Is Coal Dead?

A Speculative Look at Our Energy Future

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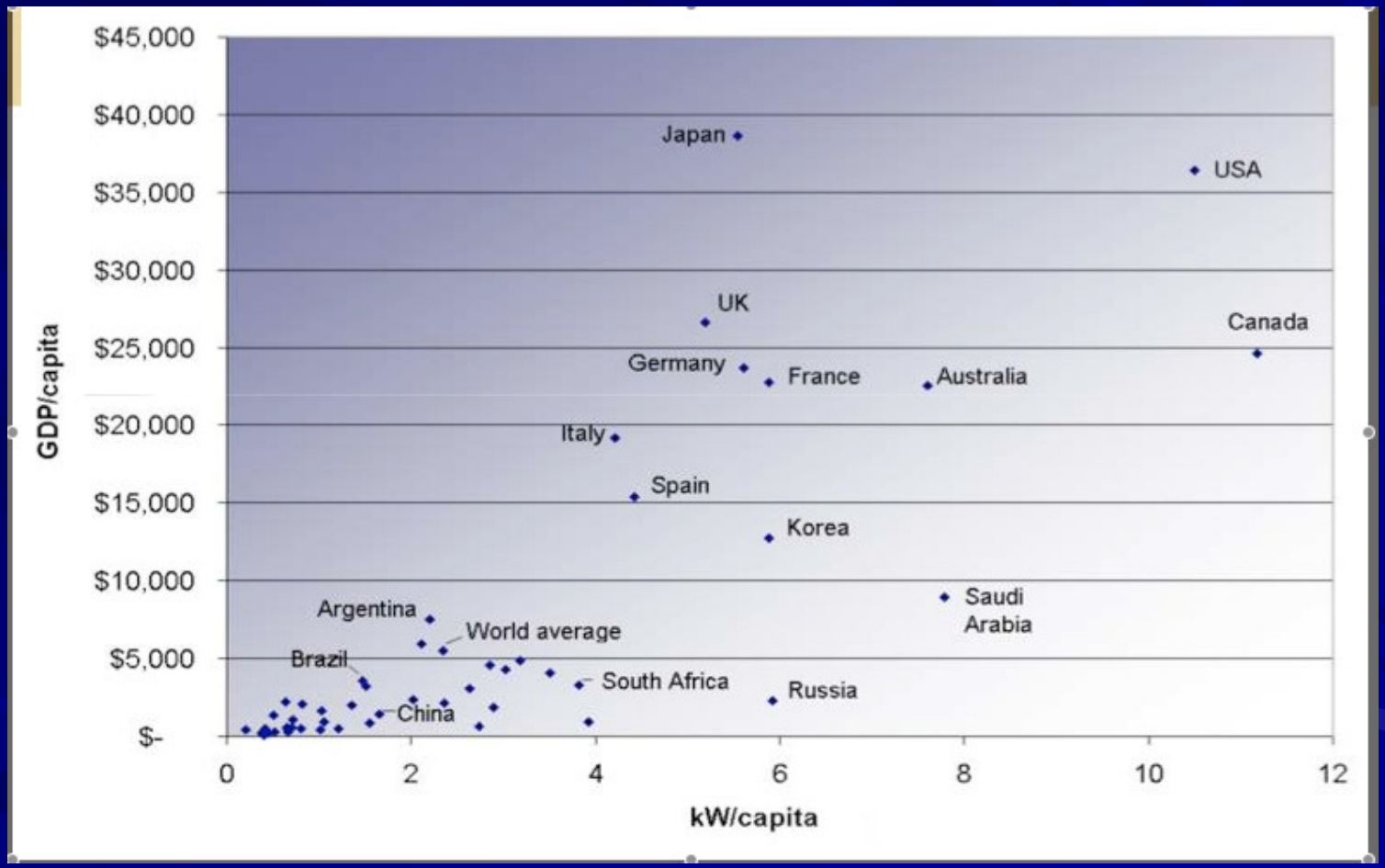
Bucknell University, February 2011

GDP correlates with energy use



World energy consumption

The current use of energy worldwide is roughly 10 TW (terawatts) annually.

That's

1,000,000,000,000 watts

or *ten billion* light bulbs!

THE 10-TW CHALLENGE

- A third to half of the world's population lives in dire circumstances, lacking food, clean water, shelter, health care, education…
- To provide even a modest level of human needs to these people will require *10 more* terawatts.
- The challenge: Where are we going to get them?

The 10 TW Answer (Part 1)

