Nuclear Hydrogen for Production of Liquid Hydrocarbon Transport Fuels

Charles W. Forsberg

Oak Ridge National Laboratory*
P.O. Box 2008; Oak Ridge, TN 37831-6165
Tel: (865) 574-6783; e-mail: forsbergcw@ornl.gov

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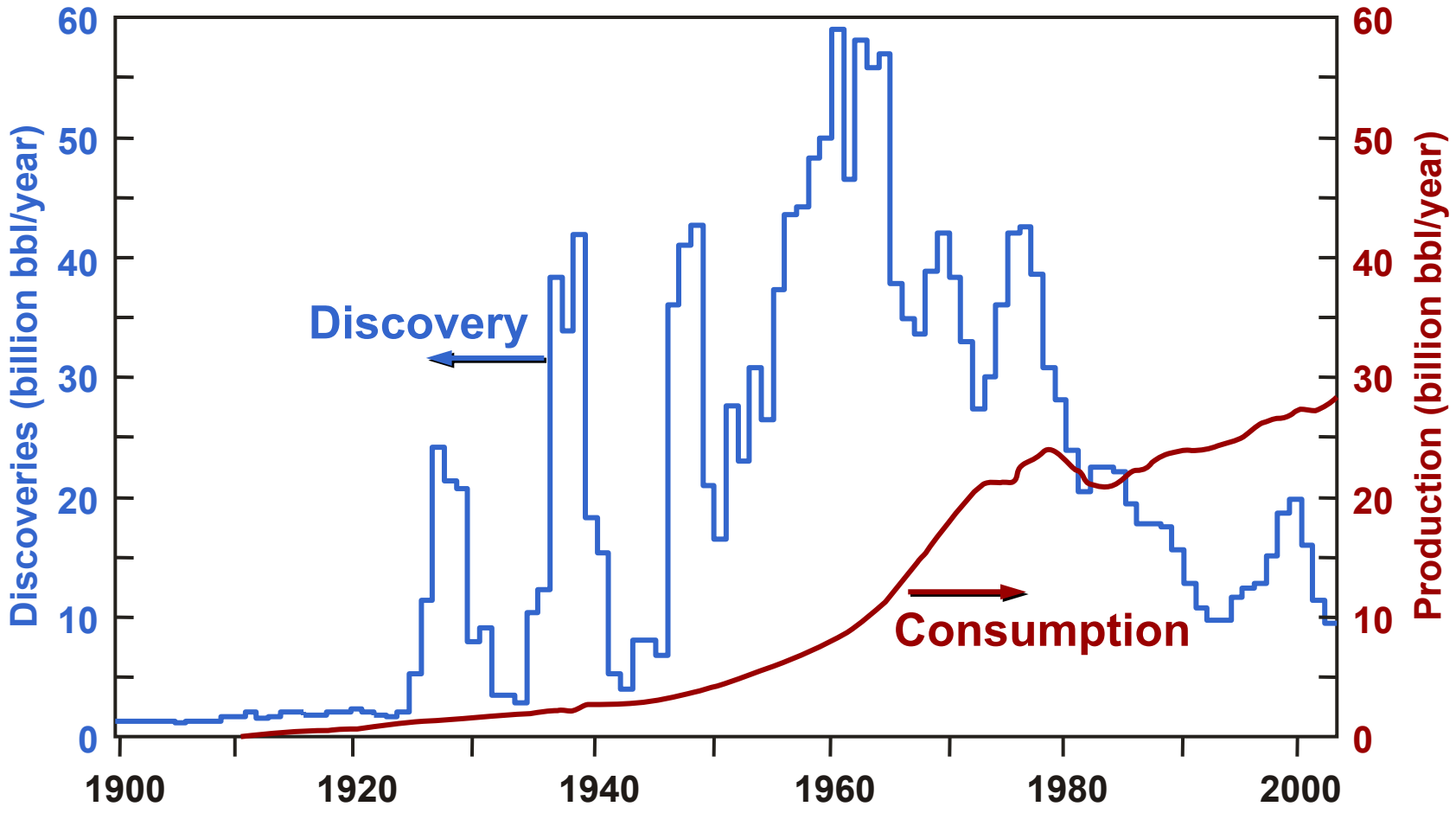
The Age of Oil for Fuels is Closing



