CO2 Capture Project

Post Combustion CO_2 Removal
Cost Efficient Design & Integration Study

Robert Chu

Nexant, Inc.

Funded by the CO2 Capture Project and the Research Council of Norway

October 14/15, 2003

This presentation was prepared with the support of the Research Council of Norway/Klimatek under Awaard No. 144737/228. Any opinions, findings, conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of the Klimatek.

www.co2captureproject.org

NGCC Post Combustion CO_2 Removal
"Cost Efficient Design & Integration Study"

Statoil Contract No. 4500478718

CCP Manager	Daniel Chinn	ChevronTexaco
Principal Authors	Robert Chu	Nexant Inc.
	Gerald N. Choi	Nexant Inc.
	Bruce D. Degen	Bechtel

Presentation Outline

- *Objective*
- *Design Criteria & Design Basis*
- *Study Methodology*
- *Base Case Add-on Amine Plant Design*
- *Cost Cutting Ideas Generation & Trade-off Evaluation*
- *Alternate Low Cost Add-on Amine Plant Design*
- *Add-on Amine Plant Capital Cost & Utility Demand Comparison*
- *Low Cost Alternate Design Uncertainties*
- *Integrated NGCC/Low Cost Alt Amine scheme selection & design*
- *Integrated Scheme Capital Cost & Utility Demand Comparison*
- *Integrated Design Uncertainties*
- *Conclusions*

Study Objective and CO_2 Removal Plant Boundary Defined

CCP Objective:

- Identify alternate designs to reduce Capital and Operating Cost of CO_2 Removal from NGCC flue gas.

CO_2 Removal Plant Boundary:

- Flue Gas Feed from HRSG outlet
- CO_2 Product at Compression outlet, exclude pipeline and final disposal facilities.

CO_2 Removal Plant as 'Added-On' to NGCC Power Plant – Design Criteria

- Base Case and Low-Cost Alternative CO_2 Removal Plants shall be designed as 'added-on' to an existing NGCC power plant.
- Added-on designs are considered near-term options (I.e., can be implemented in 3-to-10 years)
- Base Case shall be designed to meet API and Refining specifications.
- Low-Cost Alternative CO_2 shall be designed assuming non-critical service.

CO_2 Removal as an Integrated Plant to a NGCC Power Plant – Design Criteria

- Integrated NGCC and Low-Cost Alternative CO_2 Removal plant shall be designed to operate as a single plant.
- Integrated designs are considered to be long-term options (over 10 years away). Extensive equipment development efforts will be needed.

Design Basis

- Norwegian Coastal Site.
- CO_2 Product Specifications:
  - 220 barg and 60 ^{o}C B/L Pressure and Temp
  - 50 ppmv maximum moisture
- Once-through Seawater Cooling
  - 11 ^{o}C supply temperature
  - 22 ^{o}C maximum return temperature

