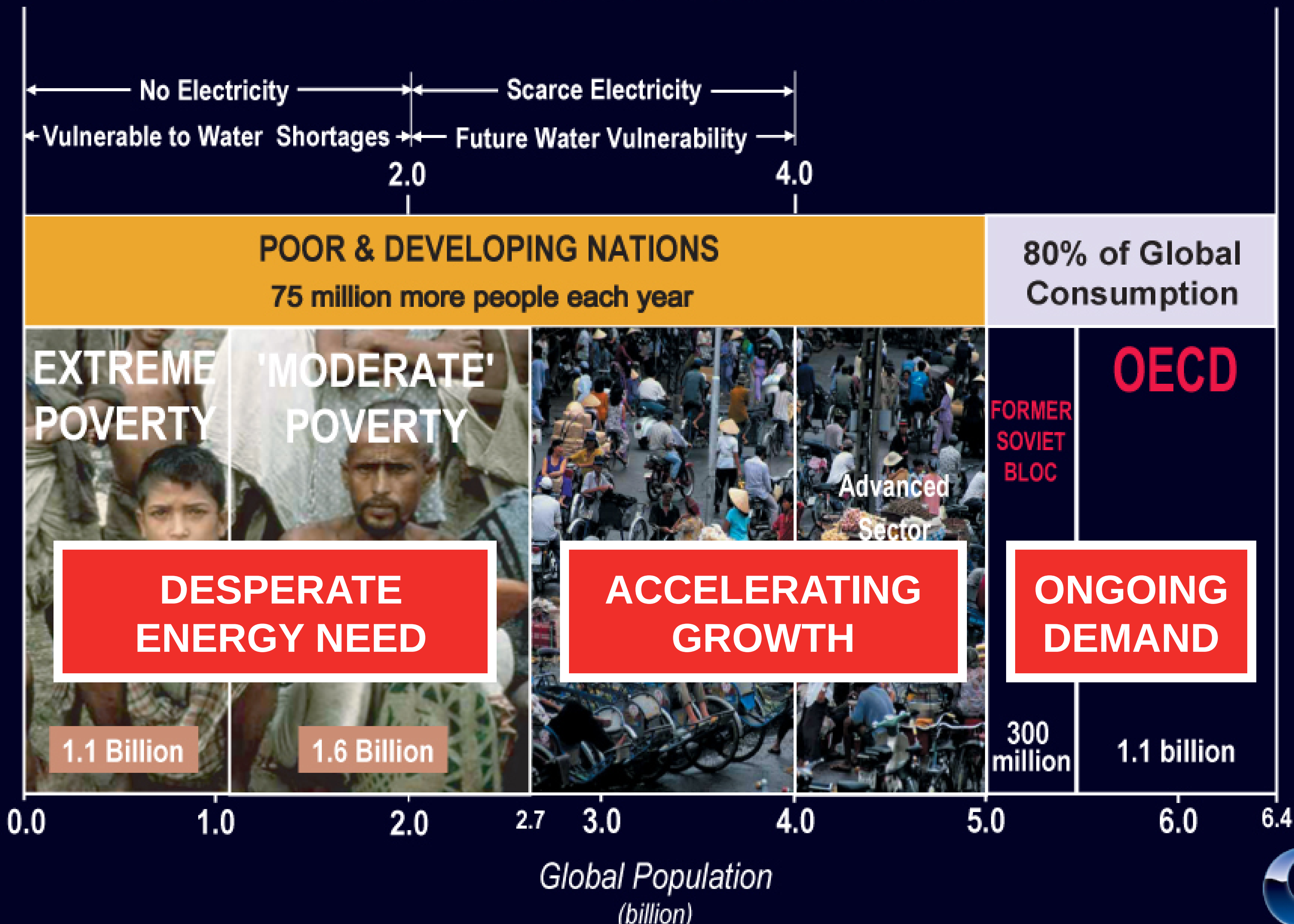
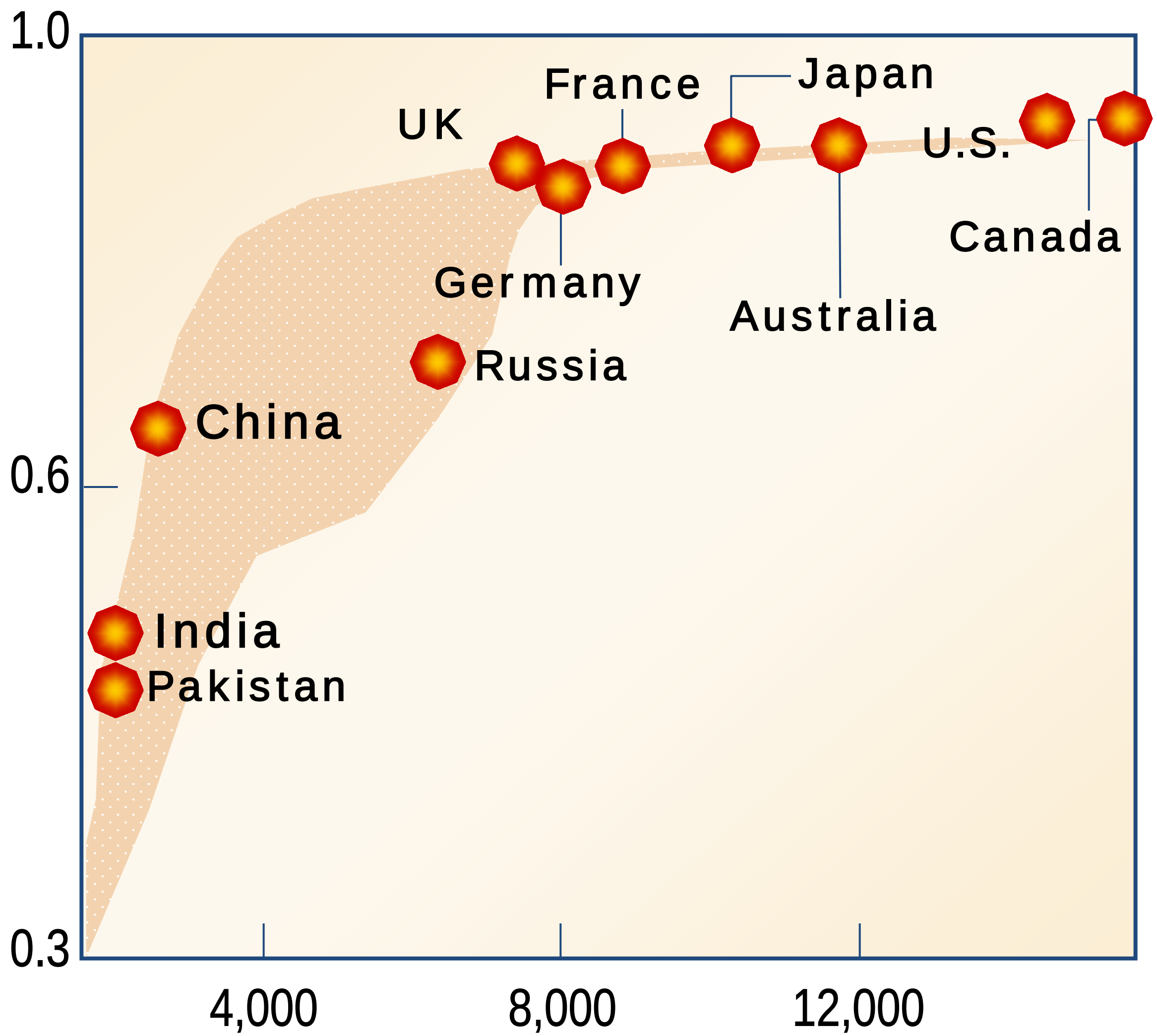
Today's Discussion

- Background
  - -Electricity Supply
  - -Fukushima
  - -Uranium Fuel
  - -Plant Design
  - -Land Use
  - -Public Safety
  - -Plant Security
- Performance
  - -Capacity Factor
  - -Production Costs
  - -Fuel Costs
- Status and Outlook
  - -World Electricity Generation
  - -Demand Growth
  - -U.S. and California Generation
  - -License Renewal for Existing U.S. Plants
  - -Potential for New U.S. Plants
- Challenges

A World of Extremes





Annual Electricity Use kWh/Capita

World Net Electricity Generation By Region

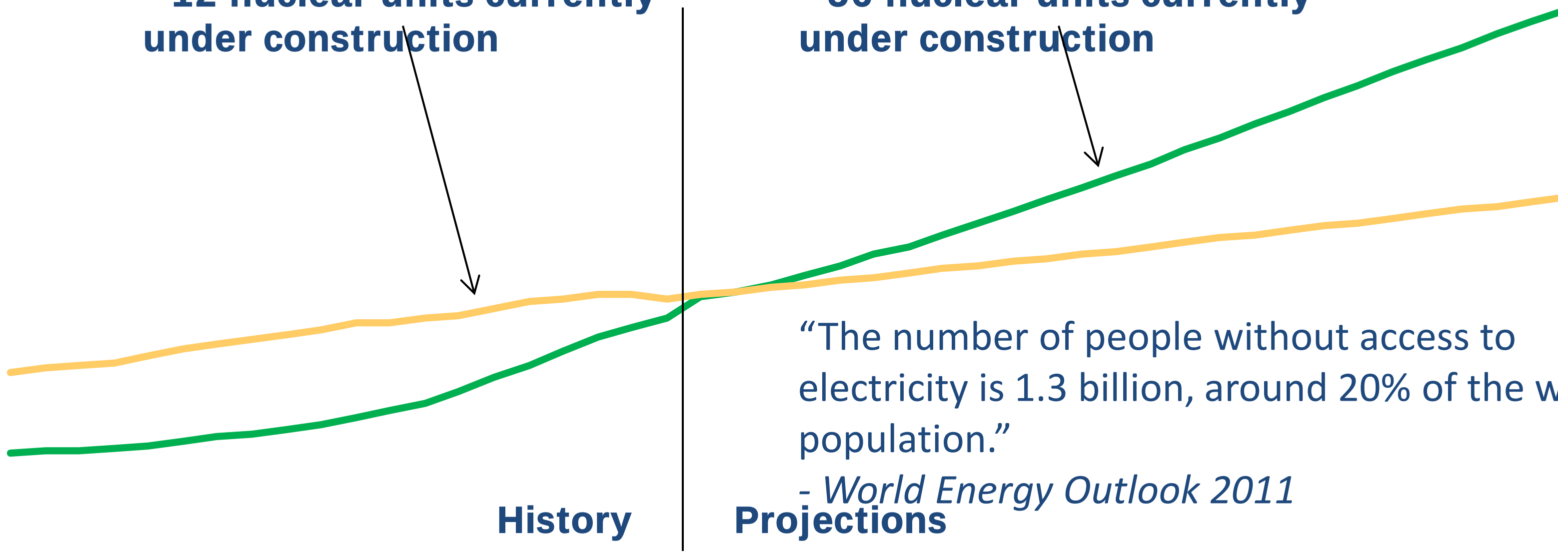
1990-2035, trillion kilowatt-hours

<u>OECD countries</u>

- 1.2% annual demand growth
- 12 nuclear units currently under construction

<u>Non-OECD countries</u>

- 3.3% annual demand growth
- 56 nuclear units currently under construction



"The number of people without access to electricity is 1.3 billion, around 20% of the world's population."

