Nuclear Power for the Transport Sector

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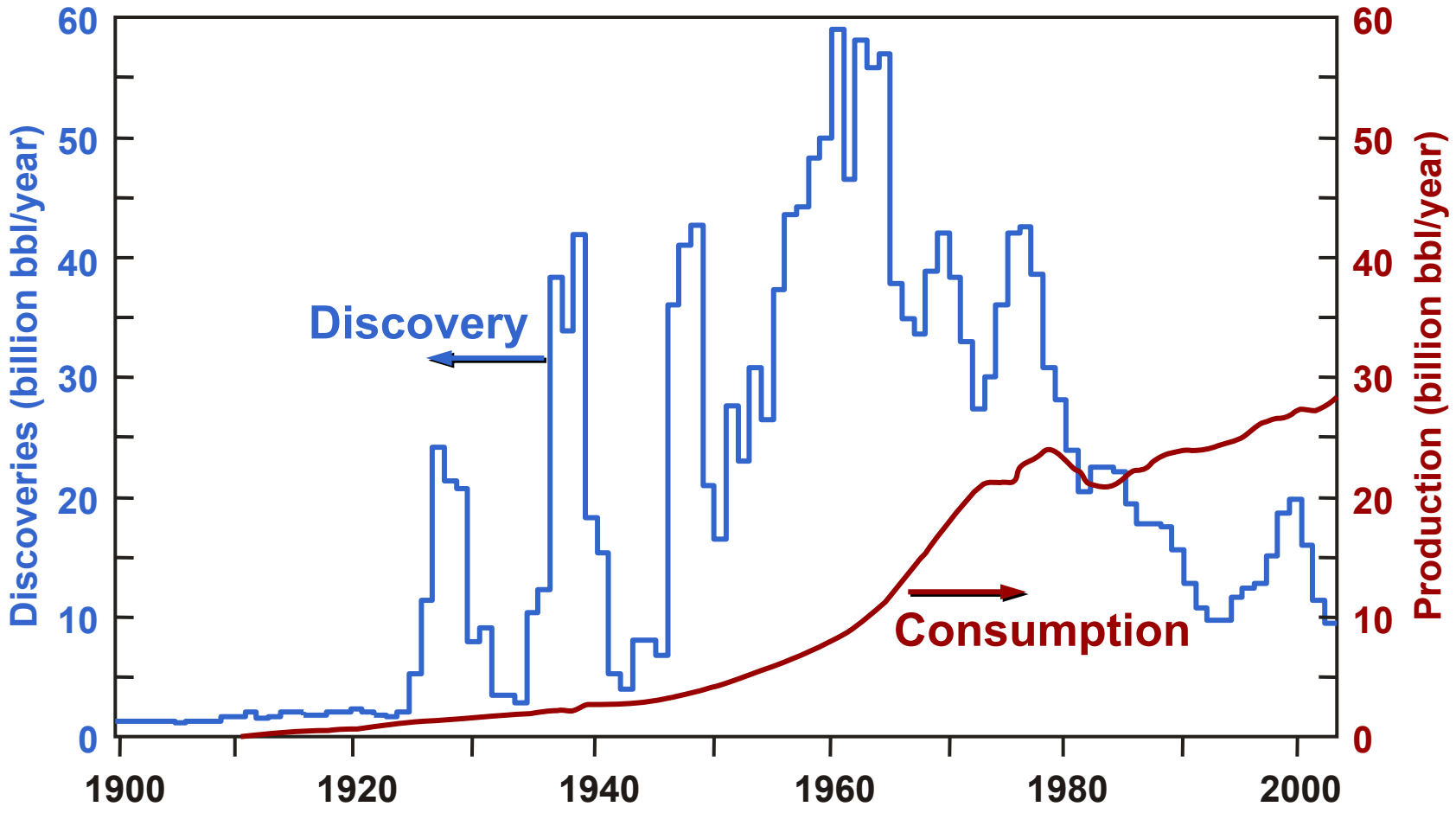
The Problem

