CO_2 - Capture from Flue Gas for EOR

HTC Purenergy

May 2007

HTC… ***"Leaders in CO_2 Capture & Management "***

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Commercial Business Activities

CO_2 Capture

- Emitter Assessment
- Design Engineering
- Process Optimization
- System Mgmt.

CO_2 EOR

- Oil Field Analysis
- Oil Field Simulation & Modeling
- CO_2 Clean up
- CO_2 Compression & Injection

CO_2 Sequestration

- Geological Profiling
- Risk Assessment
- CO_2 Audit & Monitor
- Carbon Credits Validation

International Test Centre for CO_2 Capture

World Leader in CO_2 Capture and Enhanced Oil Recovery

Home of - HTC's technical centre

Coal flue gas demonstration - Test Facilities –

HTC… *"Leaders in CO_2 Capture & Management "*

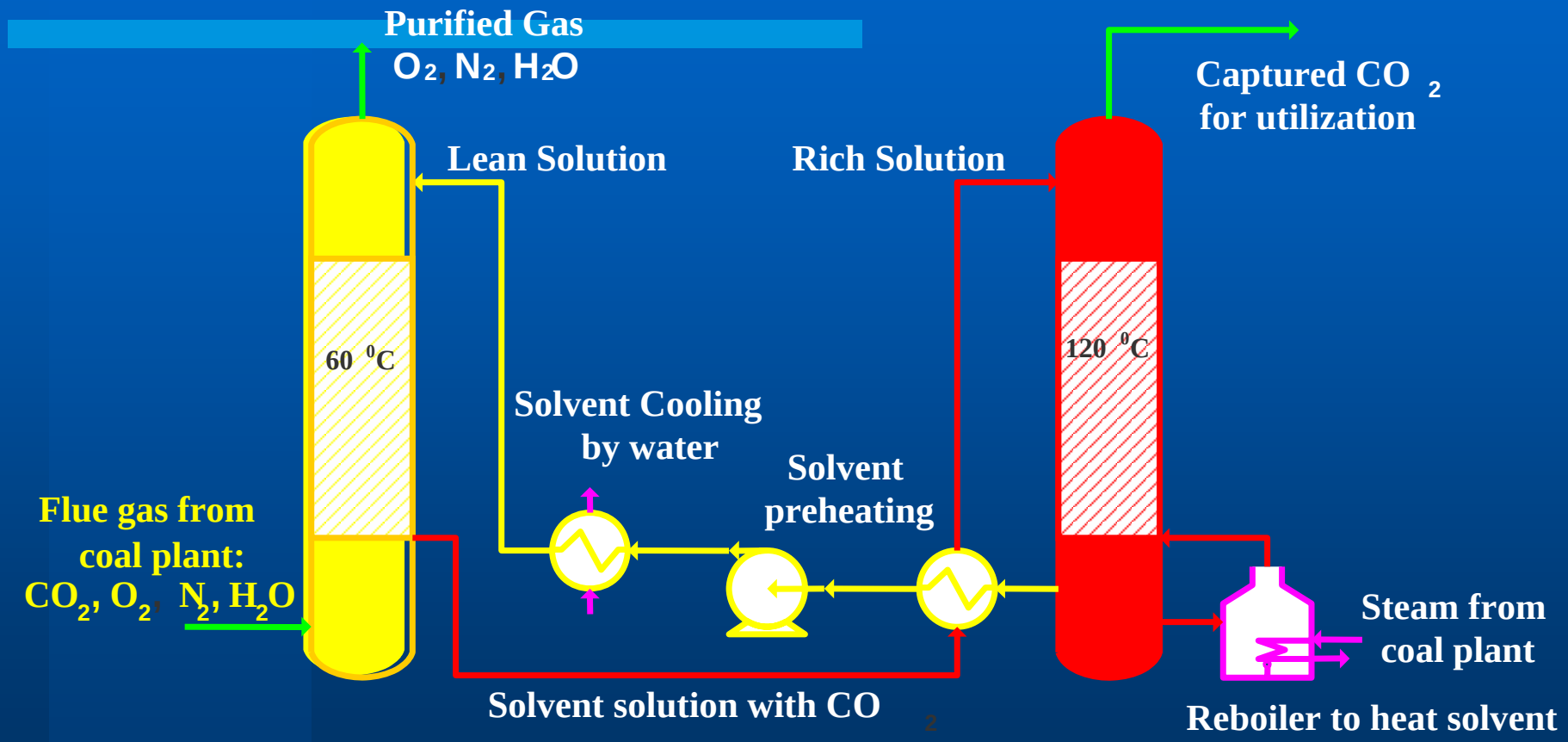
Boundary Dam – Estevan, Saskatchewan

ITC - Natural Gas flue gas capture Centre

HTC… "Leaders in CO_2 Capture & Management "

Optimization of CO_2 Removal Process

HTC… "Leaders in CO_2 Capture & Management"



CO_2 Absorption Packed Column

CO_2 Stripping Packed Column

CO_2 removal application in major industrial process

Process	*Cleanup targets*
Hydrogen Manufacture	**< 0.1% CO_2**
Ammonia Manufacture	**< 16 ppm CO_2**
Natural Gas Purification:	
Pipeline Gas	**< 2% CO_2**
LNG Feedstock	**< 50 ppm CO_2**
Synthesis Gas for Chemical (H_2/CO)	**< 500 ppm CO_2**
Coal Gasification	**~ 500 ppm CO_2**
Ethylene Manufacture (steam cracker unit)	**~ 1 ppm CO_2**
Flue Gas Cleaning in power plants	**~ 10 % CO_2**

CO_2 Process Variables

- Pressure & temp of the gas stream
- Volume of the gas stream
- Composition
- Impurities
- Cleanup target desired
- Production Capacity

Engineering efficient solvents for CO_2 separation from gas streams

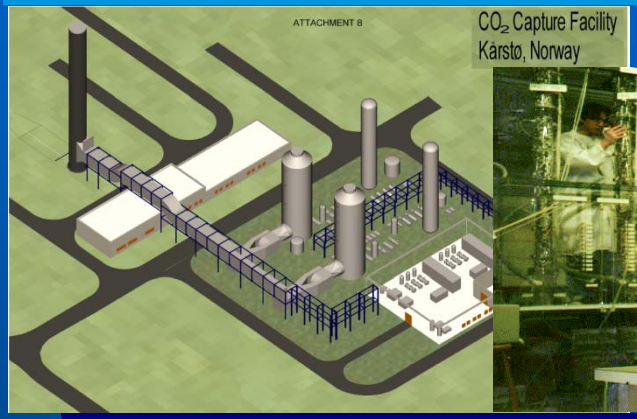
1) Rate of absorption/Kinetics of reaction, should be high.
2) Capacity, solubility of CO2 in solvent, should be high
3) Mass transfer coefficient as a function of operating conditions, packing, solvents; should be high
4) Corrosion, should be Low or Nil
5) Fouling, should be Low or Nil
6) Degradation O2, SO2, NOx, should be Low or Nil
7) Heat of regeneration, should be low
8) Maximum concentration from industrial and operation point of view.
9) Maximum loading of CO2
10) Low temperature solvent, water, ethanol, or methanol base.