Oil and Gas J.; Feb. 21, 2005

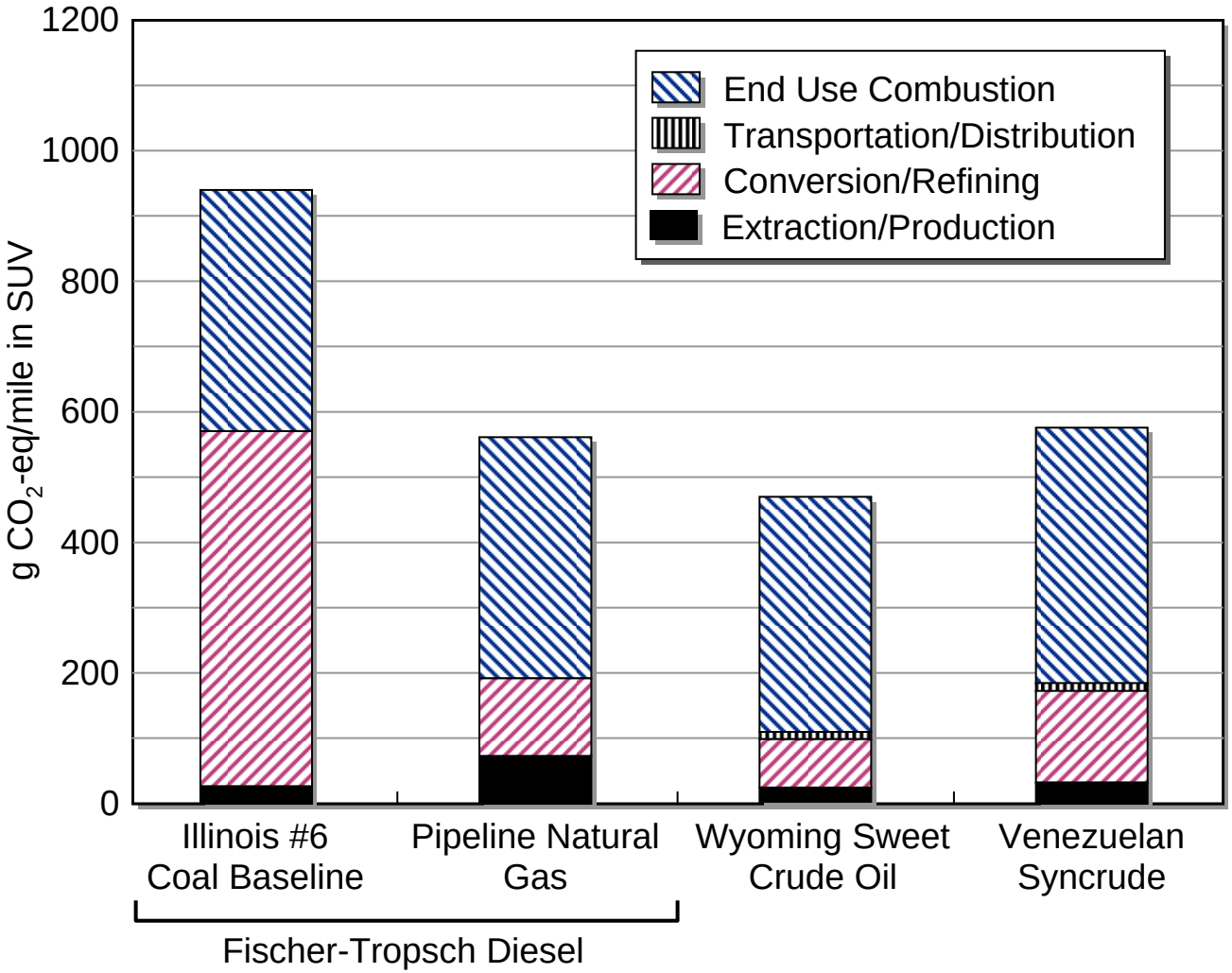
Conventional Futures: Liquid Fuels will be from Heavy Oils and Tar Sands

(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 atmosphere)**
- **Massive increase in demand for H_2**
- **Traditional technologies imply major increases in CO_2 releases per vehicle mile (greenhouse concern)**