The Era of Oil for Fuels is Ending



Oil and Gas J.; Feb. 21, 2005

Conventional Future: Liquid Fuels from Heavy Oils and Tar Sands

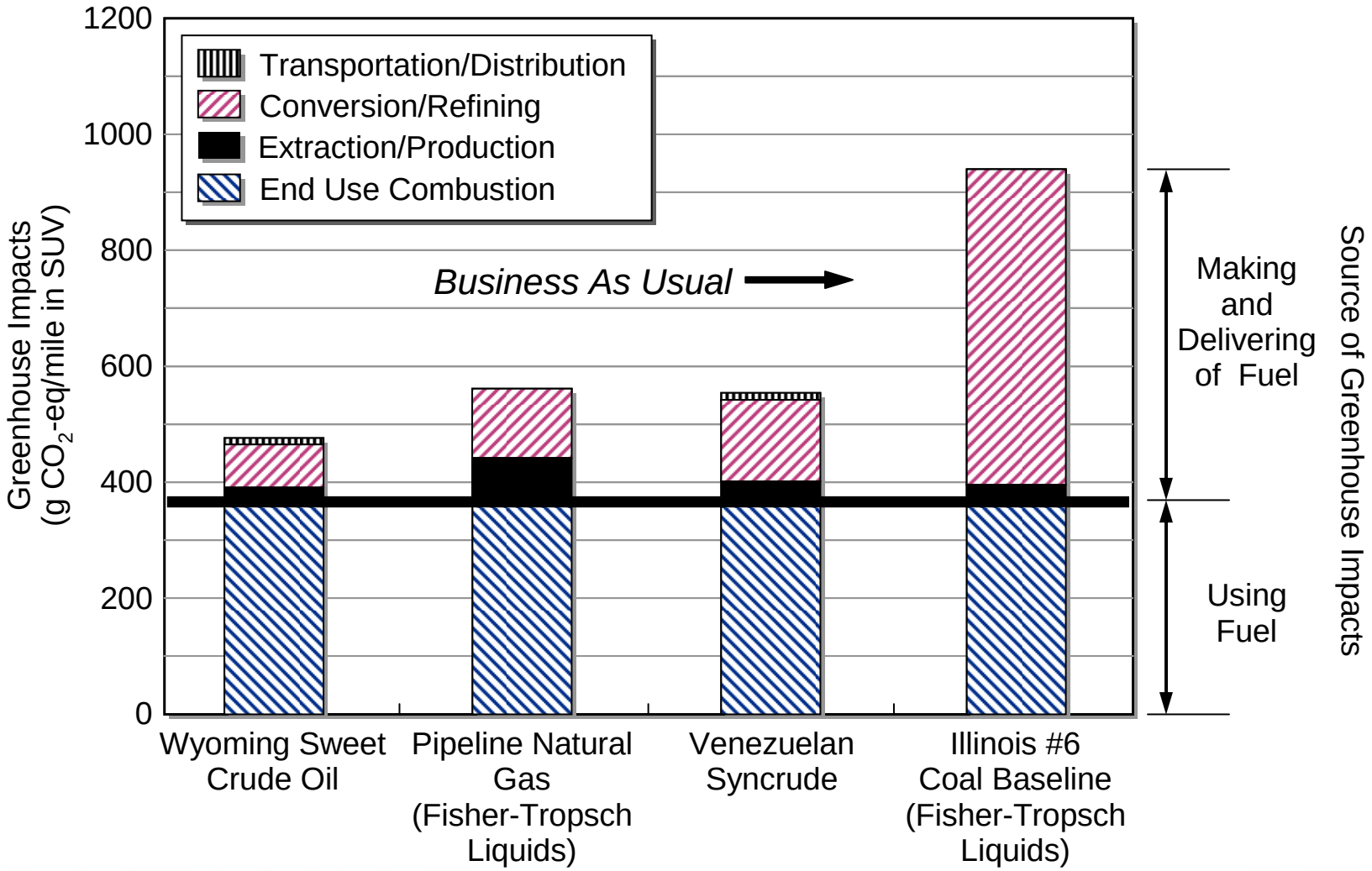
(Lower Hydrogen-to-Carbon Ratios)

Syncrude Canada Ltd.
Tar Sands Operations

- Tar sands and heavy oils are converted to liquid fuels by:
  - Addition of hydrogen
  - Removal of carbon (usually with CO_2 to the atmosphere)
- Massive increase in hydrogen demand
- Increase in CO_2 releases (greenhouse gas) per vehicle mile

Business-as-Usual Liquid-Fuel Futures Imply Increased Greenhouse-Gas Releases

(Alternative Liquid-Fuel Feedstocks Increase CO_2 Releases from the Production Process)



The Abundance of Nuclear-Energy Transport Solutions

Plug-In Hybrid Electric Vehicles

Shale Oil

Hydrogen-Rich Fuels

Plug-In Hybrid Electric Vehicles (PHEVs)

Cutting Light-Vehicle Liquid-Fuel Consumption in Half

150 to 200 Nuclear Plants Each Producing 1000 MW(e)