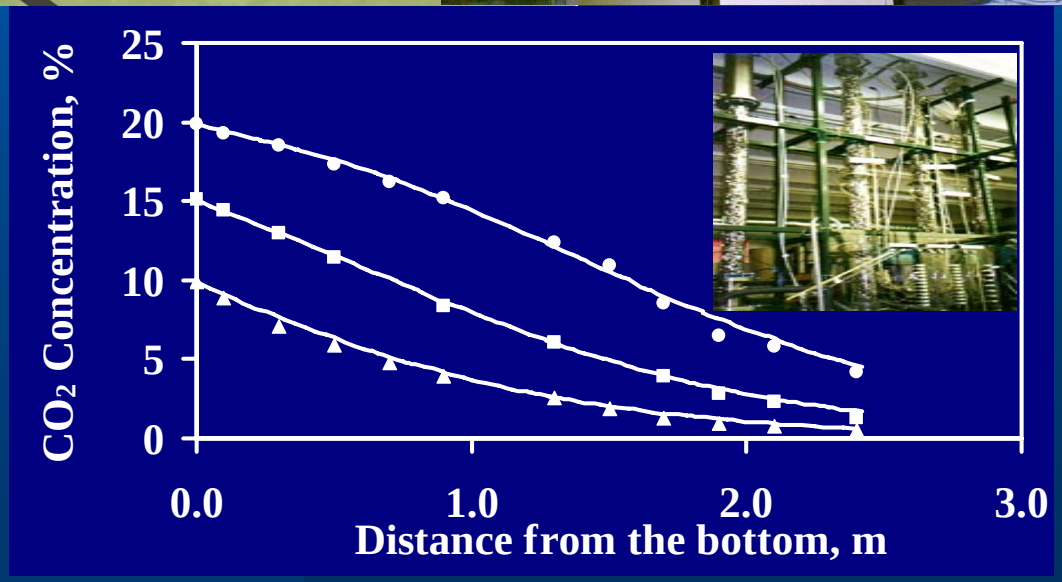
Designer Solvent

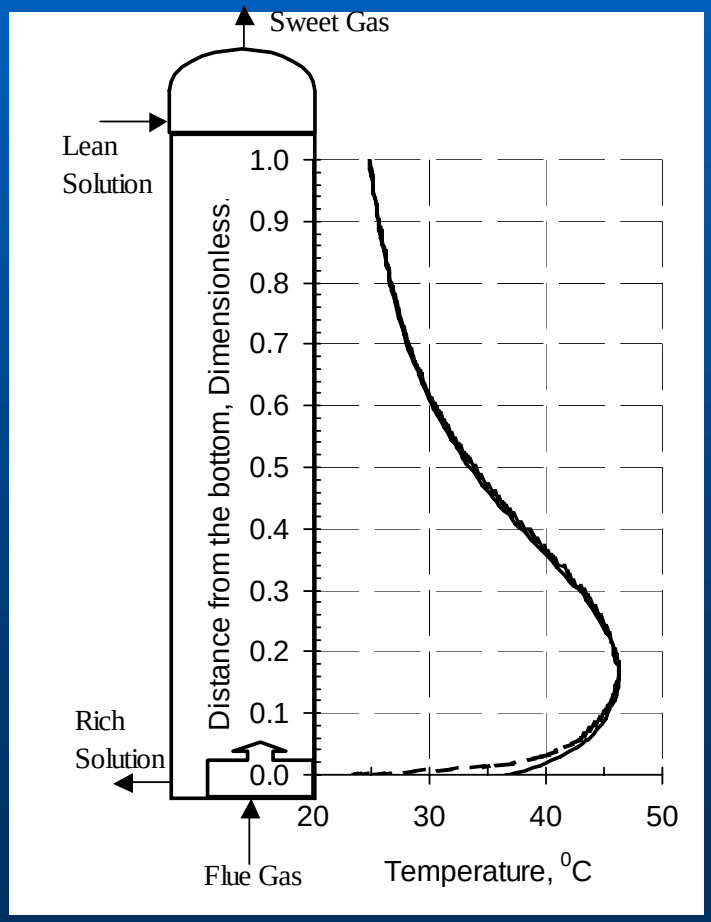
- It has:
  - Capacity Enhancers
  - Rate Promoters
  - Corrosion Inhibitors
  - Solvent Stabilizer
- It provides:
  - Flexibility in design & operation
  - Optimum utilization of the resources
  - Fuel Savings