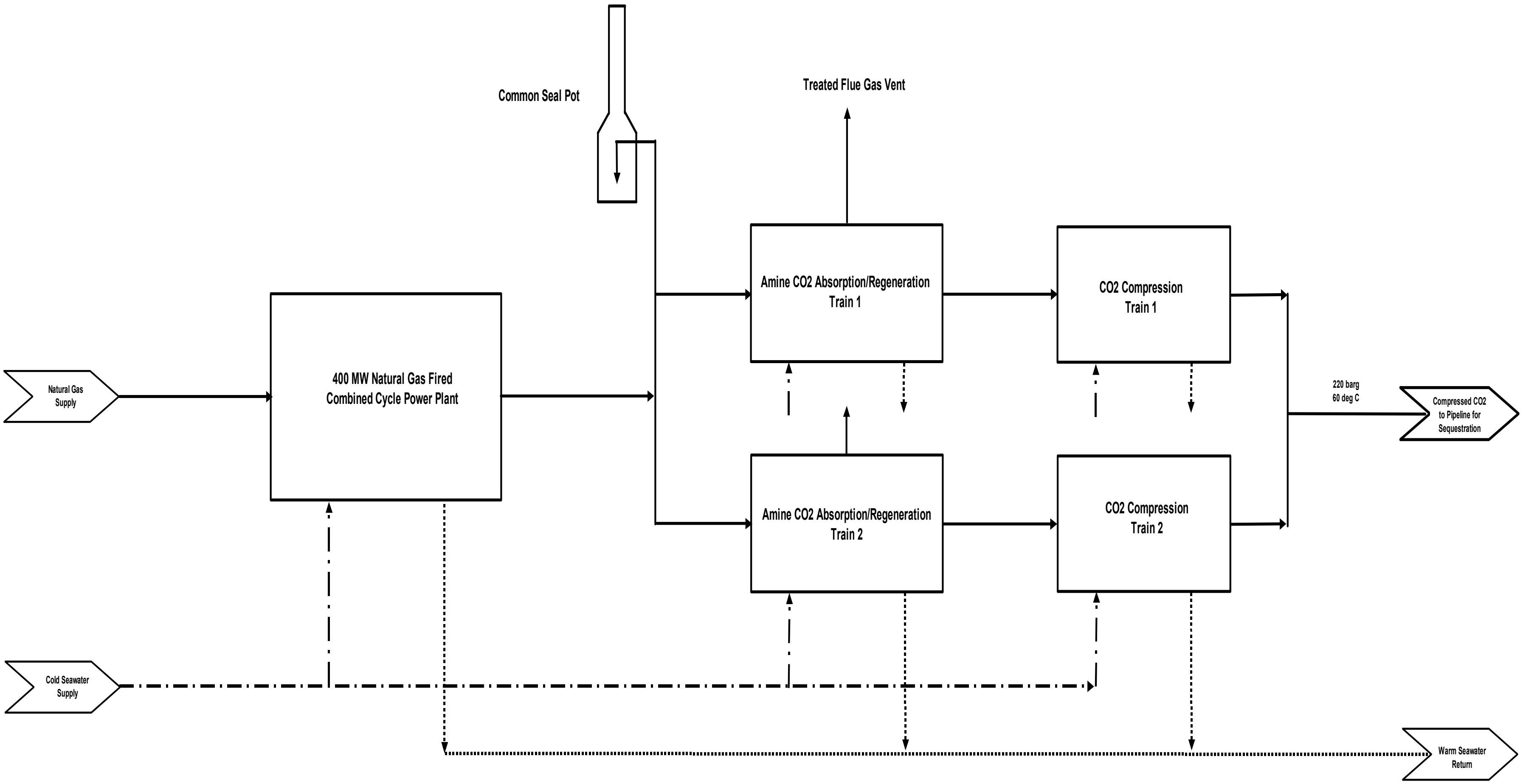
Study Methodology

- Brainstorm to generate cost reduction ideas.
- Perform qualitative screening analysis to select ideas for quantitative trade-off analysis.
- Develop Base Case design and cost estimate.
- Perform quantitative trade-off analysis on screened ideas to determine feasibilities.
- Select feasible ideas and develop Alternate Low-Cost design and cost estimate.
- Select integration ideas and develop Integrated NGCC/Low-Cost Plant design and cost estimate.