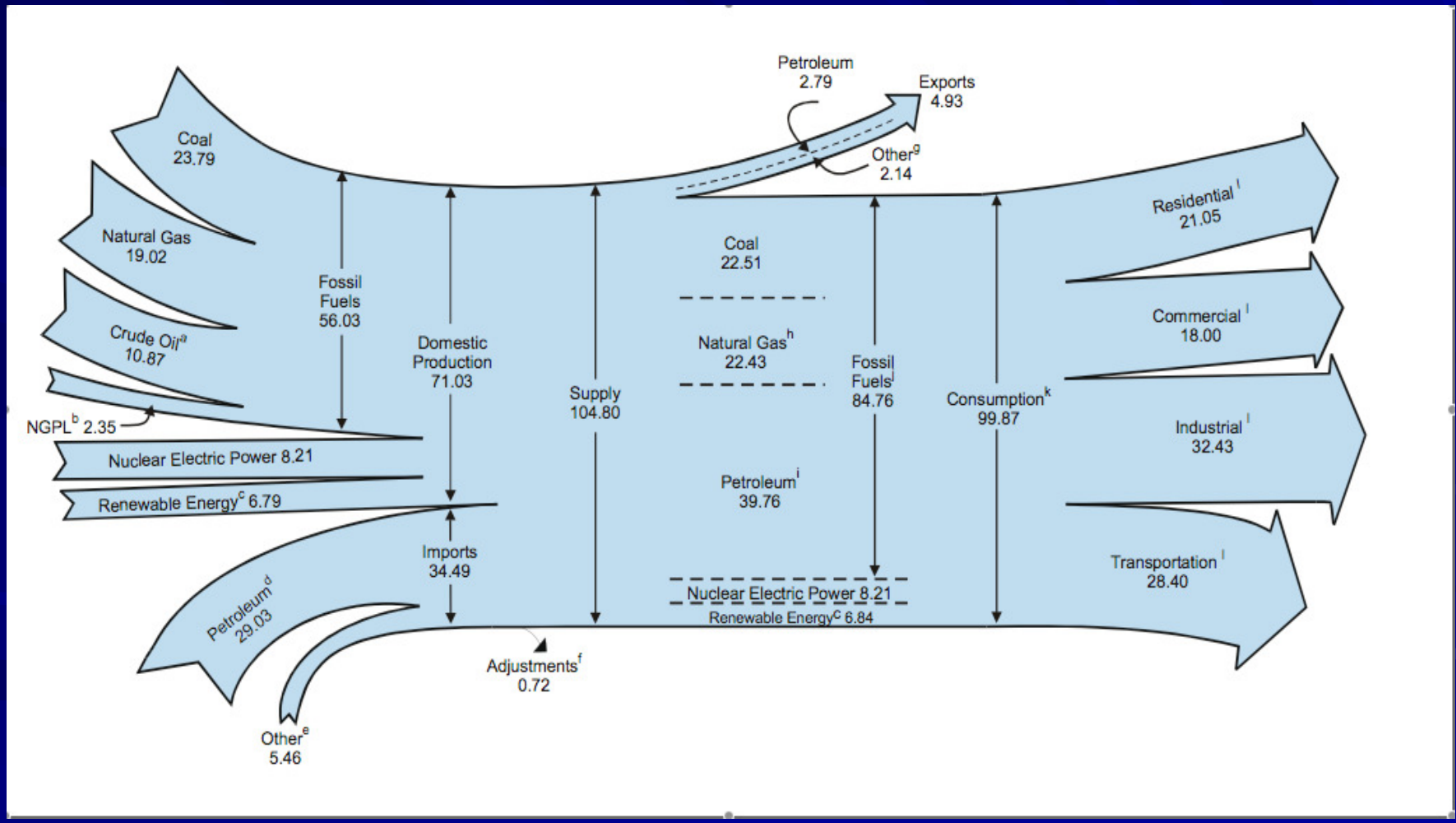
What energy resources will supply the "extra" 10 TW?

→ *We're going to need everything.*

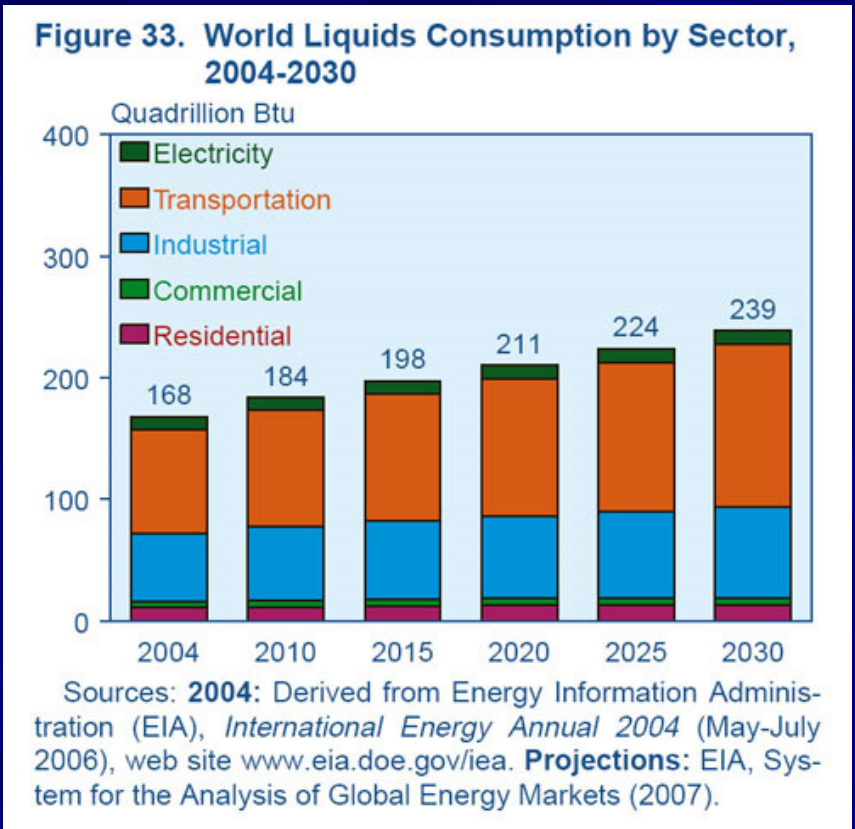
Every energy source has…

- Some technological advantages, and some disadvantages.
- Some positive economic factors, and some economic disincentives.
- Some negative impacts on the environment, and some positive effects.

Energy Flow in the United States



Transportation today depends on liquid fuels



- EIA predicts that transportation will continue to dominate use of liquid fuels.
- Liquids are likely easier to displace from other energy sectors.

“But man cannot live by trust alone. He has to have oil at reasonable prices as well.”