- *World Energy Outlook 2011*

World Overview

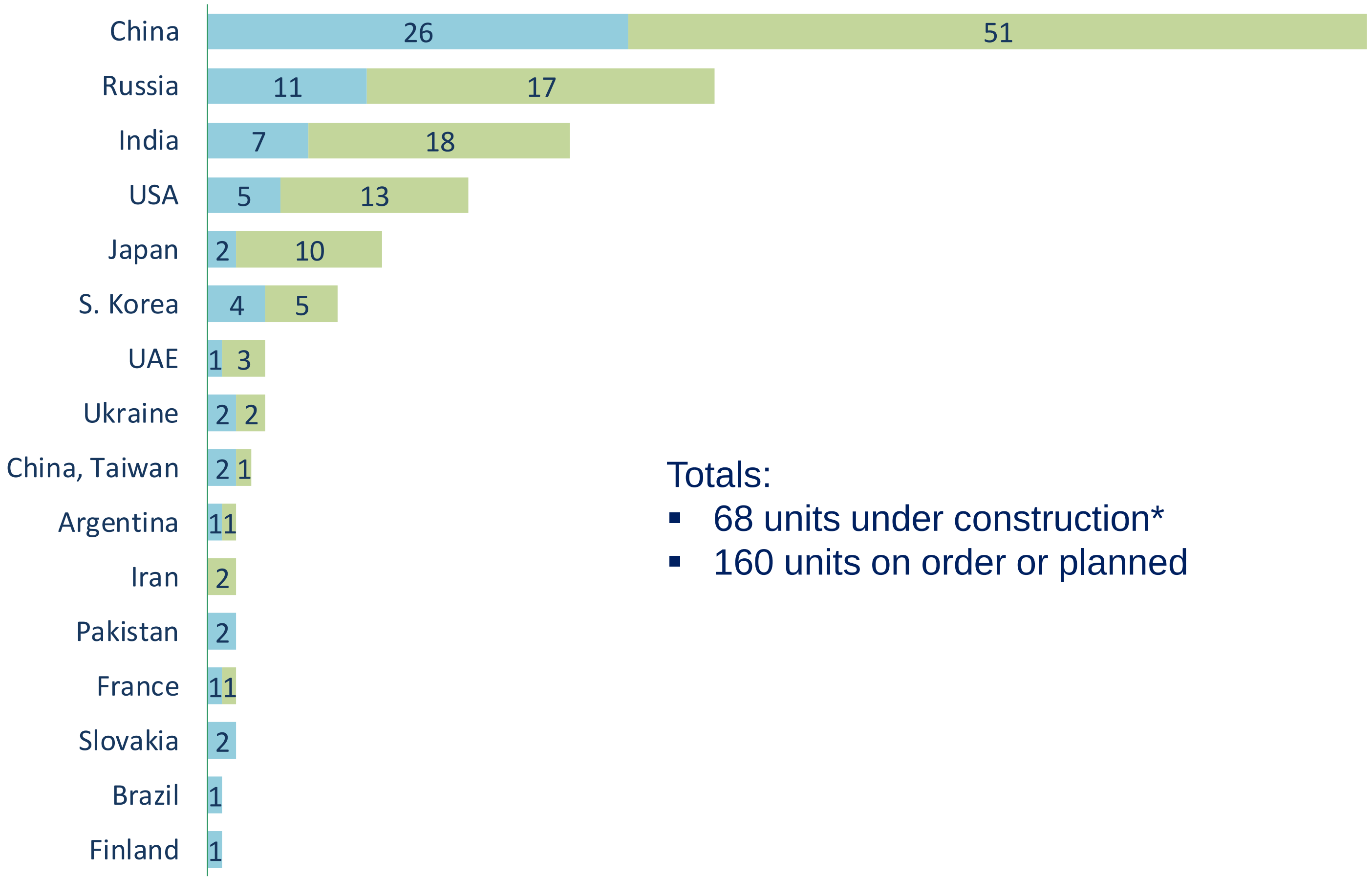
Energy-related Carbon Dioxide Emissions

- Global emissions
  - Mainly from power sector
  - 14% increase in emissions by 2020
  - 19% increase in emissions by 2030
- United States ranked #1 contributor- now #2
- China ranked #1 contributor

Potential supply-side solutions to the Energy Problem (Steve Chu list)

- Oil
- Coal, tar sands, shale oil, …
- Gas
- Fission (nuclear)
- Wind
- Solar photocells
- Bio-mass

Reactors Under Construction or Planned



Totals:

- 68 units under construction*
- 160 units on order or planned

Sources: International Atomic Energy Agency and project sponsors for units under construction and World Nuclear Association for units on order or planned.

**Chart includes only countries with units under construction. **Countries planning new units are not all included in the chart.*

Planned units = Approvals, funding or major commitment in place, mostly expected in operation within 8-10 years.

Overview

NPPs Distribution in mainland China

China - Challenge and Strategy

- Unbalanced Energy Supply Structure
- Pressure from GHG Emission
- Risks of Oil and Gas Supply

- Sustainable increase of demand on electricity
- Public challenges of nuclear due to the Fukushima accident

Fuqing Plant Site in China (six units)

Background

- **Uranium Fuel**
- Plant Design
- Land Use
- Public Safety
- Plant Security

Uranium Fuel – Processing

- Mining and Milling → Uranium Oxide
- Conversion and Enrichment
  - Uranium Hexafluoride
  - Isotopes of Uranium U-238 and U-235
  - U-238 – accounts for more than 99 percent
  - U-235 – less than 1% of uranium by weight (1% is increased to 3-5%)

Uranium Fuel – Ceramic Pellets

Uranium fuel pellets are the size of a fingertip.

Contain as much energy as:

- 17,000 cubic feet of natural gas
- 1,780 pounds of coal
- 149 gallons of oil

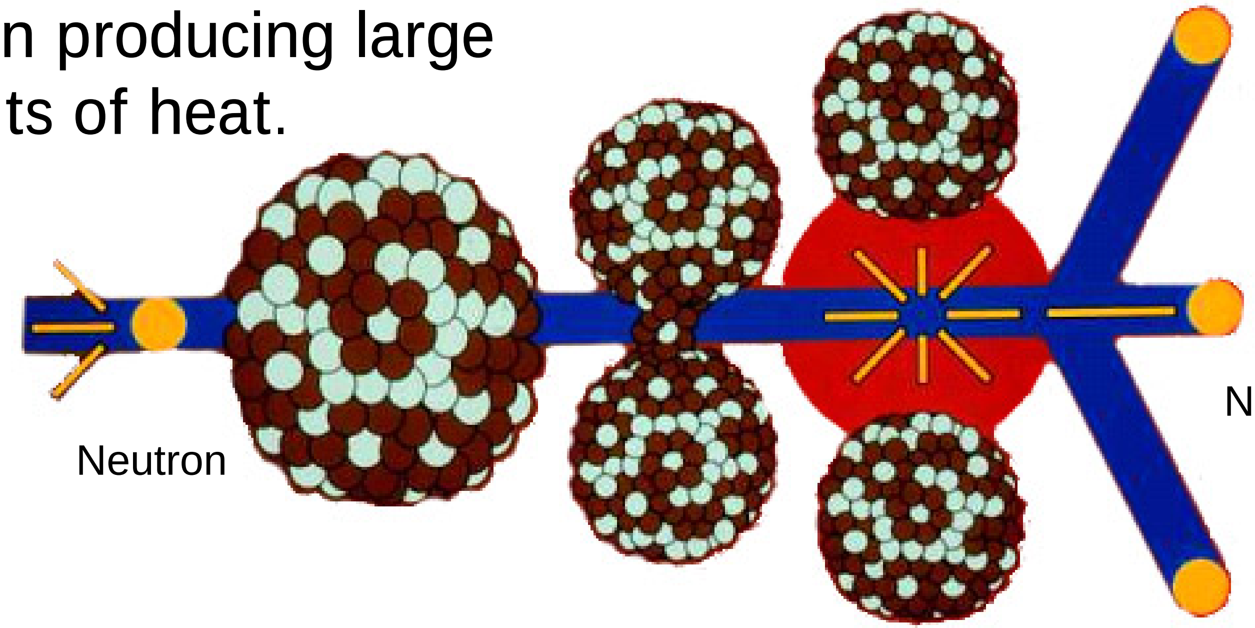
Quarter for scale purpose only

Uranium Fuel – Fuel Rods and Assemblies

- Pellets are placed and sealed inside metal tubes called fuel rods
- Rods are grouped in bundles and form a fuel assembly – 14 feet tall
- Multiple assemblies power a reactor for 36 to 54 months
- Refueling occurs about every two years

Uranium Fuel – Nuclear Fission Process

The fission process occurs when atoms are split in a controlled reaction producing large amounts of heat.



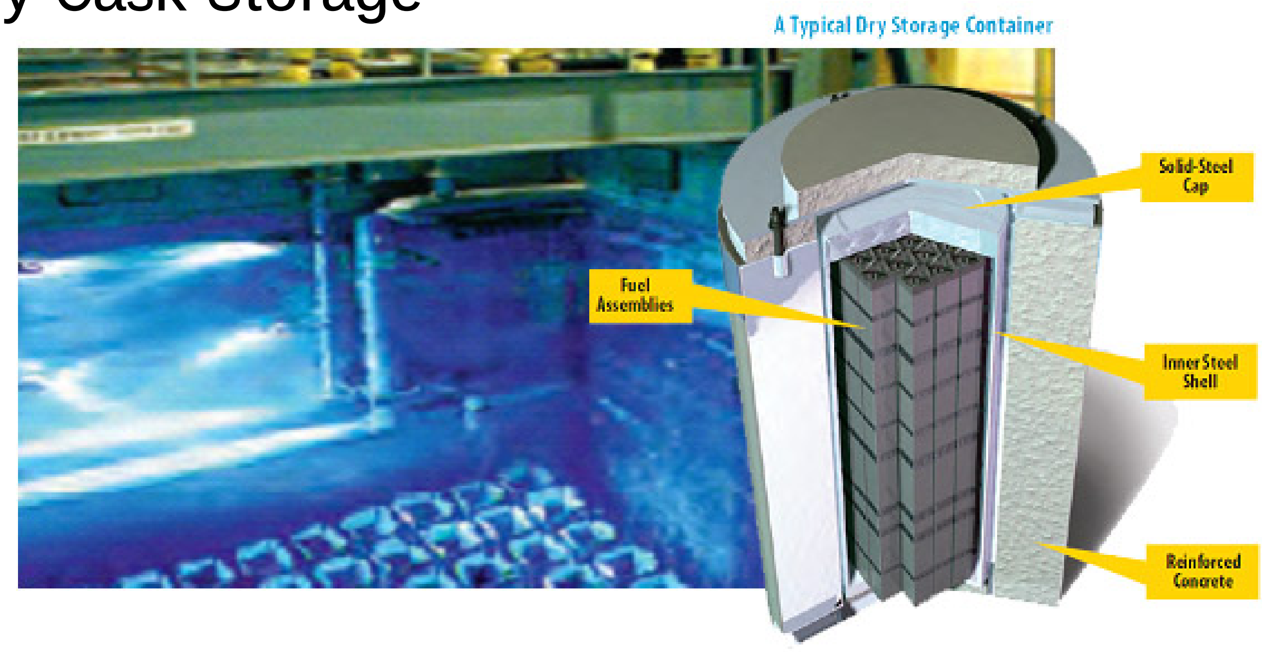
The heat turns into steam which drives a turbine to produce electricity.

