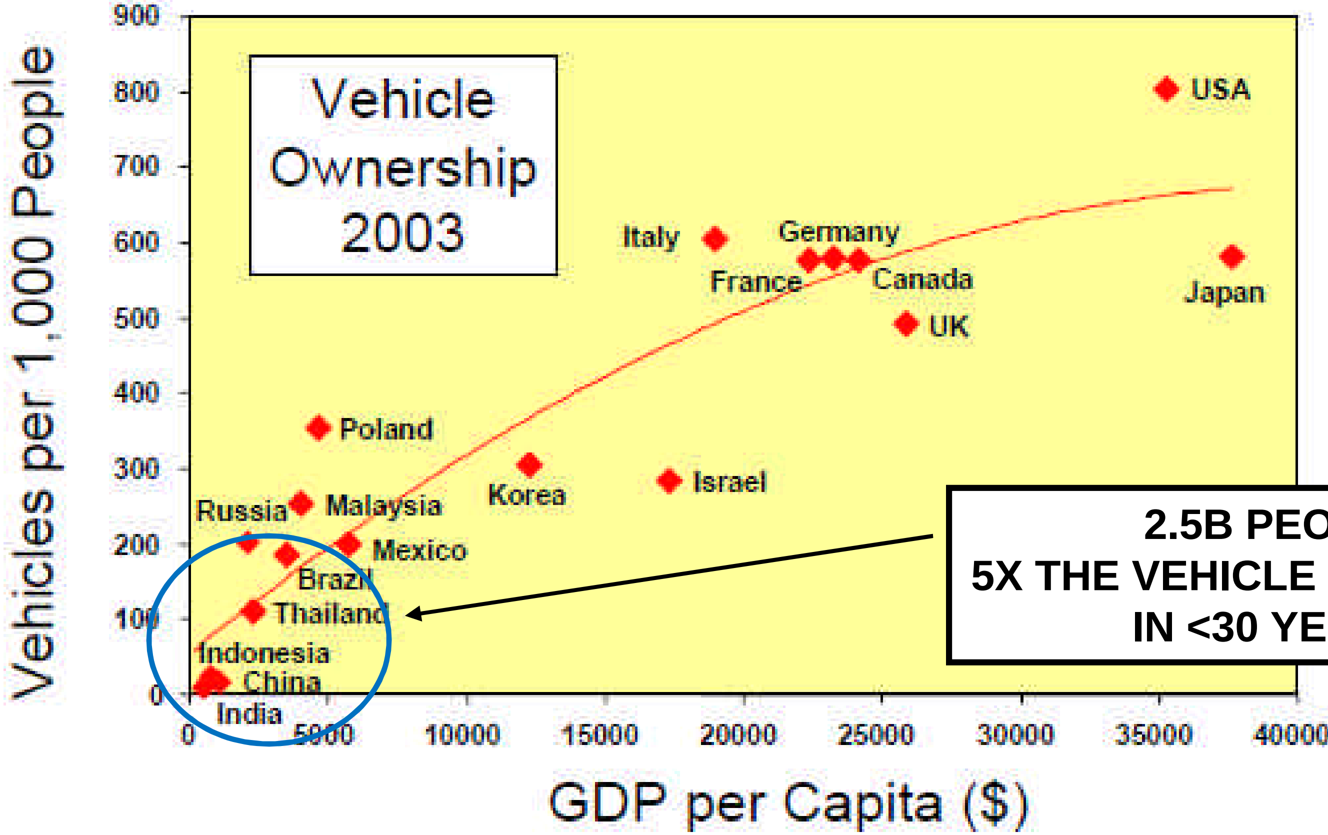
MITIGATING CO_2 PRODUCTION IN COAL-TO-LIQUIDS PROCESSES

Presented by Robert Walty
C2O Corporation

INTRODUCTION

- **Coal-To-Liquids Definition**
  - Process of converting all or part of the raw coal to liquid alternative fuels with petroleum fuel properties.
  - Requires thermo-chemical treatment to accomplish the conversion.
  - Results in CO_2 production equivalent to the net fossil-fuel energy required to drive the processes.
- **Environmental Challenges**
  - Compliance with current local, state and federal regulations.
  - Technology to capture and convert all pollutants to products.
  - Mitigate the life-cycle CO_2 footprint of synthetic fuel to less than that of petroleum fuels.

Enormous Potential for More Vehicle Use Highlights Need for Increased Liquid Fuel Supply



2.5B PEOPLE
5X THE VEHICLE OWNERSHIP
IN <30 YEARS!

SOURCE: OECD/IEA (2006) ©, copied from *Some Background on U.S. and Global Energy Flows with Implications for Energy Security*, Howard Gruenspecht, Deputy Administrator, DOE/EIA, National Bureau of Economic Research Energy Security Workshop, Cambridge, MA, February 14, 2008

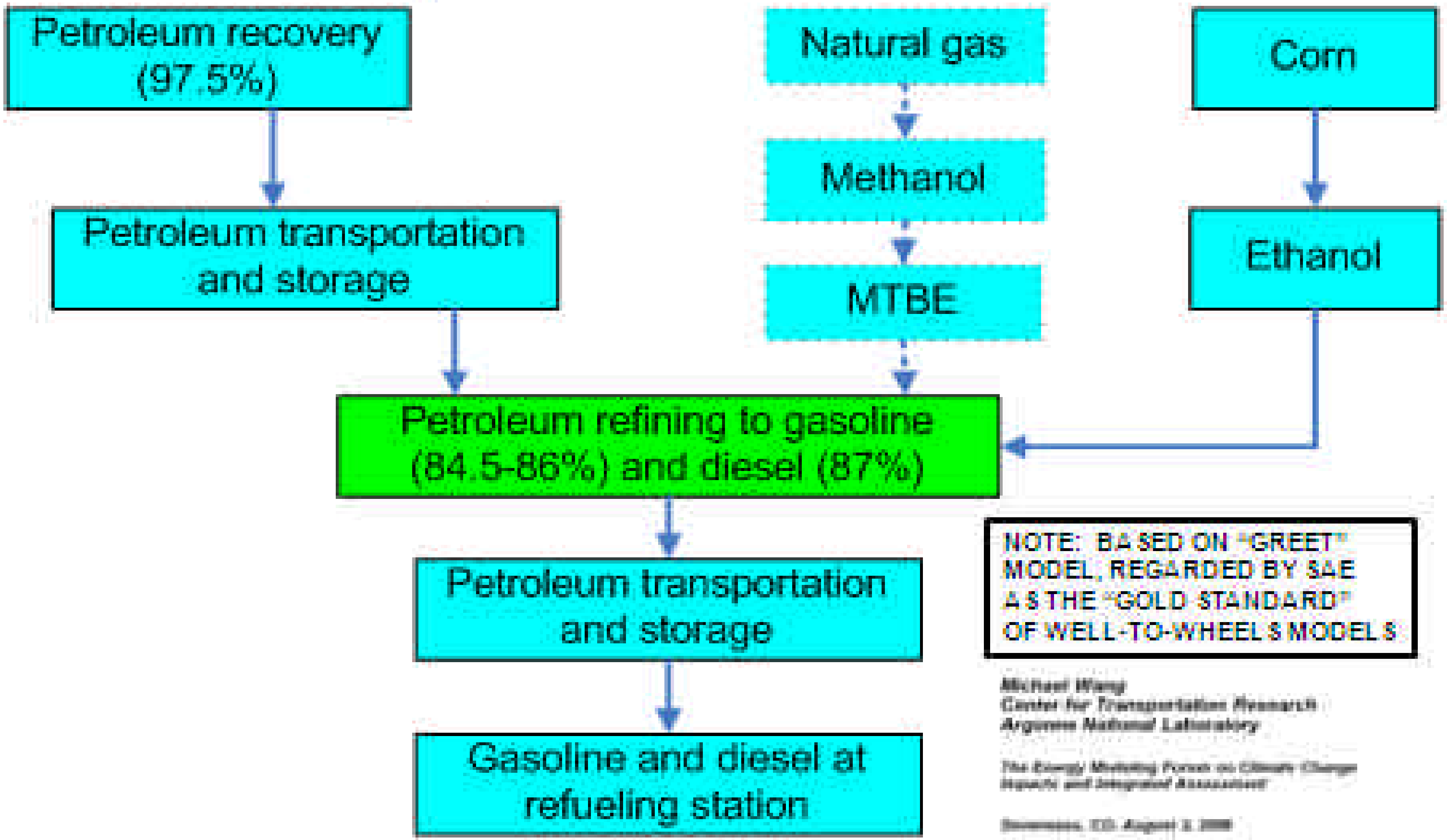
NRCCE
National Research Center for Coal and Energy

According to BP, Transport comprises 21% of CO2 emissions world wide.