Modeling and FEED…

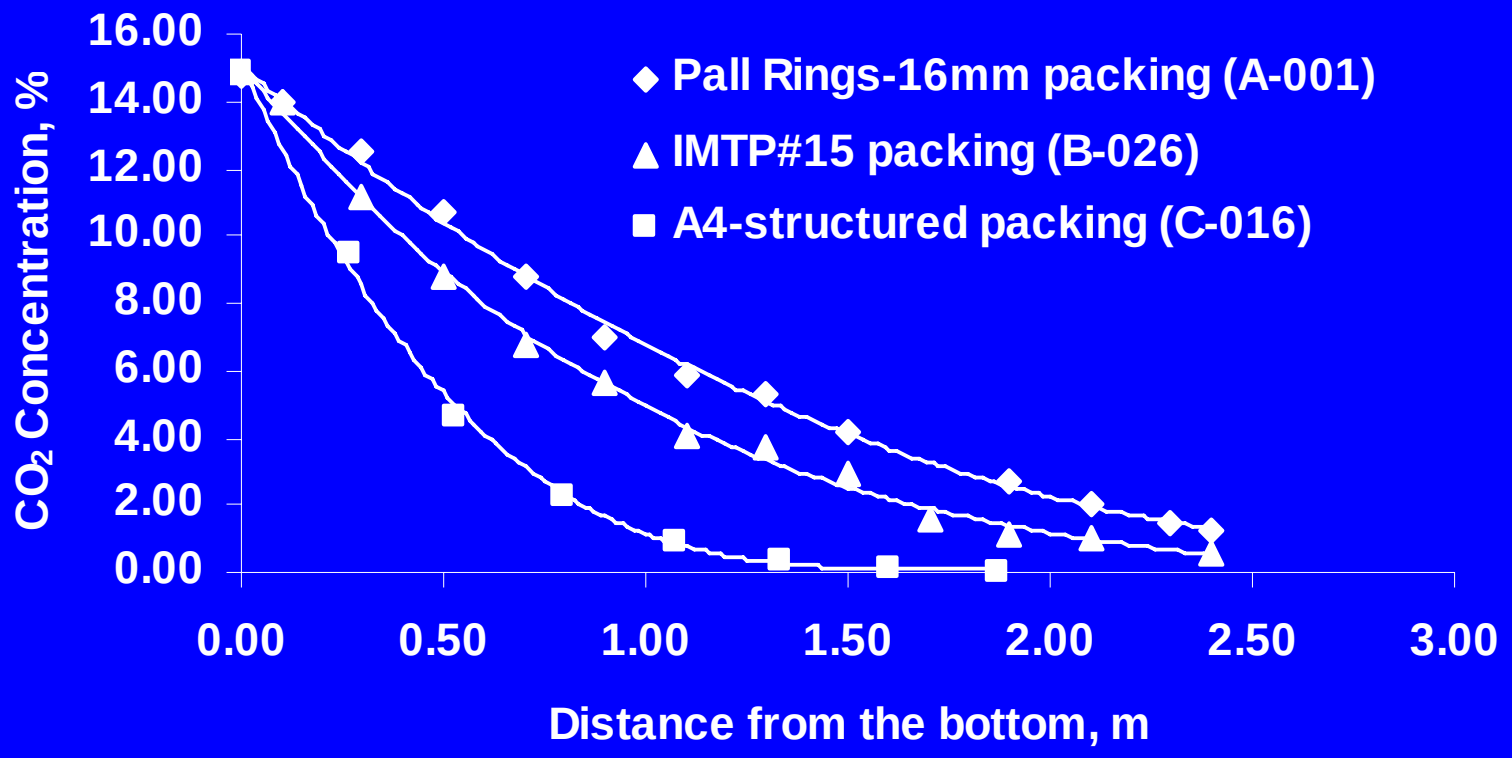
in pilot plants, modular plants and commercial CO_2 capture facilities







Effect of packing type on the removal efficiency of CO_2.

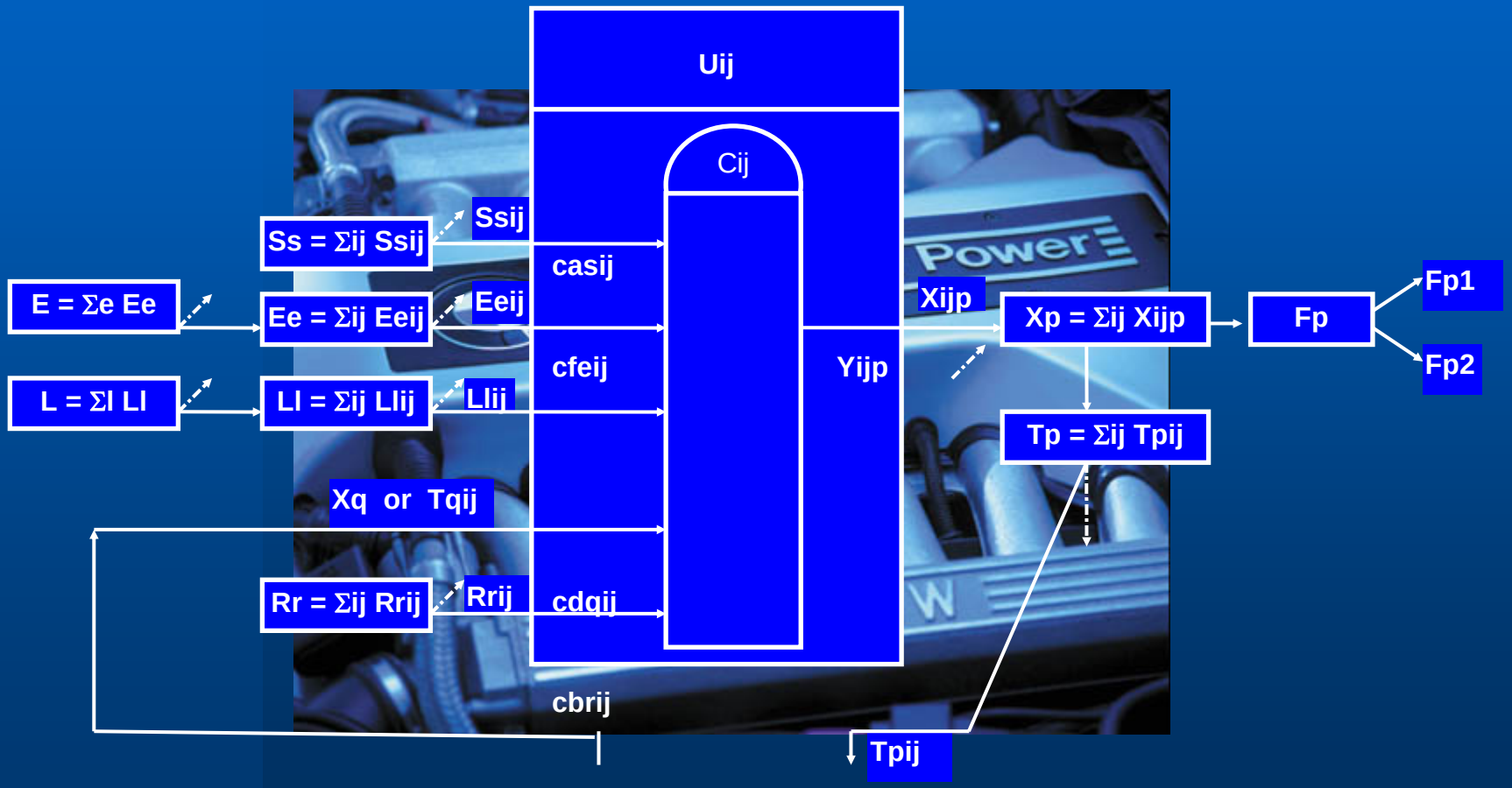


Optimization & Process Integration

- **Optimization process integration using linear & nonlinear programming model to determine the optimal allocation of scarce resources of the Absorption Process.**
- **The Proposed specification of the Model:**
  - **Optimum utilization of the resources while meeting the cleanup targets and demand.**
  - **Minimizing the operating cost.**
  - **Investigating the outcome of some changes in the limiting values of one or more of the variables (Sensitivity Analysis)**