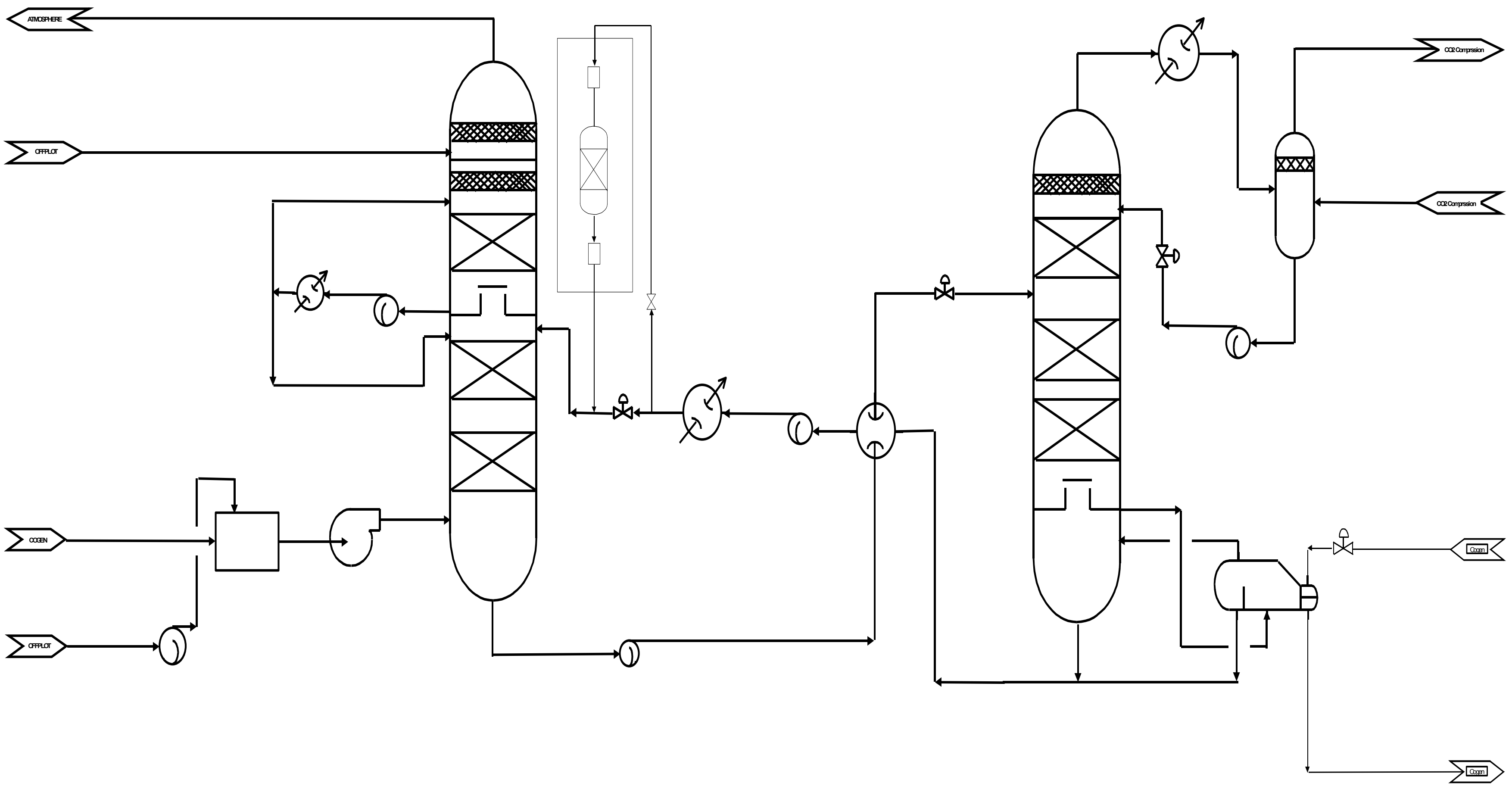
Base Case Amine Plant Design

- 86% CO_2 removal from 400 MW NGCC flue gas.
- 30 wt% MEA based CO_2 removal process.
- H&M balances and equip sizing from T-Sweet, Amsim, and in-house spreadsheet models.
- Major equipment factored cost estimate. Equip costs are per vendor quotations, ICARUS predictions, and in-house historical data.
- Bechtel's low-cost PowerLine 350 MW CCGT Power Plant, modified for this study with net power output of 385 MW, will serve as the Base Case power plant.