West Virginia University

13

Petroleum Refining Is the Key Energy Conversion Step for Gasoline and Diesel



NOTE: BASED ON "GREET" MODEL, REGARDED BY SAE AS THE "GOLD STANDARD" OF WELL-TO-WHEELS MODELS

Michael Wang
Center for Transportation Research
Argonne National Laboratory

[illegible]

[illegible]

UNITED STATES ENERGY SECURITY AT RISK

DRIVEN BY US AND FOREIGN DEMAND WITH DECREASING OIL RESOURCES

INELASTIC DEMAND

WITH DECLINING US PRODUCTION

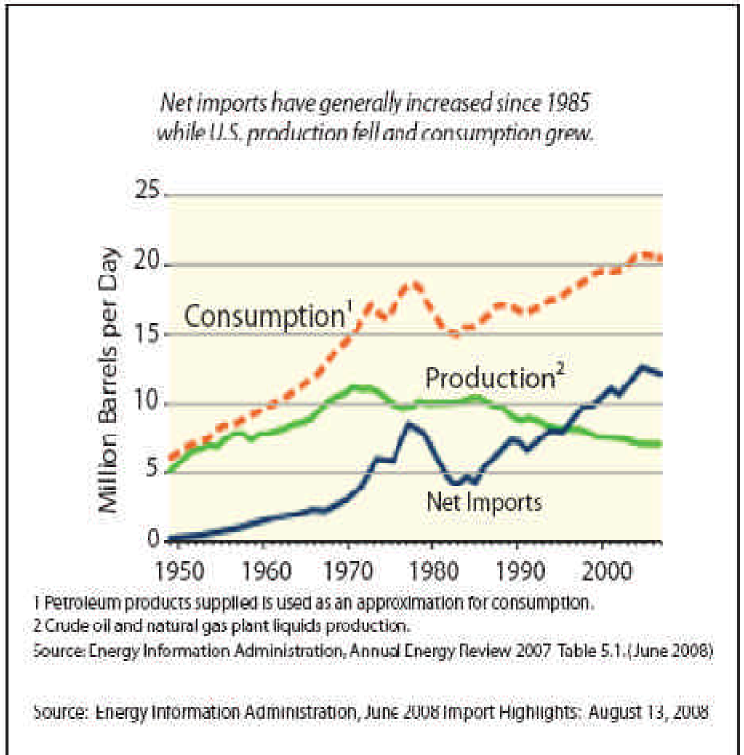
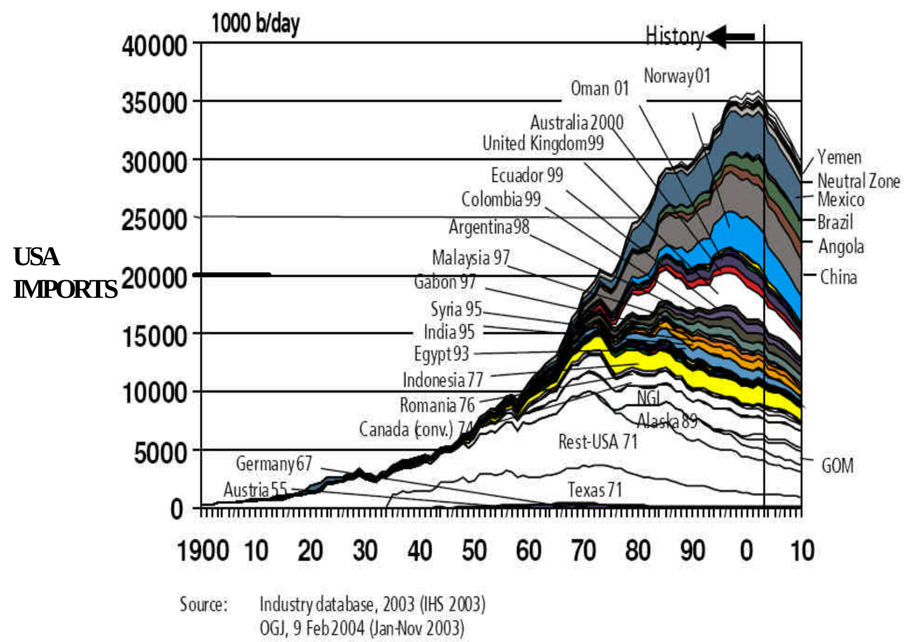


Figure 17: Consumption, Production and Import Trends for Petroleum (1950-2007)