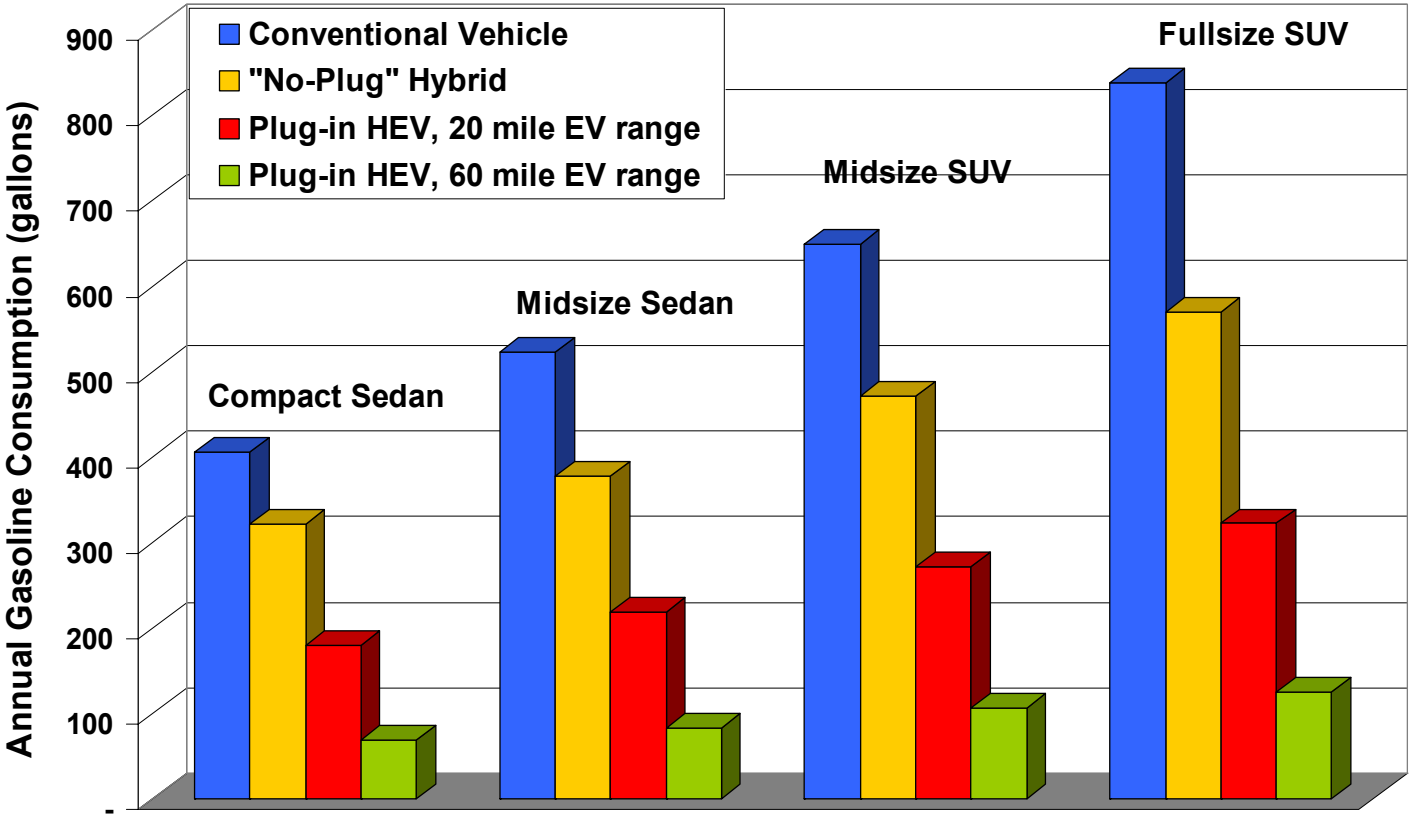
PHEVs: Recharge Batteries from the Electric Grid Plus Use Gasoline

- Two major battery-connected limitations of electric cars
  - Limited range
  - Recharge time (Gasoline refueling rate is ~10 MW)
- Hybrid vehicle options
  - Electric drive for short trips
  - Hybrid engine with gasoline or diesel engine for long trips
  - Recharge battery overnight
- Connects cars and light trucks to the electrical grid

Courtesy of the Electric Power Research Institute

PHEVs: Annual Gasoline Consumption

Connecting to the Electric Grid (Nuclear Energy) Cuts Light-Vehicle Fuel Consumption in Half



