U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Nuclear Power, Present and Future

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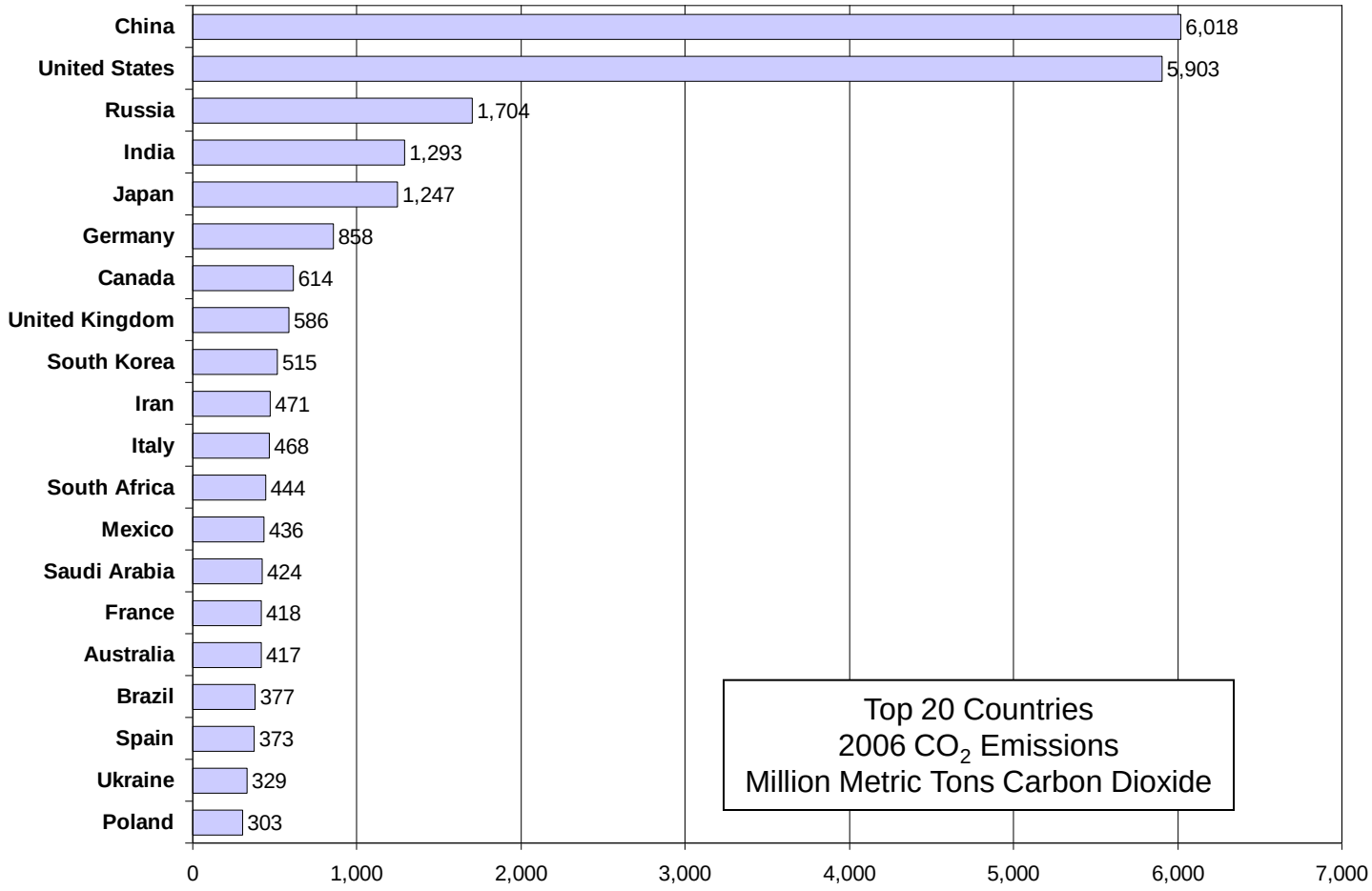
Introduction

Associated Press
September 23, 2009

"New satellite information shows that ice sheets in Greenland and western Antarctica continue to shrink faster than scientists thought and in some places are already in runaway melt mode."