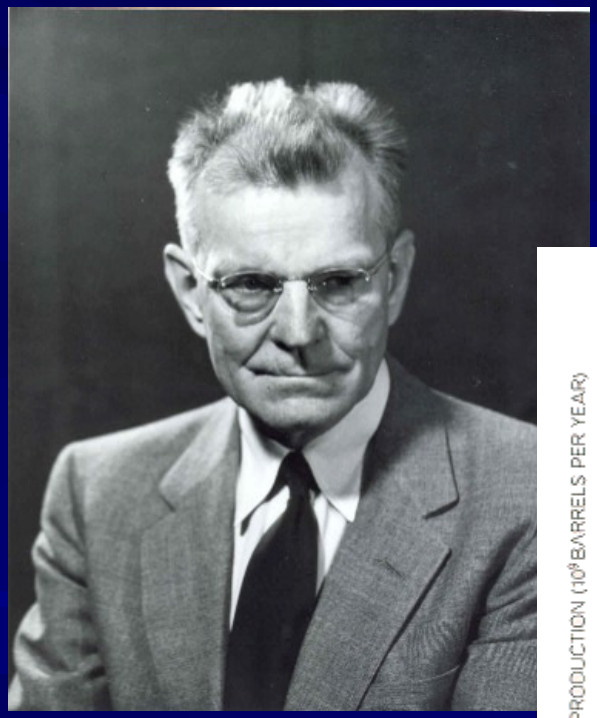
—*The Times of Zambia*
February 26, 1974

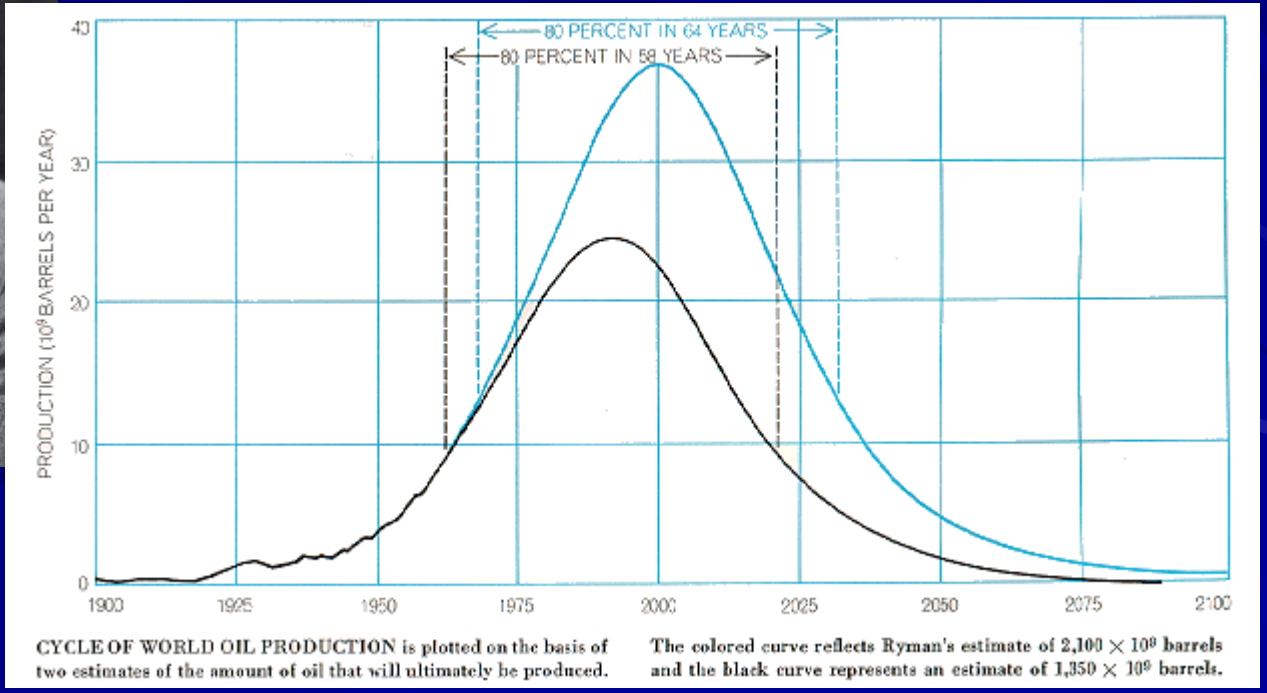
A Tale of Two Embargoes

- The 1967 Arab oil embargo was a “non-event.” The United States single-handedly broke the embargo by increasing domestic oil production.
- The 1973 Arab oil embargo resulted in major economic and societal dislocations in the U.S.
- *What happened in between?*

M.King Hubbert

"Our ignorance is not so vast
as our failure to use what we know."





CYCLE OF WORLD OIL PRODUCTION is plotted on the basis of two estimates of the amount of oil that will ultimately be produced. The colored curve reflects Ryman's estimate of $2{,}100 \times 10^9$ barrels and the black curve represents an estimate of $1{,}350 \times 10^9$ barrels.

Peak Oil

- Hubbert predicted that domestic oil production would peak in 1969. The peak was actually reached in 1970.
- Various predictions suggest that world-wide peak oil will occur sometime between 2005 and 20??.
- Have we hit peak oil already?

Regardless of When the Peak Hits, Demand is Rising Steadily

- Rapid modernization of China and India directly affects half the world's population.
- The Tata "Nano" is for sale in India and elsewhere at ≈$2,500.