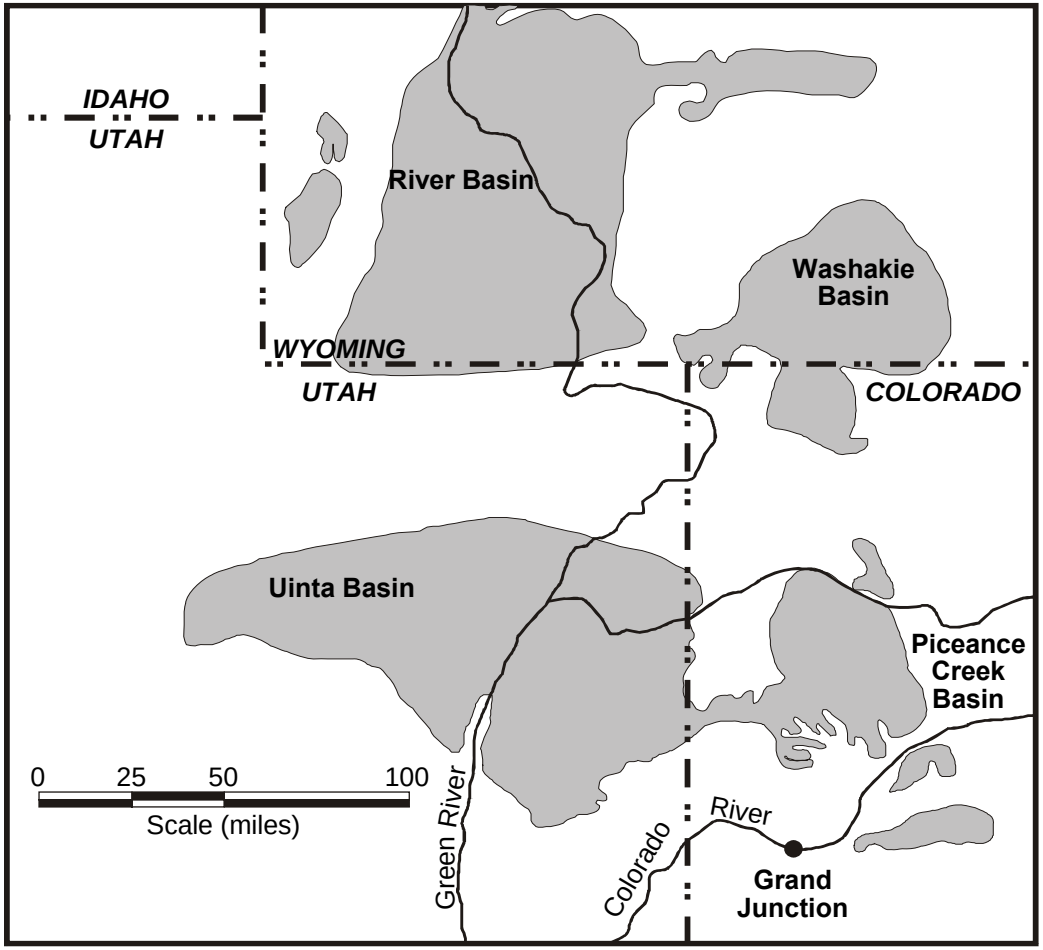
Courtesy of the Electric Power Research Institute

Shale Oil

60,000 MW(t) of High-Temperature Nuclear Heat to Meet a Quarter of U.S. Oil Needs

