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ENERGY RESEARCH: TECHNOLOGICAL AND SCIENTIFIC BARRIERS AND OPPORTUNITIES

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Energy may be the most important factor that will influence the shape of the society in the 21st century

Energy has long played a critical role in our national security, economic prosperity, and environmental quality.

Today concerns about how we produce and consume energy are at the forefront of public attention.

21st Century: Primary Challenge

Prevent life-enhancing technologies from destroying the environment

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Are we able to predict what energy we will use in the future?

Sometimes doing this is like the weather forecast:

Weather forecast for tonight: dark *(-Gregory Carlin)*

Moreover, we can follow Mark Twain who says that everybody talks about the weather (we may change this for the word *energy*), but nobody does anything about it.

Why Should We Care About Coal Technology, or Advances in Coal Technology

- **Coal ranks 2nd in consumption**
- **Half of electricity is from coal**
- **We use coal because is cheap**
- **And because is here!!!!**

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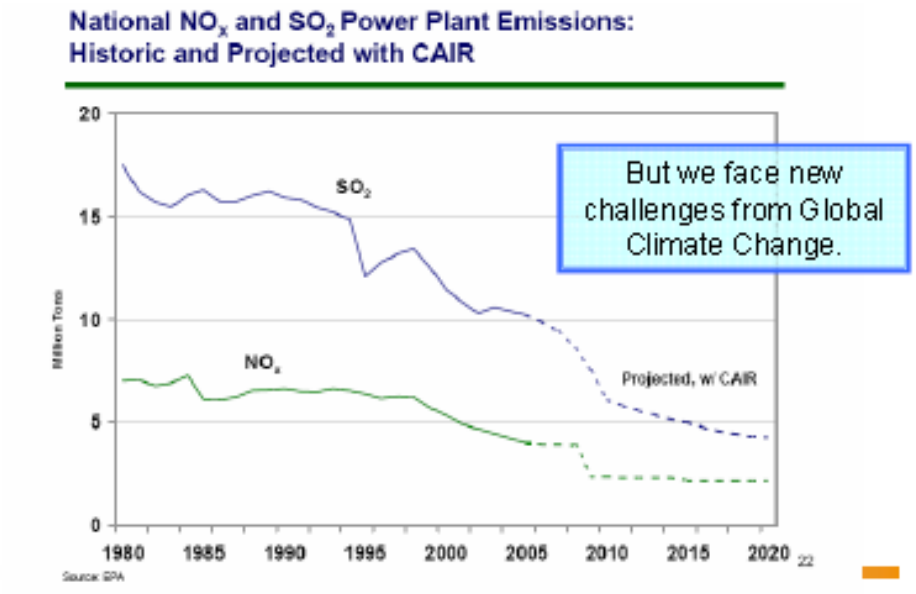
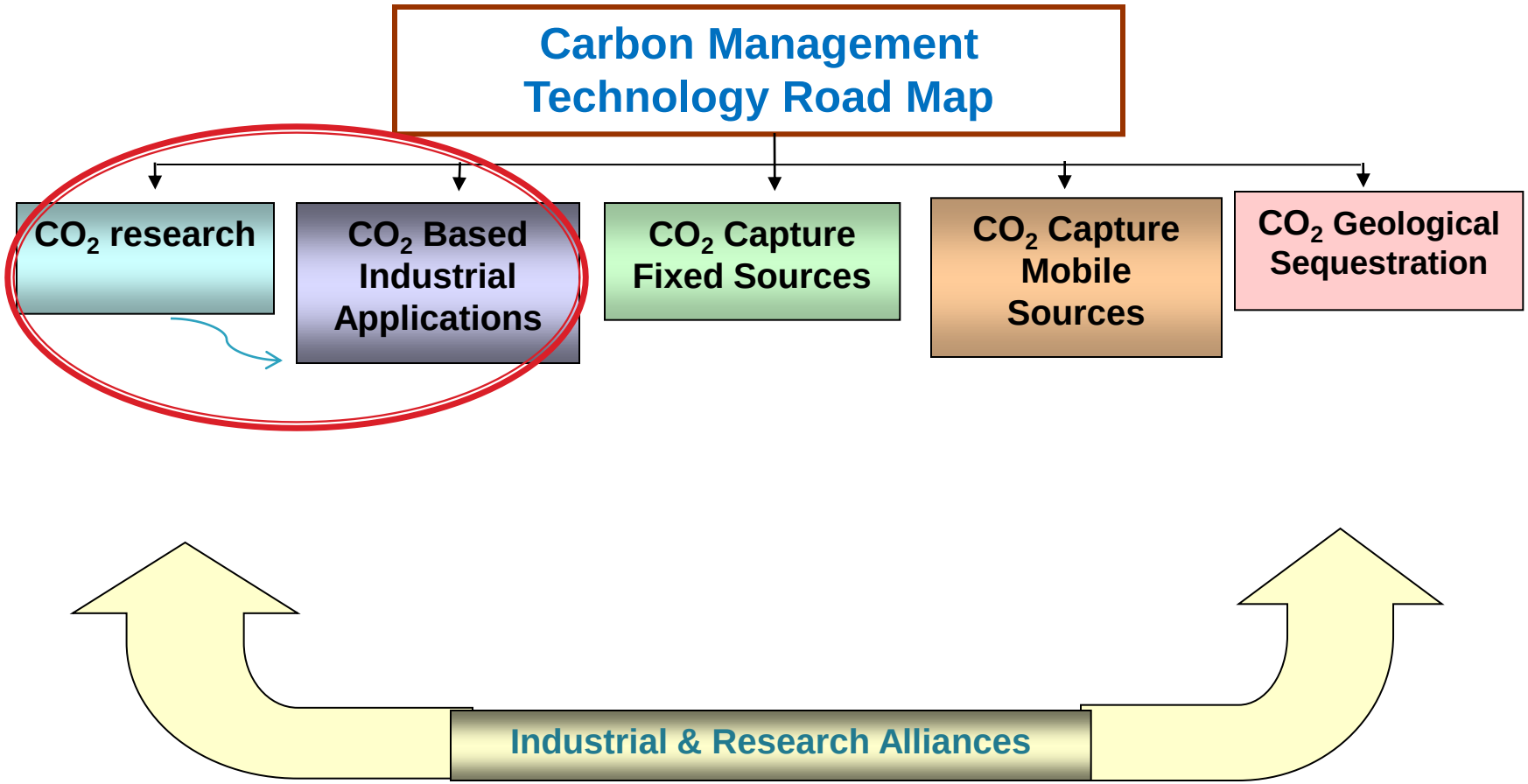
Emissions from coal continue to DECLINE