Liquid Fuels from Coal

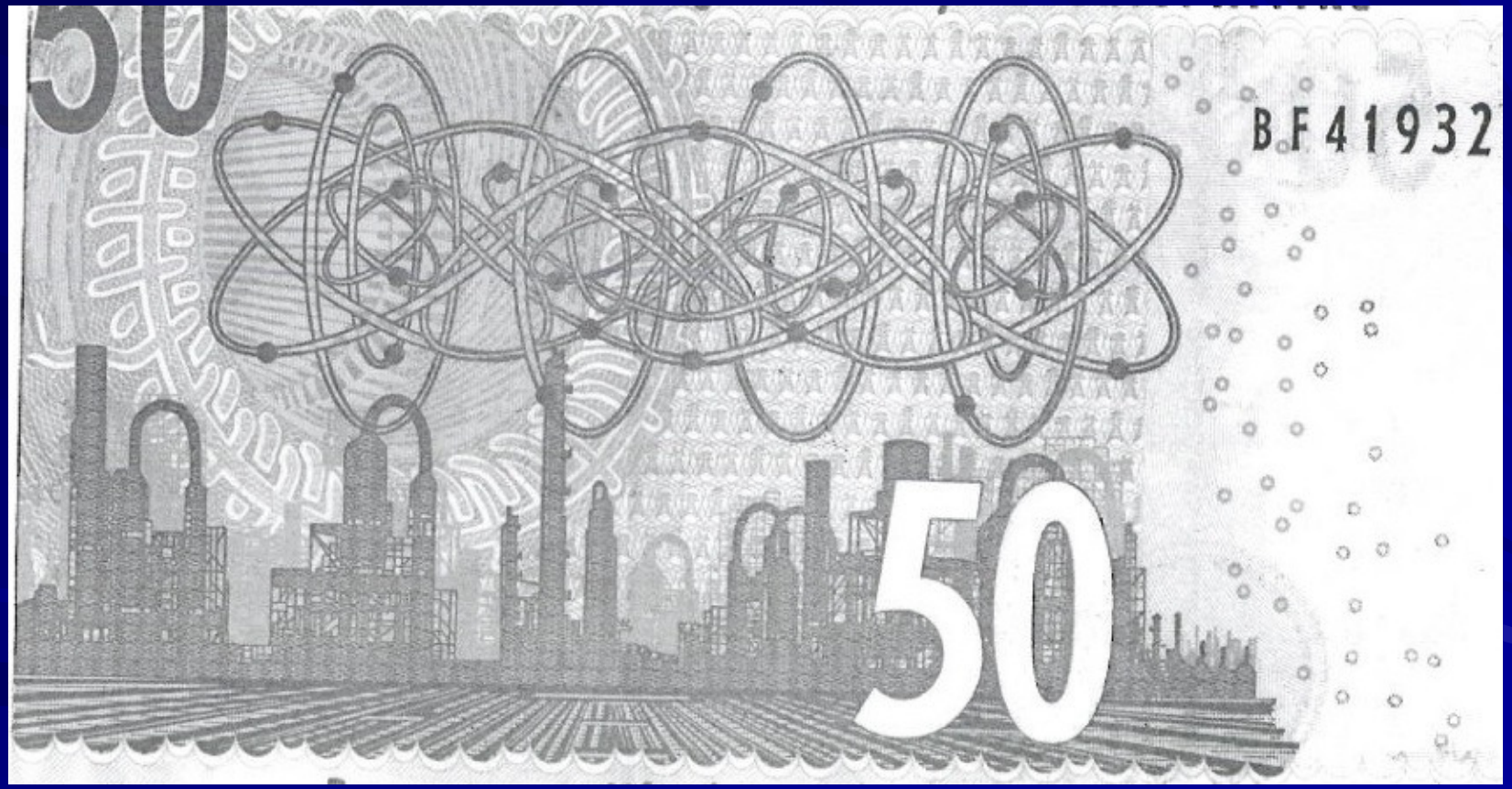
- Processes developed in Germany in the 1930s. Significant contribution to the German war effort.
- South Africa produces ≈40% of its liquid fuel needs from coal.
- A new plant just started up in China.

Coal to Liquids in 1944:

Contribution to German liquid fuels production

	Direct	Indirect
Aviation fuel	93%	—
Motor gasoline	20%	15%
Diesel fuel	33%	7%
Fuel oil	22%	—
Lube oil	5%	3%
Total	40%	7%

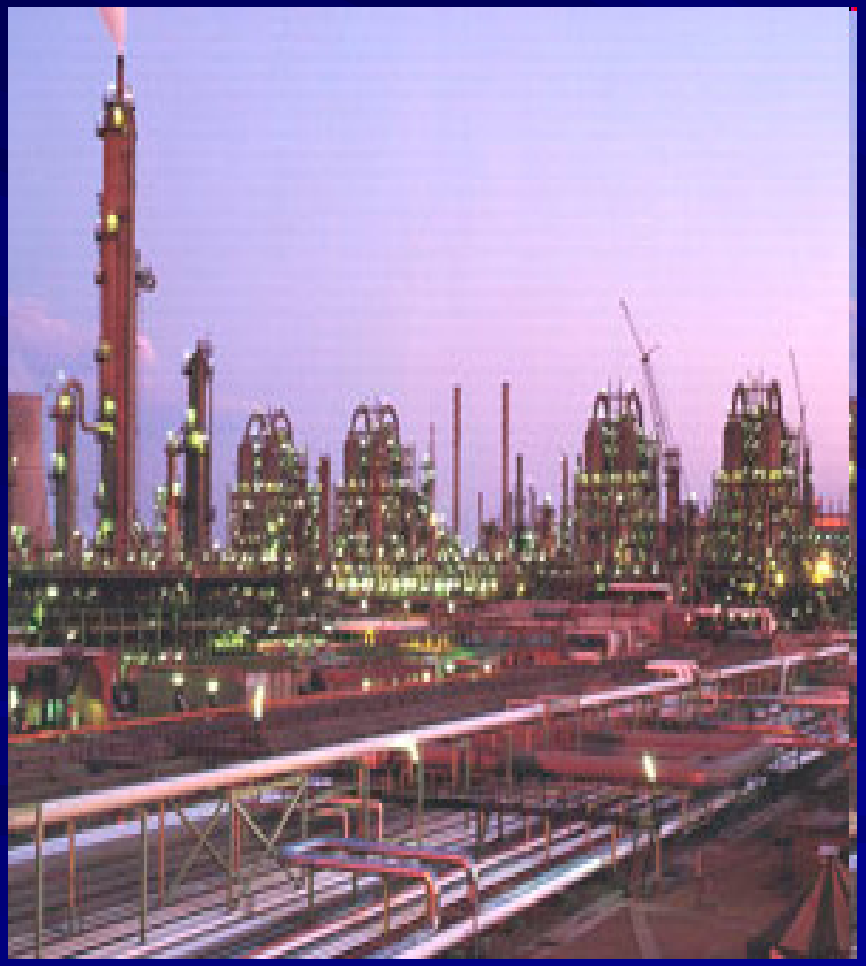
The importance of liquid fuels from coal to South Africa