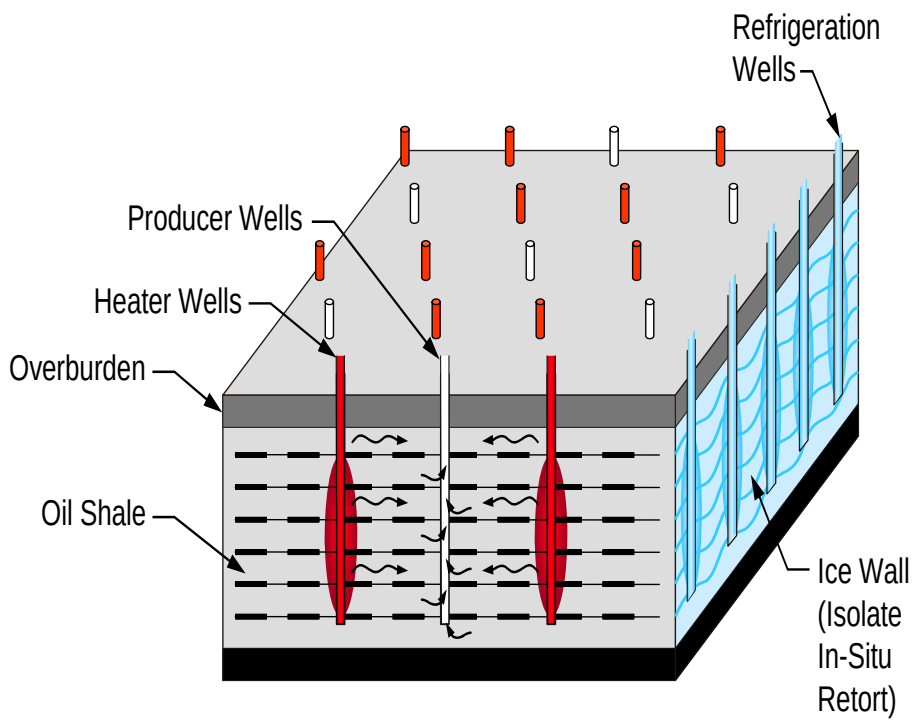
Shale Oil is a Massive United States Resource for High-Quality Crude Oil

- ~800 billion barrels of oil
- Oil resources 3 times those of Saudi Arabia
- ~100-year oil supply for the United States



The Shell In Situ Conversion Process:
Heat Oil Shale Electrically to Release Liquid Fuel

- **Heat oil shale electrically**
  - **Slow heating**
  - **High temperature**
- **Incentives for high-temperature nuclear heat option**
  - **No greenhouse gases from electricity generation**
  - **Avoid heat → electricity → heat conversion loses**
  - **Reduce water need**



Hydrogen-Rich Fuels: Liquids and Hydrogen Gas

A Market Ultimately Similar in Size to Base-Load Electricity

– A Quiz –

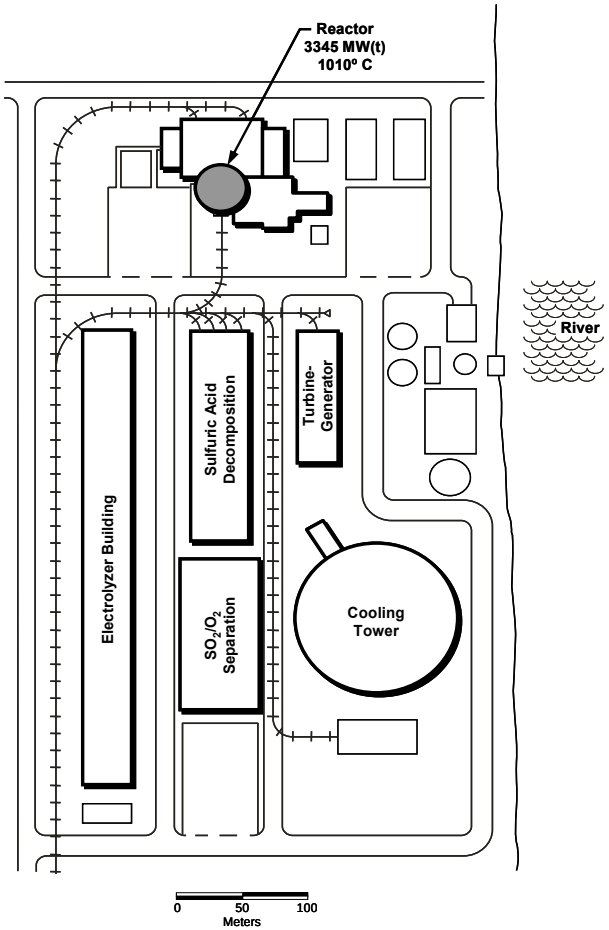
How Much Hydrogen can be Produced from Three 1000-MW(e) Nuclear Power Plants?