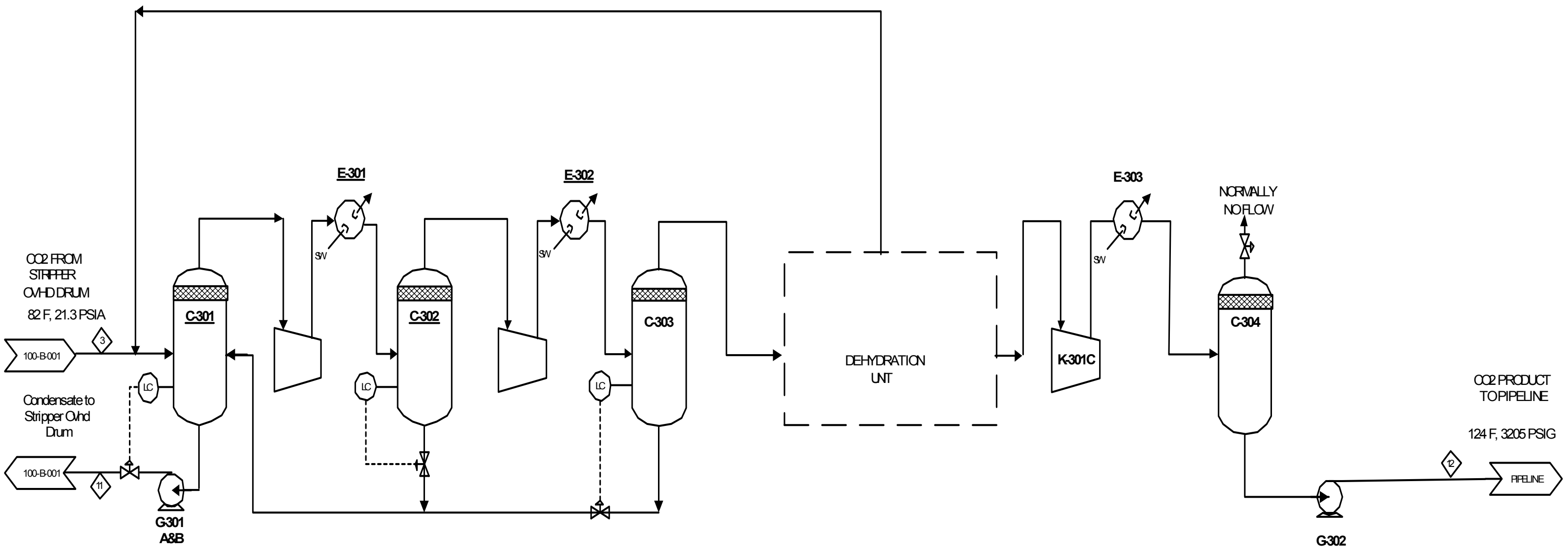
Base Case Amine Block Flow Diagram



Base Case Amine Flow Scheme



Base Case CO_2 Compression Flow Scheme



Brainstorm Results

- Generated 64 ideas.
- Rejected 39 through screening because not feasible, not practical, or redundant.
- 7 to be considered during the Integrated NGCC/CO_2 Removal design.
- Performed 18 trade-off analysis for possible implementation in Low-Cost Alternative scheme.