(despite 60% increase in cola use since 1980)

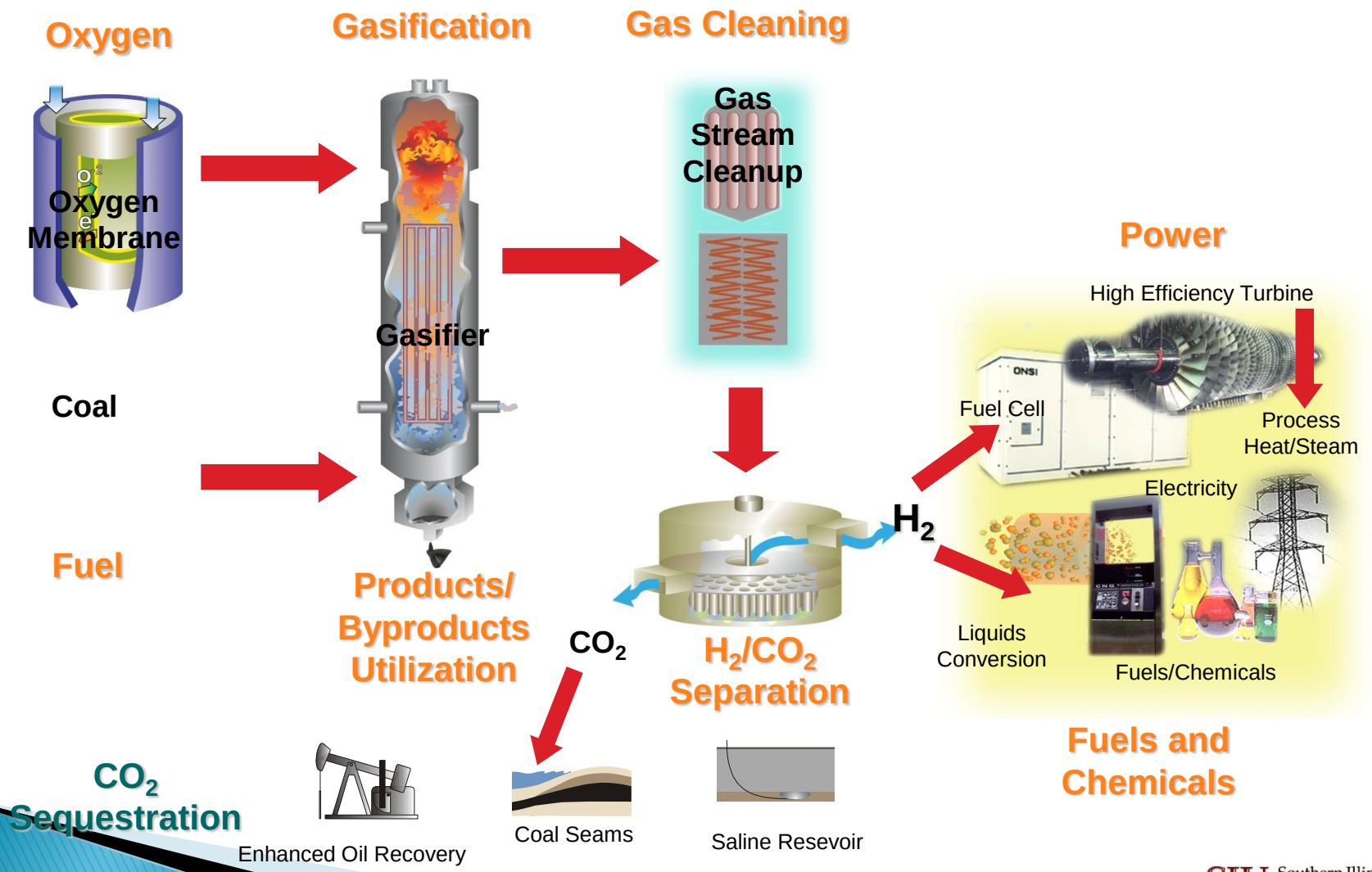




The Future of Coal

As new, cleaner coal technologies are developed, coal is likely to remain an integral part of the nation's overall power supply mix. The U.S. has more coal than any other country — by some estimates a 250-year supply.