CO_2 Is A Major Concern

- **The United States is second only to China in total emissions**



DOE Strategic Goal

- **Reduce CO_2 emissions by 80% by the year 2050**
- **Very ambitious goal**
- **Requires accurate picture of**
  - Current energy sources
  - How energy is being used
  - How much CO_2 is being emitted by each sector of economy

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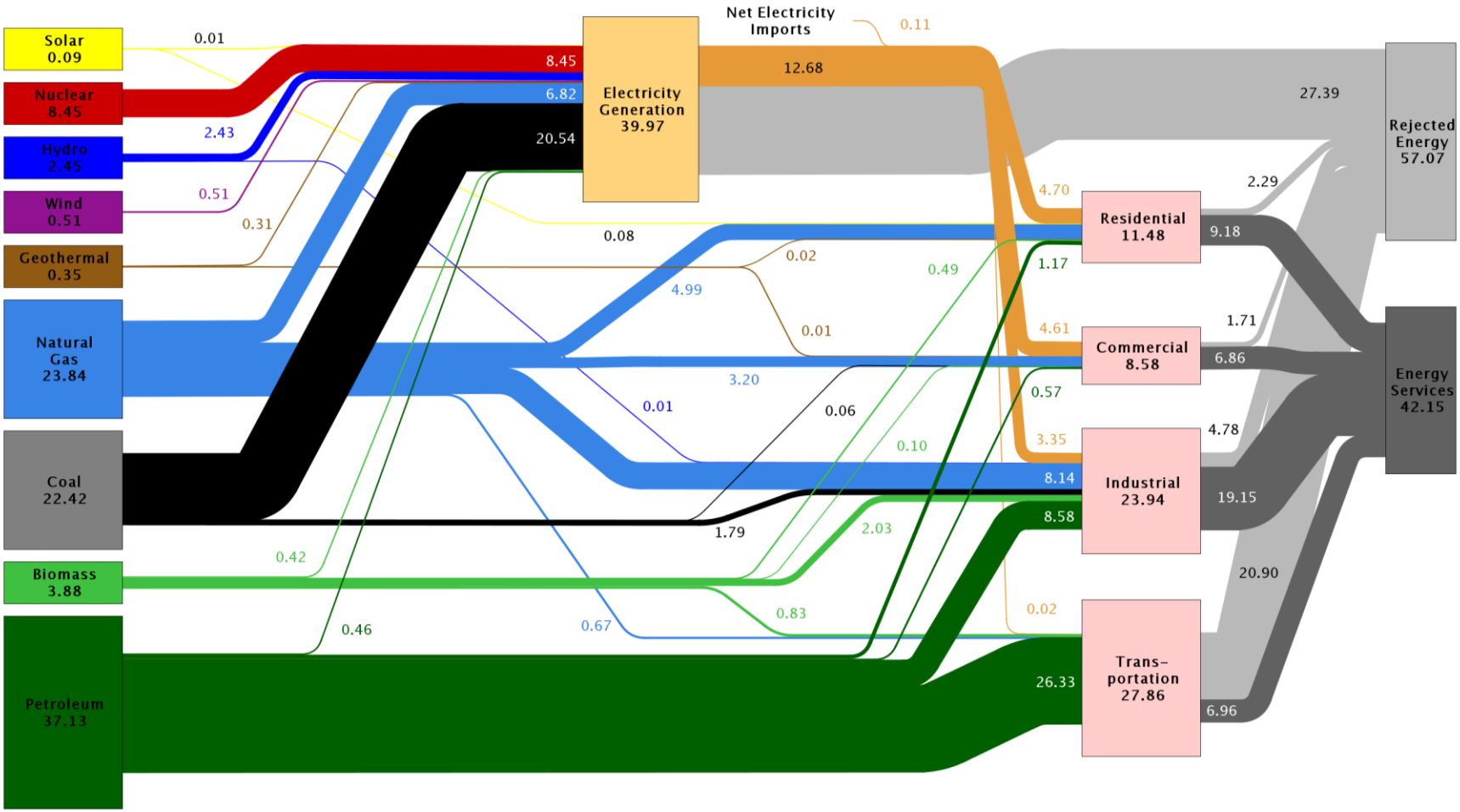
Estimated U.S. Energy Use in 2008: ~99.2 Quads



Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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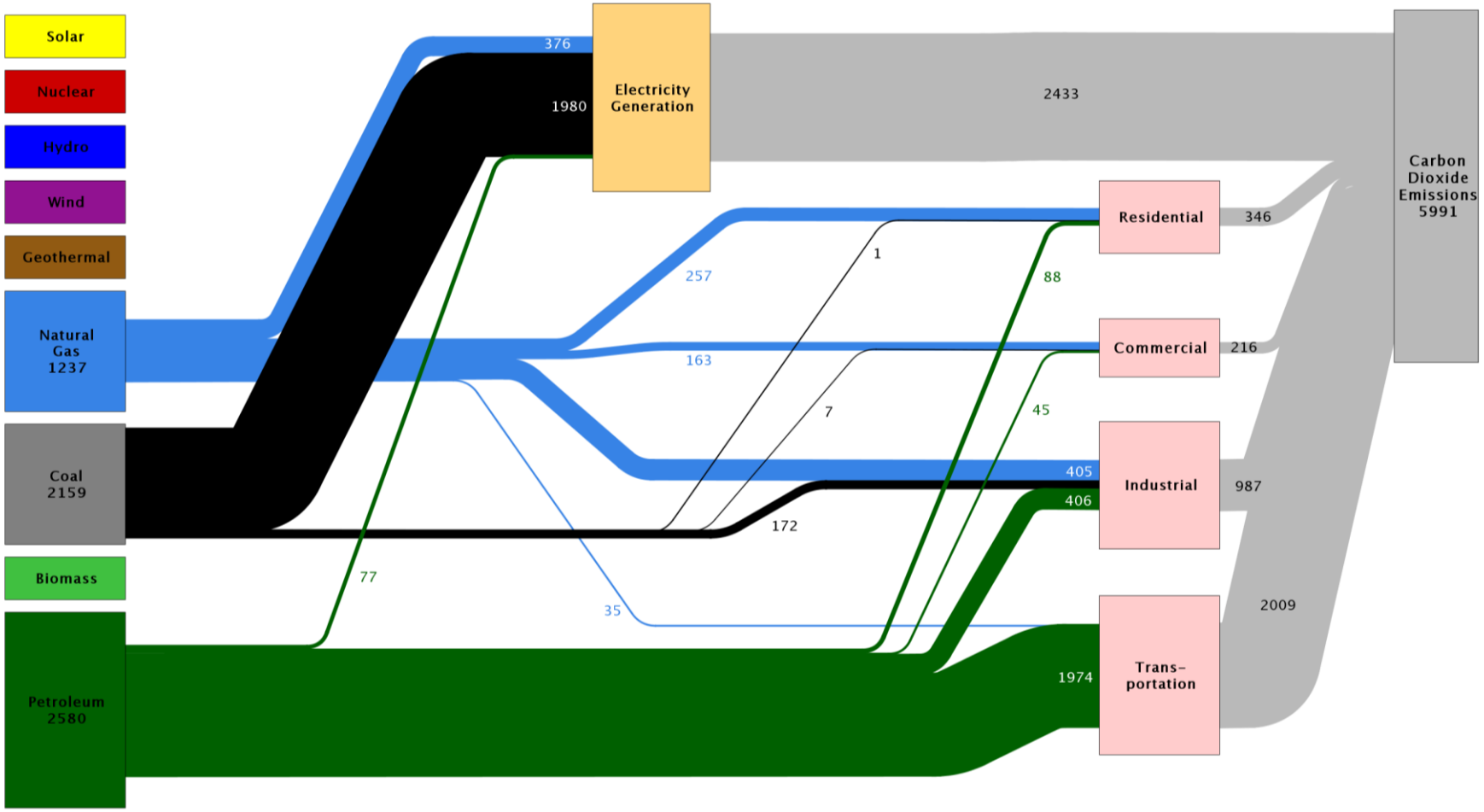
Estimated U.S. Carbon Dioxide Emissions in 2007: ~5,991 Million Metric Tons



Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions – lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Totals may not equal sum of components due to independent rounding. LLNL-MI-411167

Nuclear Advantages

- **Minimal CO_2 emissions**
- **Fuel (uranium, thorium, MOX) readily available in U.S. and from friendly nations; no foreign dependence**
- **Provides large volumes of continuous, baseload electricity**
  - Does not need the sun to shine or wind to blow
  - Perfect, for example, for recharging cars overnight
- **Small transportation footprint:**
  - Coal: train of coal cars 1 mile long to fuel 1,000 MW plant for **one day**
  - Nuclear: 7 trucks can carry enough fuel for 1,000 MW plant for **1.5 years**

Nuclear Advantages

- **Today about 70% of our carbon-free electricity generation comes from nuclear**
- **Recent projections show that even with…**
  - expanded renewables
  - greater conservation
  - carbon capture for coal

…nuclear has a significant and growing role to play in fighting climate change

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Nuclear Energy

Where We Are Today

- 104 Nuclear plants provide about 20% of U.S. electricity generation
- High capacity factors above 90%. They have become much more efficient.

Where We Are Today

- **Existing plants avoid emission of almost 700 million metric tons of CO_2 a year when compared to fossil fuels- equal to emissions of all U.S. passenger cars**
- **Over half of existing plants have received license extension to 60 years**
- **Almost all existing plants will receive license extensions**
- **Extending operation of existing reactors will avoid ~12 billion metric tons CO_2 and provide enough electricity for 70 million homes during an additional 20 years of operations**

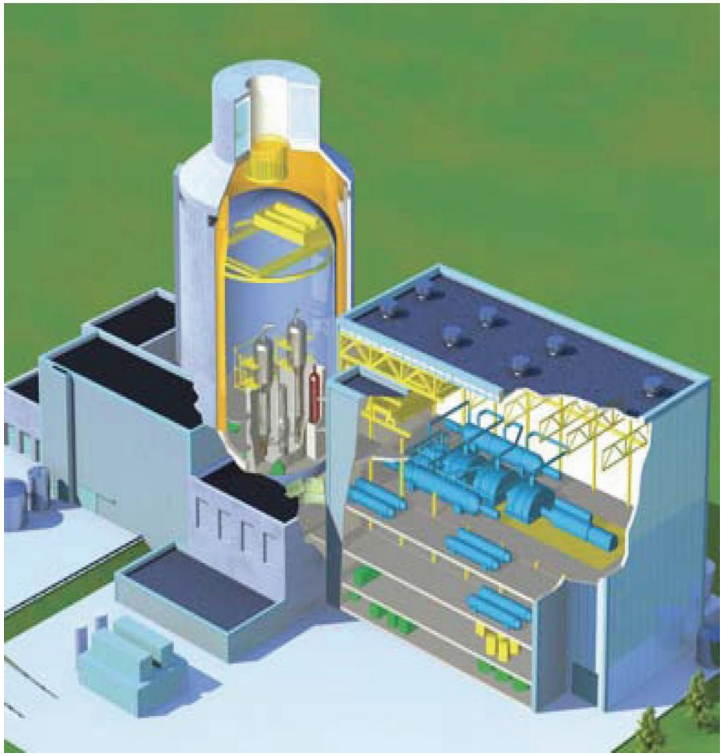
Where We Are Today

- **No new nuclear plant has begun construction in the U.S. in over 30 years**
- **The nuclear benefits we enjoy today are the result of planning and work done 30-40 years ago**