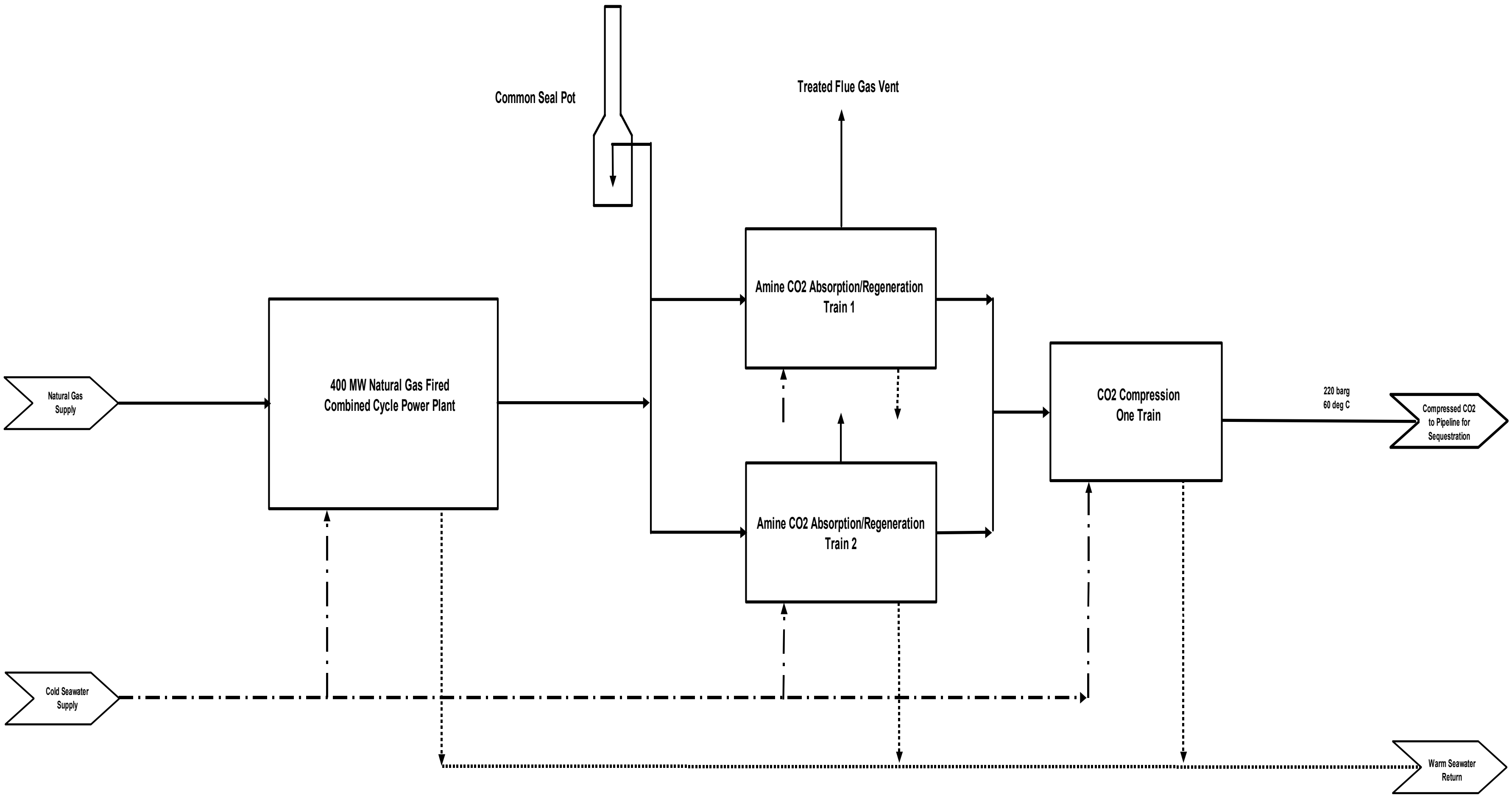
Trade-Off Analysis Results

- 13 of the 18 ideas evaluated deem un-feasible.
- 5 were selected for implementation in the Low-Cost Alternative scheme:
  - Eliminate flue gas cooling.
  - Depressure hot lean amine with ejector.
  - Use plate & frame exchangers.
  - Use ANSI pumps instead of API pumps.
  - Use structured packing in Absorber.
- Added 6^{th} idea: use single train CO_2 Compression.