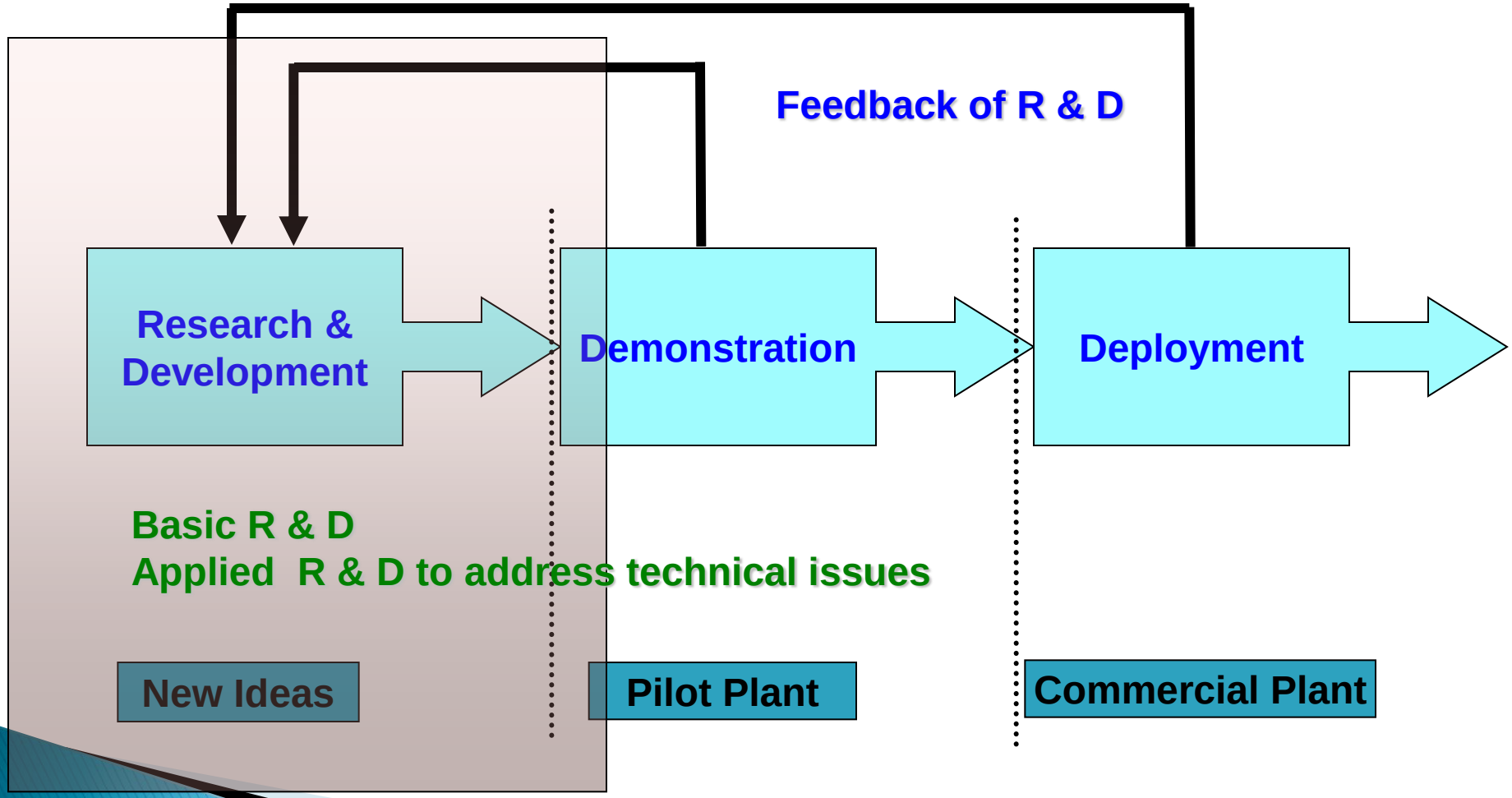
GASIFICATION



Summary of Technical Needs

- advanced filtration,
- Rankine cycle improvement,
- reliability and cost reductions,
- advanced combustion system design and analysis
- emission
- demonstration of mercury control technologies
- IGCC – improved reliability of gasifier and cost reduction for oxygen, advanced turbines and fuel cells, and carbon capture
- combustion – advanced materials and low cost carbon capture technologies
- turbines – rich hydrogen combustion (for CO_2 capture)
- carbon sequestration – issue is need for long-term demonstration of storage
- MUST ALSO RECOGNIZE GAP IN POLICY: long term liability issue