COMPOUNDED BY DWINDLING GLOBAL SUPPLY

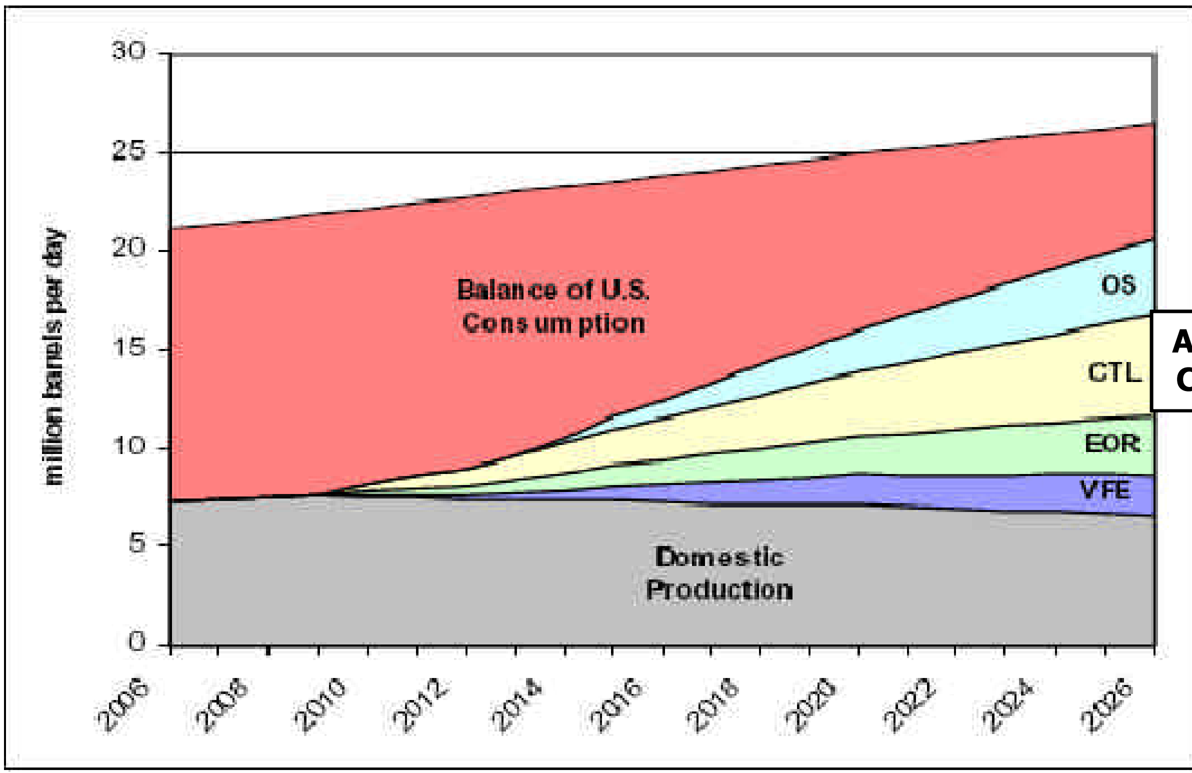
THE WORLD'S OIL PRODUCTION IS IN DECLINE



6/10/2009 C_2O Confidential 8

REDUCING AMERICA’S DEPENDENCE ON IMPORTS

Figure EX-5. Mitigation Impacts if Initiated in 2006



A 5MM BBL/DAY CONTRIBUTION

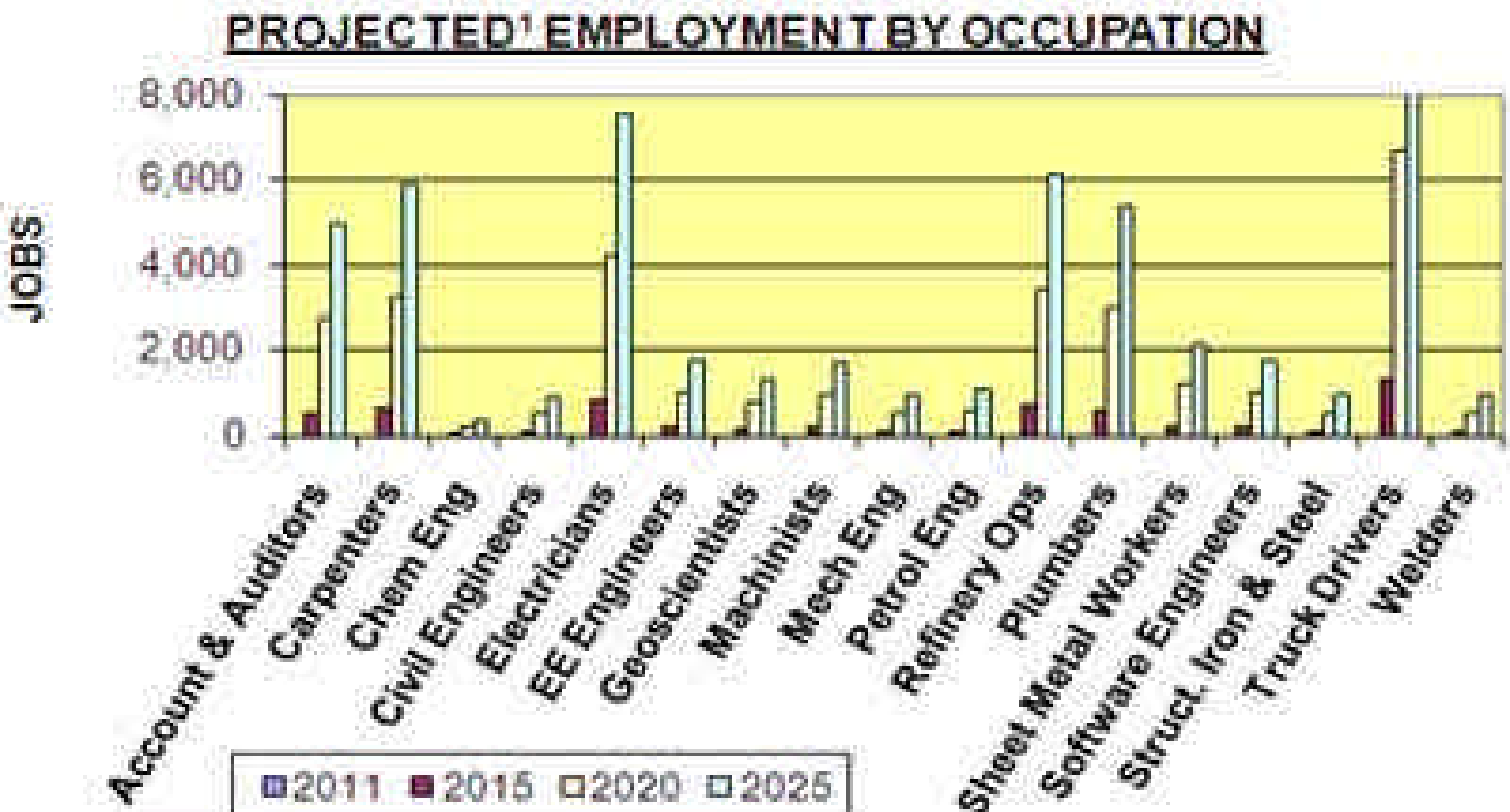
A $180B/YR MARKET OPPORTUNITY
(at $100/bbl)

VFE: Vehicle Fleet Efficiency **EOR: Enhanced Oil Recovery**
CTL: Coal to Liquids **OS: Oil Sands**

PRODUCTS MUST CONFORM TO PETROLEUM STANDARDS

July 8, 2006

PROJECTED ECONOMIC IMPACT BASED ON A BUILD-OUT OF 2 PLANTS PER YEAR									
YEAR	2009	2011	2013	2015	2017	2019	2021	2023	2025
ADDED/YR (BBLS/DAY)			3800	7,600	15,200	15200	15,200	15200	15,200
INSTALLED CAP (BBLS/DAY)			3,800	19,000	49,400	79,800	110,200	140,600	171,000
FEED COAL (MM t/YR)		0	2	10	27	43	60	76	92
INSTALLED CAPITAL ($MM)	$0	$0	$380	$1,900	$4,940	$7,980	$11,020	$14060	$17,100
EST. REVENUE ($MM/YR)		$0	$130	$754	$2,271	$4,248	$6,793	$10062	$14185

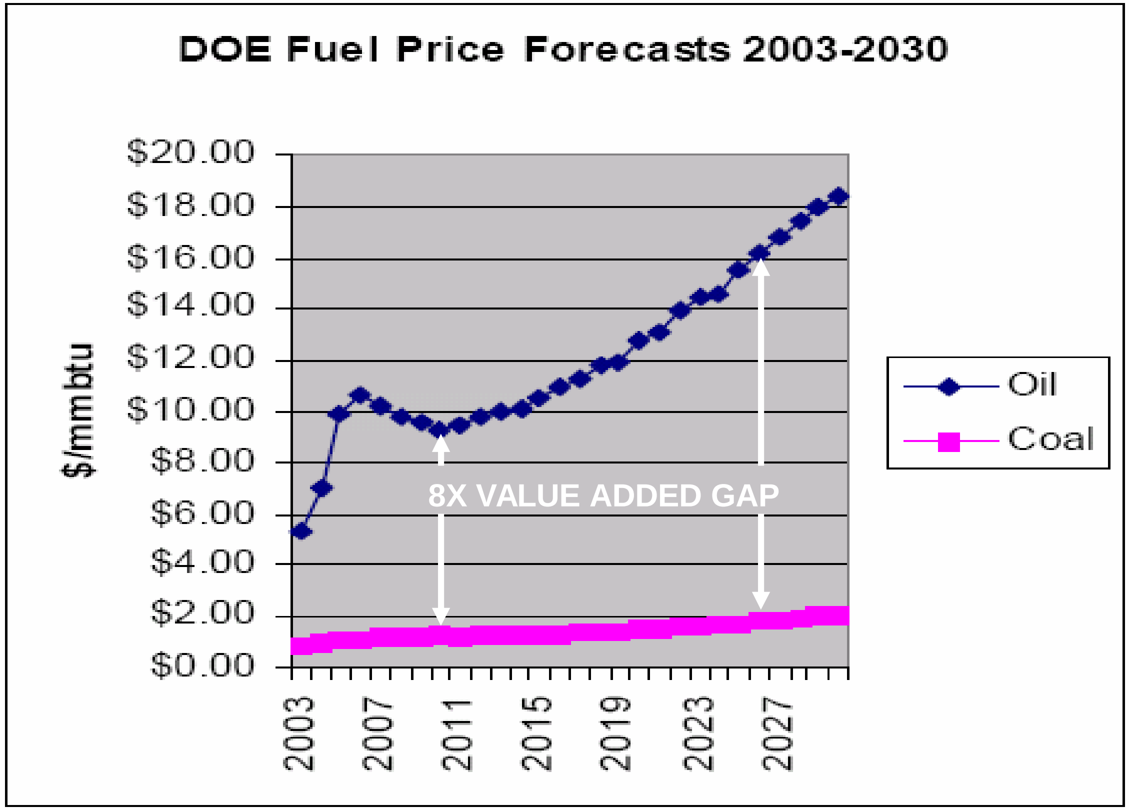


JOBS (X1,000)	6.2	31	56

1. Based on DOE/NETL-2006 1237

LONG-TERM ECONOMIC VIABILITY

DRIVEN BY THE VALUE OF OIL RELATIVE TO COAL



Source: US DOE Annual Energy Outlook 2006

Coal is Projected to Have a Significantly Lower Cost Than Oil Over the Next 25-30 Years—Btu Arbitrage

SUMMARY OF COAL-TO-LIQUIDS TECHNOLOGIES

- **DIRECT CONVERSION**
  - Finely ground coal is mixed with solvent and reacted in the presence of hydrogen and catalyst to produce synthetic crude oil.
  - Requires moderate temperature and high pressure.
  - Processing results in high process energy and water consumption.
  - Equipment is high in foreign content.
- **INDIRECT CONVERSION**
  - Finely ground coal is gassified to produce syngas which is reformed over a catalyst to produce synthetic diesel and other products.
  - Requires moderate pressures at very high temperatures, (>2,800 deg. F).
  - Processing results in high process energy and water consumption.
  - Equipment is high in foreign content incorporating expensive ceramic lined hot gas handling components and catalysts.
- **PARTIAL CONVERSION**
  - Corse ground coal is heated producing coal char and condensable gasses which are converted into synthetic crude oil by hydrogenation over a catalyst.
  - Requires moderate temperatures, pressures.
  - Processing results in moderate energy consumption and produces water.
  - Equipment is simple steel and stainless steel construction with high US content.