Uranium Fuel – Used Fuel Storage

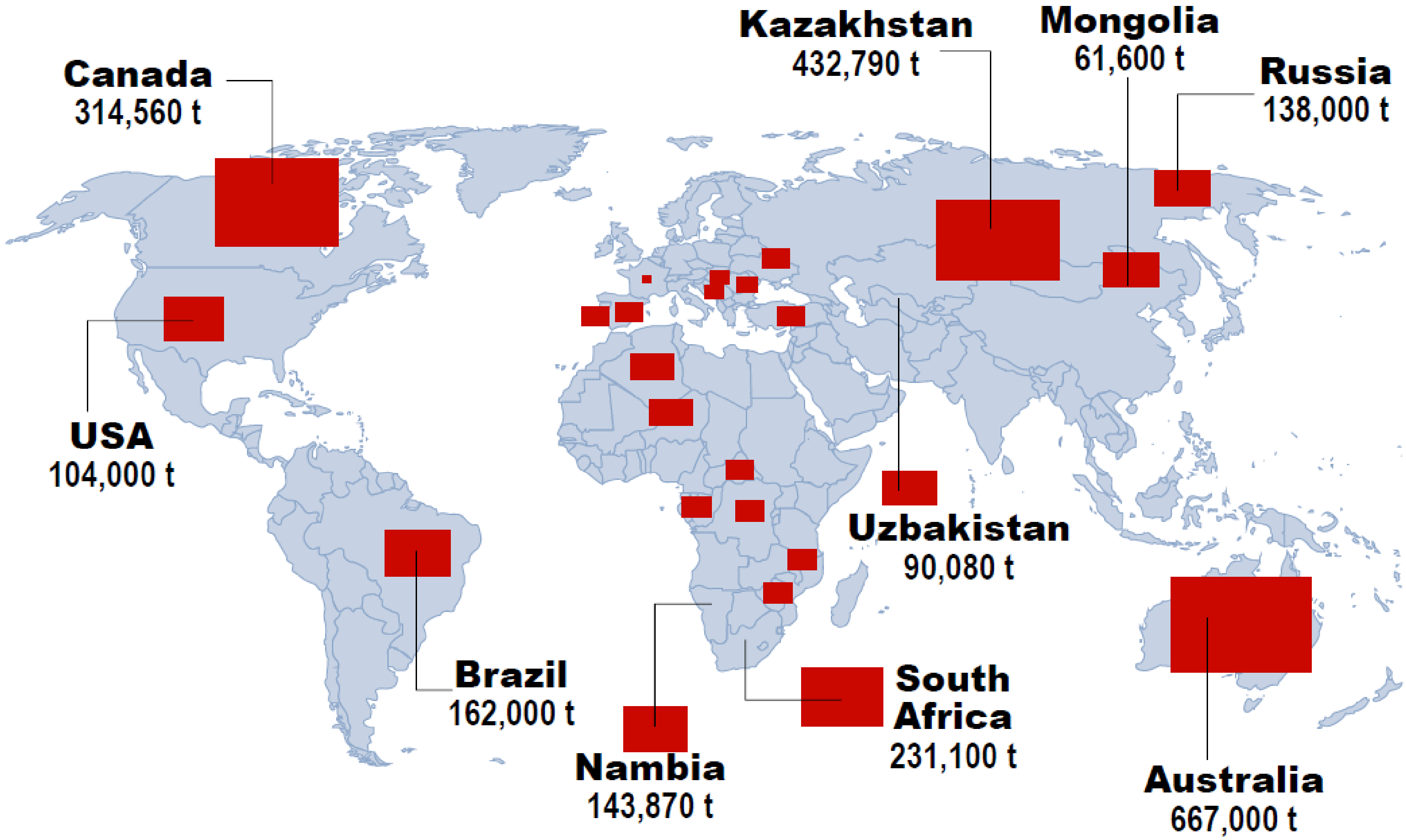
Used fuel is a solid material safely and securely stored at nuclear plant sites.