Issues with Coal to Liquids Technologies

- Environmental
- Economics
- Mining impact
- Time to availability

South African Synthetic Fuel Plant

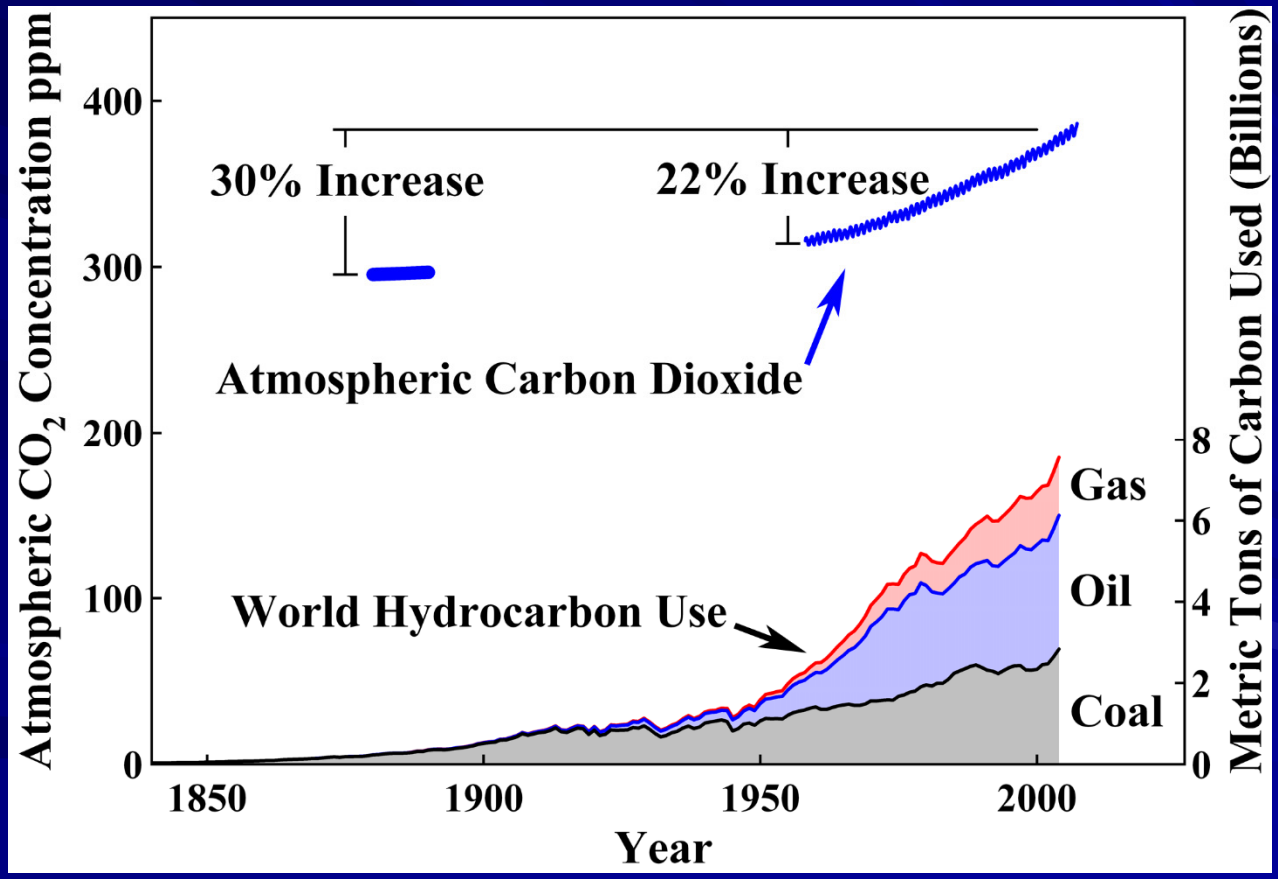


- This is the most successful synthetic liquid plant in history.