Greenhouse-Gas Emissions per Vehicle Mile for Alternative Sources of Diesel Fuel



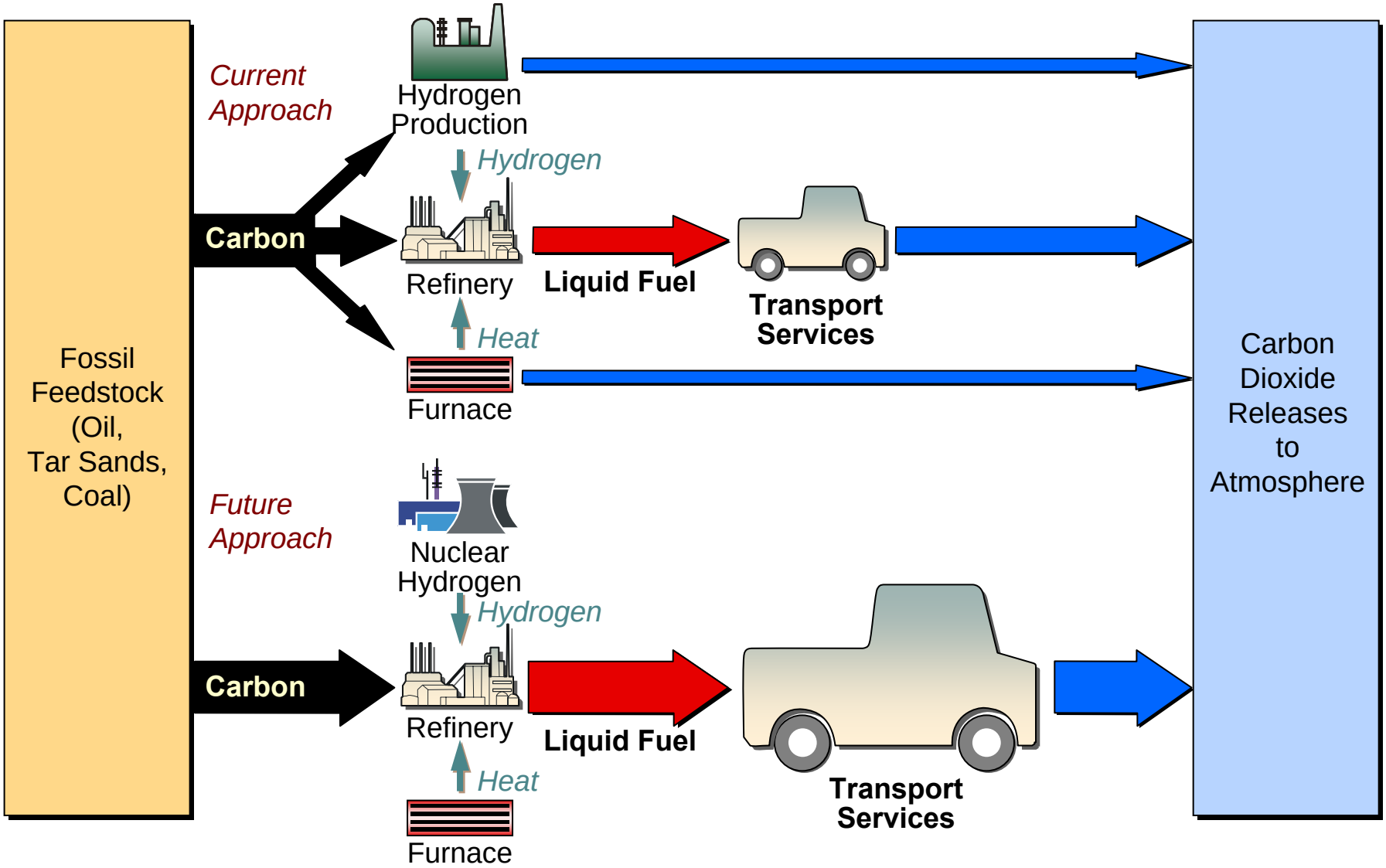
Basis: Full Diesel SUV Life-Cycle Greenhouse-Gas Emissions for Crude Oil and Other Feedstocks with Fisher-Tropsch Conversion

Alternative Liquid Fuels Strategy

- **Problem**
  - **Crude oil supply insufficient or expensive**
  - **Traditional alternatives imply increases in greenhouse gas releases per vehicle mile**
- **Alternative Strategy**
  - **Carbon feedstocks converted to liquid fuels**
  - **Carbon feedstocks not used for energy in the fuel production process**
  - **Nuclear energy provides hydrogen and oxygen for the fuel conversion processes**
  - **Carbon feedstocks used only for energy in transportation vehicles**

