What is Ultimate "Energy Carrier" for a Post Crude Oil World ?

- **Are there choices for "Energy Carriers" for Sustainable Mobility ?**

  Bio-Ethanol in Flex Fuel Vehicle
  FT Liquids in IS / CIDI Power-trains
  Electrons in EV
  H2 in FCEV
  Others ?

- **What are their strengths and weaknesses?**

- **How will the market-place rank the options and externalities?**

Can Alternative "Energy Carrier" Options Provide a Competitive and Sustainable Mobility Market for the US ?

- **What are the possible "Energy Carrier & Power Train" Options for the future ?**
- **What are the "drivers" and their costs ?**

  Sustainability - Crude Oil replacement

  Energy Security ? Sending Money to the Middle East ?

  Green House Gases ? Are they good or bad ?

- **What are the <u>timing possibilities</u> versus <u>timing requirements</u> (needs) ?**

- **Will Government or the Customers have patience, and wait for Industry ?**
  or will they decide for Industry through mandates or purchase choices ??

"Energy Carrier" Fuel Options from the Primary Energy Sources to VMT

- **Liquid Hydrocarbon Based Fuels well understood / accepted :**

  FT Fuels (Carbon based)

  Ethanol (Carbon Based)

  Bio-Diesel (Carbon Based)

- **Electrons :**

  Limited Storage in Batteries and Ultra Super Capacitors

  Large Scale Production and Distribution infrastructure is commercial

- **H2 :**

  Storage options being investigated

  Large Scale Production and Distribution infrastructure being studied

- **Gaseous Hydrocarbon Fuel Options being considered again :**

  CNG from remote gas via LNG supply chain

  DME from Coal and Remote Gas

Possible Energy Carrier / Vehicle Pathways into the Future

For Replacing Crude Oil

Commercial Issues

Y (Yes) is favorable -		H2 FCV	SI/DI FT Liq	EV	SI E85
Energy Sources Options:					
Carbon-based	Nat Gas	Y	Y	Y	No
	Biomass	Y	Y	Y	Y
	Coal	Y	Y	Y	No
Non-Carbon Electricity	Wind	Y	No	Y	No
	Nuclear	Y	No	Y	No
Commercial Status ?					
Bulk Fuel Production		No	Y	Y	Y
Bulk Fuel Distrib. System		No	Y	Y	No
Commercial Vehicles		No	Y	No	Y
Low Capital Requirements ?					
Fuel Production Infrastructure		No	No	No	No
Fuel Distribution Infrastructure		No	Y	No	No
Vehicle Manufacturing		No	Y	No	Y

Possible Energy Carrier / Vehicle Pathways into the Future

Environmental Issues

Y (Yes) is "un" favorable -		H2 FCV	SI/DI FT Liq	EV	SI E85
Localized Air Pollutants (WTW)					
Carbon-based	Nat Gas	Y	Y	Y	
	Biomass	Y	Y	Y	Y
	Coal	Y	Y	Y	
Non-Carbon Electricity	Wind	No		No	
	Nuclear	No		No	
Some GHG					
Carbon-based	Nat Gas	Y	Y	Y	
	Biomass	Y	Y	Y	Y
	Coal	Y	Y	Y	
Non-Carbon Electricity	Wind	No		No	
	Nuclear	No		No	

What is the Cost of Displacing Crude Oil Use ? *

Fuel Source	Vehicle Power Train	Crude Oil Displaced M BPD	GHG Decrease %	Cash Flow Change $ MM / Day WTT	Vehicle	Total	Premium Over Crude Price $ / BBL	Reduced GHG CO2 e $ / mt
Conventional (Crude)	Hybrid (15%)	37	16	-1.3	7.9	6.6	179	400
Gas -								
CNG	PISI	238	14	1.0	6.2	7.2	30	528
FT Diesel - NG	CIDI DPF	238	-14	2.3	0.0	2.3	**10**	**NA**
Bio Fuel -								
ETOH Sugar Beet	PISI	238	65	20.1	0.0	20.1	84	**305**
ETOH Wood Biomass	PISI	238	78	32.5	0.0	32.5	137	410
Bio Diesel Rape seed	CIDI DPF	238	38	16.4	0.0	16.4	69	429
H2 -								
H2 Thermal NG Reforming	FC	238	32	18.7	41.8	60.5	254	1840
H2 Thermal Coal Gas	FC	238	-19	16.8	41.8	58.5	246	**NA**
H2 Elect Wind	FC	238	95	39.8	41.8	81.5	343	850
H2 Elect Nuclear	FC	238	95	50.6	41.8	92.4	388	963