Step 1 - Spent Fuel Pool

Step 2 – Dry Cask Storage



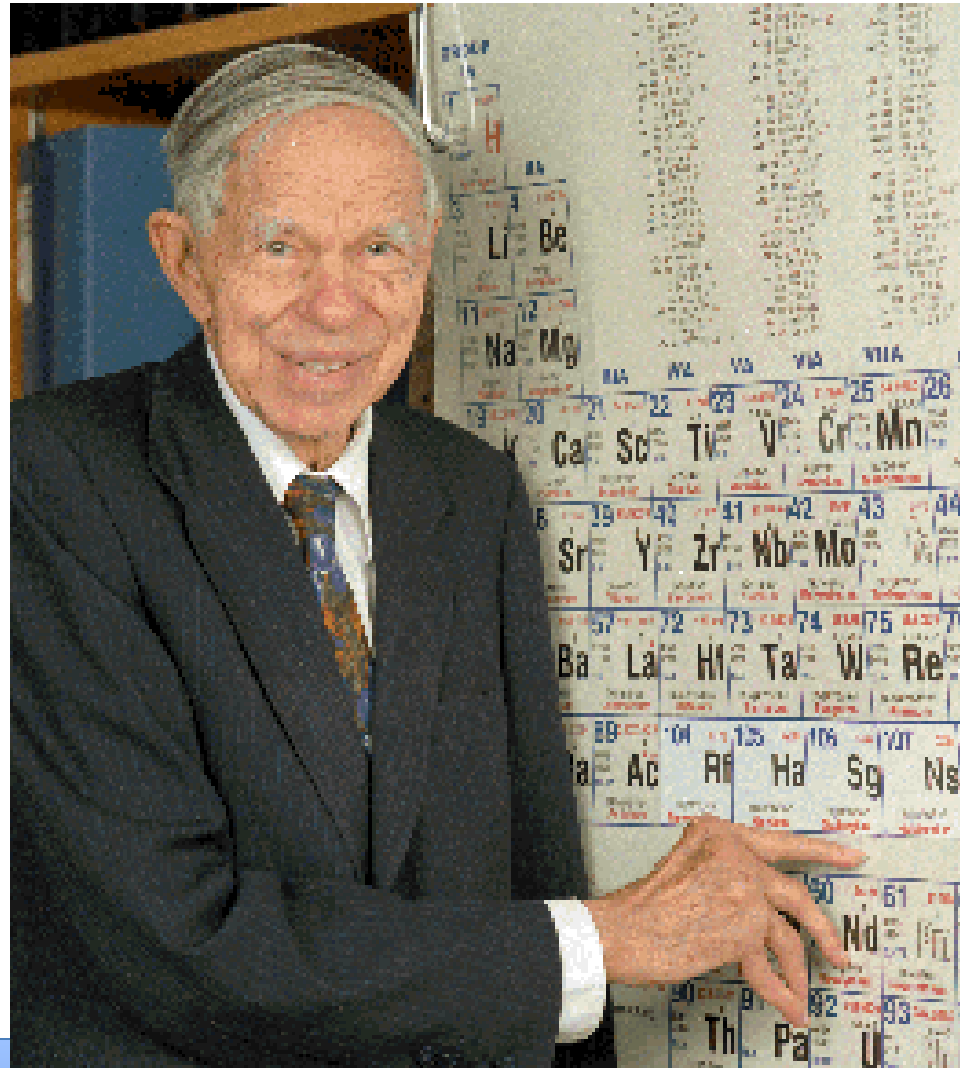
Uranium Fuel – Availability



Source: British Nuclear Energy Society, September 2005

25

Glenn T. Seaborg – Nobel Laureate from CA



Madame Marie Curie --- 1st Nobel Prize 1911

Background

-Uranium Fuel

-**<u>Plant Design</u>**

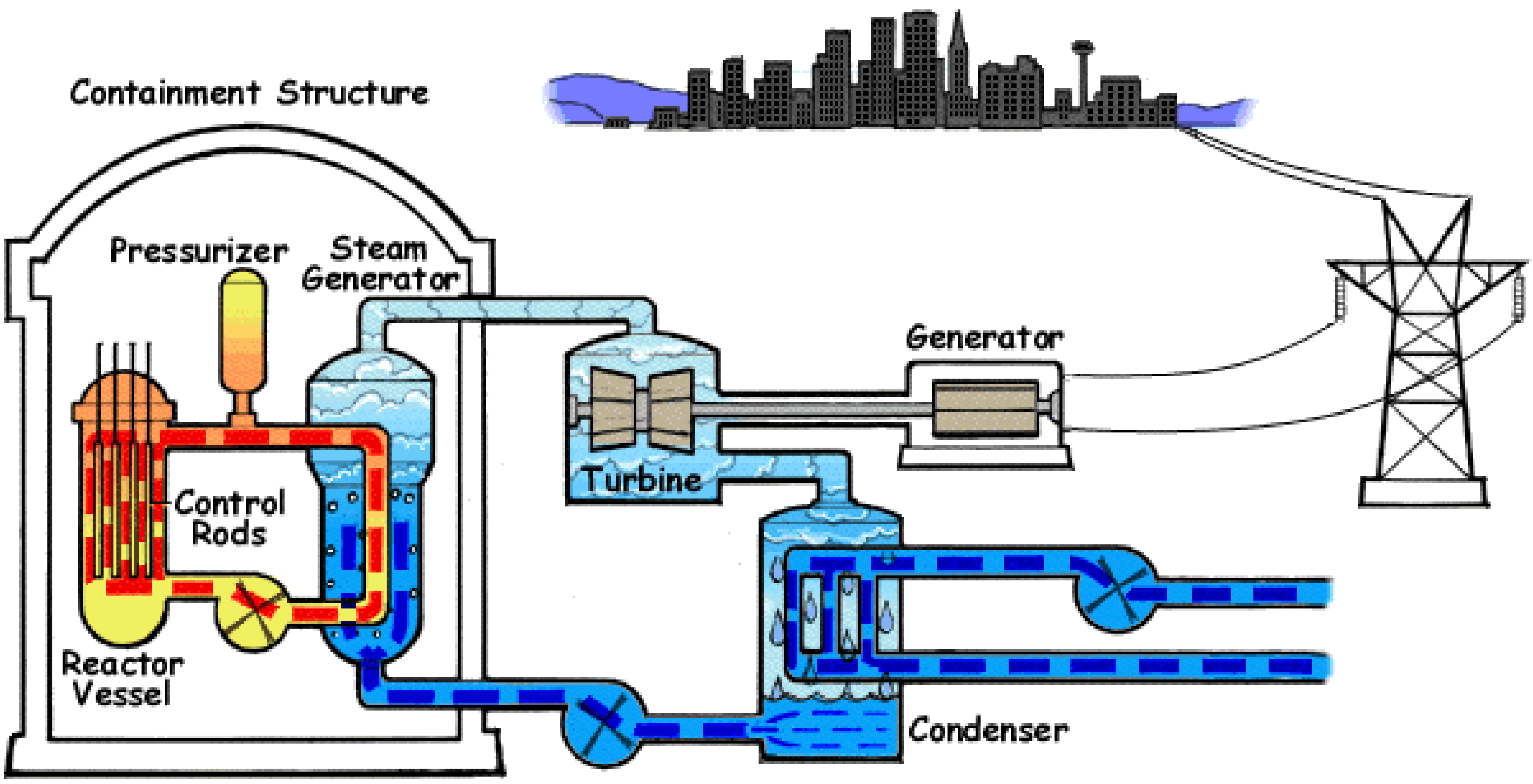
-Land Use

-Public Safety

-Plant Security

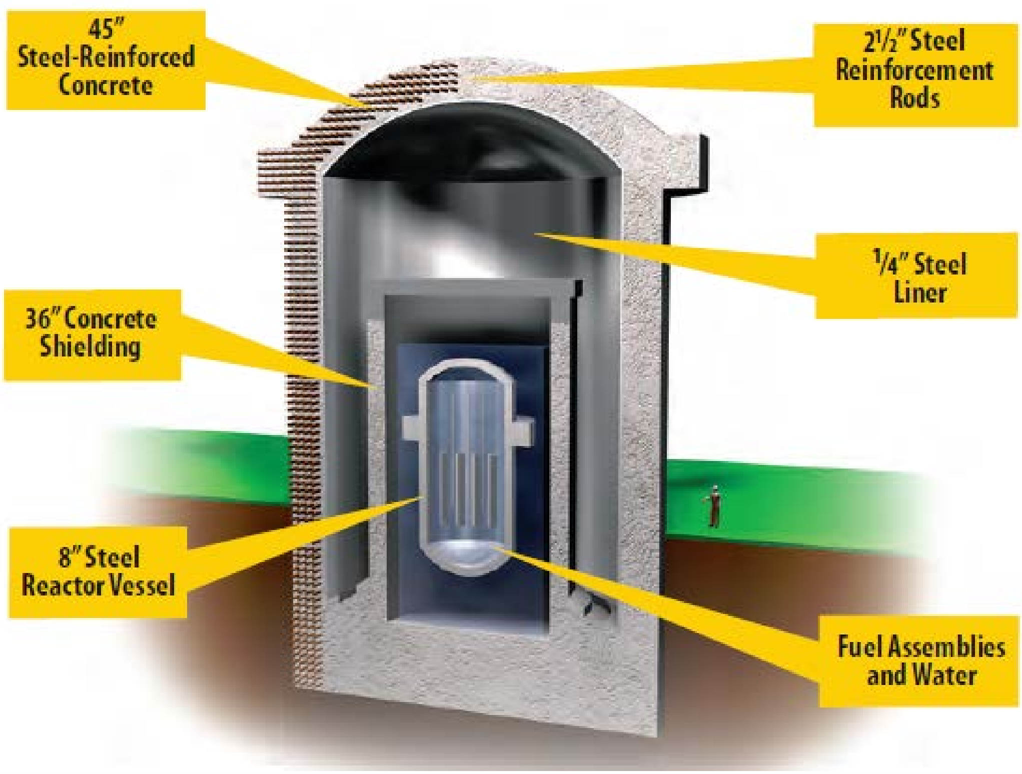
Plant Design – How a Nuclear Plant Works

Pressurized Water Reactor



Plant Design – Safety Systems

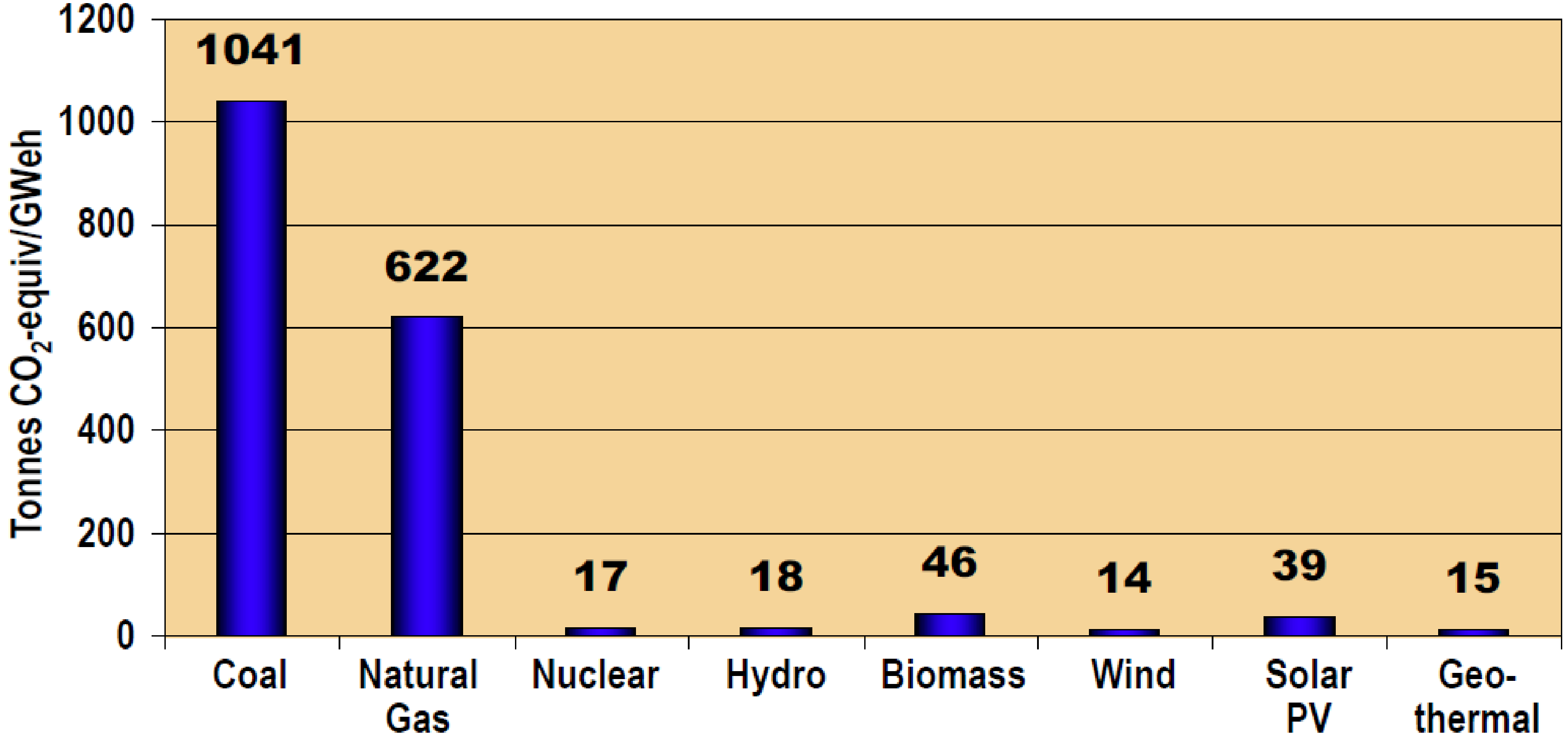
- Nuclear power plants have multiple back-up safety systems, including automatic shutdowns
- Multiple safety barriers - containment



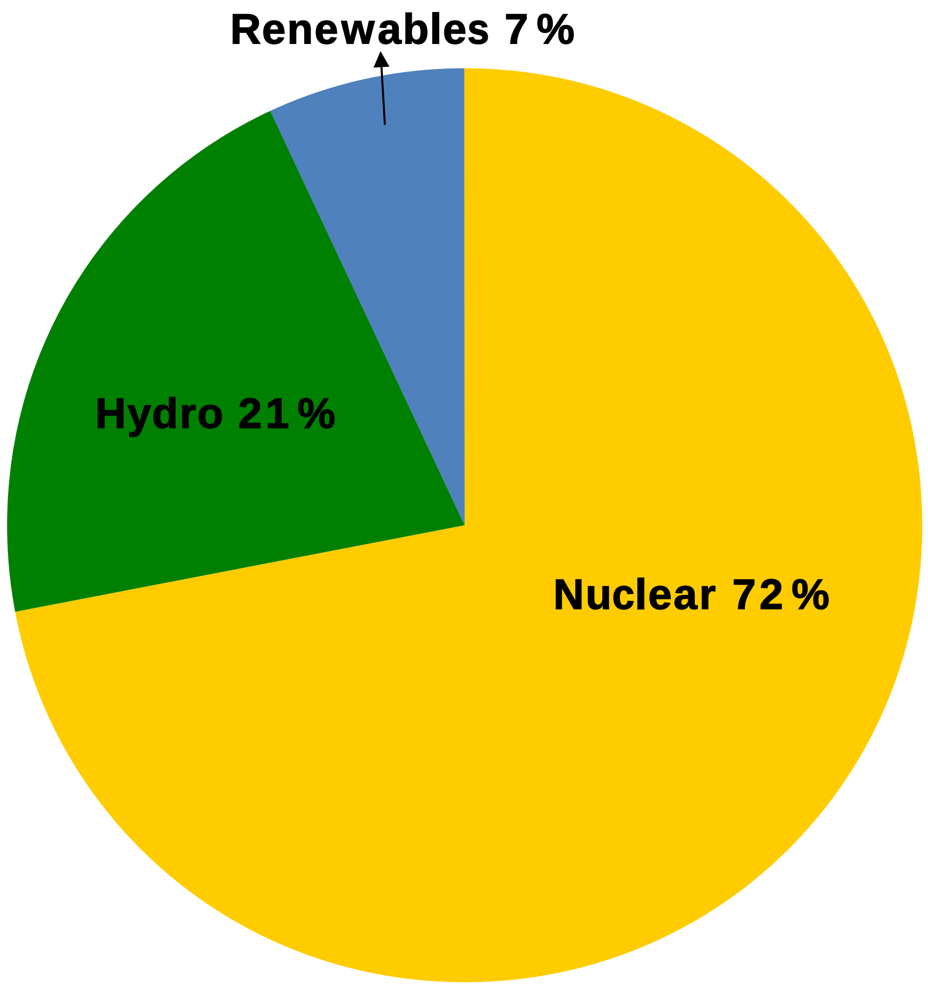
Plant Design – Addressing the Environment