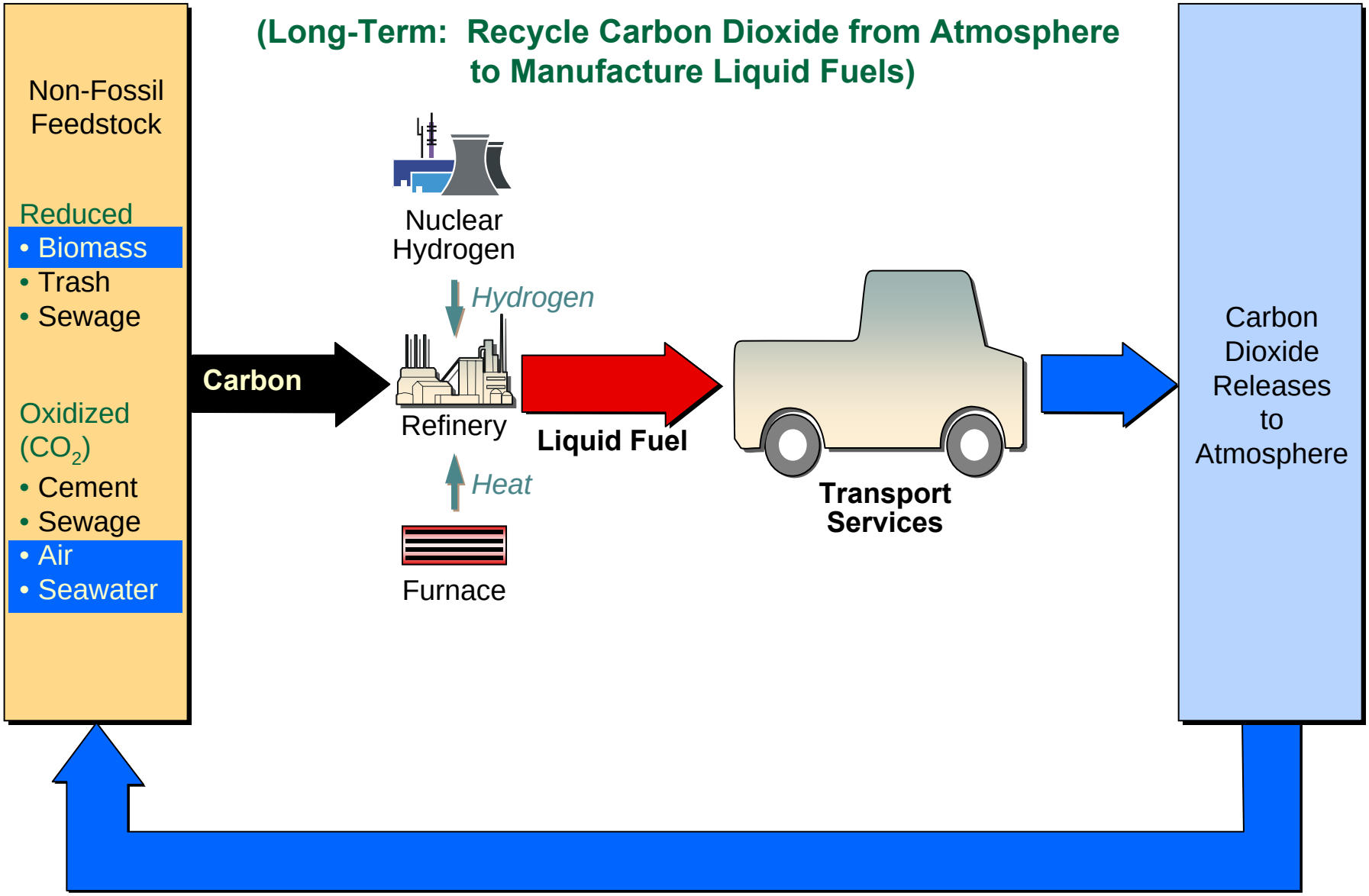
Reduced-Greenhouse-Gas Fuel Strategy

(Maximize Liquid Fuels per Unit of Carbon Input)



Zero-Greenhouse-Gas Fuel Strategy

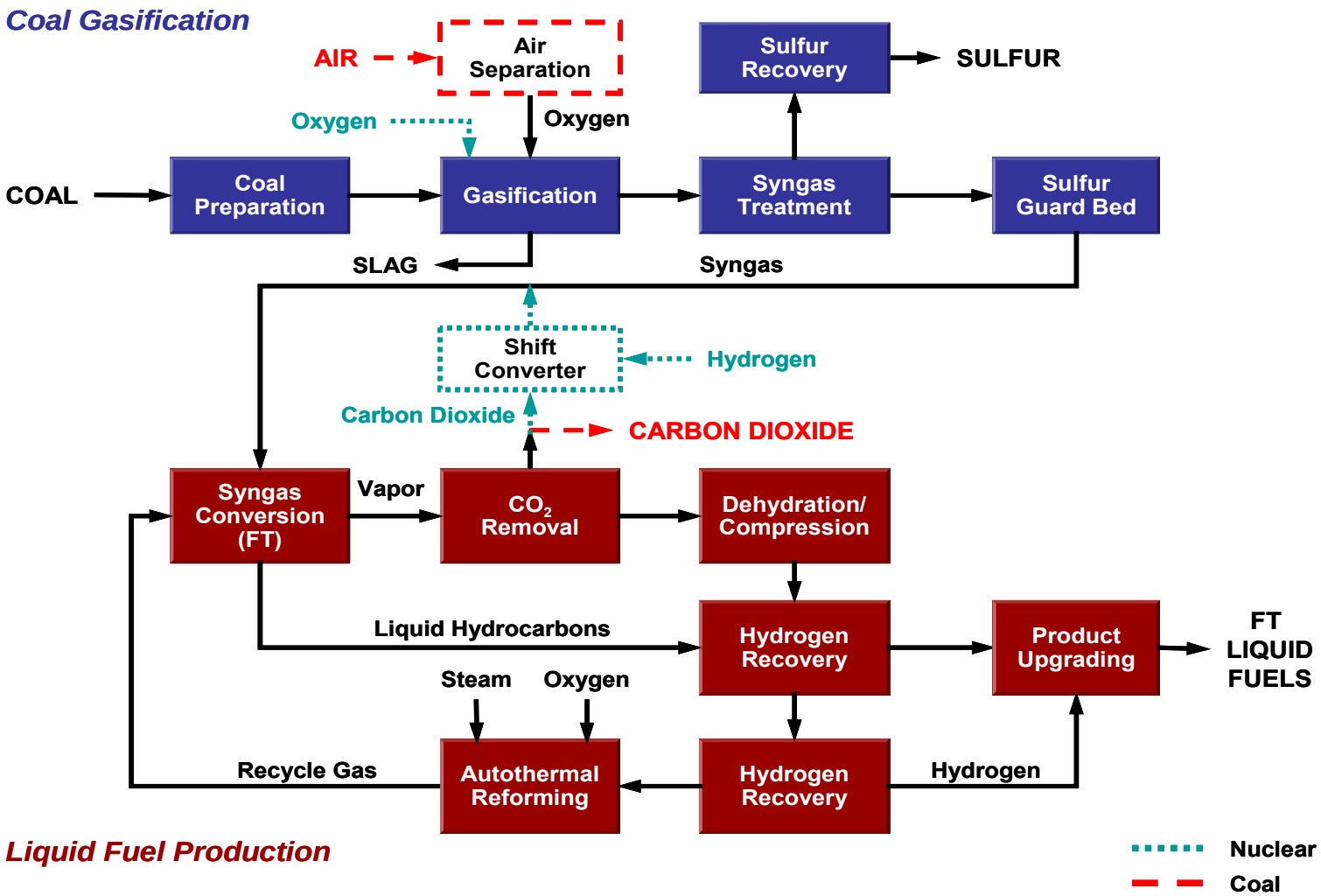
(Long-Term: Recycle Carbon Dioxide from Atmosphere to Manufacture Liquid Fuels)