UNIVERSITY ROLE IN THE ENERGY INNOVATION CHAIN

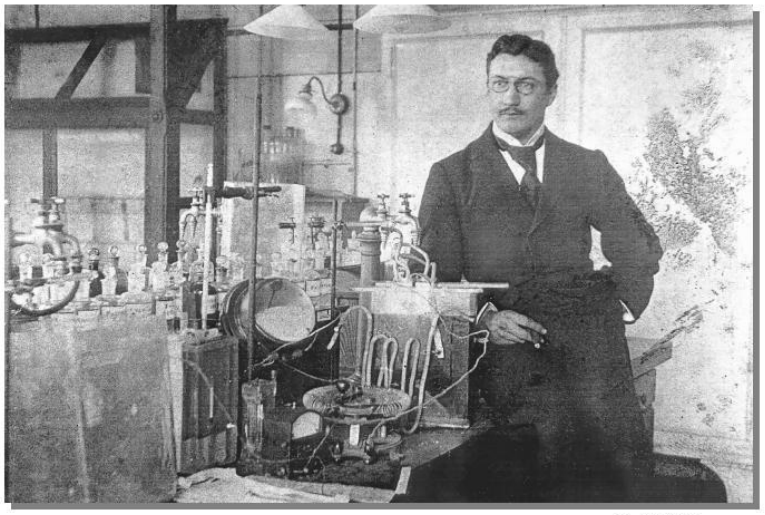


Coal conversion to oil, gas and chemicals

(Fischer – Tropsch Synthesis)

- A solid fossil fuel, such as coal, can be converted into oil, gas or other chemicals.
- Depending on the process, these initial products can be refined to produce transport fuels, substitute natural gas and a wide of range other products, such as plastics and solvents.

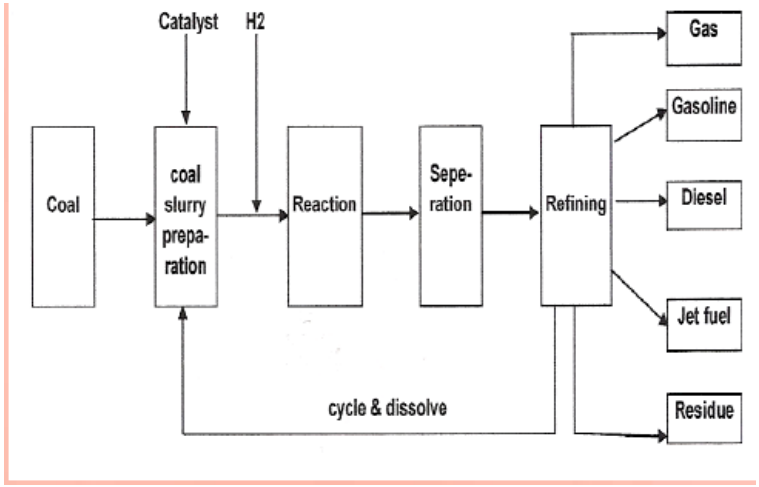
Franz Fischer at Work in 1918



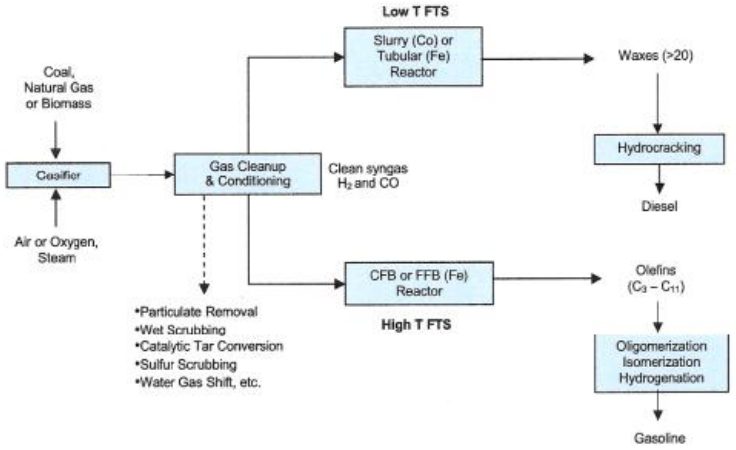
Financial Mail, 2000

Coal conversion routes and key products

Direct liquefaction process



Fischer Tropsch indirect process



Gasoline and Diesel fuel, synthetic natural gas, olefins dimethyl glycol, alcohols, ethylene glycol