HTC's CCS FEED Engine™

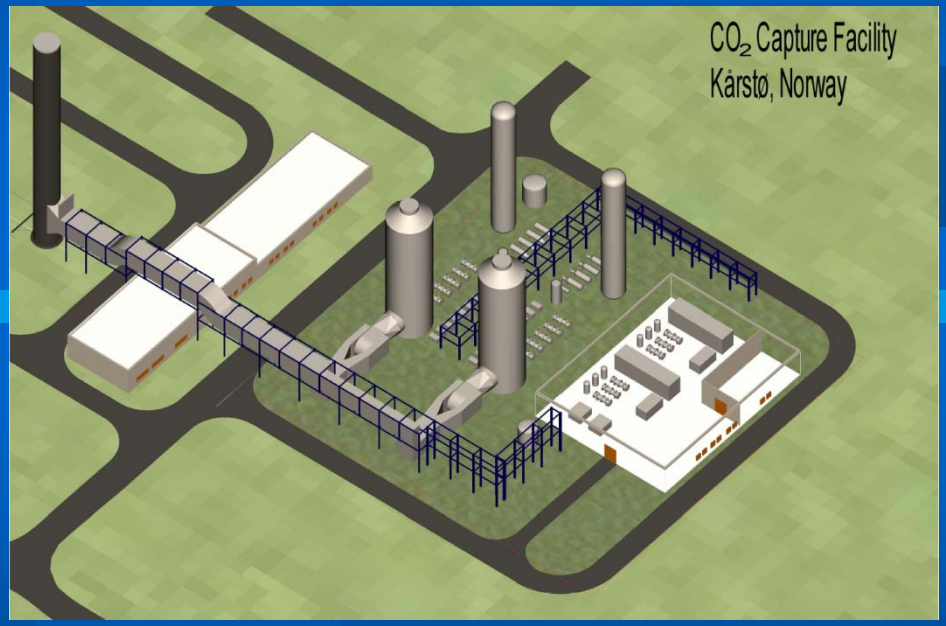
HTC's proprietary "process integration & Front End Engineering Design (FEED) Engine" that delivers customized precision design solutions for optimized carbon capture systems (CCS)

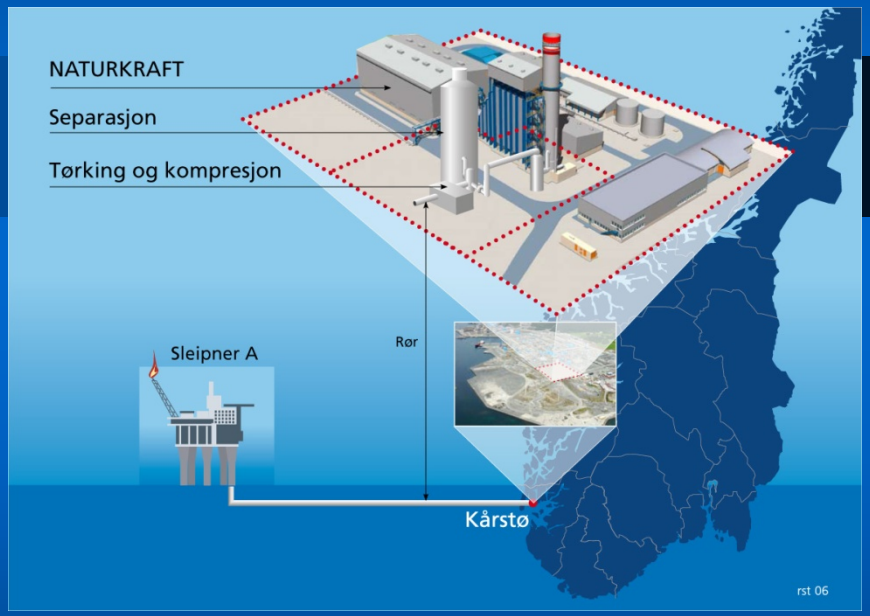


Formulation of the commercial model

- **Objective Function:**
  - **Maximum profit**
  - **Minimum production cost**
- **Model's Constraints:**
  - **Location constraints**
  - **Output constraints**
  - **Input constraints**
  - **Process constraints**
  - **Operation & control constraints**
  - **Financial constraints**
  - **Policy constraints**
- **Process Integration for optimum utilization of:**
  - **Space**
  - **Equipment**
  - **Material**
  - **Heat**

Commercial Solution for CO_2 Capture Plant Kårstø, Norway





HTC Purenergy and Bechtel

November 2006

Site Constraints: Kårstø, Norway

- **The Kårstø gas terminal has a maximum allowable module dimension of:**
  - **2000 ton,**
  - **12m width, and 45m length**
  - **no height restriction for the route to the CO2 Capture Plant plot.**
- **Therefore, the equipment must either be limited in size to meet these constraints or be constructed on-site.**

Integration with the Power Plant & Modules Delivery to the Site

Scope of Work

- To provide an energy efficient CO_2 capture plant design.
- To capture 85% of the total flue gas from the 420 MW power plant.
- It is required to evaluate the effects of varying the CO_2 capture rate between 80 and 90%.
- The captured CO_2 is liquefied for pump out for EOR applications, CO_2 purity > 99 mol% and 300 bar.

Kårstø Project, 420 MW, Norway
Flue gas composition:

Flue Gas From Stack	Units	Specification
Flow	Kg/sec	725, design capacity
Temperature	^{o}C	105
Pressure	Bar g	Atmospheric
Draft Type in Stack		Natural
Composition		
Oxygen	wt%	14.40
Nitrogen	wt%	73.58
Carbon Dioxide	wt%	5.92
NOx	ppm (vol)	2.00
NH_3	ppm (vol)	5.00
SO_2	ppm (vol)	0.10
Argon	wt%	1.23
Water	wt%	4.86
Total	**wt%**	**100**

Available Utilities

Item	Specification
Reboiler Steam	270 ^{o}C @ 3 bar g superheated steam 365,000 kg/hr available steam
Condensate Return	25 bar g
Reclaimer Steam	200 ^{o}C @ 6 bar g
Sea Cooling Water	8 ^{o}C supply temp 10 ^{o}C max temp rise 4 – 5 bar g Maximum Allowable seawater rate: 23,000 m^3/hr

- **Other Input Data Provided:**
  - **Fuel Gas, Nitrogen Specifications, Meteorological Data, Raw Water, etc**

Design Critical path …

- **Use of a Designer Solvent**
  - **The HTC formulated solvent is recommended because of its inherent advantage that it can be customized to meet the specific needs of a specific application, thus allowing for optimal design and operation of the CO_2 capture plant leading to reduction in operating & production costs of CO_2**