Fischer Tropsch (FT): Preferred Process for Conversion of Fossil Fuels to Liquid Fuels

- **Advantages**
  - **Accepts any reduced-carbon feed**
  - **Produces high-quality liquid fuels**
  - **Industrial (new plants in Mid-East and China)**
- **Process**
  - **Oxidation:** $2C + O_2 \rightarrow CO$
  - **Water-gas-shift:** $CO + H_2O \leftrightarrow CO_2 + H_2$
  - **FT:** $(n/2 + m)H_2 + mCO \rightarrow C_mH_n + H_2O$

Fischer-Tropsch (FT) Liquid Fuels



Traditional Fisher-Tropsch Process

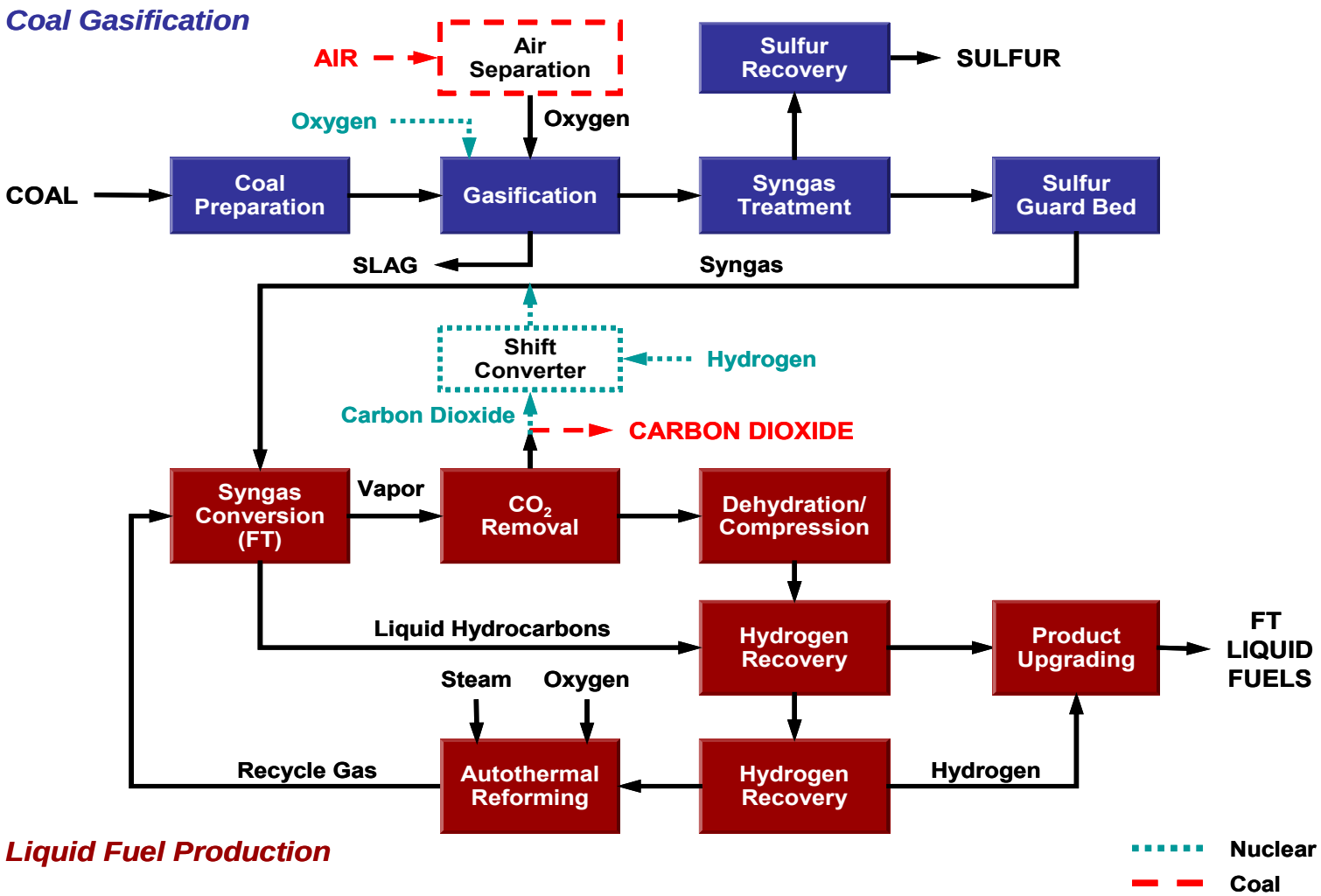
- **FT hydrogen, oxygen, and heat produced using fossil fuels**
- **FT challenges if greenhouse constraints**
  - **Greenhouse gas releases from processing plant can be eliminated by CO_2 sequestration**
  - **Major constraints on sequestration**
    - **Feasibility**
    - **Cost**
      - **Intrinsic cost for sequestration**
      - **Transport of fossil fuel to the refinery or CO_2 to sequestration site. Non-oil fossil fuels are not normally near acceptable sequestration sites**