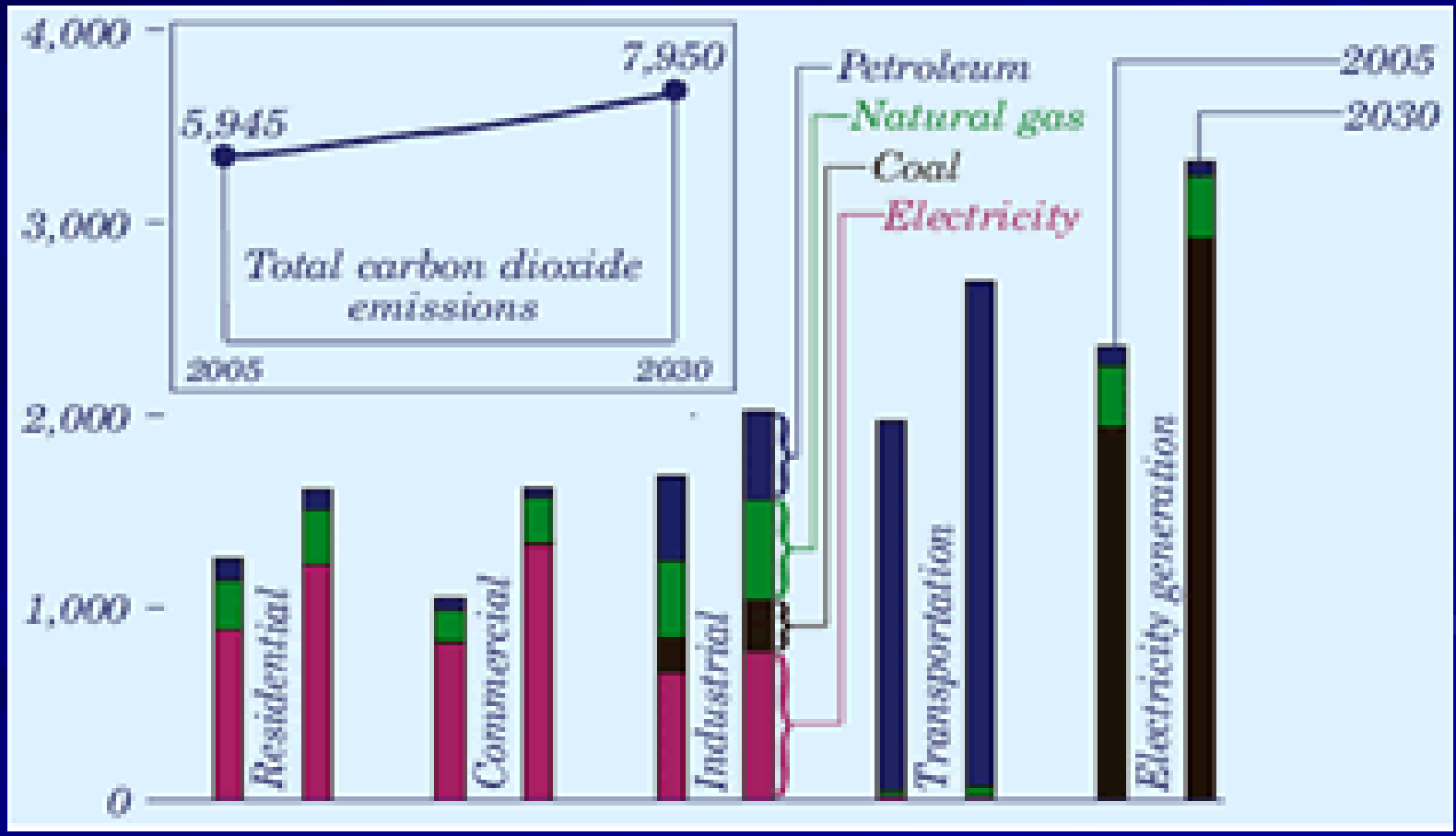
and

- It is the largest point source of CO_2 on the planet.

Increasing CO_2 Correlates with Hydrocarbon Use



U.S. Carbon Dioxide Emissions, EIA data (million metric tons)



Part of the Problem

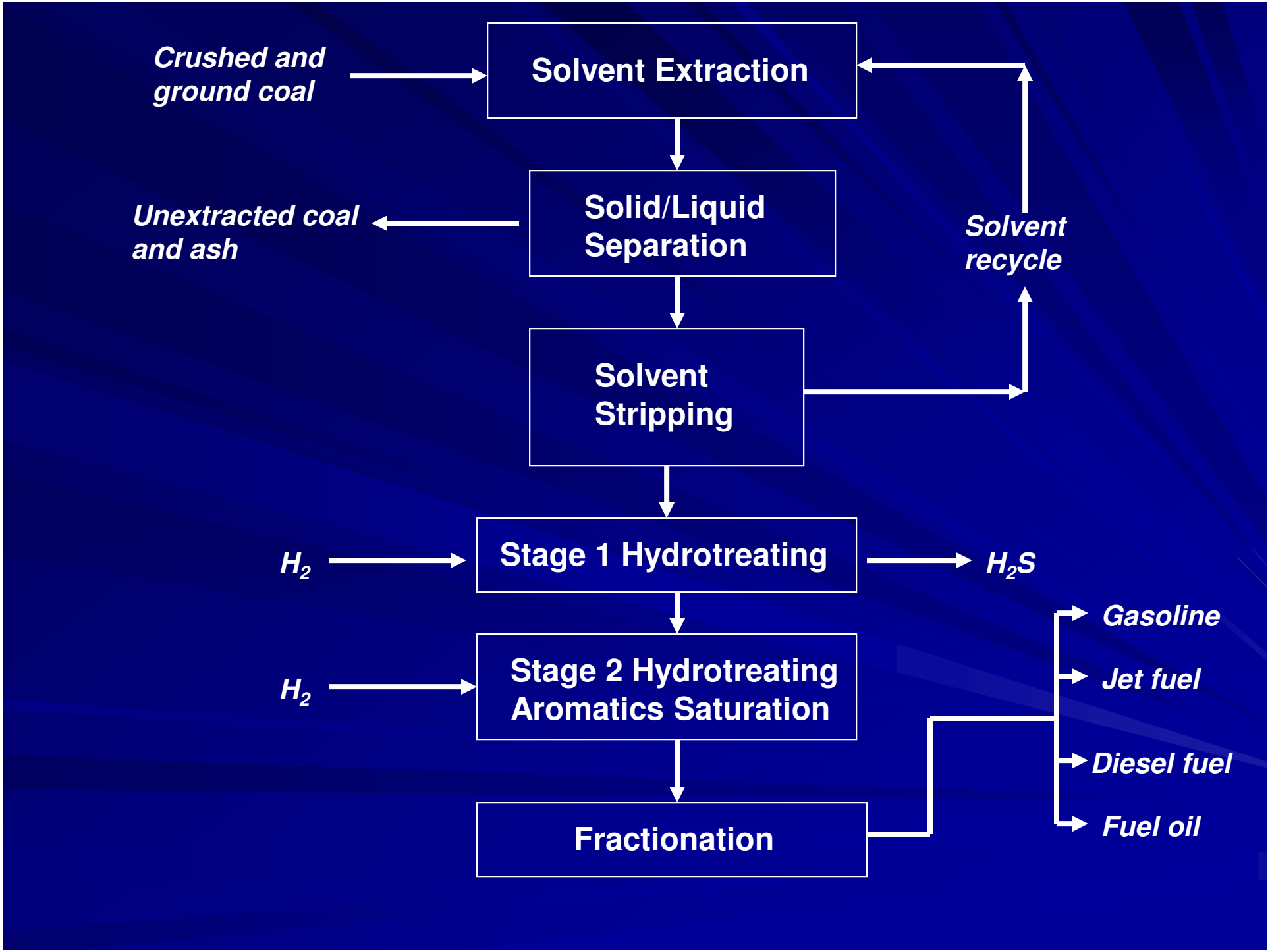
- Estimates from U.S. Environmental Protection Agency show that making coal liquids via standard technology would double the lifecycle CO_2 emissions relative to petroleum fuels.
- Estimates from other sources are fairly similar.