…Design Critical path…

- **Use of two capture trains**
  - **Smaller vessels that can be shop fabricated and delivered via the coastal.**
  - **Higher flexibility with higher turndown capacity and the ability to turn off one train.**
  - **Smaller size equipment such as orifice flow measuring devices, pumps, exchangers, etc is typically more readily available.**
  - **Bigger column could have problems in uniform liquid distribution at 60% flue gas capacity.**
  - **Smaller equipment startup in the two-train configuration puts less power demand on the power plant.**
  - **Larger compressor, very few manufacturers are able to offer, and its economy of scale becomes less certain due to the lack of competition.**

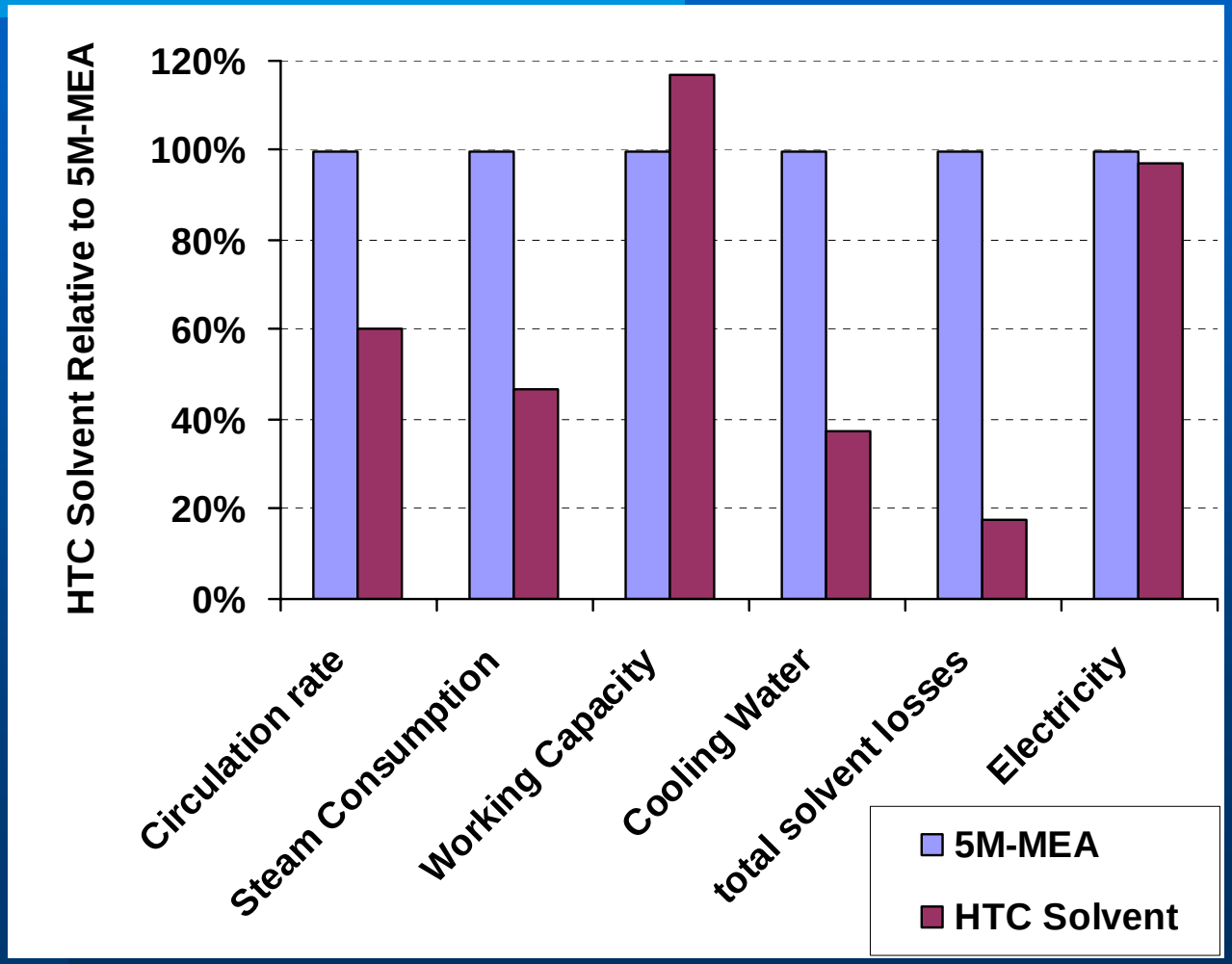
…Design Critical path…

- **Circular columns vs. rectangular columns:**
  - Circular column offers the benefits of a free standing design
  - Rectangular columns requires additional structure to hold.
  - The circular column can be designed a much higher pressure rating than that of similar rectangular design.
  - The circular column is also more blast resistant, as well as more tolerant to wind load.
  - Liquid distribution is much more understood with circular columns and can be modelled with a great deal of accuracy.
  - Engineering properties of a circular column is much more advanced, has been historically utilized and as such the modelling and simulation of the column has been proven over many years.