WORLD’S LARGEST DIRECT CONVERSION PROJECT

WVU/NRCCE Supporting Shenhua Project

- Shenhua (China’s largest coal Co.) building 100,000 bpd plant*
  - 20,000 bpd production starts this year
  - Construction 99.5% complete
  - Direct liquefaction technology

Mr. Ren (Shenhua), Drs. Fletcher and Sun (WVU) at Shenhua Liquefaction Pilot Plant

- $1.5 million study of plant's economic and environmental effects underway
- Carbon sequestration to be included
- Collaborators:
  - USA: DOE/FE and WVU/NRCCE
  - China: Shenhua Group and National Development Reform Commission

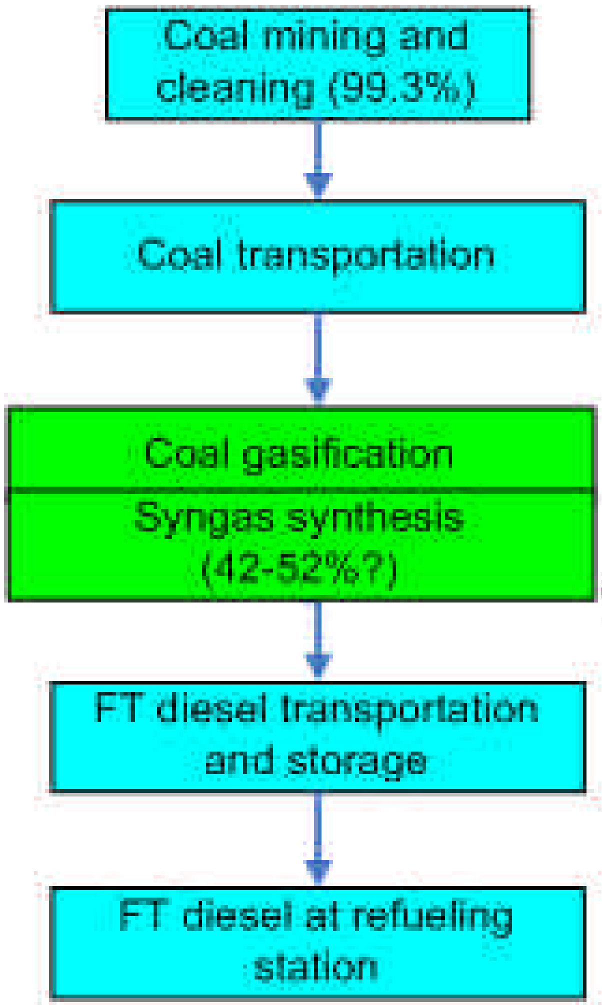
NRCCE National Research Center for Coal and Energy

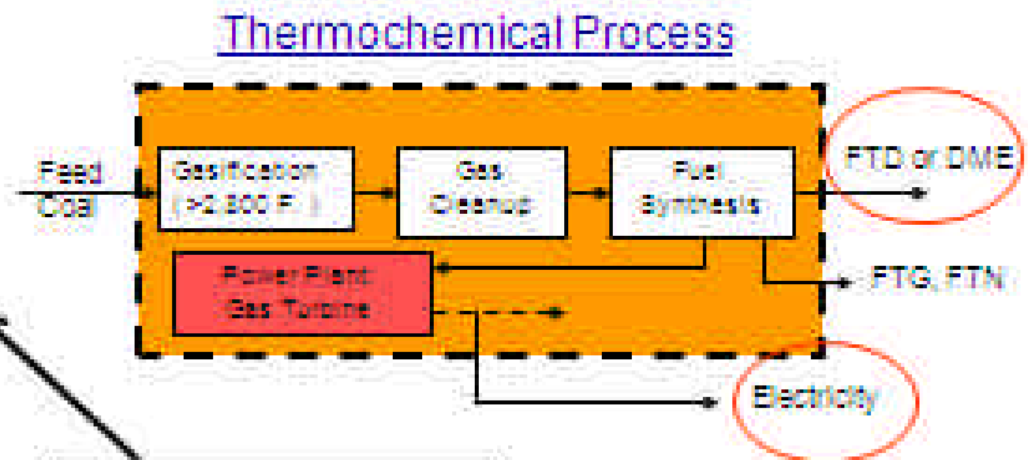
West Virginia University

* From website GOV.CN, China Governments Official Web Portal, August 10, 2006

25

INDIRECT CONVERSION IS VERY ENERGY INTENSIVE





NOTE: FROM NATURAL GAS, F-T DIESEL IS 61% EFFECIENT

Michael Wang
Center for Transportation Research
Argonne National Laboratory

The Energy Modeling Forum on Climate Change Impacts and Integrated Assessment

PARTIAL CONVERSION: CLEAN COAL PLUS OIL

ENCOAL PLANT OPERATED 1992 - 1997

DOE Final Report No. DE-FC21-90MC27339 Sept. 1997
Demonstration plant - 1,000 tons of feed coal per day

Truck & semi-trailer

CLEAN COAL FUEL

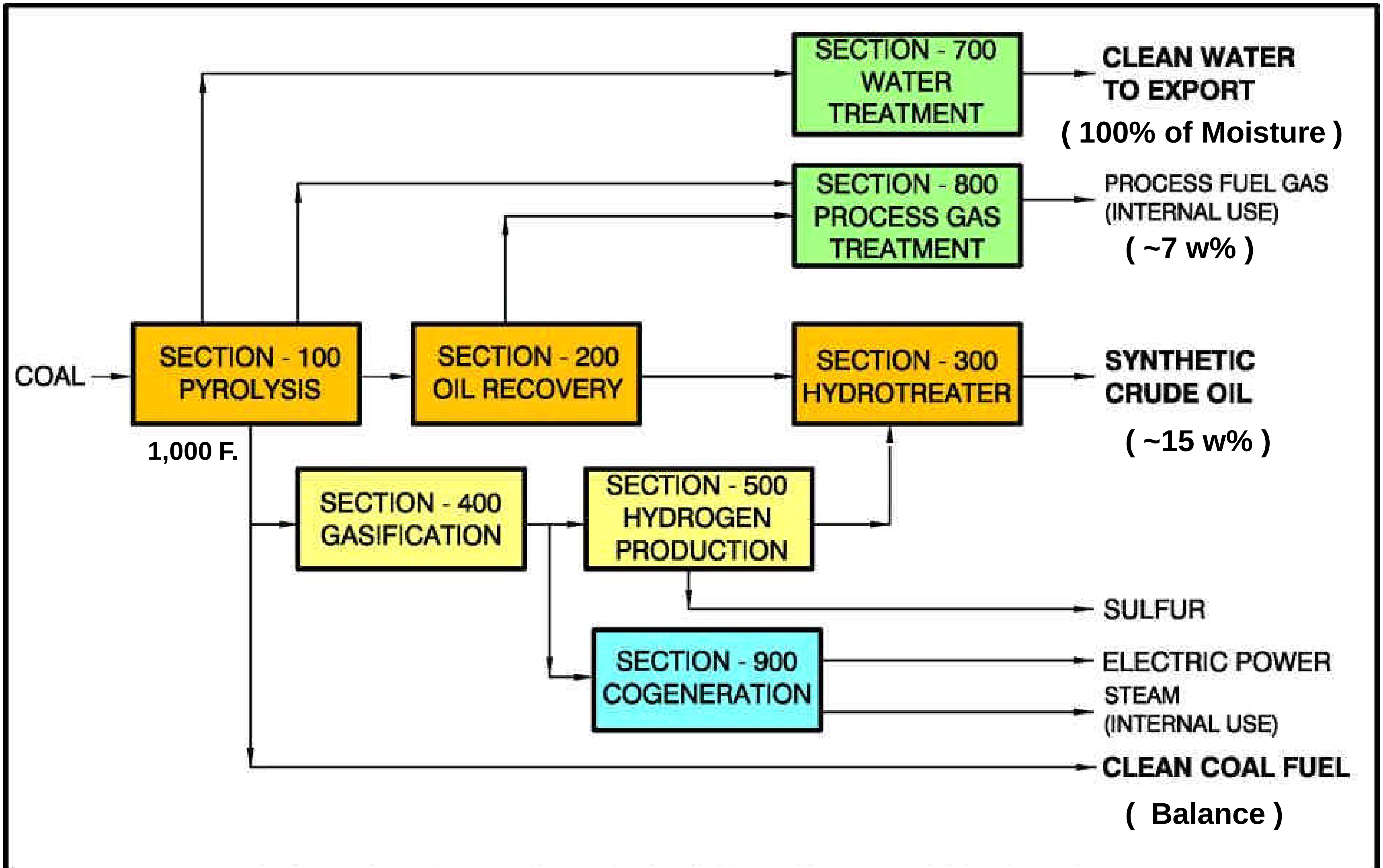
SUCCESSFULLY TESTED IN SEVEN POWER PLANTS
+7% EFFICIENCY, -70% SULFUR, (-85% Mercury)
NOTE: POWER PRODUCTION IS DECOUPLED
FROM FUEL PRODUCTION