Browns Ferry Nuclear Power Plant (Courtesy of TVA)

– The Answer –

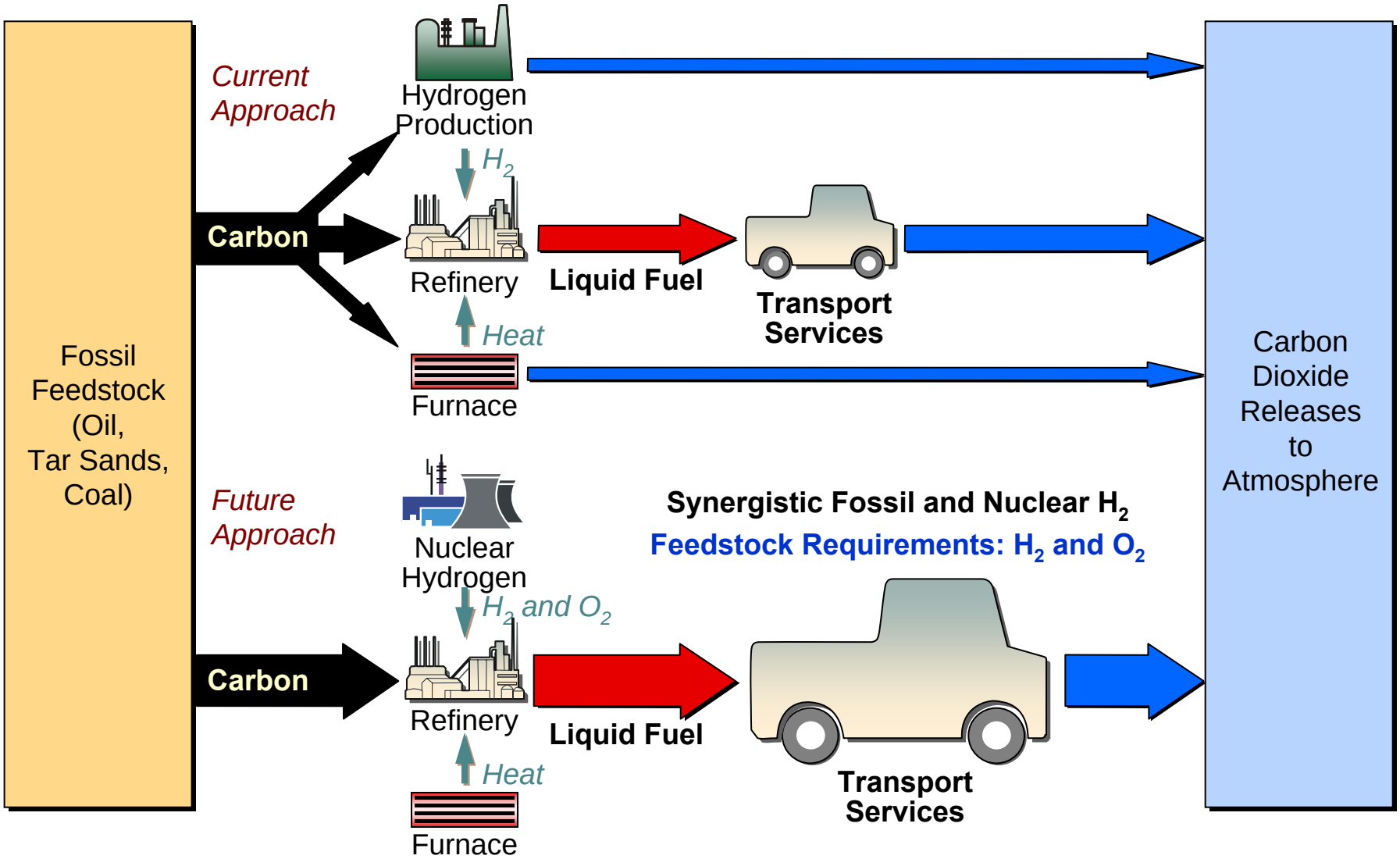
Match the Largest H_2 Plant Under Construction for Upgrading Crude Oil*

- Hydrogen plants today
  - Large capacity
  - Large markets
  - Consume 5% of U.S. natural gas
- Westinghouse 1970s nuclear-H_2 plot plan
  - 3300-MW(t) HTGR
  - H_2 for coal liquefaction
  - Nuclear reactor (to scale) is the shaded circle in the drawing