- Air
  - No emission of greenhouse gases
  - U.S. plants displace 680 million metric tons of CO_2/yr
  - Equivalent to 131 million passenger cars/yr
- Water (once-through cooling)
  - Marine environment protective measures
- Solid Waste
  - Used fuel – safely and securely stored, fully contained
  - Long-lived

Plant Design - Life Cycle CO2 Emissions Analyses



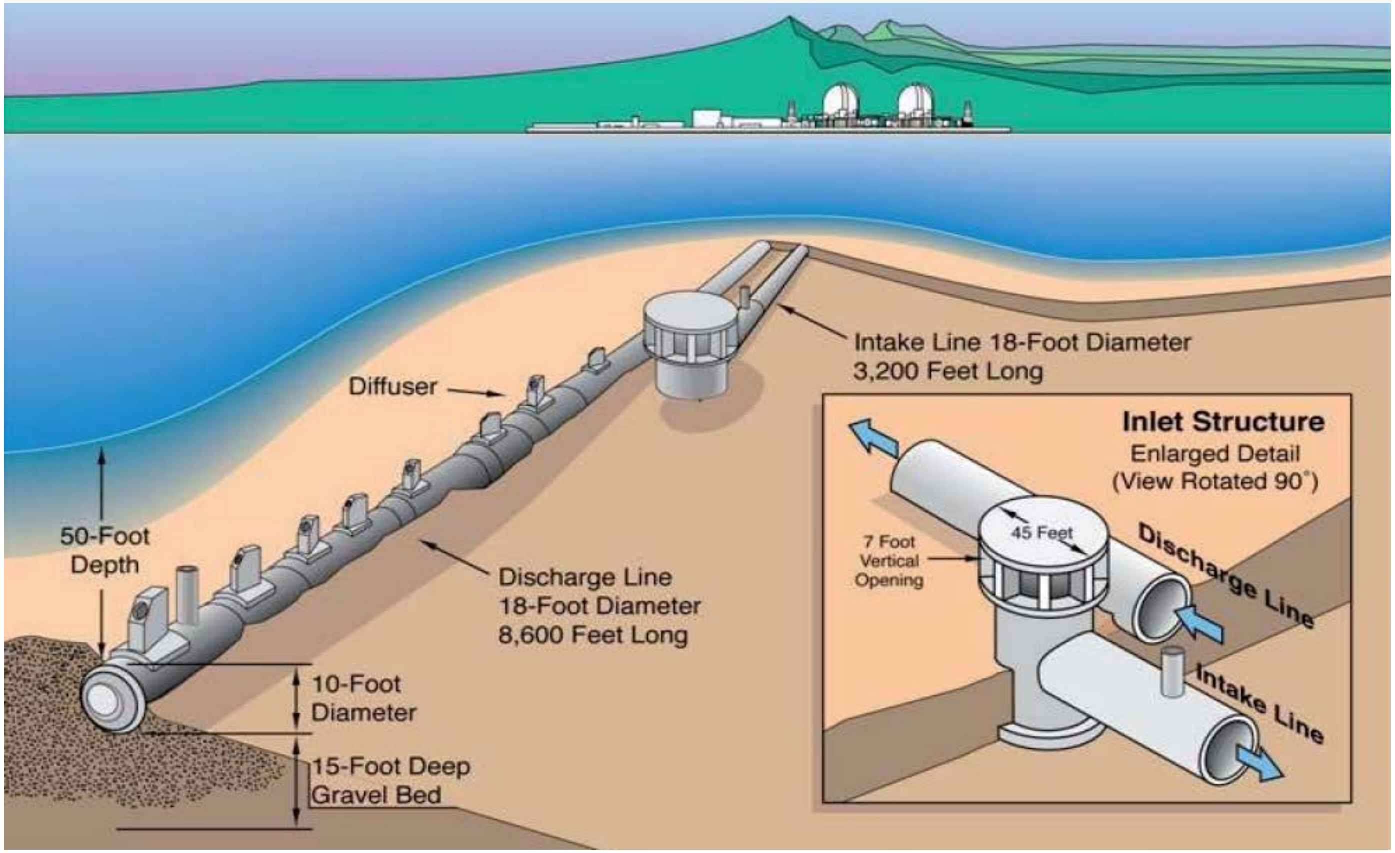
Plant Design – U.S. Emission-Free Power Sources



Plant Design – Intake and Discharge Structures

"Marine environment effects are fully mitigated."

– Coastal Commission



Plant Design - Environmental Care

Wheeler North Giant Kelp Reef

171-acre artificial reef off San Clemente

Adds significant marine habitat

Creates marine habitat for as many as 50 varieties of fish and invertebrates

Increases recreational opportunities

Cost - $46 million

Plant Design - Environmental Care

Creates more than 150 acres of coastal wetlands

Restores tidal flows, natural habitat and vegetation

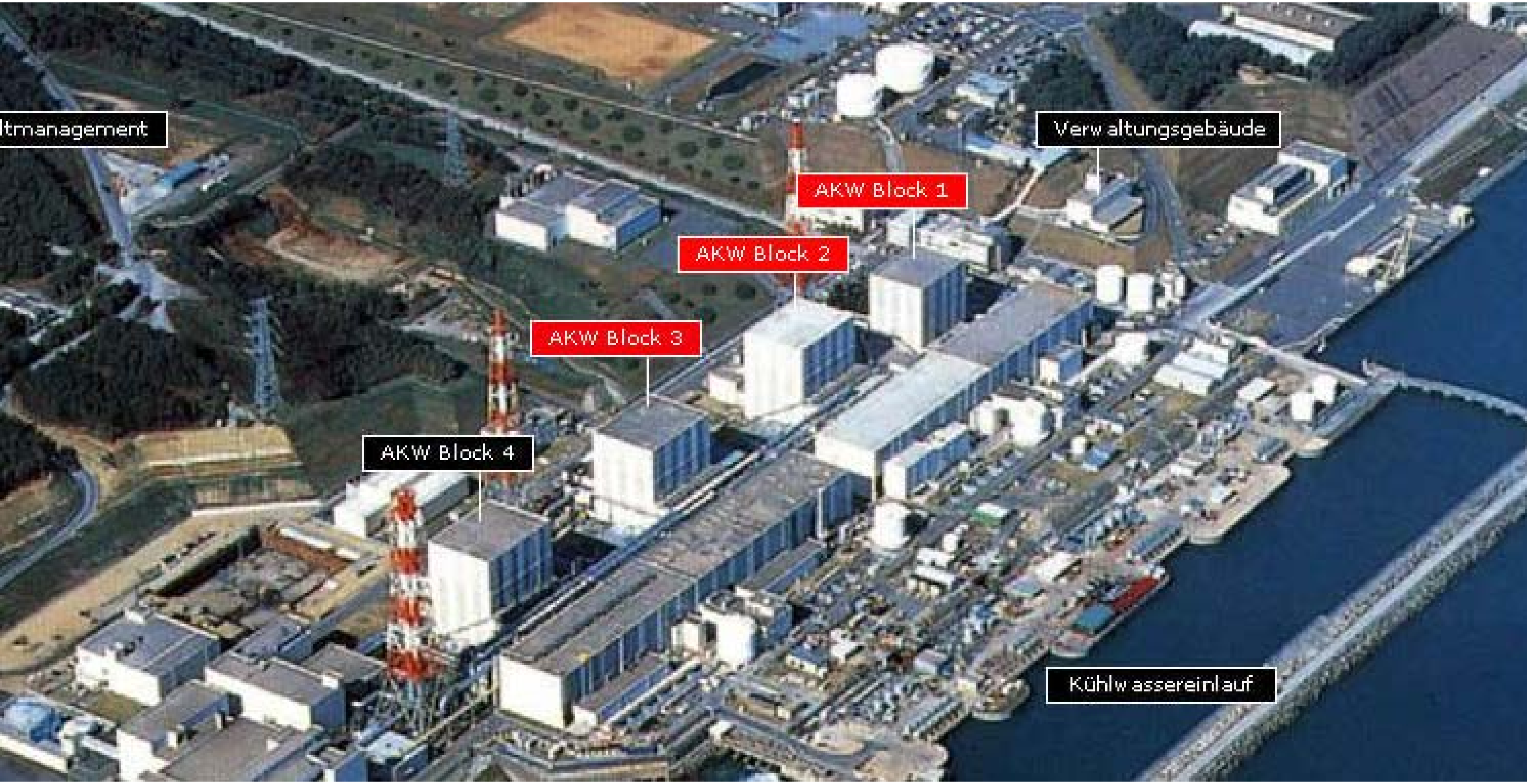
Protects the wetlands from flood-borne sediment buildup