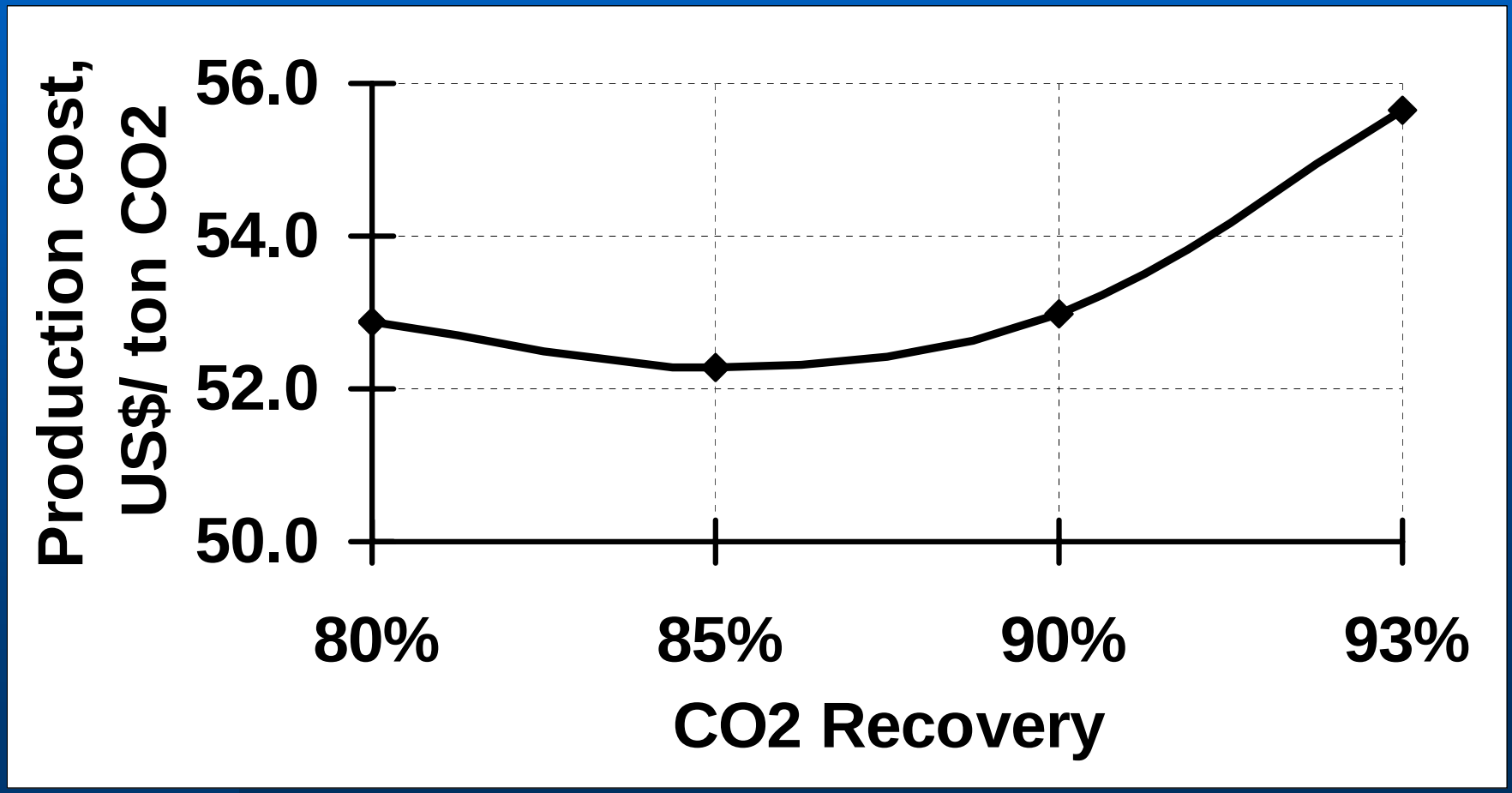
…Design Critical path…

- **Use random packing vs. structured packing**
  - **Based on the CO_2 recovery range, random packing is selected**
  - **Less cost relating to installation.**
  - **Random packing can be delivered in bulk poured into the column**
  - **Structured packing must be pre-cut to the specific dimension and installed layer by layer manually.**
  - **The structured packing must also be crated for shipping to prevent damage.**
  - **Random packing more resistance to corrosion due to the thickness of metal.**
  - **Plastic packing material can be used in the absorber and wash section, which is another possible solution to potential corrosion problems.**

Comparison of HTC solvent with 5 M MEA
3150 TPD CO_2 from NGCC Power Plant



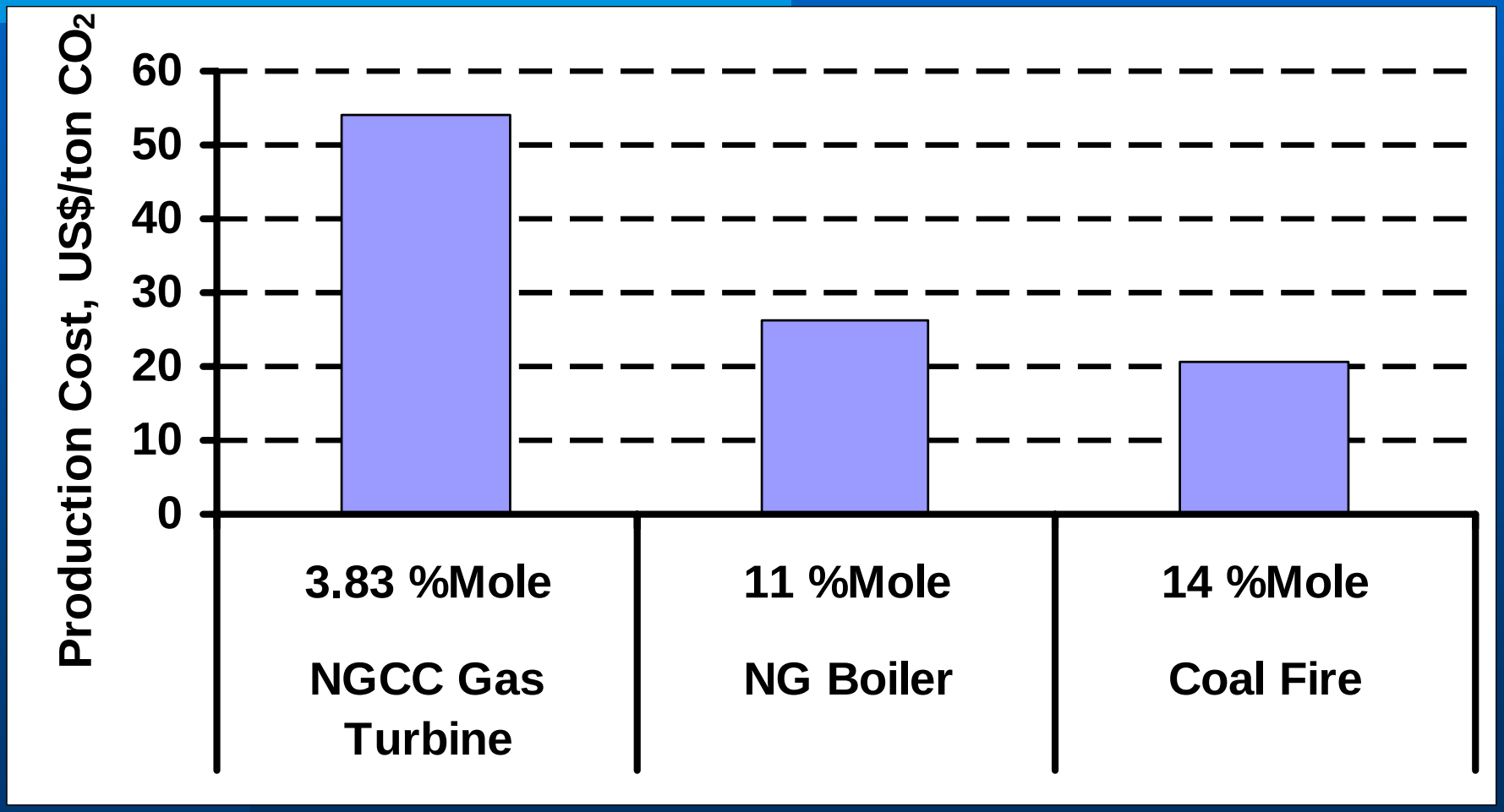
Project: Production cost versus operating range based on straight-line depreciation