Which leads to concern…

Should coal be dead?
Is coal-to-liquids a “dirty lie”?

- Coal to liquids plants *can be* environmental nightmares….
- ….**if** we’re dumb enough to build them using 1970s technology!
- Is there an alternative?

Can we make coal “green”?


Crushed and ground coal
Solvent Extraction
Solid/Liquid Separation
Unextracted coal and ash
Solvent recycle
Solvent Stripping
H_2
Stage 1 Hydrotreating
H_2S
H_2
Stage 2 Hydrotreating Aromatics Saturation
Fractionation
Gasoline
Jet fuel
Diesel fuel
Fuel oil

A different route to coal liquids

- This process was developed at Penn State.
- It makes very clean liquid fuels (3 parts per million sulfur).

Results of testing prototype middle distillate fuels

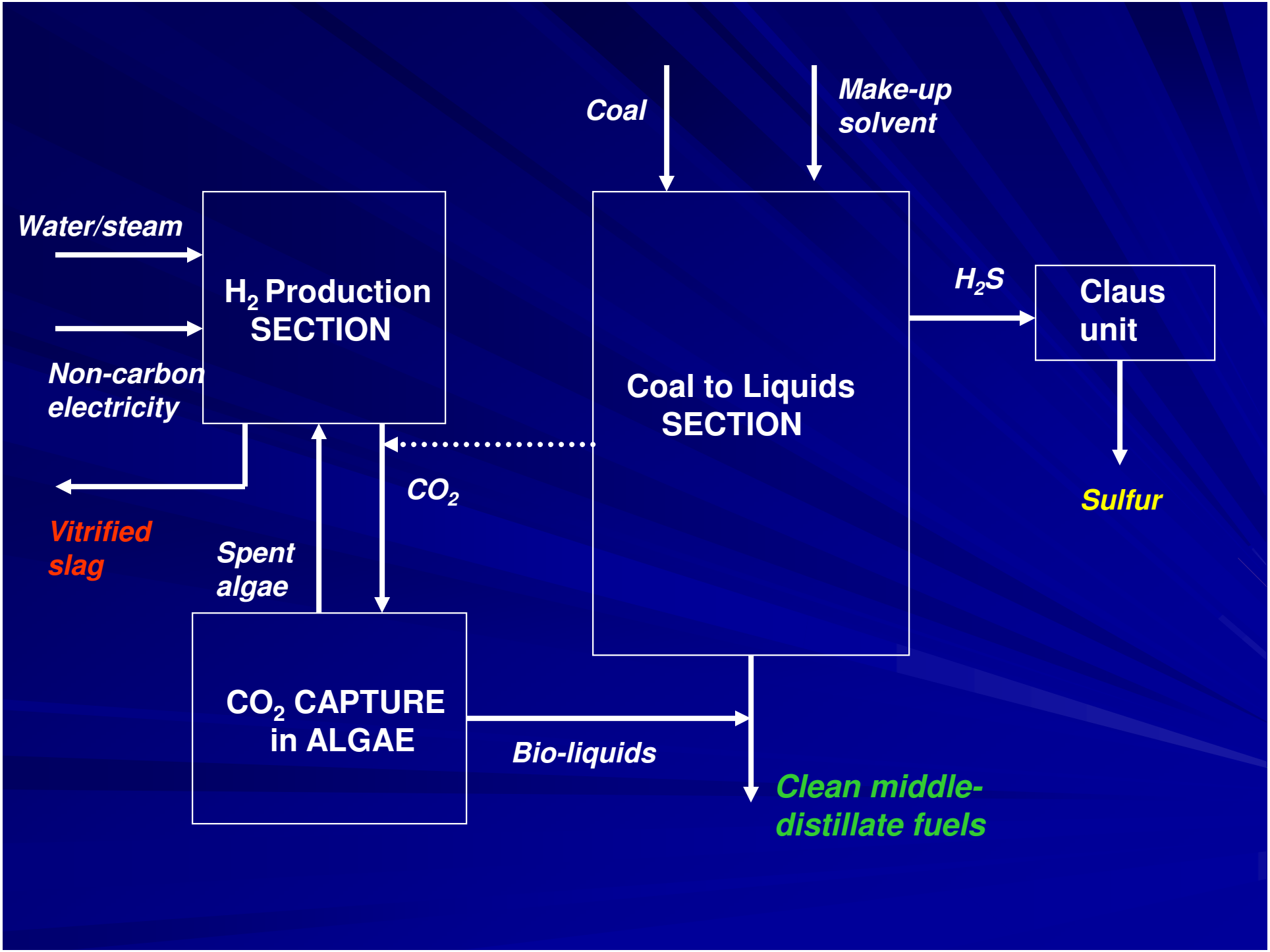
- ✓ Successfully operation of jet engine on 8,400 L of prototype fuel. “Just like Jet A.”
- ✓ Successful 560-km road test of diesel pick-up truck; and successful test with 1:3 blend with petrodiesel.
- ✓ Successful operation of solid oxide fuel cell using the liquid.