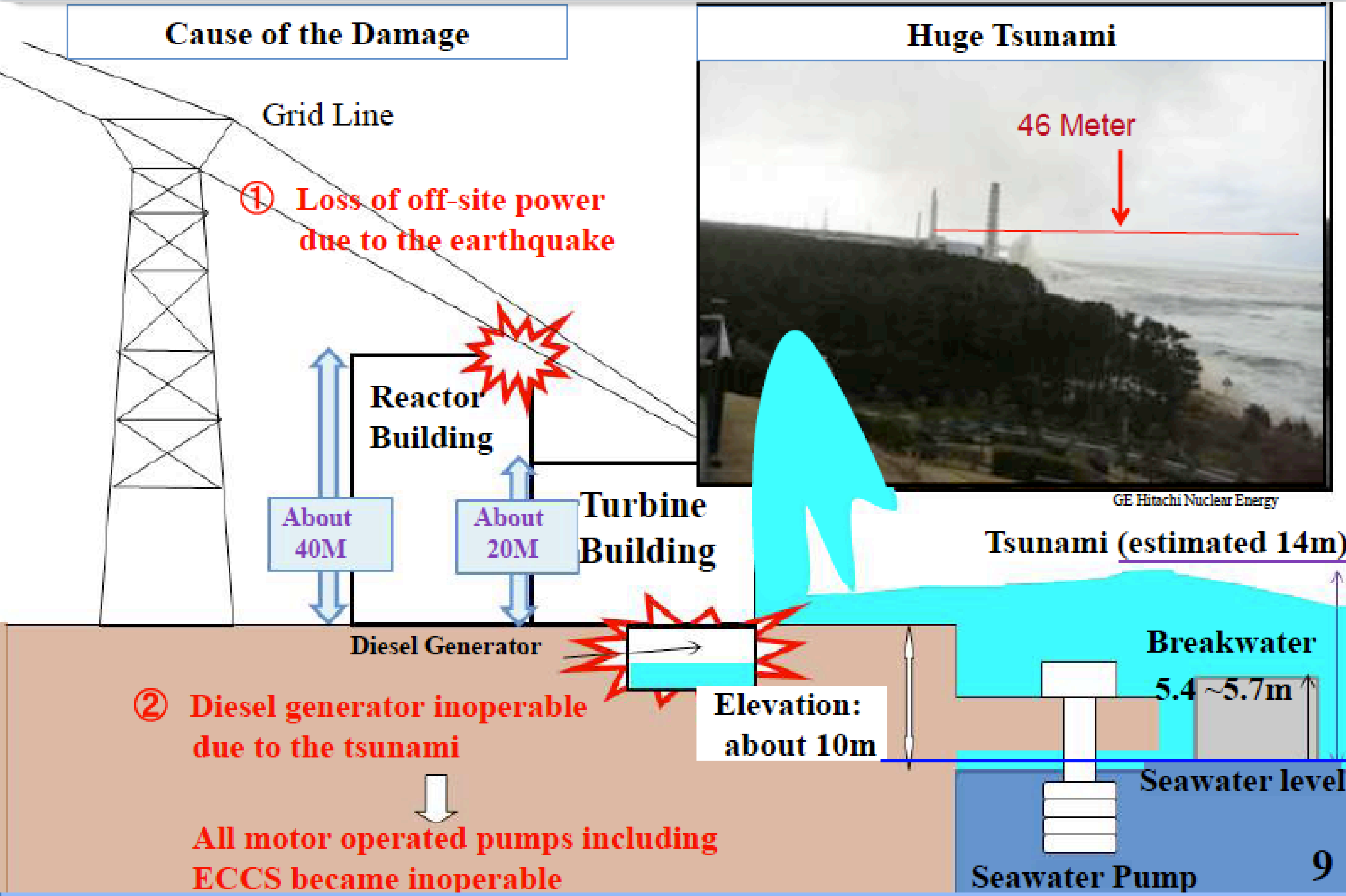
Significantly increases fish and wildlife

Cost - $90 million

San Dieguito Wetland Restoration

Fukushima Daiichi (Plant I) March 2011
Unit I - GE Mark I BWR (439 MW), Operating since 1971
Unit II-IV - GE Mark I BWR (760 MW), Operating since 1974




Cause of the Damage
Huge Tsunami
Grid Line
① Loss of off-site power due to the earthquake
46 Meter
Reactor Building
About 40M
About 20M
Turbine Building
GE Hitachi Nuclear Energy
Tsunami (estimated 14m)
Diesel Generator
② Diesel generator inoperable due to the tsunami
All motor operated pumps including ECCS became inoperable
Elevation: about 10m
Breakwater
5.4 ~5.7m
Seawater level
Seawater Pump
9

Lessons Learned by Japan

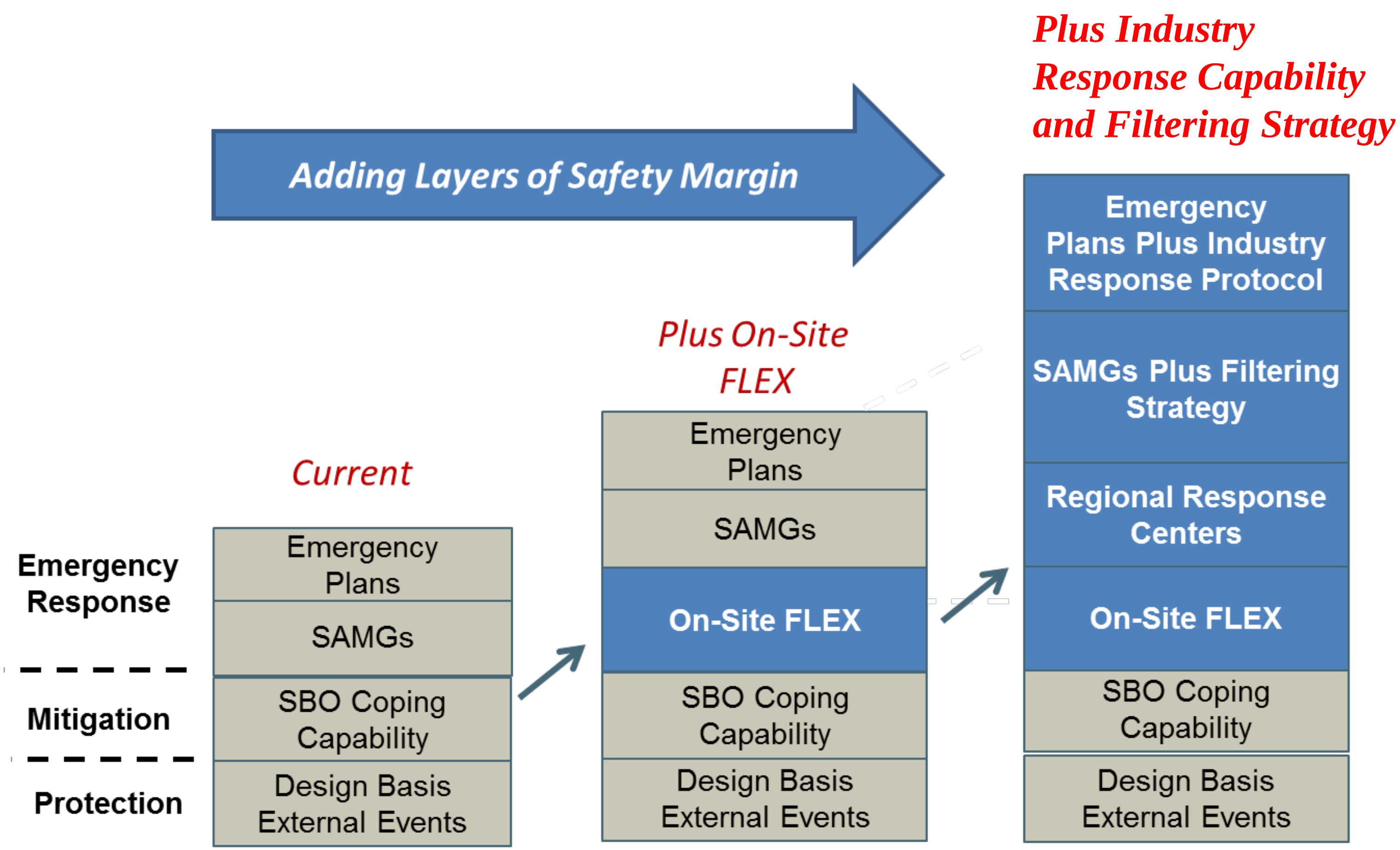
- Earthquake design basis adequate

- Tsunami design basis and emergency planning insufficient for NPP and other key infrastructure

- Must diversify, increase and secure onsite power supply to avoid core damage

32

U.S. Industry Post-Fukushima Actions



Perspective

Background

-Uranium Fuel

-Plant Design

-**Land Use**

-Public Safety

-Plant Security

Land Use – Requirements

Land required for 1000 megawatts:

-**Nuclear ... 1,000 acres (operates at 90% capacity factor)**

-Solar ... 10,000 acres

-Wind ... 50,000 acres

- Both wind and solar are intermittent resources (operate at approx. 30% capacity factor)
- Need gas-fired back-up for grid reliability

Background

-Uranium Fuel

-Plant Design

-Land Use

-**<u>Public Safety</u>**

-Plant Security

Public Safety – Top Priority

Safety is highest priority for nuclear power plants.

- Power plants have multiple barriers
- Redundant and diverse plant safety systems
- NRC is effective regulator
- Additional industry oversight
- Highly-trained personnel and licensed operators
- Procedural compliance

U.S.-Style Nuclear Reactor—Defense in Depth

Background

-Uranium Fuel

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-Land Use

-Public Safety

-Plant Security

Plant Security – Extensive Protective Measures

Nuclear plants are among the most secure and safest industrial facilities in the nation.

- Physical security measures – multiple access barriers
- Armed security forces
- Plant and perimeter surveillance
- Intrusion detection systems
- Access systems
- Coordination with federal, state, local and intelligence authorities
- NRC inspections and drills