Other External Comparisons for Crude Oil :

1/3 US Military Budget / BBL of Imported Oil	32	
Cost of Stationary Alternatives of Tier II Emissions (Nox, VOC, CO, PM) ($ 2.5 M / ton)	1	
DOE estimate for current CO2 capture cost from existing Power Sources	75	← 165
CO2 Capture at new Coal IGCC (Bechtel Estimate)	17	← 38
Coal replaced by Wood at $100 / Dry ton in existing Power Plant	25	← 55

*** Extracted from Concawe / EUCAR WTW Analysis of Future Automotive Fuels and Power-trains in the European Context, January 2004 (for 5% Fleet Replacement in 2010)**

Concawe / EUCAR WTW Study for 5% Fleet Replacement

Energy Price Assumptions

	€ / GJ *	$ / MM BTU (LHV)	
Crude Oil Brent	4.6	5.82	$ 30 / BBL
Natural Gas @ 75% Crude	3.4	4.30	
Coal	1	1.27	
Nuclear Fuel	1.1	1.39	
Gasoline and Diesel @ 1.3 x crude	5.9	7.47	
FT Diesel @ 1.2 x Diesel	7.1	8.99	
Biomass -			
Waste Wood	4.5	5.70	
Farmed Wood	6.6	8.36	
Wood	6.2	7.85	
Sugar Beets	7.9	10.00	

What are cost of "Fuel and Power Train" Replacement Options ?
Per Recent European WTW Study

- **Bio-fuel options have cost premiums of ~$ 70 / BBL over Crude Oil for Farm Products and $ 130 for Wood Biomass, And CO_2 avoidance cost of $ 300 to 430 per mt**
- **H2/FCV options have cost premiums of ~$ 250 / BBL over Crude Oil for fossil sources and ~$ 350 for Wind and Nuclear sources, And CO_2 avoidance cost of $850 to 1840 per mt**
- **FT Diesel from remote gas has only $10 / BBL cost premium over crude oil based on the assumption that FT Diesel costs 20% more But doesn't avoid CO_2 if the CO_2 not captured at the GTL plant**
- **Bechtel suggests that CO_2 capture cost on new Coal IGCC is < $38 per mt**
- **European Study did not evaluate EV options or FT Liq from Coal**

Can Co-Producing FT Liquids in Coal IGCC Power Plants Provide Economic Sustainable Fuel Supplies ?

- **Mitretek Study in 2001 suggests Power Cost from Co-Producing FT Liquids is competitive with Coal IGCC Power-only Plants under right prices**

  Also provides "Flexibility" to capture much of the CO2 if necessary

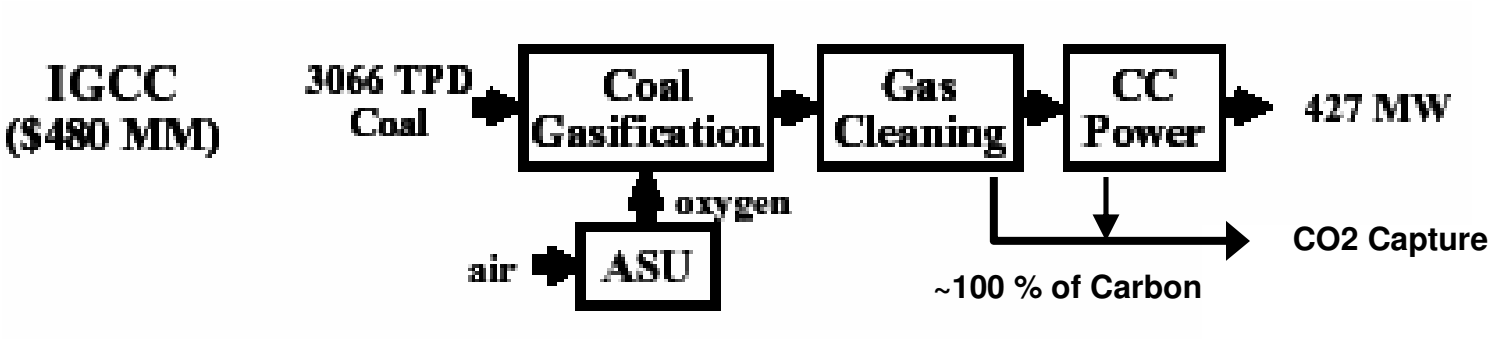
- **Detailed Study by Bechtel (2003) reconfirmed competitiveness**