DIRECT CONVERSION

Advantages

- Conceptually simple process
- Produces high-octane gasoline
- More energy efficient than indirect conversion
- Products have higher energy density than indirect conversion

Disadvantages

- High aromatic content
- Low-cetane number diesel
- Potential water and air emissions issues
- Fuels produced are not a good environmental fit for certain markets
- May have higher operating expenses than indirect conversion

INDIRECT CONVERSION (FT Process)

Advantages

- Ultra-clean products
- Well suited for CO_2 capture
- Well suited for electric power co-production
- May have lower operating costs than direct conversion

Disadvantages

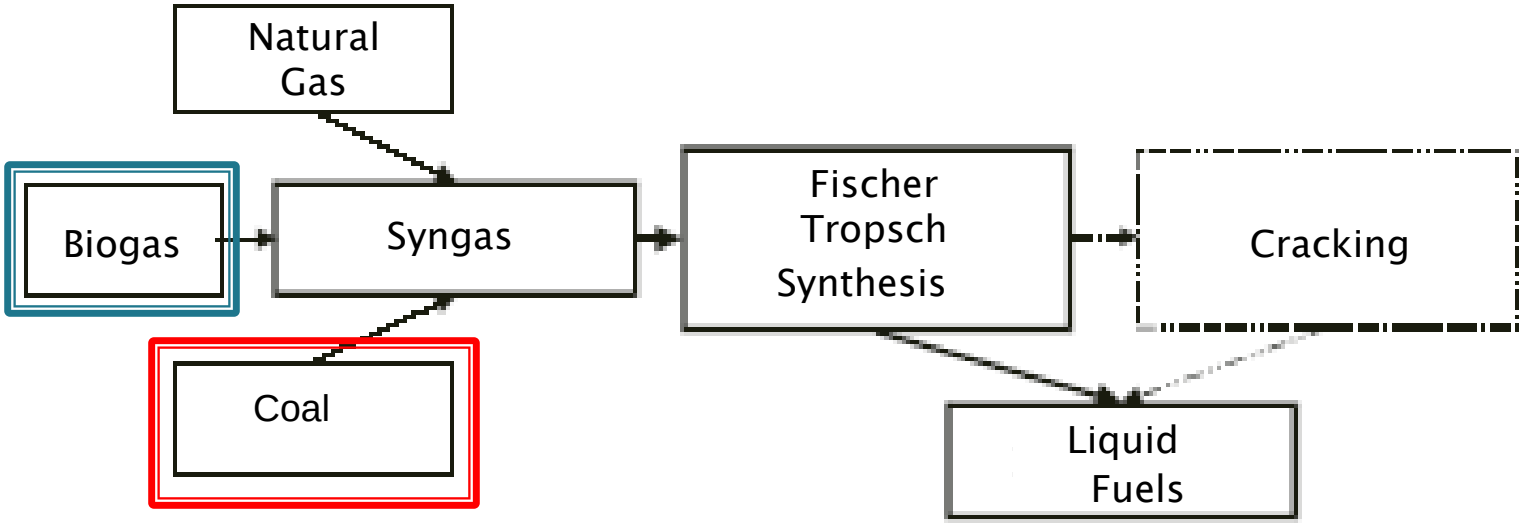
- Conceptually more complex than direct conversion
- Less efficient fuel production than direct
- Produces low-octane gasoline
- Lower energy density than direct conversion products

Economic overview

- CTL will be expensive to build and expensive to run.
- Economies of scale important ((80,000 bbl/day)
- Capital cost US$ 5-6 billion
- Annual operating costs of US$ 250 million.
- 28000t/day of bituminous coal or double that if lignite
- Production cost per bbl will rise by US$5/bbl if CCS is added.
- Vulnerability to oil and coal price fluctuations
- Coal to chemicals vulnerable to imported products produced from low cost gas
- Commercial considerations include decision on scale and product mix (e.g. chemicals, power, CO2), coal cost and security, products off-take agreements, and financing mechanisms.