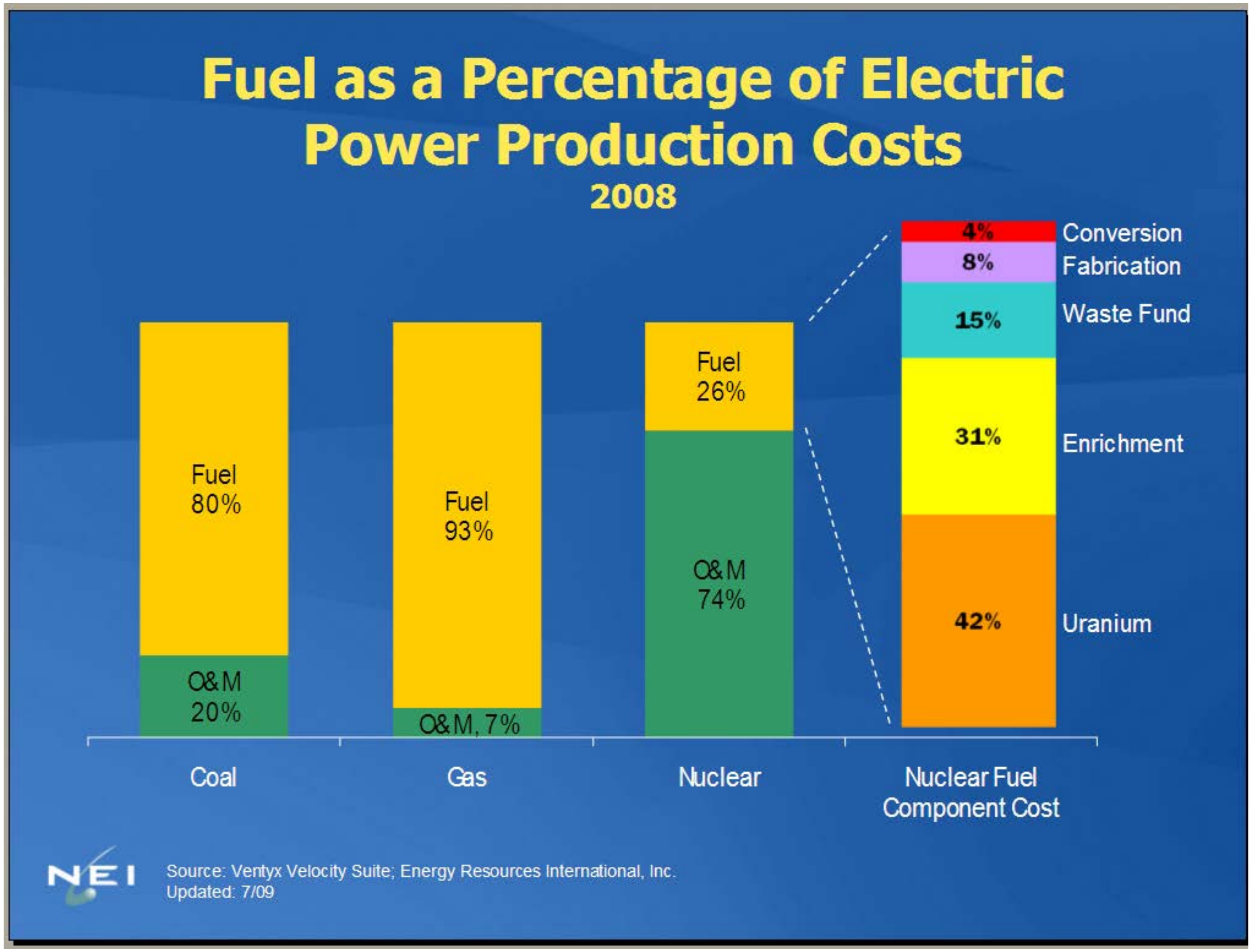
Performance

-Capacity Factors (90% industry average)

-Production Costs

-Fuel Costs

Performance – Fuel Cost Impact



Status and Outlook

- -Demand Growth

-U.S. and California Generation

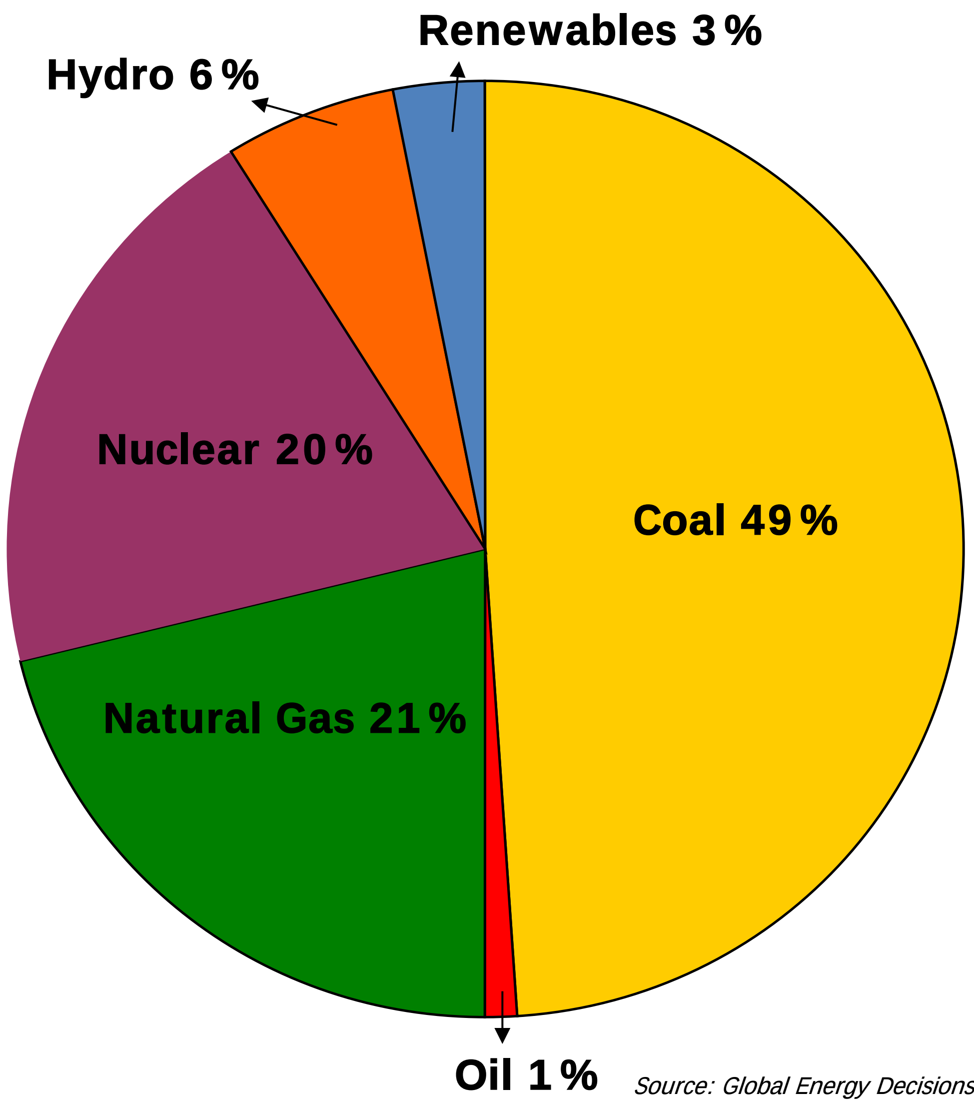
-License Renewal for Existing U.S. Plants

-Potential for New U.S. Plants

Status – United States

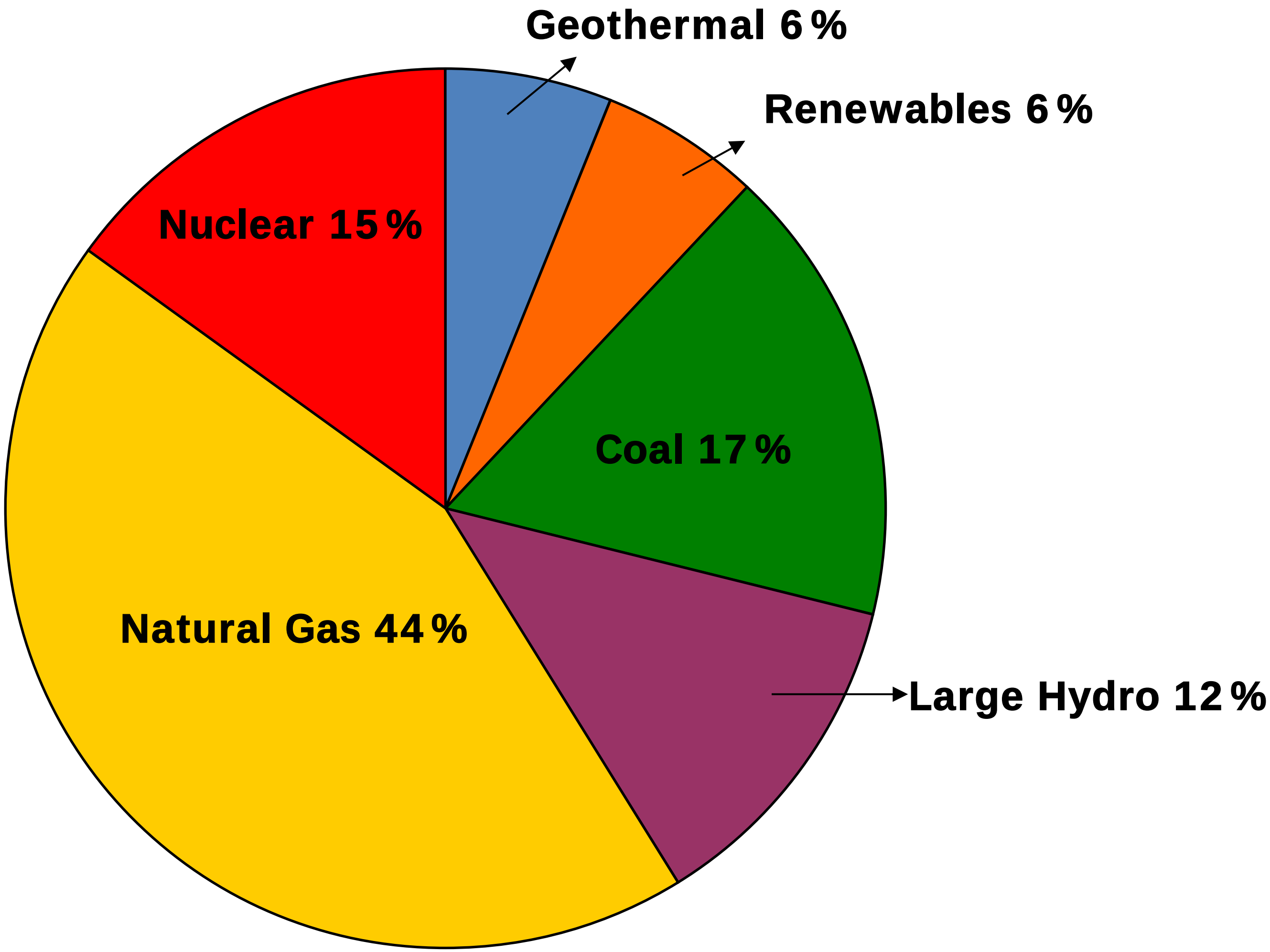
Nuclear Power Plants

Status – U.S. Portfolio Mix



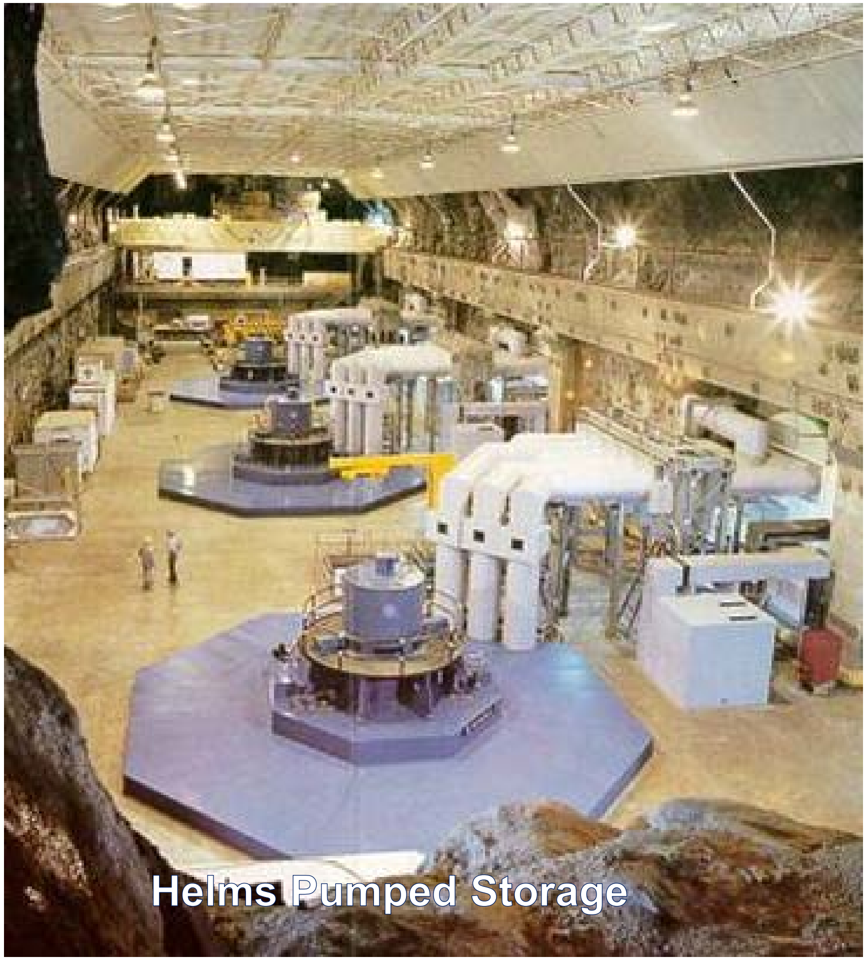
Source: Global Energy Decisions/Energy Information Administration 2008