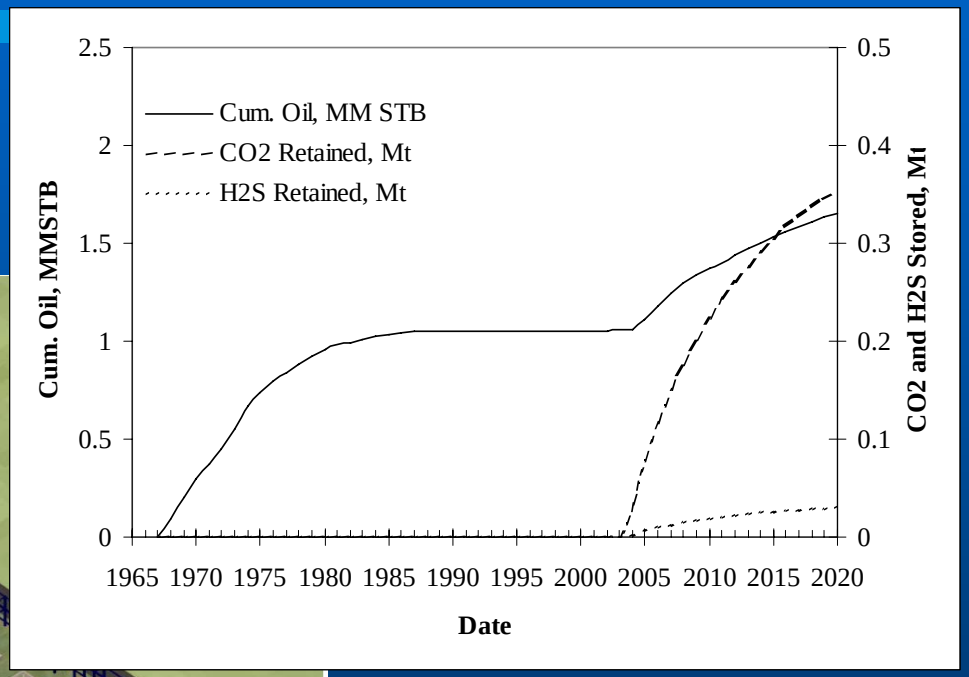
Comparative Production Cost for NG Boiler & Coal Fired Power Plants … Assumptions …

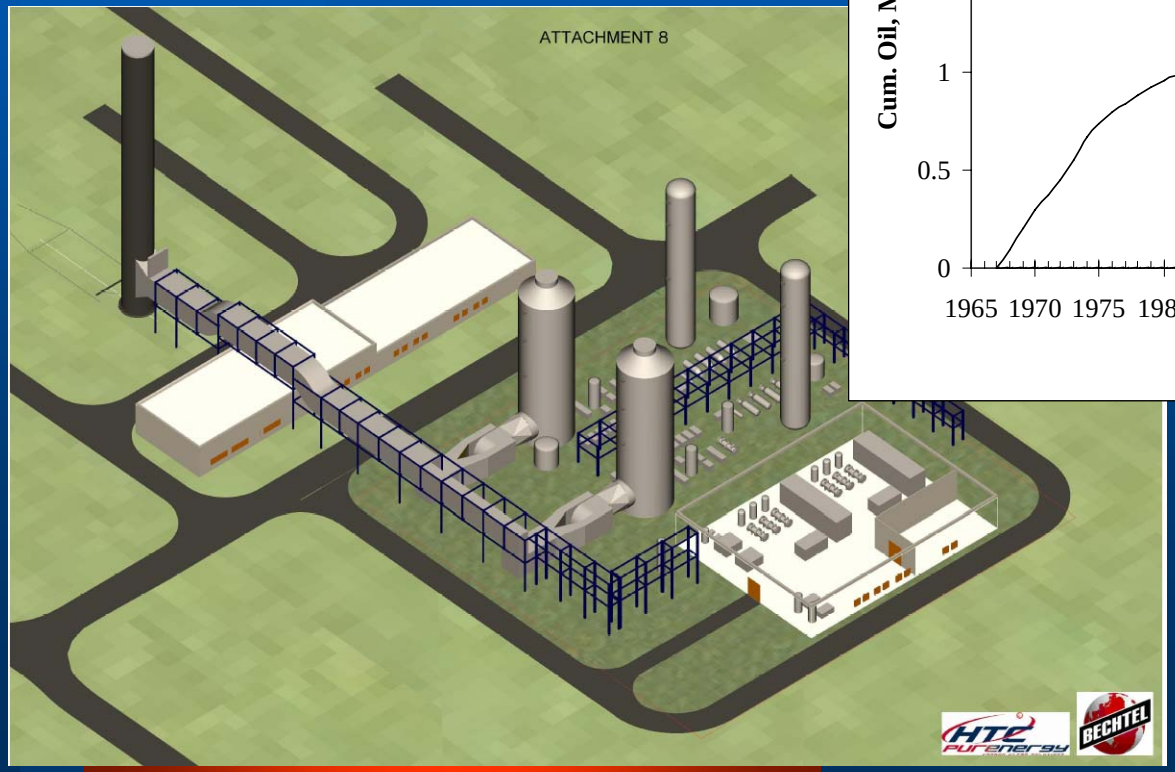
- **The base case is based on NGCC flue gas.**
- **Flue Gas rate remains constant for all cases. Actual flue gas rate may decline with a natural gas boiler and coal fired plant due to reduced air requirements.**
- **Operating costs based on this study.**
- **Electricity consumption estimated for additional compression.**
- **Capital cost estimated for additional compression.**
- **All other operating conditions remain constant.**

Comparative Production Cost for 90% CO_2 Recovery.



The final product is…





HTC Purenergy

CCS Purenergy 1000

Product Description:

- World's first Modular Design and constructed, truck transportable 1000 ton/day CO_2 capture system
- Approx. 50 mw coal plant capture capacity/unit
- Retrofit or Green field CO2 emitter sites
- Reduced Capex via reduction of in-field construction costs
- Multi-unit train installation for expanding capacities
- Markets: - Phased introduction for EOR
  - Incremental Cap and Trade
  - DOE/Govt. Initiator sites

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CCS Purenergy 1000 cont.