Potential emission problems

- Making hydrogen from coal will have substantial CO_2 footprint (because of the process used).
- Burning fuel to make process heat: CO_2 production even with natural gas.
- Residual solids (wet with solvent) from extraction—what do we do with them?
- H_2S from removing sulfur from the fuels.

Toward the zero-emission coal-to-liquids plant

- Make most of the hydrogen from water, using "non-carbon" sources of electricity—solar or wind.
- Convert the H_2S to sulfur using known technology—sell the sulfur for additional revenue.
- Capture any CO_2 using algae; capture bio-oils from the algae to blend with the fuels.
- Gasify the left-over coal and dead algae; convert the ash to a glass for, e.g. road fill.


Coal
Make-up solvent
Water/steam
H_2 Production SECTION
Non-carbon electricity
Coal to Liquids SECTION
H_2S
Claus unit
Sulfur
CO_2
Vitrified slag
Spent algae
CO_2 CAPTURE in ALGAE
Bio-liquids
Clean middle-distillate fuels

Input / output

Inputs

- Coal
- Water/steam
- Make-up solvent
- “Non-carbon” electricity

Outputs

- Clean middle-distillate liquids, with bio component
- Sulfur
- Vitrified slag

Status

- ✓ Core CTL technology is proven at various scales.

Student projects currently involve

- ➢ The H_2 production section, including coal/biomass co-gasification.
- ➢ A preliminary economic analysis of entire plant.

Transportation Energy from Coal…

…but with a few problems…

- Air pollution
- A voracious thirst for water—need large infrastructure for water supply
- “Hammering” the rails—frequent maintenance of the tracks
- Very low efficiency

…which brought us to where we are today.

Most “diesel” locomotives are really diesel-electrics. The diesel engine operates a generator that supplies DC to electric traction motors that actually propel the locomotive.

The diesel-electric locomotive

- Much less air pollution, especially smoke and cinders.
- No water consumption for the locomotive.
- Less damage to the track.
- Greater efficiency of converting energy in the fuel into moving the train.

Coal in diesel locomotives?

- ✓ Several processes can convert coal into clean diesel fuel.
- ❖ Direct use of coal in a diesel engine—not one of Rudolf Diesel's better ideas!

- ➢ *But now for something entirely different…*

The UC-AC Locomotive

- UltraCoal is a process under development to produce a near-zero ash and sulfur solid coal.
- UltraCoal can be used in a turbine—not reciprocating engine (such as a diesel).

The UC-AC Locomotive

- The turbine operates a generator that supplies energy to AC traction motors. No steam (water) needed
- No air pollution, significant efficiency gains in turbine and AC motors, low track damage, no water consumption.

Transportation energy from electric traction

- Electricity has been made using coal for over a century.
- *New* coal-fired power plants can be very clean; old ones were not.
- But, can't we come up with something better?

Making electricity from coal

Solar cells (photovoltaics)

- Solar cells convert the energy in sunlight directly into electricity, with minimal impact on the environment.
- The key component of solar PV cells is silicon.

Solar cells (photovoltaics)

- Silicon works in solar cells because it is a semiconductor, and can be modified ("doped") to obtain the desired PV effect.
- In 1955, it was discovered that anthracite is a semiconductor. Can we make PV cells from anthracite?
- Nobody knows!

Speculations about coal's future

- *Near term*—continued contribution to electricity generation. *But*, we can press for greater compliance with mine safety and environmental regulations.
- *Medium term*—liquid fuels or direct use of coal in transportation. *But*, not using old technology.
- *Long term*—don't waste coal by burning it! High-tech uses as a carbon material (maybe PV cells???)

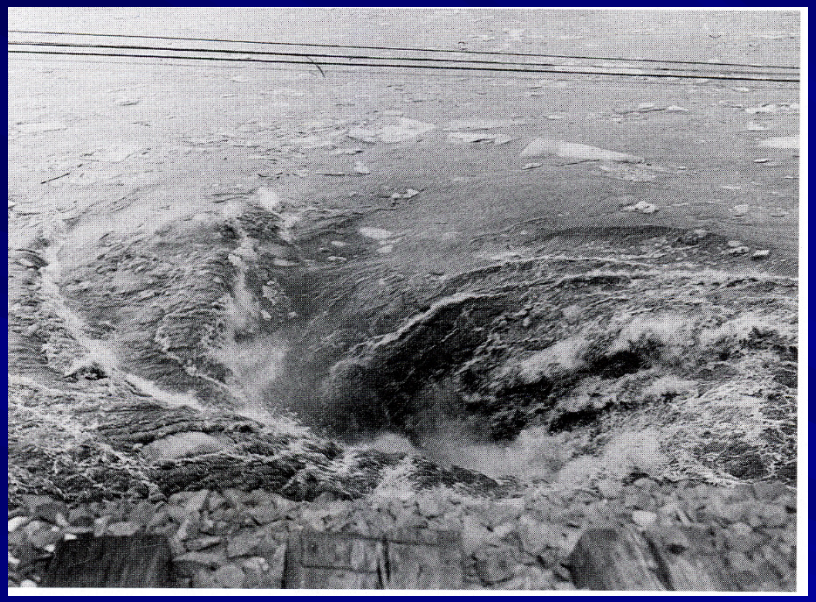
The 10 TW Answer (Part 2)

What energy resources will supply the "extra" 10 TW?

→ *We're going to need everything.*

And we're going to need everybody!

Coal is Dead (?)…



The Knox Mine Disaster - January 1959

Is Coal Dead?

“The report of my death was an exaggeration.”

Mark Twain, 1897

Is Coal Dead?

"….theres a dance or two in the old dame yet"

Don Marquis,
the song of mehitabel