COAL- OIL

HYDROTREATED TO
SYNTHETIC CRUDE OIL

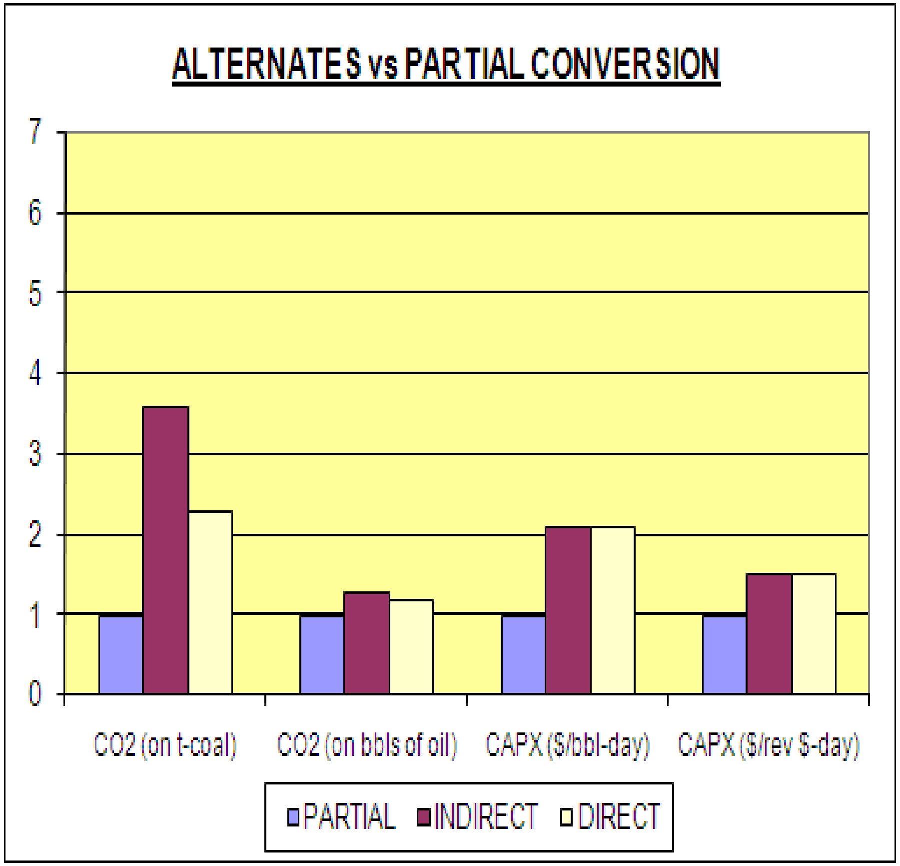
FRESH WATER

PARTIAL CONVERSION PROCESS

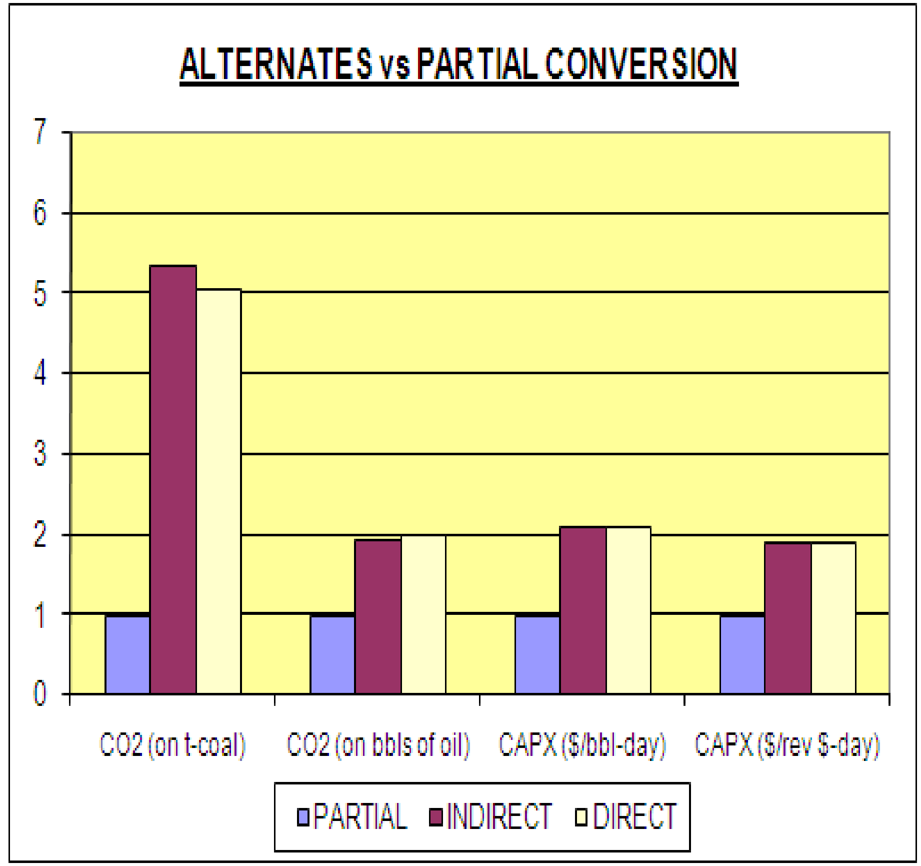


EFFECIENCY DRIVES CO_2 EMISSIONS AND CAPITAL

COAL WITH 30% MOISTURE



COAL WITH 10% MOISTURE



Carbon Emissions Could Be a Major Concern for Coal to FT Diesel

- If coal-to-liquid (CTL) plant has an energy efficiency of 52%, CTL WTW CO_2 emissions will be two times as much as those of petroleum diesel
- With carbon capture and storage, CTL WTW CO_2 emissions will be about the same as those of petroleum diesel
- If CTL plant has an energy efficiency of 42%, CTL WTW CO_2 emissions will be 2.3 times as much as those of petroleum diesel
- Integrated design of CTL plants to produce fuels and power will help improve plant efficiency

Michael Wang
Center for Transportation Research
Argonne National Laboratory

The Energy Modeling Forum on Climate Change Impacts and Integrated Assessment

Snowmass, CO, August 3, 2006

NOTE: CO_2 EMMISSIONS ARE INVERSELY PROPORTIONAL TO EFFICIENCY AND ARE NOW <u>THE MAJOR CONCERN</u>

THE CO_2 CHALLENGE TO F-T SYNTHETIC FUELS

Secretary of Air Force Goals *

- By 2011, certify entire AF fleet to use 50/50 synfuel blends
- By 2016, acquire 50% of CONUS aviation fuels from domestically produced synthetic fuel blends

* EPACT 2007 says fuel must have equal or lower carbon footprint than petroleum fuels