Where We're Going Near-Term

Generation III+ plants

- The next stage of nuclear
- Evolutionary extension of existing fleet
- Enhanced safety and security
- Applications for combined construction and operation have been submitted for 28 plants
- Estimate: 6 to 8 new Generation III+ plants operating by 2020



Where We're Going Near-Term

- **Challenges include**
  - High initial cost
    - Difficult to get financing for $6-8 billion plants
    - Loan guarantees being sought
  - Resources
    - U.S. nuclear construction has been dormant. Large components and expertise will come from overseas
    - Craft workers in short supply

Longer Term: Next Generation Nuclear Plant (NGNP)

- **Next Generation Nuclear Plant (NGNP) /High Temperature Gas Reactor (HTGR) is focus of next step**
- **Last September, $40 million in funding was announced by Secretary Chu to support design and planning work for NGNP**
- **NGNP will extend use of nuclear energy into industrial and transportation sectors**
- **NGNP will produce *process heat* in addition to electricity**

Longer Term: Next Generation Nuclear Plant (NGNP)

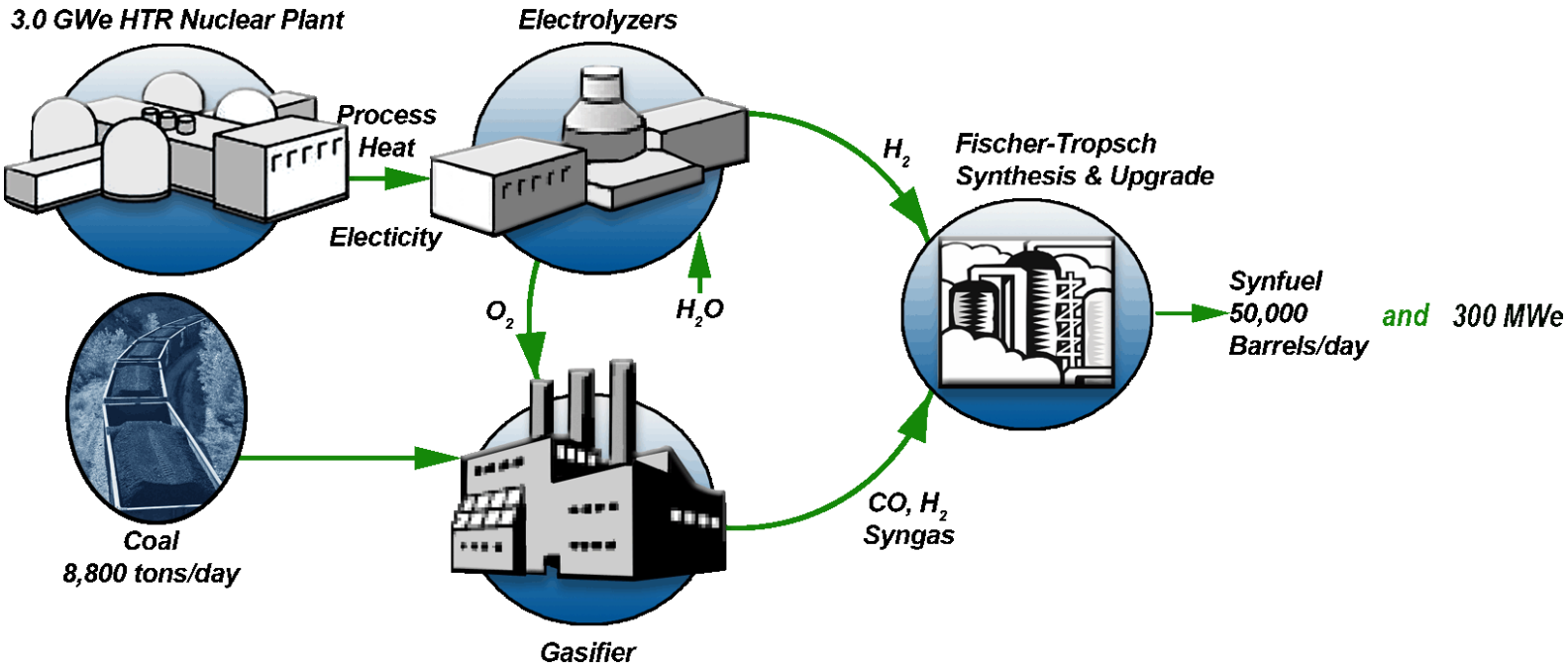
- **Process heat**
  - Used to make glass, plastics, steel, ammonia for fertilizer, and to desalinate water
  - Used to make hydrogen, which is needed to refine oil and biofuel into gasoline
  - Is produced today using fossil fuels producing CO_2
  - Can be produced by HTGR, replacing fossil fuels with zero-emitting nuclear
  - By producing process heat, future reactors will reduce CO_2 emissions in the industrial sector, as well as in electricity generation sector
- **High temperature reactors can also be used in hybrid systems in transportation sector**