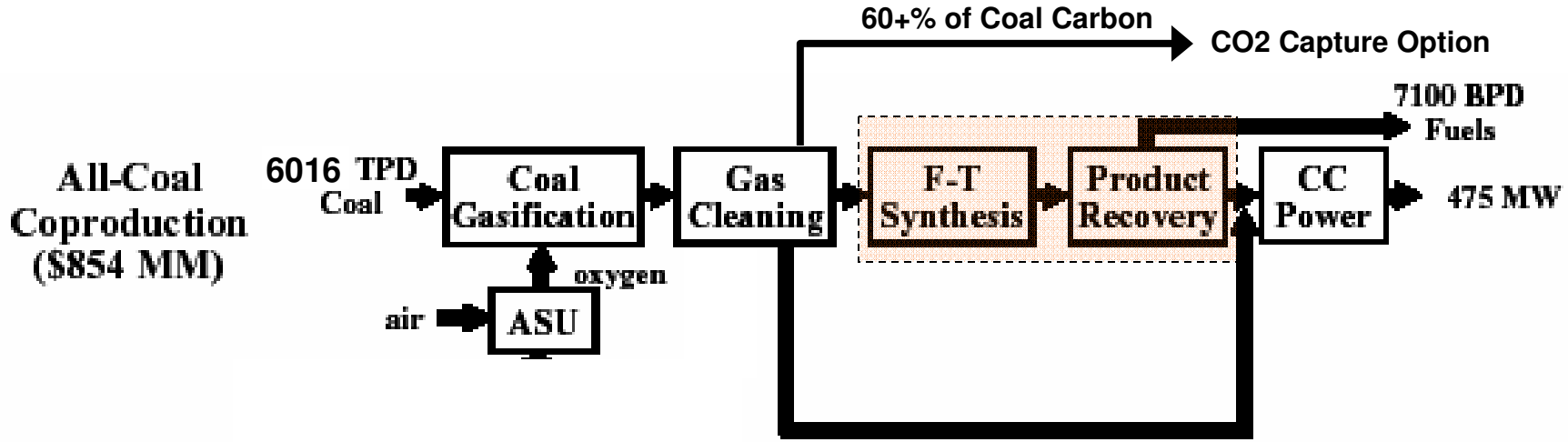
  Shows "Economies of Scale" can lower unit capital cost by ~18%

  Shows the lower unit capital cost makes it competitive with Advanced Gas Power Plants with gas prices at $4 MM BTU and higher