RESULT: 25,000 BPD F-T DEMONSTRATION IN MONTANA WAS CANCELED IN 2008

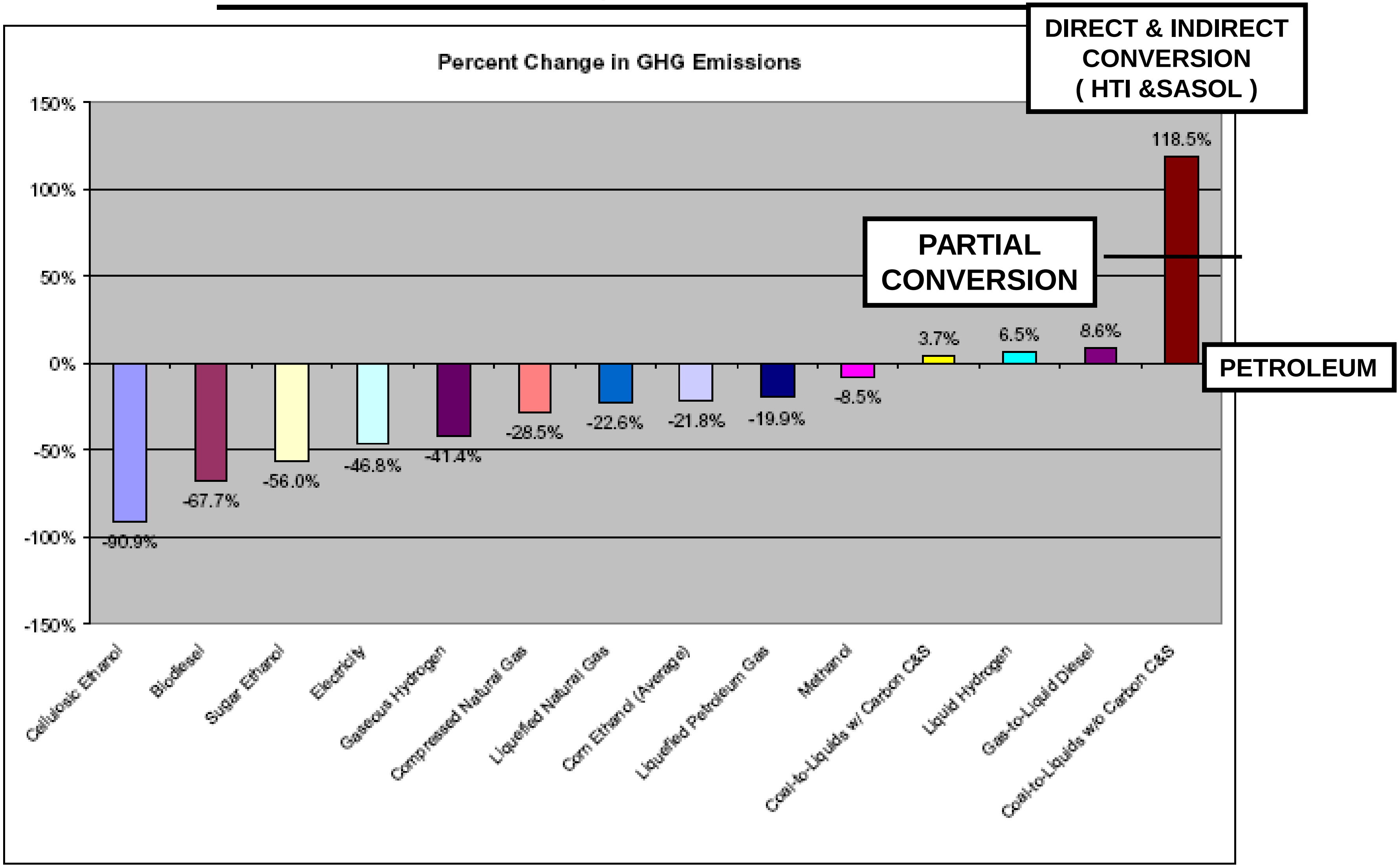
***CTL MUST BE CO_2 NEUTRAL OR NEGATIVE!**

NRCCE National Research Center for Coal and Energy

West Virginia University

Air Force Energy Strategy, Dr. Ron Sega, Under Secretary of the Air Force, August 15, 2007 23

MEETING THE "0" CO_2 ALTERNATATIVE FUEL CHALLENGE



Office of Transportation and Air Quality EPA420-F-07-035 April 2007

CO_2 STRATEGY #1- CAPTURE AND SEQUESTER

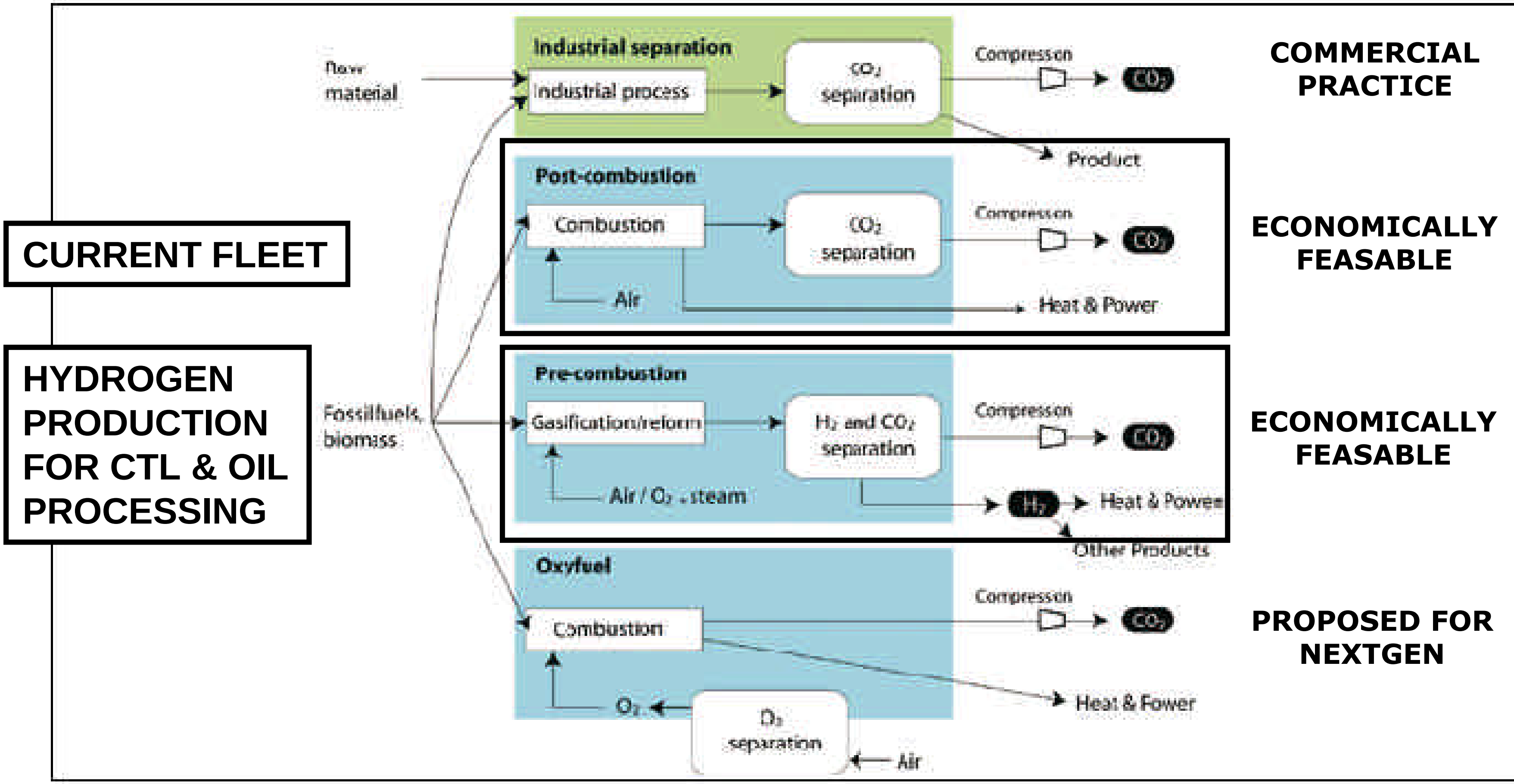
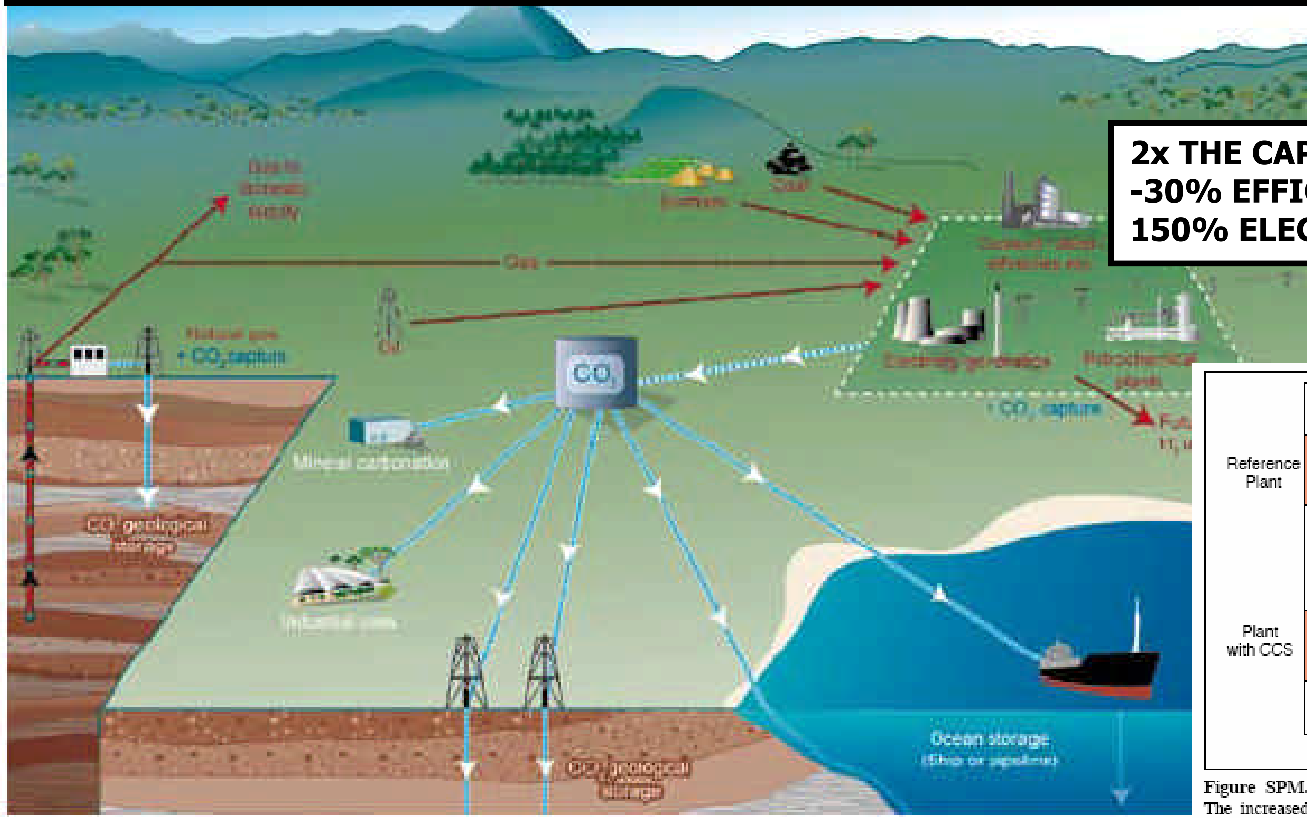