Longer Term: Next Generation Nuclear Plant

Hybrid systems

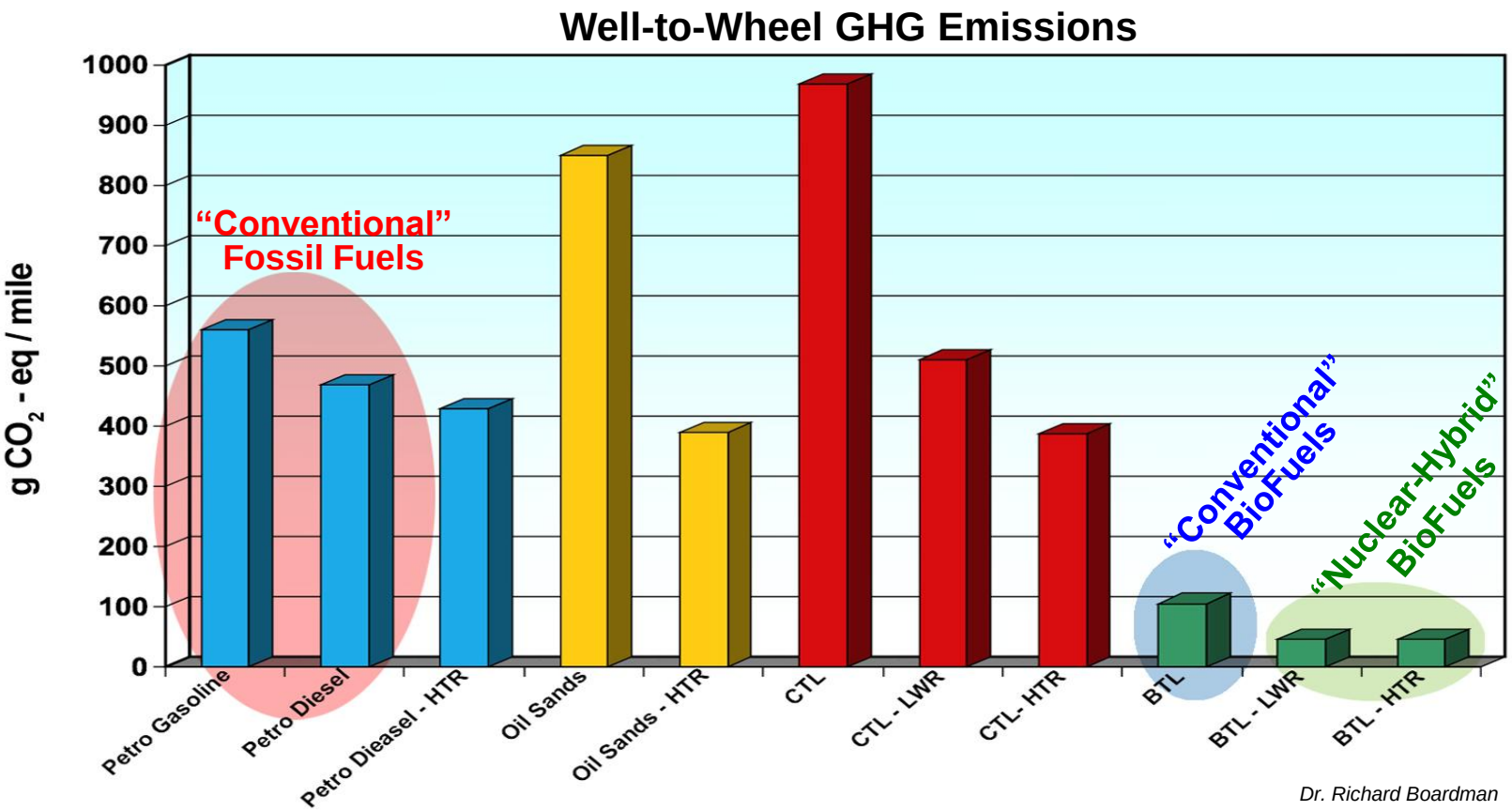
- Integrate two or more primary energy/carbon sources to produce a suite of energy products in an optimal way
- Combine carbon and energy sources in a way that accentuates the positives and mitigates negatives inherent in each