Environmental considerations

- **Indirect impacts**-It takes about 4t of coal to produce 1t of synthetic oil so more coal will be needed and, if CCS is introduced, even more again.
- **Direct impacts** - Needs up to 10 t of water to produce 1t of synthetic oil, which may well introduce constraints in terms of where plants might be sited. There are also local emissions, effluents and residues from a CTL plant to be considered.
- **High carbon intensity concerns** unless CCS is included, although NETL suggests that environmental footprint could be less than oil with CCS at comparatively modest cost.



Research has to be done on…..

1. More selective catalysts
2. Gas-phase FT synthesis with simultaneous cracking
3. Enhancing selectivity by mass transfer limitations
4. Termination to either paraffins or olefins
5. Re-adsorption of olefins
6. Secondary reactions on different active sites such as cracking and hydrogenation

Final Thoughts

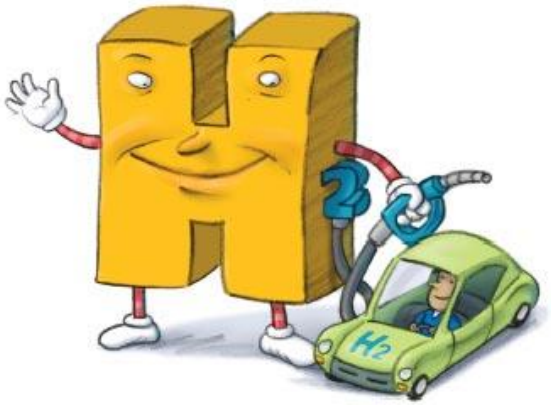
- Coal based liquid and gaseous fuels will have to compete with other energy sources in the coming decades – not just traditional crude oil, but also biofuels, natural gas and non-traditional hydrocarbon fuels.
- The future development of coal conversion technologies will depend on the process plants being able to produce products that are competitive in the transportation fuel and chemicals markets - and also being able to meet increasingly strict environmental operating standards.
- Strong government support must be a key element in the future development of such projects.

Transition to Hydrogen

the "forever fuel" that we can never run out of

Water + energy ⟶ hydrogen + oxygen

Hydrogen + oxygen ⟶ water + energy



Transition to Hydrogen

- Not found naturally in the pure state
- Energy carrier rather than energy source
- Fuel cells
- Local air quality improvement short-term
- Potential GHG reduction longer-term
- $billions to convert gasoline network

Hydrogen buses in Luxembourg

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Is it safe?: A primer on Hydrogen safety

- **All fuels are hazardous, but…**
- **Hydrogen is comparably or less so, but different:**
  - **Clear flame can't sear you at a distance; no smoke**
  - **Hard to make explode; can't explode in free air; burns first**
  - **22× less explosive power**
  - **Rises, doesn't puddle**
  - ***Hindenburg* myth (1937) – nobody was killed by hydrogen fire**
  - **Completely unrelated to hydrogen bombs**