Figure SPM.3. Schematic representation of capture systems. Fuels and products are indicated for oxyfuel combustion, pre-combustion (including hydrogen and fertilizer production), post-combustion and industrial sources of CO_2 (including natural gas processing facilities and steel and cement production) (based on Figure 3.1) (Courtesy CO2CRC).

Eighth Session of IPCC Working Group III

CO_2 CAPTURE AND SEQUESTRATION

MITIGATING CO_2 IS ESSENTIAL BUT SEQUESTERING CO_2 IS A DIFFICULT AND EXPENSIVE PROPOSITON.



2x THE CAPITAL (1)
-30% EFFICIENCY
150% ELECTRICITY COST

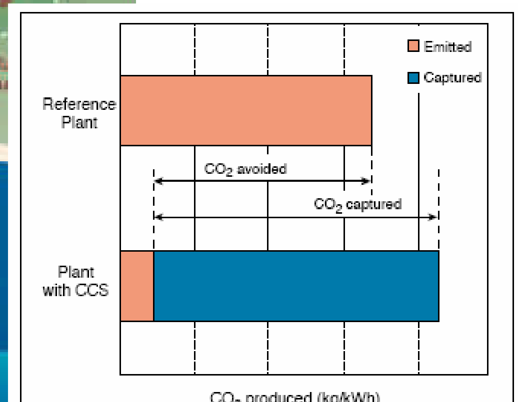


Figure SPM.2. CO_2 capture and storage from power plants. The increased CO_2 production resulting from the loss in overall efficiency of power plants due to the additional energy required for capture, transport and storage and any leakage from transport result in a larger amount of "CO_2 produced per unit of product" (lower bar) relative to the reference plant (upper bar) without capture (Figure 8.2).

Figure SPM.1. Schematic diagram of possible CCS systems showing the sources for which CCS might be relevant storage options (Courtesy of CO2CRC).

This summary, approved in detail at the Eighth Session of IPCC Working Group III (Montreal, Canada, 22-24 September 2005), represents the formally agreed statement of the IPCC concerning current understanding of carbon dioxide capture and storage.

(1) MIT THE FUTURE OF COAL 2007
Confirmed by AEP & NETL

“CLOSED LOOP” CO_2 MITIGATION W/ BIOMASS (TERRESTRIAL OR AQUATIC)

- Plants absorb CO_2 and biomass can fuel processes.
- Waste heat is available for drying the biomass.
- Biomass can be co-fired with other solid fuels like coal.
- Biomass can yield additional oil products.
- Land can be used which is not suitable for food crops.

CTL ENVIRONMENTAL & ECONOMIC COMPARISON			
PLANT DESIGN	**REF 01**	**SASOL**	**HTI**
	Reference	South Af.	Shenhua
Feed Coal (t/day)	10,000	23,400	9,450
bbls/day	7,600	80,000	20,000
CTL PROCESS	**PARTIAL**	**INDIRECT**	**DIRECT**
Oil Product	15%	29%	32%
Metallurgical Coal Product	60.0%	0	0
Water (% of Coal)	10.0%	10.0%	10.0%
Ash (% of Coal)	5%	5%	5%
Energy (% of Coal)	10%	56%	53%
Water (gal/bbl oil)	29	-294	-815
Relative % CO_2	19%	100%	94%
CO_2 (tons / ton feed coal)	0.26	1.39	1.32
CO_2 (tons / bbl oil)	0.29	0.56	0.58
Nul CO_2 w/Biomass (t/bbl)	0.22	0.41	0.43
Biomass (t/d) @10k bbl/d	2,153	4,134	4,318
CAPX ($/bbl-year)[1]	$100	$208	$208
CAPX ($/rev $-day)	$530	$1,000	$1,000

(1) CCI CAPX allocated based on revenue split between M-Coal & Oil

FOREST BIOMASS PROCESS FUEL EXAMPLE

Kentucky State Energy Plan, 2008 for Forest Products or Miscanthus

Table 3: Renewable Electricity Generation Targets to 2025

Renewable Resource	Thousand Megawatt-Hours (MWh)			
	Existing[1]	2012	2018	2025
Total Generation	**3,052**	**4,509**	**6,694**	**9,244**
Wind Energy	0	69	172	293
LFG / Biogas	88	191	347	528
Solar PV	0	272	679	1,154
Hydropower	2,592	2,708	2,883	3,087
Forest Biomass	372	1,268	2,613	4,182
Equiv. tons Biomass / day	739	2,516	5,185	8,298

At an oil production rate in bbls/day =	7,600	79,800	171,000
F-T diesel / Direct t/day to "0" CO_2 =	3,116	32,718	70,110
Partial Conversion t/day to "0" CO_2 =	1,672	17,556	37,620

(BASED ON COAL DRY WEIGHT)