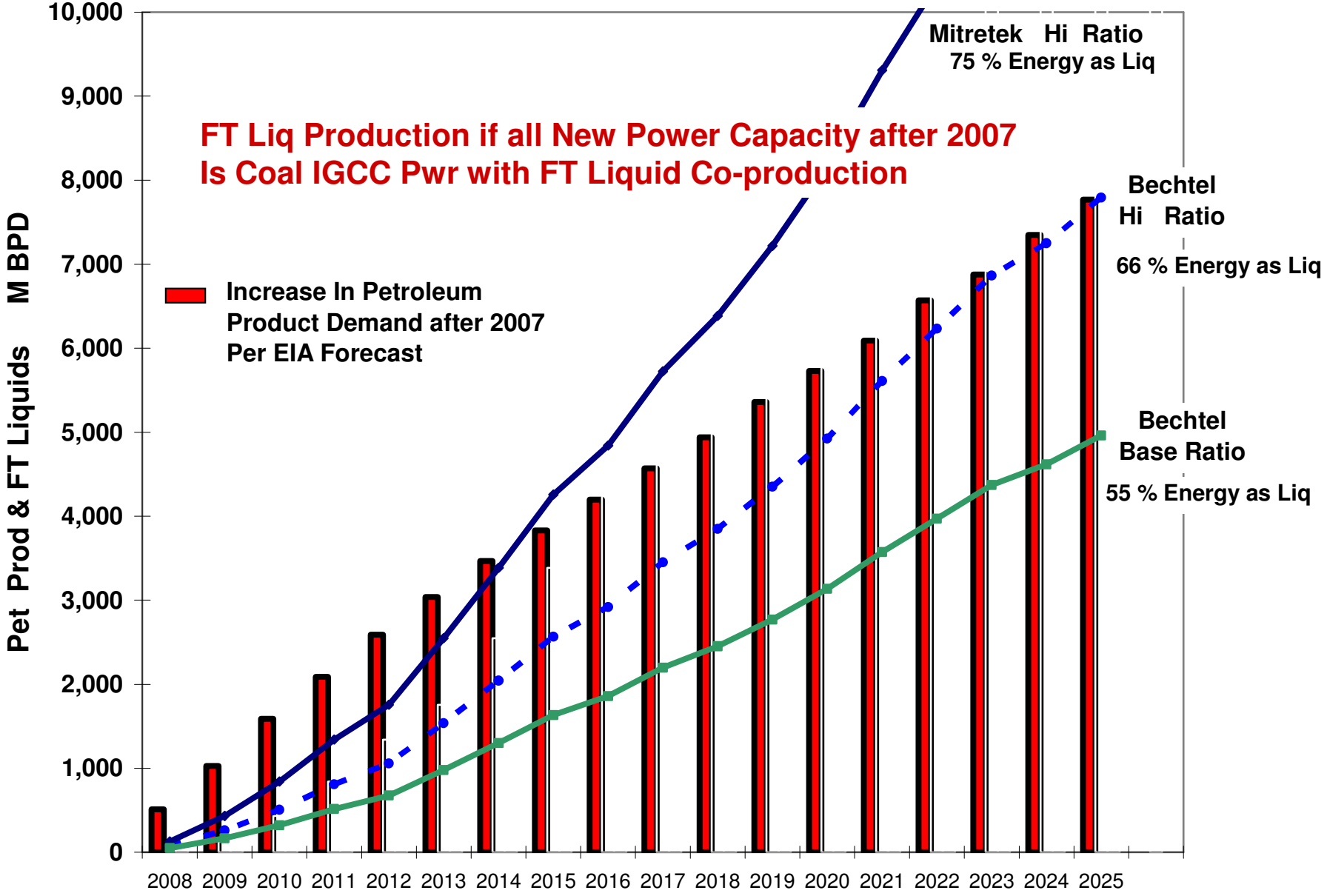
- **But, can FT Liquids from COAL IGCC Power Plants meet growing petroleum product demand in US ?**