Nuclear Hybrid Synthetic Fuels



- **Hybrid systems use 70% less coal**
- **Little carbon is converted to CO_2**

Lifecycle Emissions of Liquid Fuels



- Fischer-Tropsch: $CO + 2H_2 \longrightarrow -(CH_2)- + H_2O$
- Nuclear energy decreases the carbon cost of all systems to levels well below the current baseline
- Best results are with a nuclear-biomass hybrid

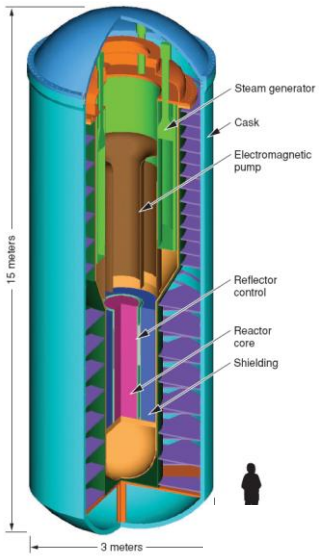
Nuclear Hybrid Systems

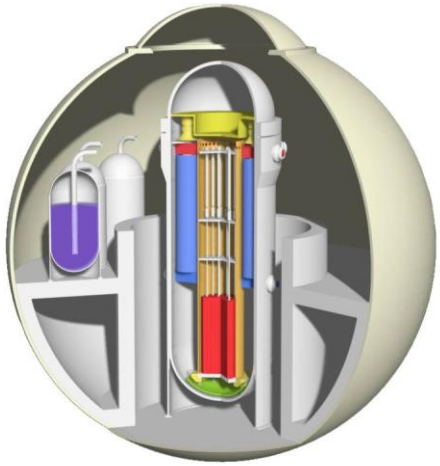
- **Nuclear – Biomass Fuels Can Potentially Replace Oil if we**
  - Use nuclear as the biorefinery energy source
  - Use biomass as the carbon feedstock

- **Other hybrid possibilities**
  - Replace fossil fuel now used to turn corn into ethanol with low pressure steam from nuclear power plants.
  - Use nuclear energy to convert coal into liquid fuel without creating CO2 emissions from coal liquefaction process
  - Use nuclear power as a back up to renewable energy sources