CO_2 RECYCLING RETROFIT WITH ALGAE BIOMASS

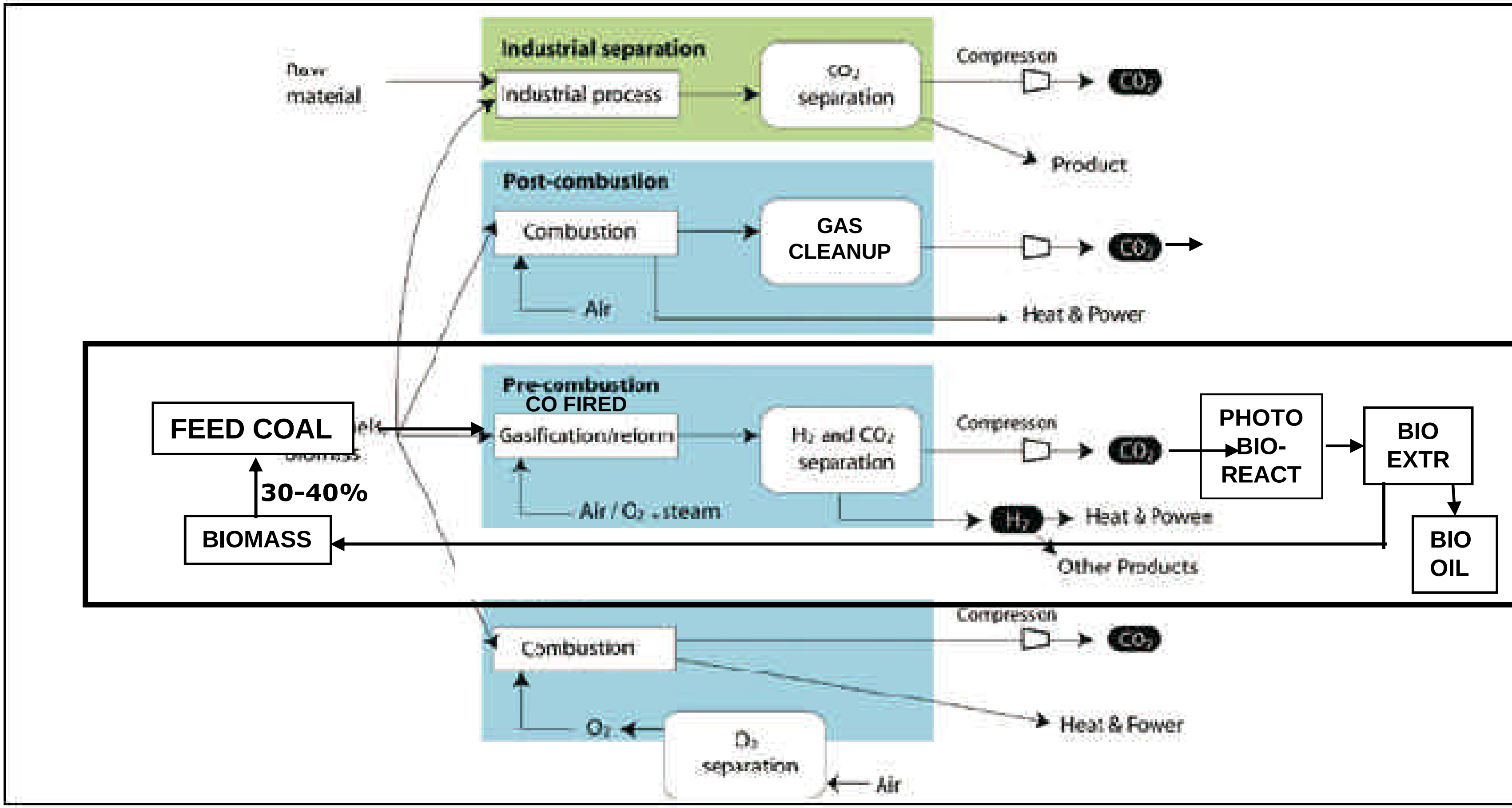
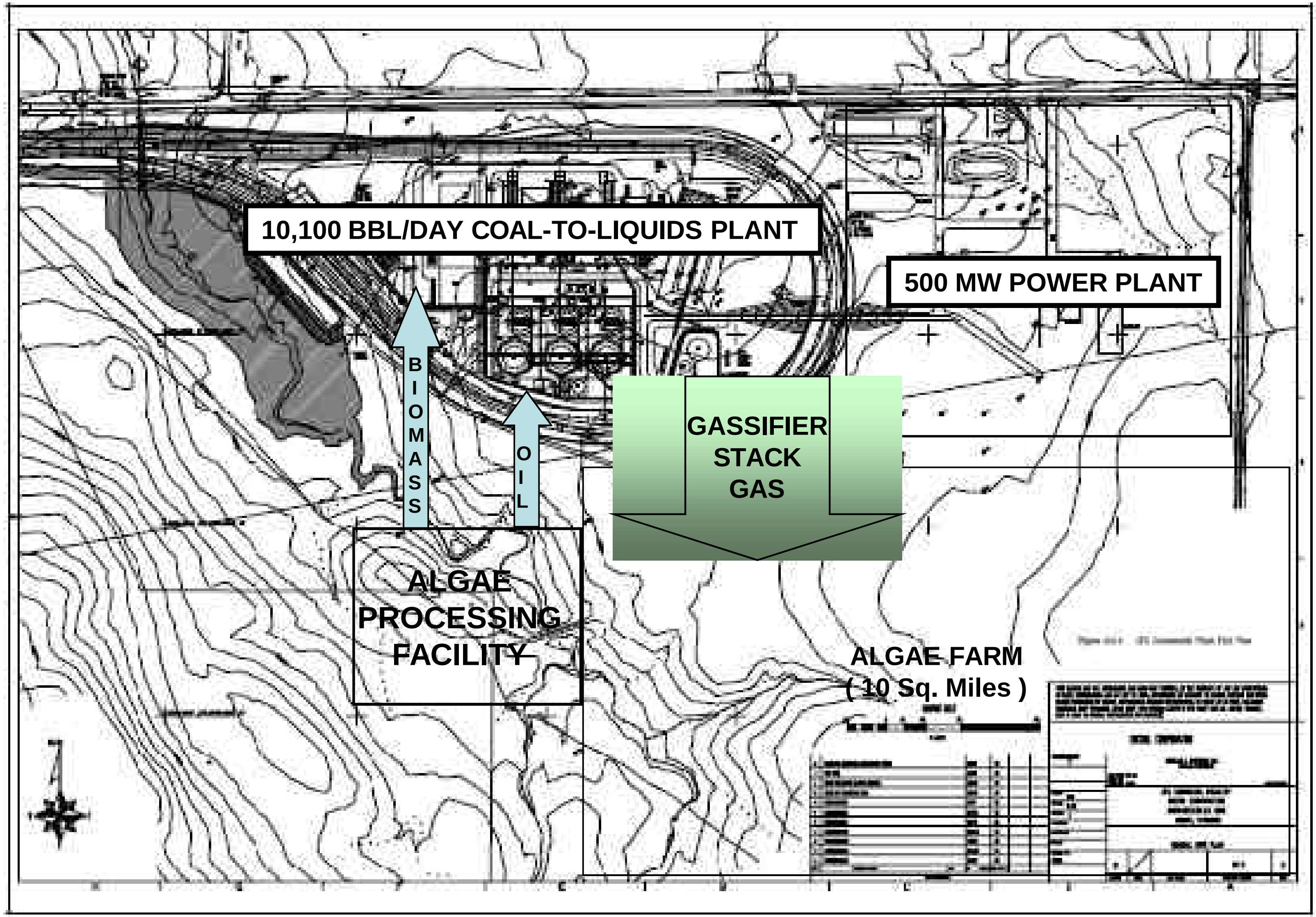


Figure SPM.3. Schematic representation of capture systems. Fuels and products are indicated for oxyfuel combustion, pre-combustion (including hydrogen and fertilizer production), post-combustion and industrial sources of CO_2 (including natural gas processing facilities and steel and cement production) (based on Figure 3.1) (Courtesy CO2CRC).

Eighth Session of IPCC Working Group III

CLEAN ENERGY PLANT CONCEPT



SUMMARY

- Coal-to-liquids process offers opportunities for domestic fuel supply and energy security.
- While these technologies are technically mature they face significant environmental challenges, especially from CO_2 emissions.
- Advances in bio-energy production can significantly mitigate the CO_2 issues when integrated with the right CTL processes.
- Work is needed to integrate these processes and scale them up for industrial application.

THANK YOU!