Simple Process Flow for Coal IGCC with and without FT Liq Co-product

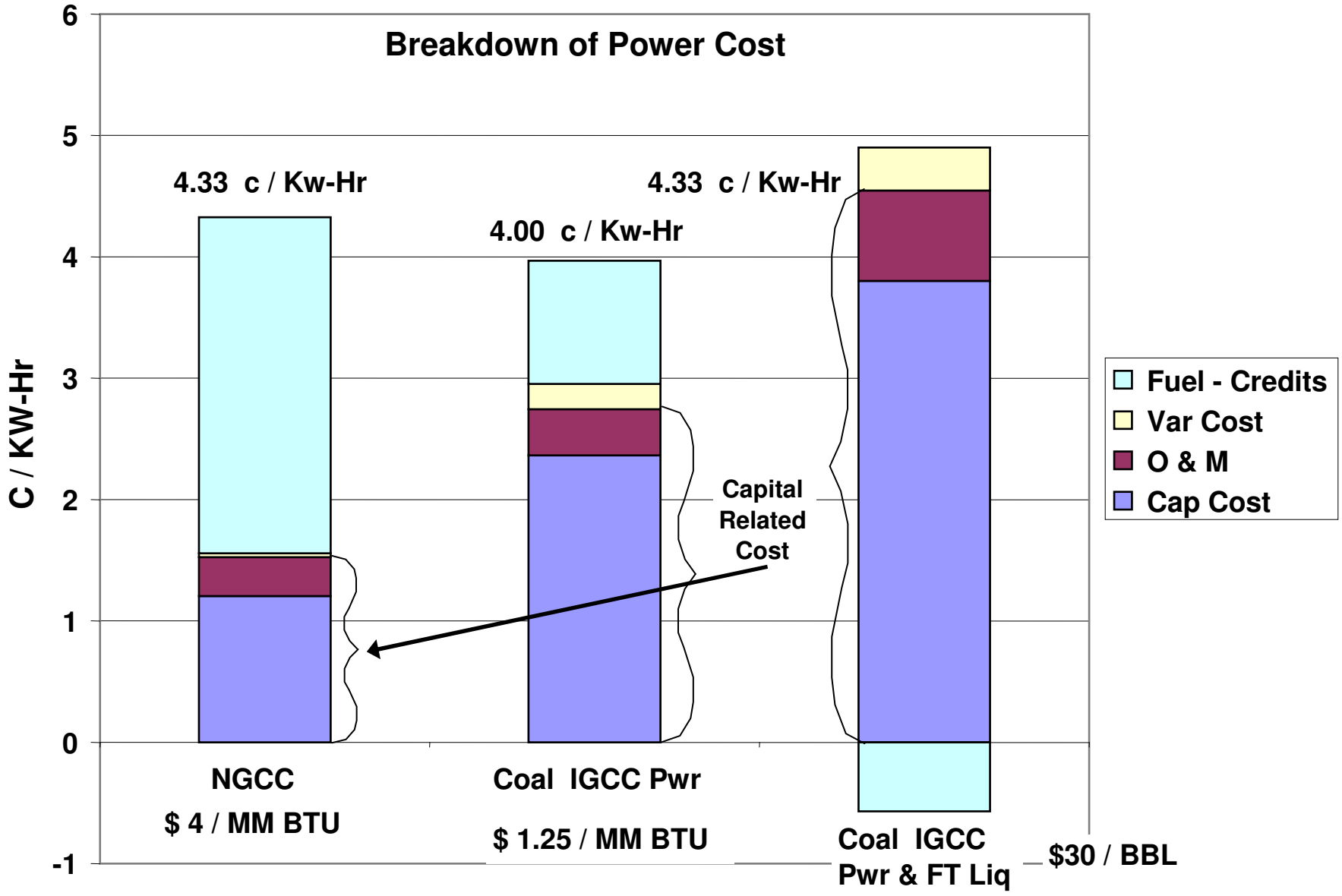




MITRETEK Case Studies

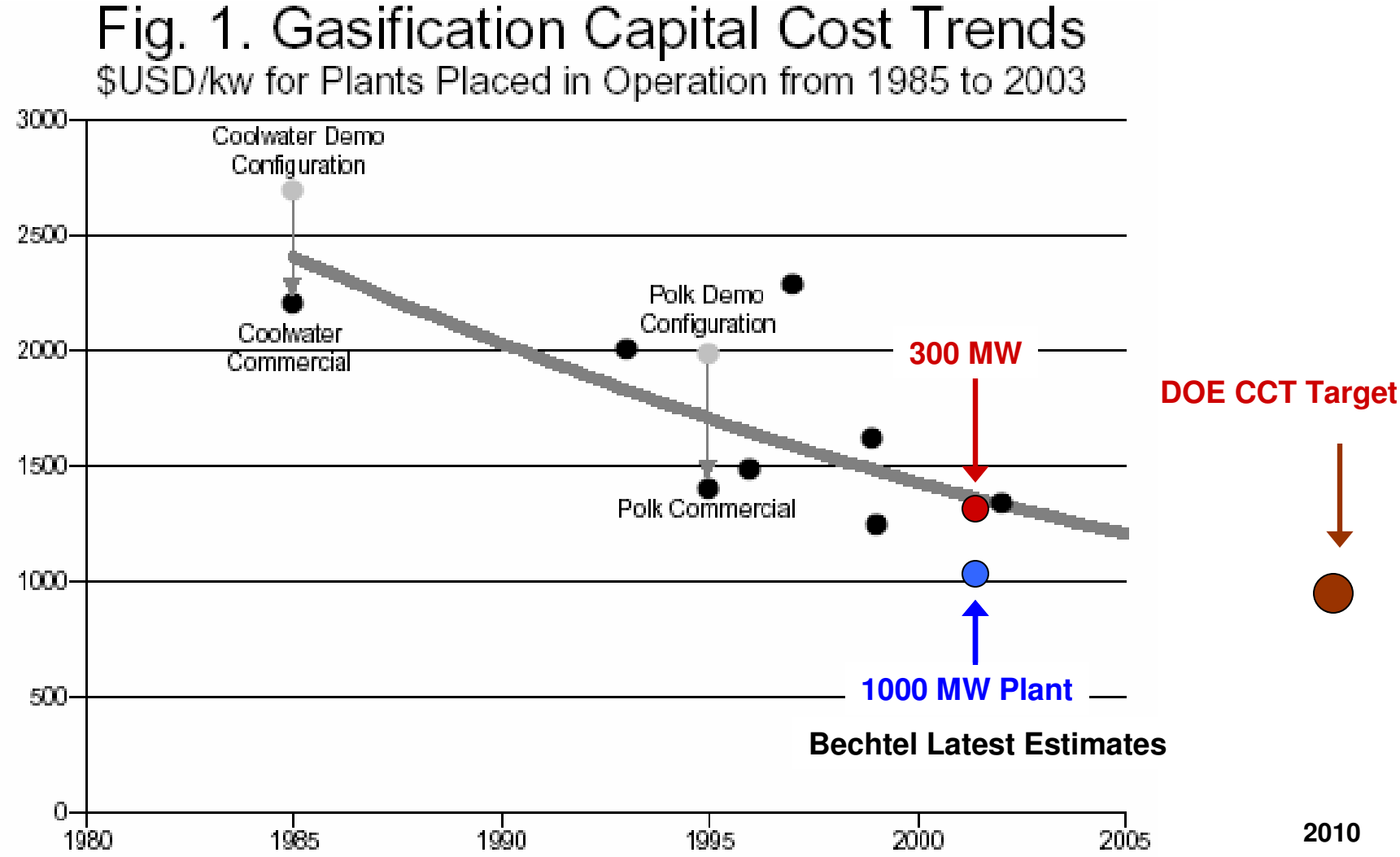

FT Liq Production if all New Power Capacity after 2007
Is Coal IGCC Pwr with FT Liquid Co-production
Pet Prod & FT Liquids M BPD
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Increase In Petroleum
Product Demand after 2007
Per EIA Forecast
Mitretek Hi Ratio
75 % Energy as Liq
Bechtel
Hi Ratio
66 % Energy as Liq
Bechtel
Base Ratio
55 % Energy as Liq