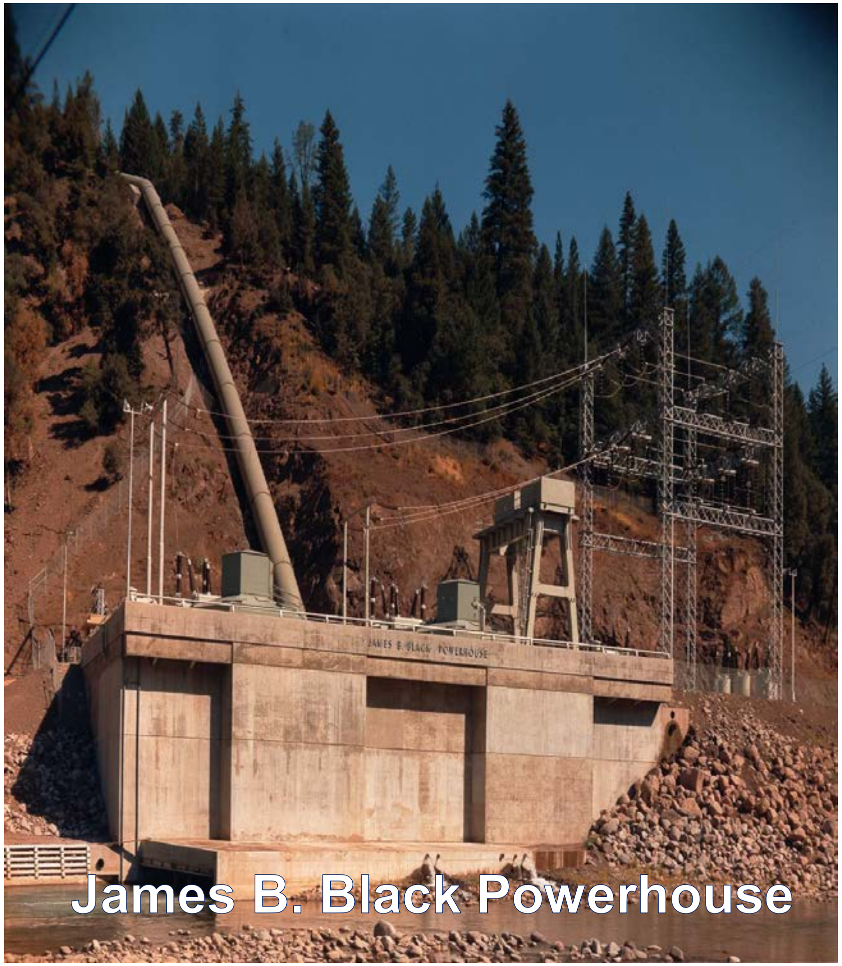
Status – California Portfolio Mix



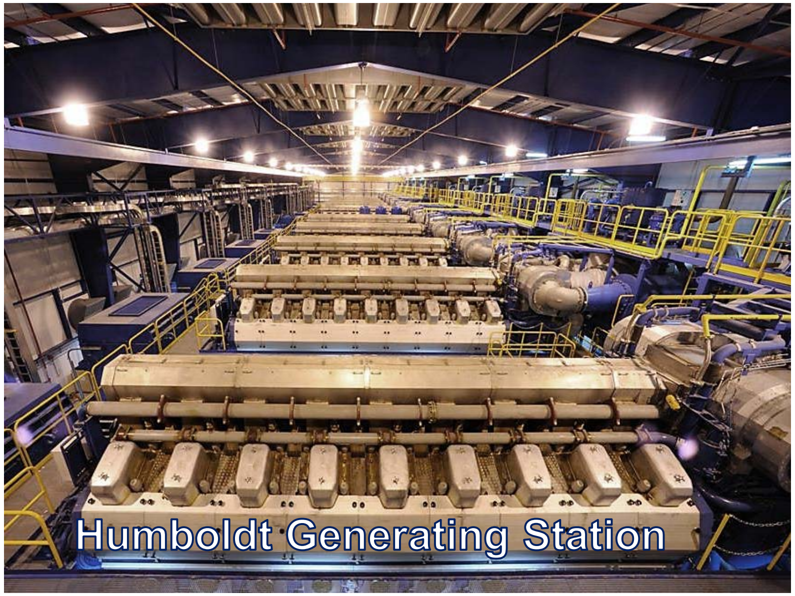
Nuclear Generation

Hydro Generation



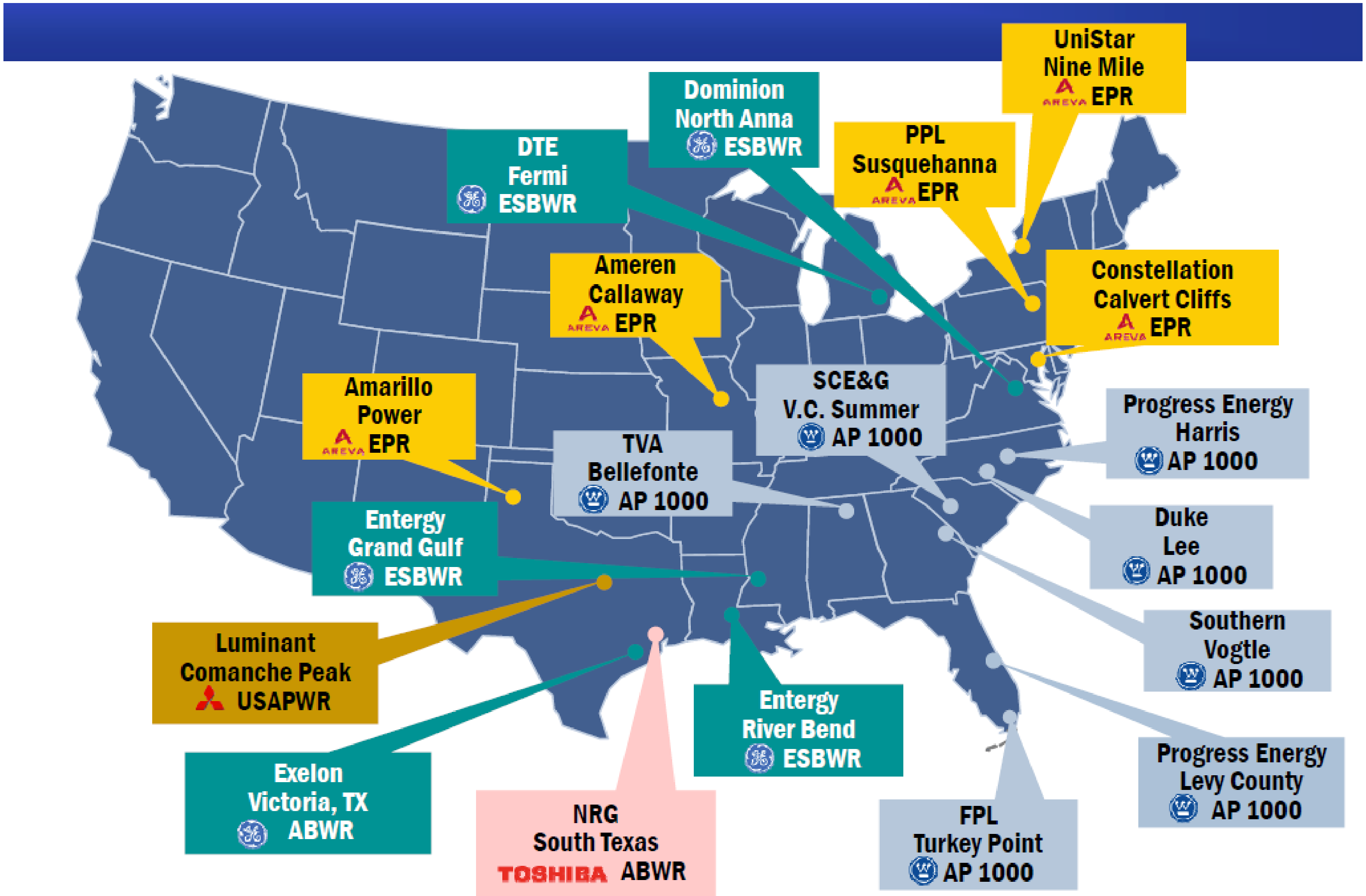


Fossil Generation



Renewables: Solar, Wind, Geothermal, Biomass

Outlook – New U.S. Plants



New Reactor Projects In The U.S.

Vogtle 3 & 4

- **2,200 workers now on the project**
- **3,000 during peak construction**
- **600 to 800 permanent jobs when the new reactors are operating**

V.C. Summer 2 & 3

- 1,000 workers now on the project
- 3,000 during peak construction
- 600 to 800 permanent jobs when the new reactors are operating

Challenges

-Overview

-High Capital Costs

-Facts About Used Fuel

Challenges - Overview

- **High capital costs ($10-15 billion)**
- **Used fuel issue**
- Availability of nuclear qualified components
- Availability of skilled personnel
- Lengthy licensing and construction schedule
- Cost and schedule performance
- Anti-nuclear resistance/concerns/misunderstandings

Summary

Current plants:

- Operate safely
- Continued operation is cost-effective
- Baseload plants have a high-capacity factor
- Environmental benefits – essentially zero greenhouse gas emissions
- Used fuel fully contained and safely stored

Summary

Potential for new U.S. plants:

- Attractive attributes

  -Avoids GHG emissions

  -Baseload power 24/7 with high reliability

  -Relative security/stability of fuel supply

- Significant challenges

  -High capital cost

  -Understanding the used fuel issue