Product Roll Out:

- May 25 – June 15 07
- Canada, United States, U.K., Australia –

- (HTC Purenergy announces launch of the " CCS Purenergy 1000" Post Combustion CO2 Capture System)

- Projected cost ~ $35 million USD
- Manufactured and Assembled by strategic industrial partner: Pinnacle Industrial Services (Regina)

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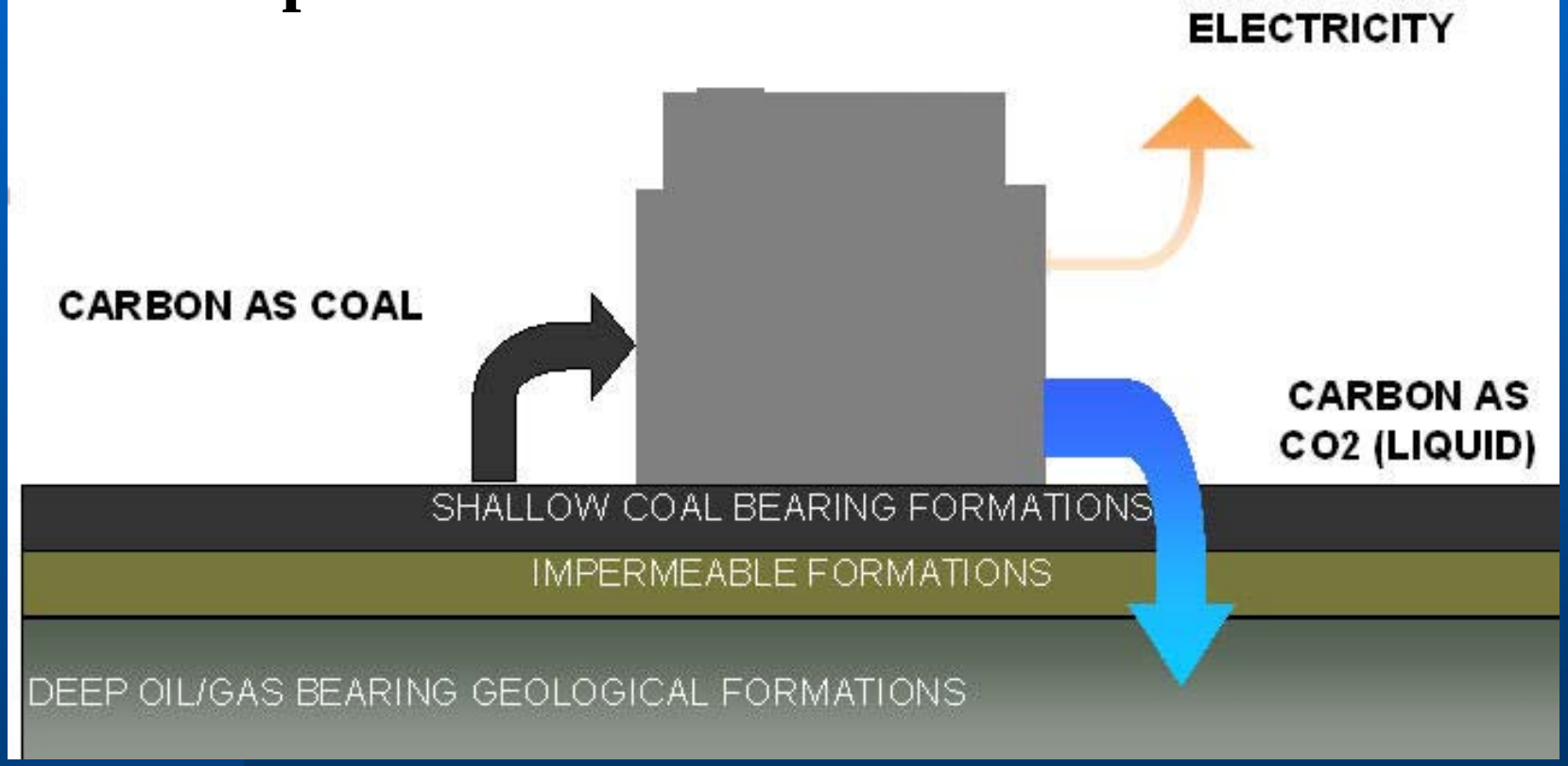
Solution = Clean Coal Plants

- 750 mwh plant = CO2 emissions from 2 million cars



Global Warming's ¢1.5 to ¢2.0/KW

"Inconvenient Solution™"

There's more than one way to clean coal

Thank You from Team CO_2

TIME

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HOW'S THE WEATHER?

Digital models of climate change are the tools that keep Canada's scientists at the forefront of a vital—and sometimes scary—field

Looking to Bury Greenhouse Gases

There's a simple fact about carbon dioxide—the most troublesome of the gases that contribute to global warming—that often gets lost in the debate about reducing greenhouse emissions. CO_2 is not intrinsically toxic. Pumped back into the earth, it's potentially a useful tool for extracting more of the oil and gas that led to CO_2 pouring into the sky in the first place. For Paitoon Tontiwachwuthikul, Thailand-born dean of the engineering faculty at the University of Regina, that suggests a lucrative way of dealing with the problem: "Let's capture the carbon and put it back underground where it belongs." Putting Tontiwachwuthikul's idea into practice is the goal of the International Test Centre for CO_2 Capture (ITC), a $9.6 million complex under construction at the Regina campus. By early 2003, the ITC will employ 35 researchers and technicians and put Regina at the forefront of burying the greenhouse problem once and for all.

ITC's technology isn't new, but it gathers under a single umbrella a next-generation testing laboratory for developing carbon-capturing technologies, a small-scale pilot plant, and a commercial-size plant for capturing CO_2 and injecting it underground, located in the oil-and-gas corner of Estevan, Sask., 200 km southeast of Regina. "The top-to-bottom approach they're taking is right on the money," says Perry Bergman of the U.S. government's Federal Energy Technology Center in Pittsburgh, Pa.

The basic science of CO_2 sequestration is well established. So-called flue gases—pollutants that come from smokestacks—are gathered in a cylindrical column and united with a chemical that binds the CO_2 in a stable compound at normal temperatures. Then the mixture is heated to produce pure CO_2 gas for industrial use. The ITC's goal is to improve the efficiency of the process, making captured CO_2 more affordable.

The chief customer for CO_2 is one of its biggest producers: the oil industry. Compressed CO_2 gas is used to force oil out of declining fields or hard-to-reach deposits. Other markets include agriculture (it can be sprayed on stored grain as a natural pesticide) and food preparation (for carbonated beverages). The oil-and-gas industry also has a tidy way to store CO_2. When it's used to force oil or gas out of a hard-to-reach pocket, it simply remains there, exactly like the world's unexploited natural-gas deposits.

The boom in CO_2 demand is likely to grow out of Canada's commitment to reduce CO_2 emissions. "I don't believe renewable-energy sources and energy efficiency alone will allow us to reach our targets" for reduction of greenhouse gases under the Kyoto Protocol, says ITC director Malcolm Wilson. "Storing carbon underground is a very real option." And he intends to explore it well. —C.T. With reporting by Kevin O'Connor/Regina

HTC Purenergy