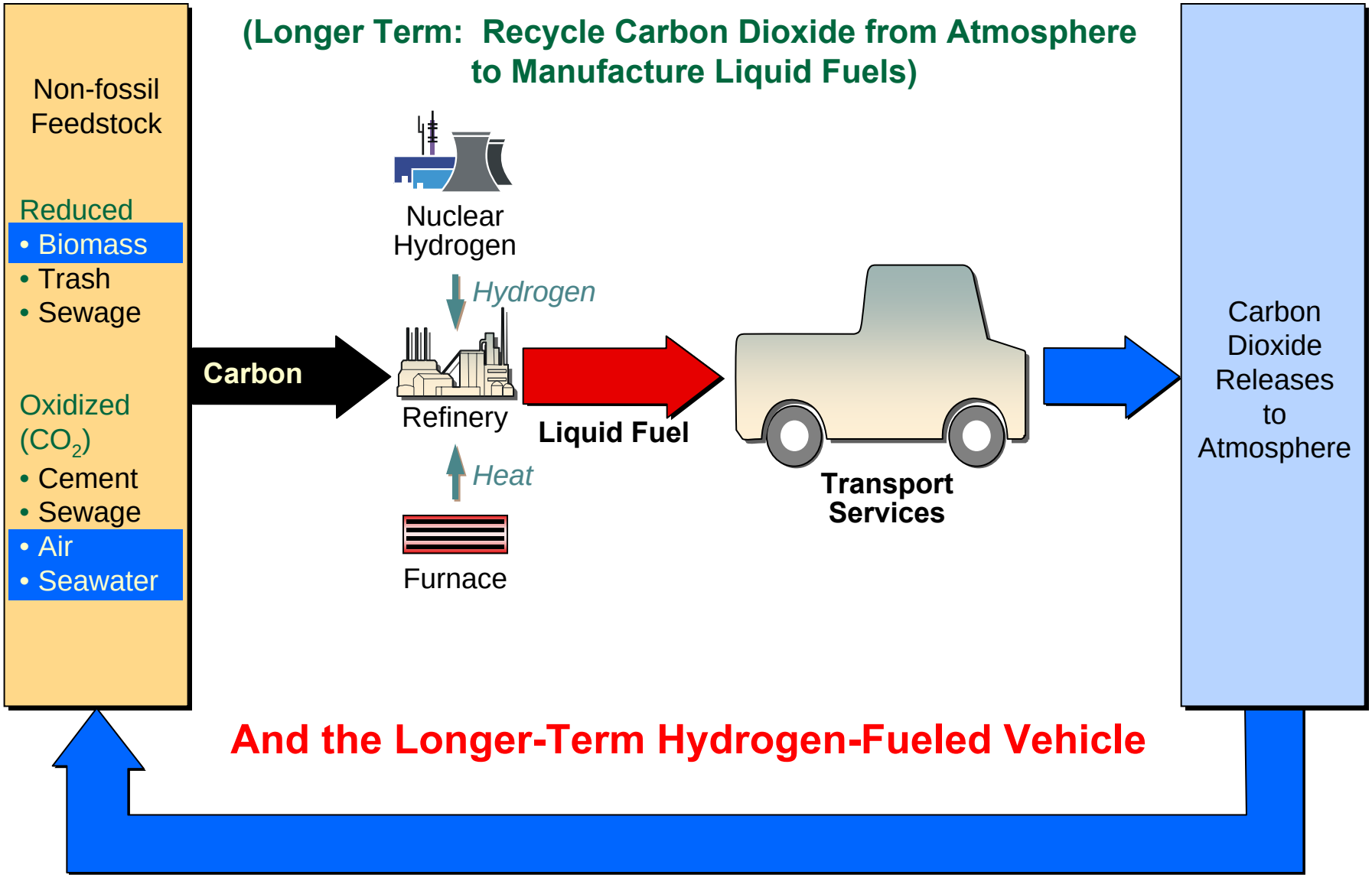


*Natural gas to H_2 plant with total output from four trains of $15.6 \cdot 10^6$ m^3/day