Small Modular Reactors

- **Let's say:**
  - You're a utility in a rural area
  - You need more electricity
  - Your grid cannot accommodate the 1,000 MW of a conventional nuclear reactor but could handle 300-400 MW
  - You only need a few hundred MW of new power anyway
  - You can't afford the cost of a conventional new nuclear plant
  - You want to avoid CO_2 emissions





Small Modular Reactors (SMRs)

- Up to 300 MW as opposed to 1,000 MW or more
- "Plug 'n play" modular construction, factory-assembled, shipped to site intact
- More affordable ~$2 billion as opposed to ~$6-8 billion
- Goal: Comparable dollar per kilowatt cost
- Some designs use existing technology, easier to license
- Can replace aging fossil plants with clean nuclear
- May allow developing world to use nuclear
- May have first SMR in place by 2020

Major challenges going forward

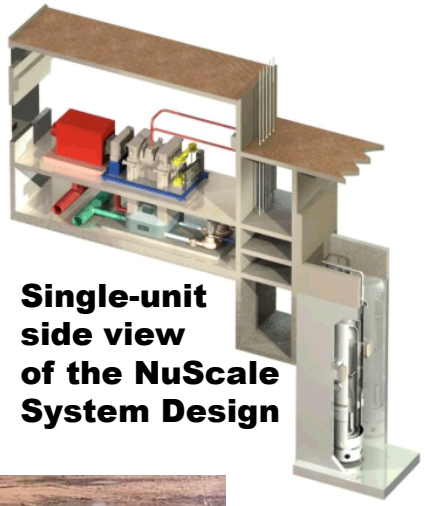
- **Need widely acceptable solution to nuclear waste**
- **Need to build public acceptance**
  - Clearly communicate long-term benefits
  - Continued strong safety culture and record
- **Need to address cost and human resource issues**
- **Need smart R&D to take nuclear to the next level**

Crystal Ball Gazing to 2050

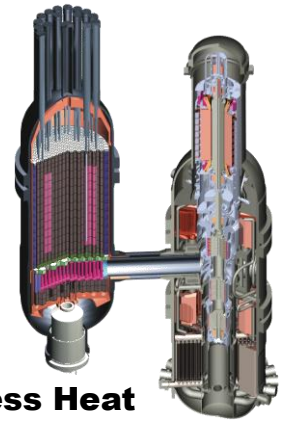
- **Keep existing plants operating safely as long as possible**
- **6-8 new Generation III+ plants by 2020**
- **One or more SMRs in place by 2020**
- **Gen IV high temperature reactors become economically viable, delivering electricity and process heat, and reducing the need for fossil fuel plants**
- **Hybrid plants use nuclear energy to reduce carbon footprint in the transportation and industrial sectors while also producing electricity**

Crystal Ball Gazing to 2050

- **R&D continues to produce gains and public understanding grows, so that nuclear waste becomes less of an issue over time**
- **Small modular reactors bring benefits of nuclear energy to the developing world**

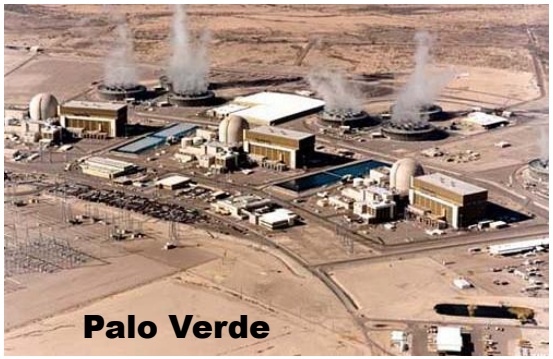


Single-unit side view of the NuScale System Design



Process Heat

AP1000



Palo Verde

Nuclear energy plays a larger role in providing cost-effective, continuous baseload electricity while helping the U.S. meet the climate change challenge