Fischer-Tropsch Requirements Match Nuclear Hydrogen Plant Characteristics

(Large, H_2 Demand, and O_2 Demand)

Energy Source	Scale	O_2	Siting
Nuclear	Large (Centralized)	Yes	Population; Seismic
Fossil	Variable	No	Fuel Source; CO_2 Disposal
Solar	Small (Distributed)	Variable	Energy source

Fischer-Tropsch With Nuclear Energy Input



Conclusions

- **Challenges with liquid fuels**
  - **Shortages or high costs**
  - **Traditional production of liquid fuels from alternative fossil feedstocks implies major increases in greenhouse gas production per vehicle mile**
- **Nuclear option can provide hydrogen, oxygen, and heat to FT conversion of carbon feedstocks to liquid fuels**
  - **All carbon is incorporated into the final liquid fuel**
  - **Minimize greenhouse gas production at the fuel plant**
- **The intrinsic requirements of FT and the intrinsic characteristics of nuclear energy potentially favor nuclear-fossil systems for liquid fuels production in a greenhouse-constrained world**
  - **Hydrogen demand**
  - **Oxygen demand**
  - **Scale of operation**
  - **Centralized facility**
  - **Co-siting with fossil sources**

BACKUP

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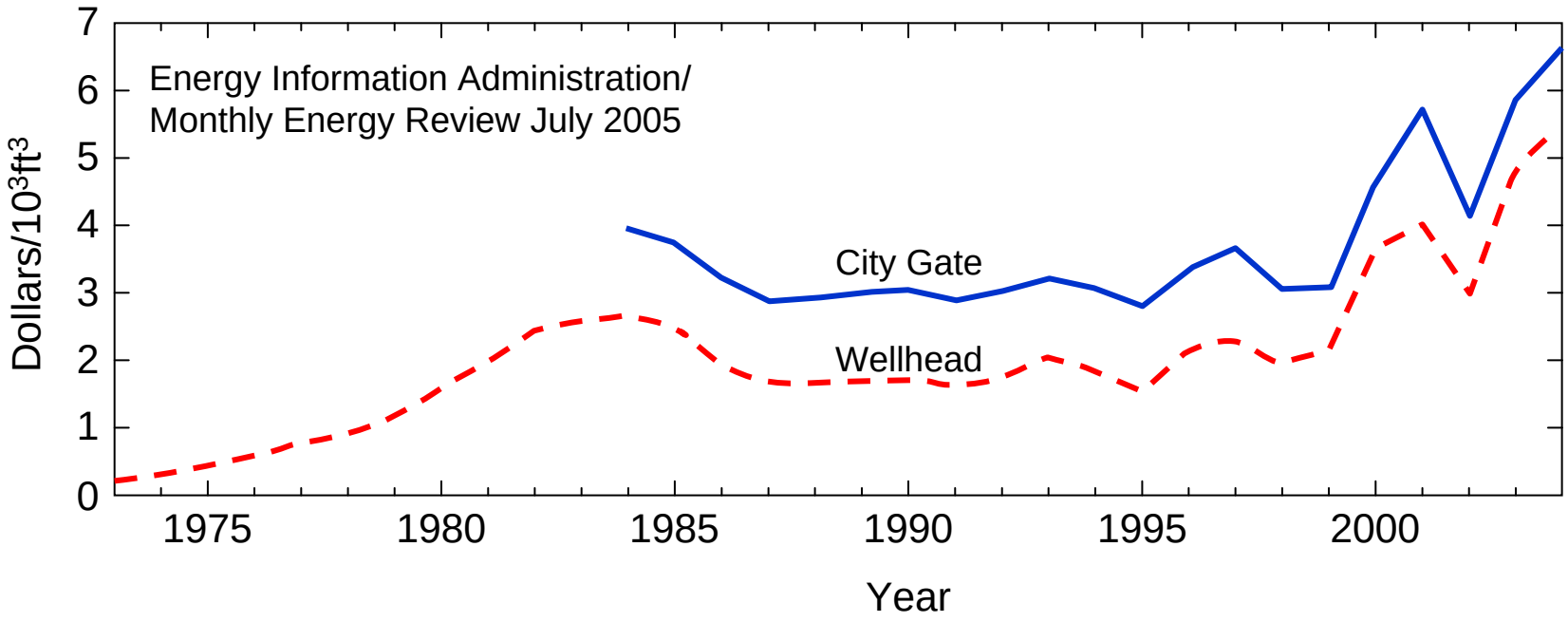
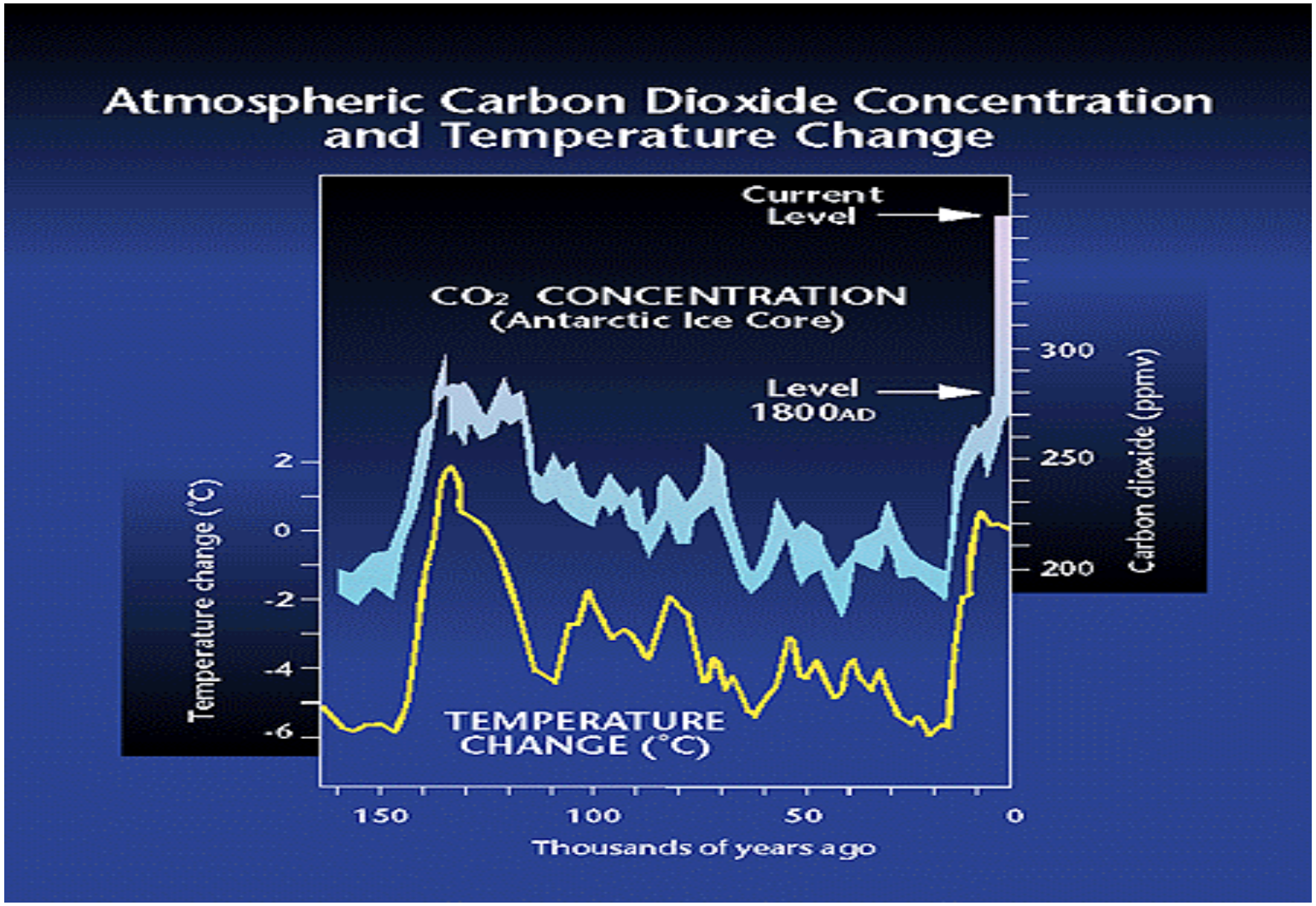
Natural Gas Prices in the United States