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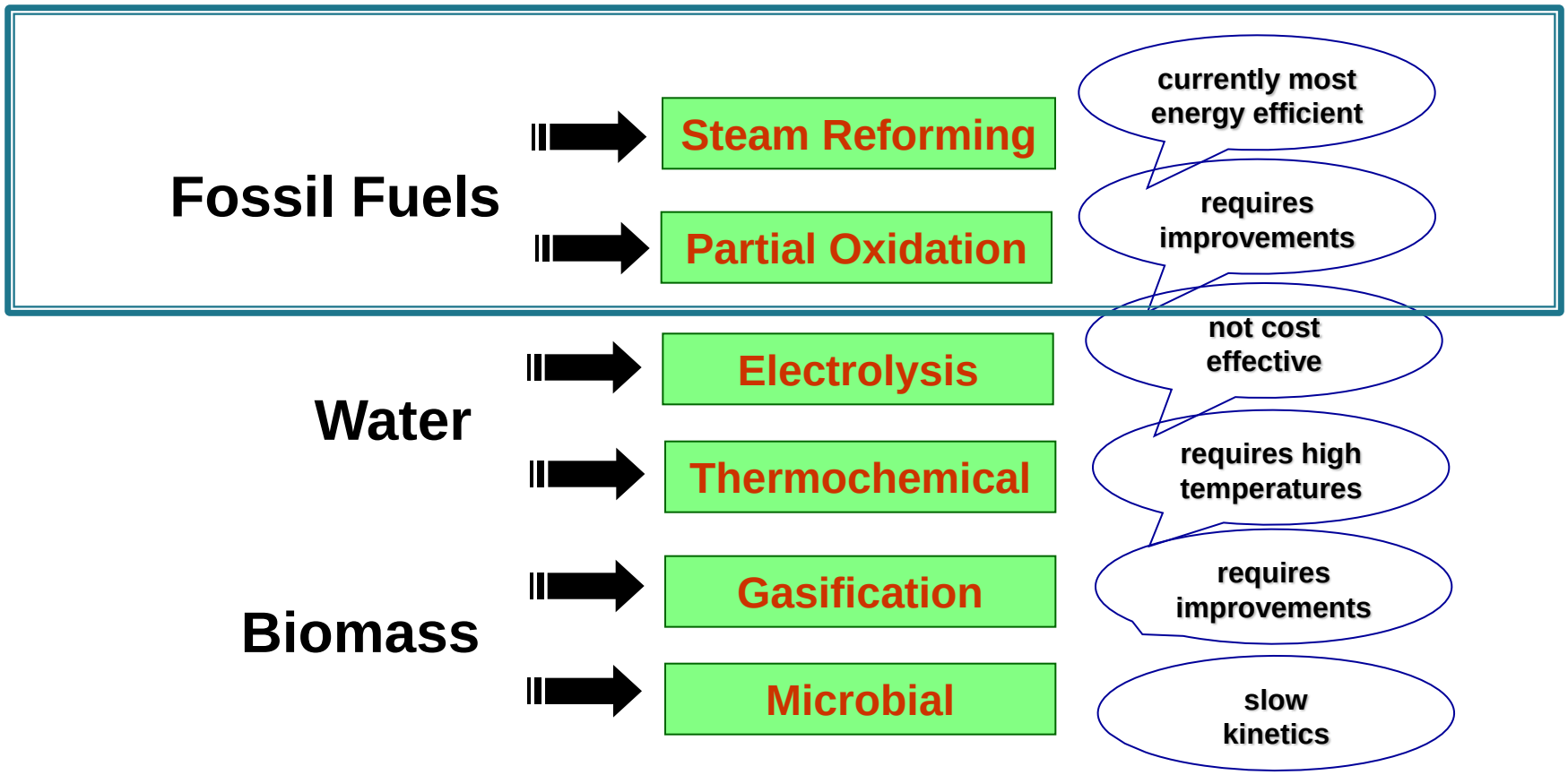
Where Does Hydrogen Come From?



95% of hydrogen is currently produced by steam reforming

Vision 21 *The "Ultimate" Power Plant Concept*

- Multiple products - electricity in combination with liquid fuels and chemicals or hydrogen or industrial process heat.
- Not restricted to a single fuel type.
- Coupled with carbon sequestration technologies.
- Technology modules interconnected to produce selected products.
- Very High efficiencies with near-zero emissions.
- Uses low-polluting processes.

THANK YOU