Nuclear H_2 can Increase Liquid Fuel per Unit of Feedstock and Reduce Emissions



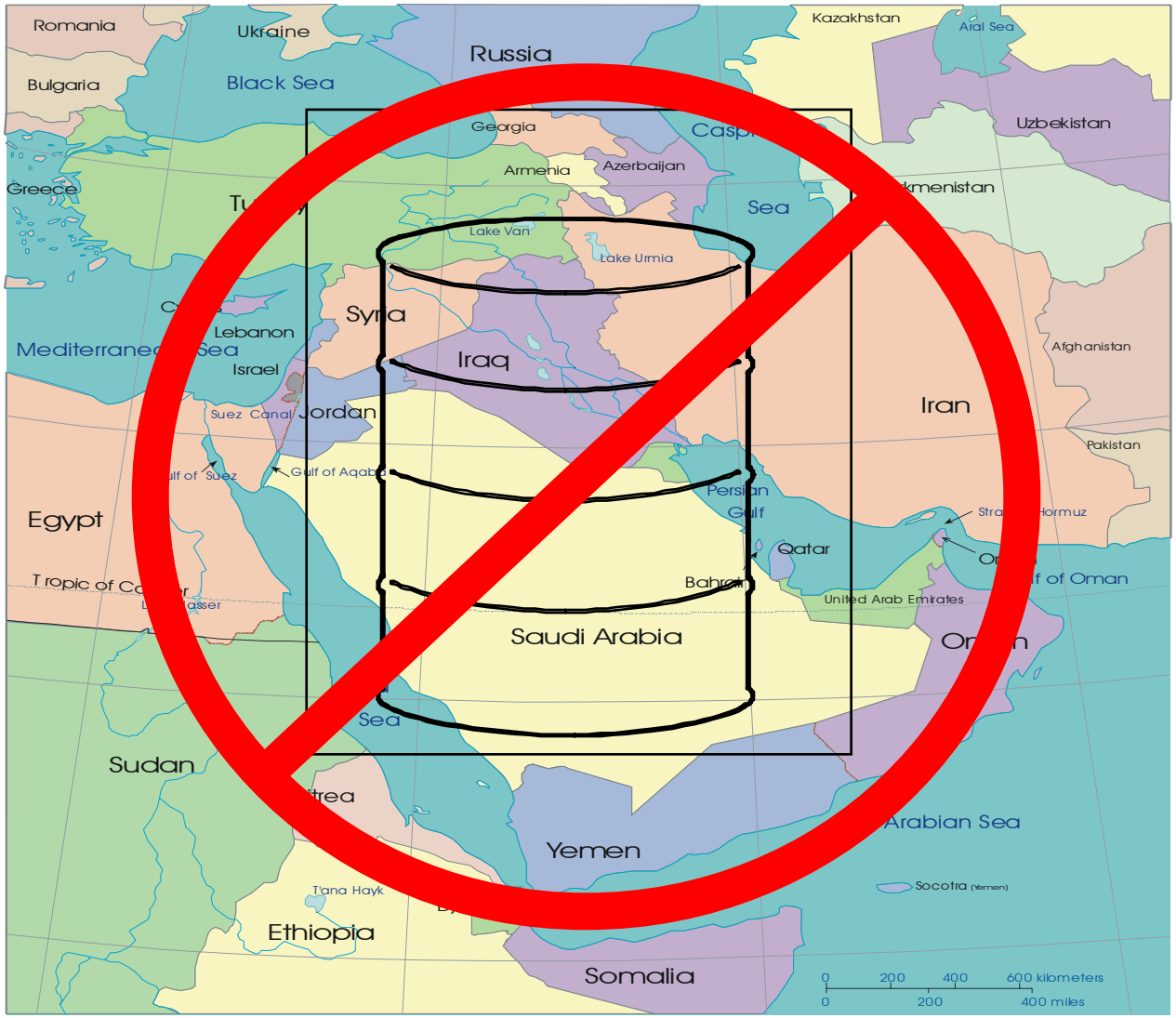
Zero-Greenhouse-Gas Liquid-Fuel Strategy



Conclusions

Achievable Goals

Oil


Romania
Ukraine
Russia
Kazakhstan
Aral Sea
Bulgaria
Black Sea
Uzbekistan
Georgia
Armenia
Azerbaijan
Greece
Sea
Lake Van
Lake Urmia
Syria
Lebanon
Mediterranean Sea
Israel
Iraq
Afghanistan
Iran
Suez Canal
Jordan
Pakistan
Gulf of Aqaba
Persian Gulf
Egypt
Qatar
Bahrain
United Arab Emirates
Saudi Arabia
Sea
Sudan
Yemen
Arabian Sea
Socotra (Yemen)
T'ana Hayk
Ethiopia
Somalia
0 200 400 600 kilometers
0 200 400 miles

Man-Made Greenhouse Impacts

Athabasca Glacier, Jasper National Park, Alberta, Canada

Photo provided by the National Snow and Ice Data Center

Biography: Charles Forsberg

Dr. Charles Forsberg received his bachelor's degree in chemical engineering from the University of Minnesota and his doctorate in Nuclear Engineering from MIT. After working for Bechtel Corporation, he joined the staff of Oak Ridge National Laboratory, where he is presently a senior scientist. Dr. Forsberg is a fellow of the American Nuclear Society and received the 2005 American Institute of Chemical Engineers Nuclear Energy Division Robert E. Wilson Award for outstanding chemical engineering contributions to nuclear energy, including his work in hydrogen production and other technologies to use nuclear energy. He also received the Oak Ridge National Laboratory Engineer of the Year Award in 2005. Dr. Forsberg has been awarded 10 patents and has published over 200 papers, many on hydrogen futures.