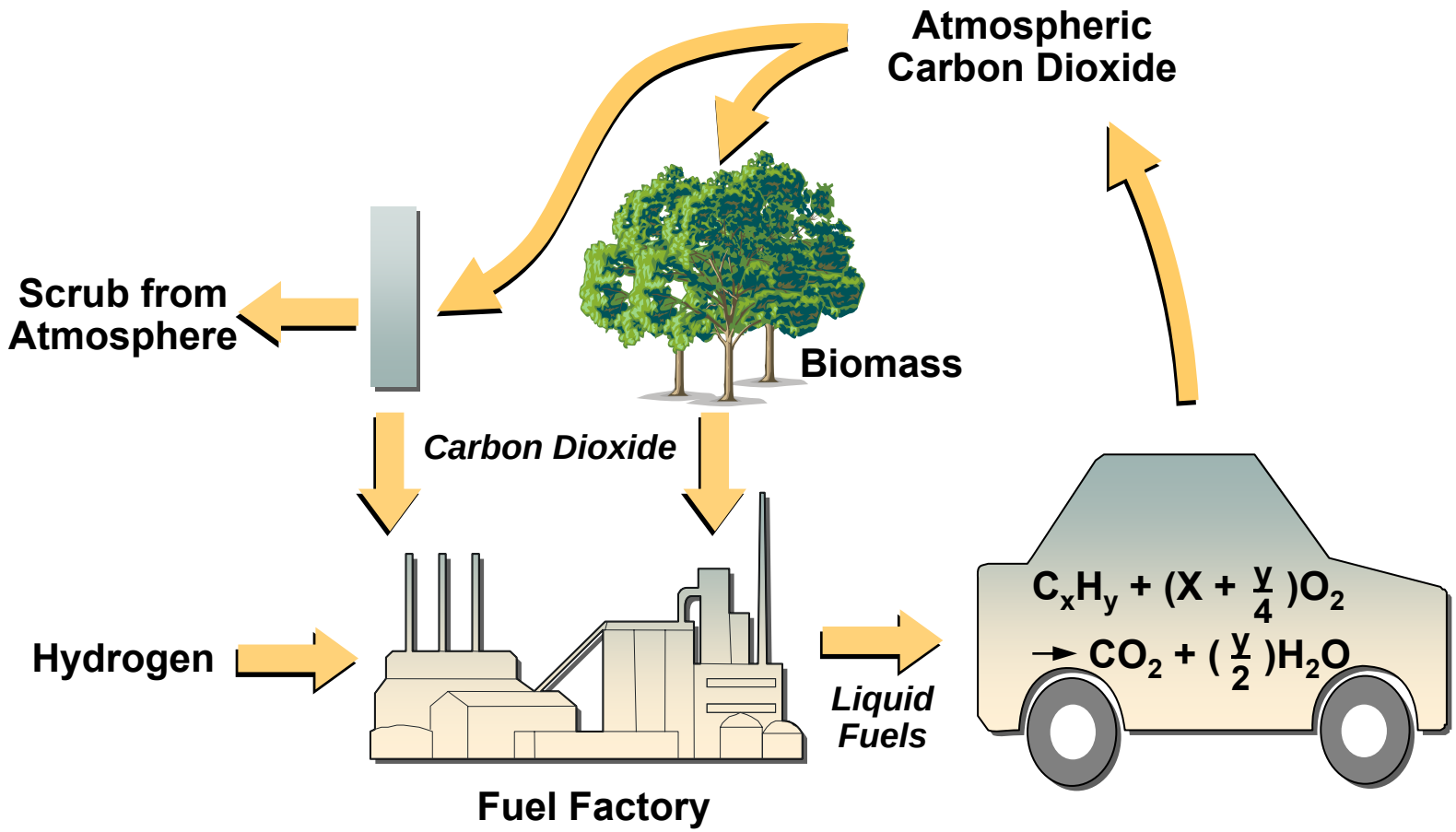


Earth's Temperature and CO_2 Correlate: Adding CO_2 Implies Climatic Change



Liquid Fuels can be Made from H_2 and Atmospheric CO_2

(80% of Energy is for H_2 Production)



Fischer-Tropsch Requirements Match Nuclear Hydrogen Characteristics

Better Match Than Other Energy Sources

- **Economics requires large plants**
- **Centralized processing**
- **Steady-state process operations**
- **Chemical feedstock requirements**
  - **Hydrogen**
  - **Oxygen**