Unit Power Cost from Coal IGCC Mostly Capital Related



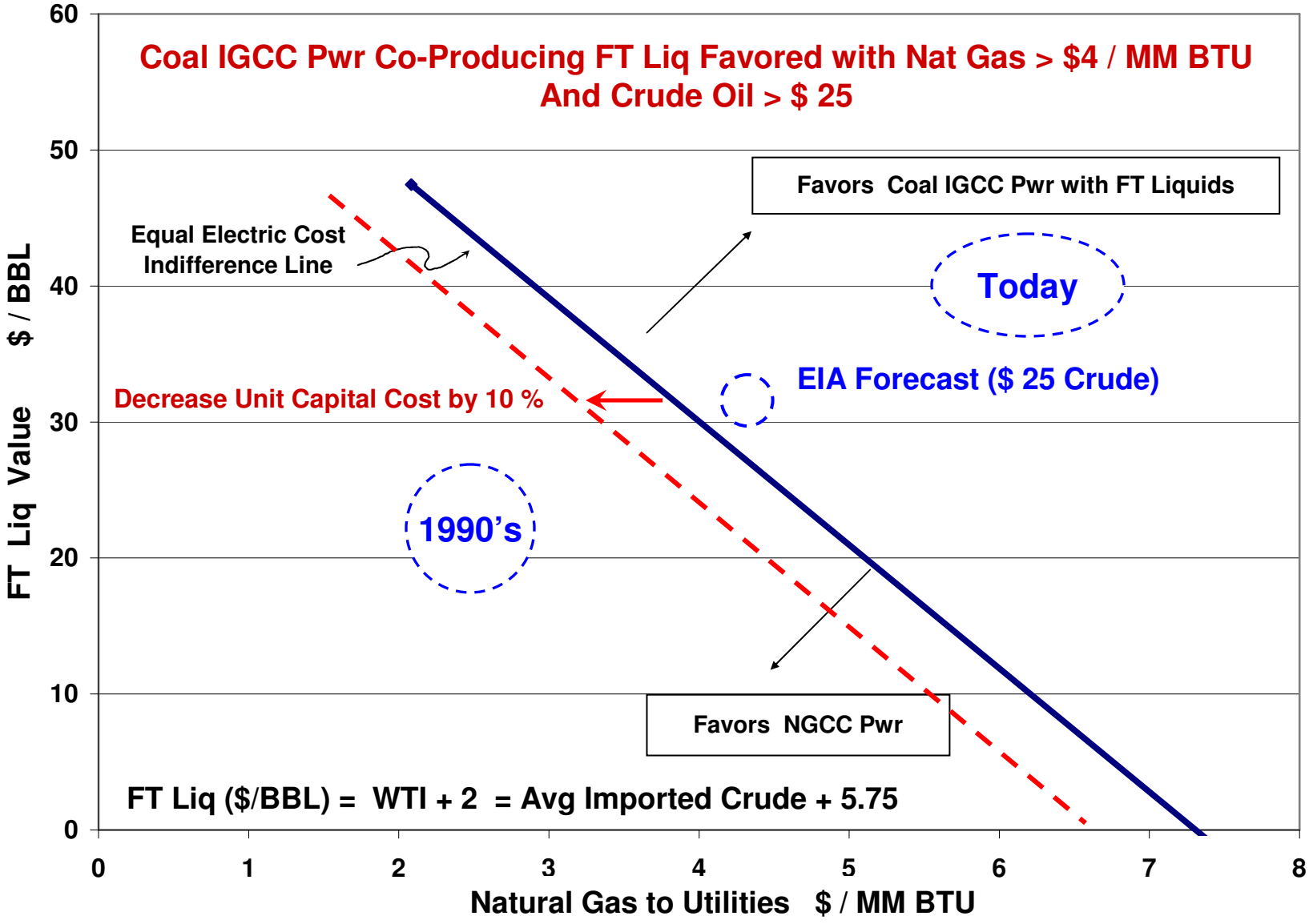
Unit Power Cost from Coal IGCC can be improved with Economies of Scale

Bechtel Study Shows that COAL IGCC Costs Continue to Decline



Economies of Scale significantly reduces Unit Capital Cost

Source: GE Power Systems, PowerGen 2002 Presentation



10% ATROR & Coal @ $ 1.22 MM BTU

Can COAL IGCC Co-Production Provide Sustainable Mobility ?

- Appears competitive with $ 4+ MM BTU Gas for producing power even in a $25 Crude Oil world (EIA forecast) with 10+ M TPD Plants

- Technology exists today. No break-thru's required, but there is more room for "engineering" the cost down further

- FT LIQ co-production with Power from Coal appears to have the lowest economic hurdles (lowest cost with lowest risk) to a sustainable future for US Economy

- Fossil Carbon can be neutralized in future if necessary :

  - 60+ % of Coal's CO2 can easily be "Captured" at the Plant
  - Remaining < 40% in FT Liquid can be off-set by displacing 40% of the coal feed with biomass feed

- China has already initiated coal gasification for transportation fuels