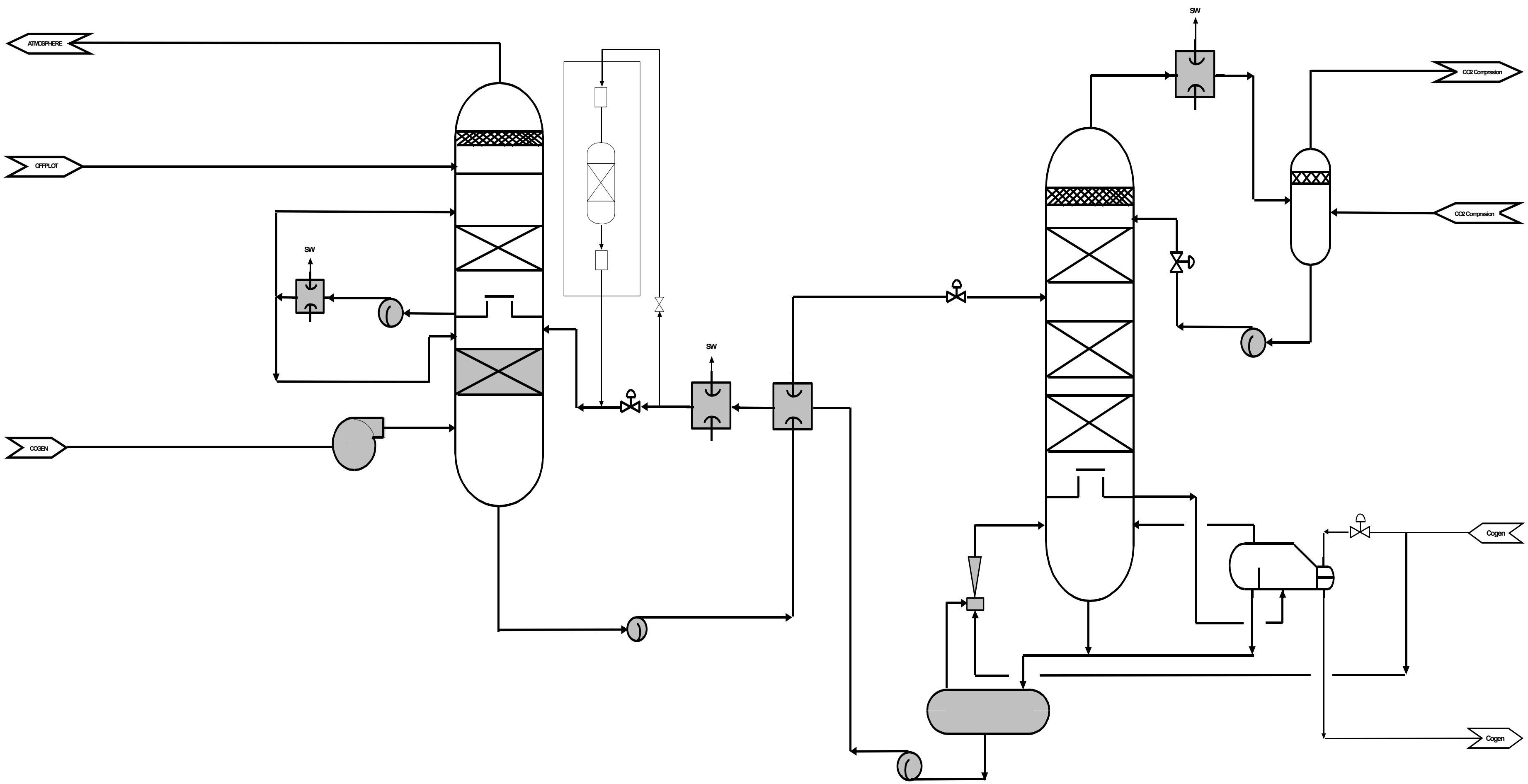
Low-Cost Alternative Design

- 30 wt% MEA based CO_2 removal process.
- Implemented the 6 recommendations from the trade-off analysis.
- Identical H&M balances and equipment sizing procedures as Base Case.
- Identical cost estimate procedures as Base Case.
- Identical NGCC Power Plant design as Base Case.

Low Cost Amine Block Flow Diagram



Low Cost Amine Flow Scheme



Added-On CO_2 Removal – Utility Demands

	Base Case	Low-Cost
Utility Demands:		
Steam Import, mT/h	238	201
Power Import, MW	20	19
Condensate Export, m^3/h	177	147
SW Cooling Duty, 10^6 KJ/h	623	550
CO_2 Recovered, mT/D	2,850	2,850

NGCC Performances

	Design	Base Case	Low-Cost
Power Export, MW:			
To CO2 Removal	0	20	19
To Grid	385	314	323
Steam Export, mT/h	0	238	201
Condensate Import, m^3/h	0	177	147
SW Cooling Duty, 10^6 KJ/h	824	358	432
Nat Gas Burned, MW(LHV)	687	687	687
CO_2 Generated, mT/D	3,314	3,314	3,314

Low-Cost Alternative Design – Performance Verification Required

- Absorption performance without flue gas cooling.
- Structure packing absorption performance.
- Local Codes & Standards requirement on using ANSI pumps instead of API pumps.

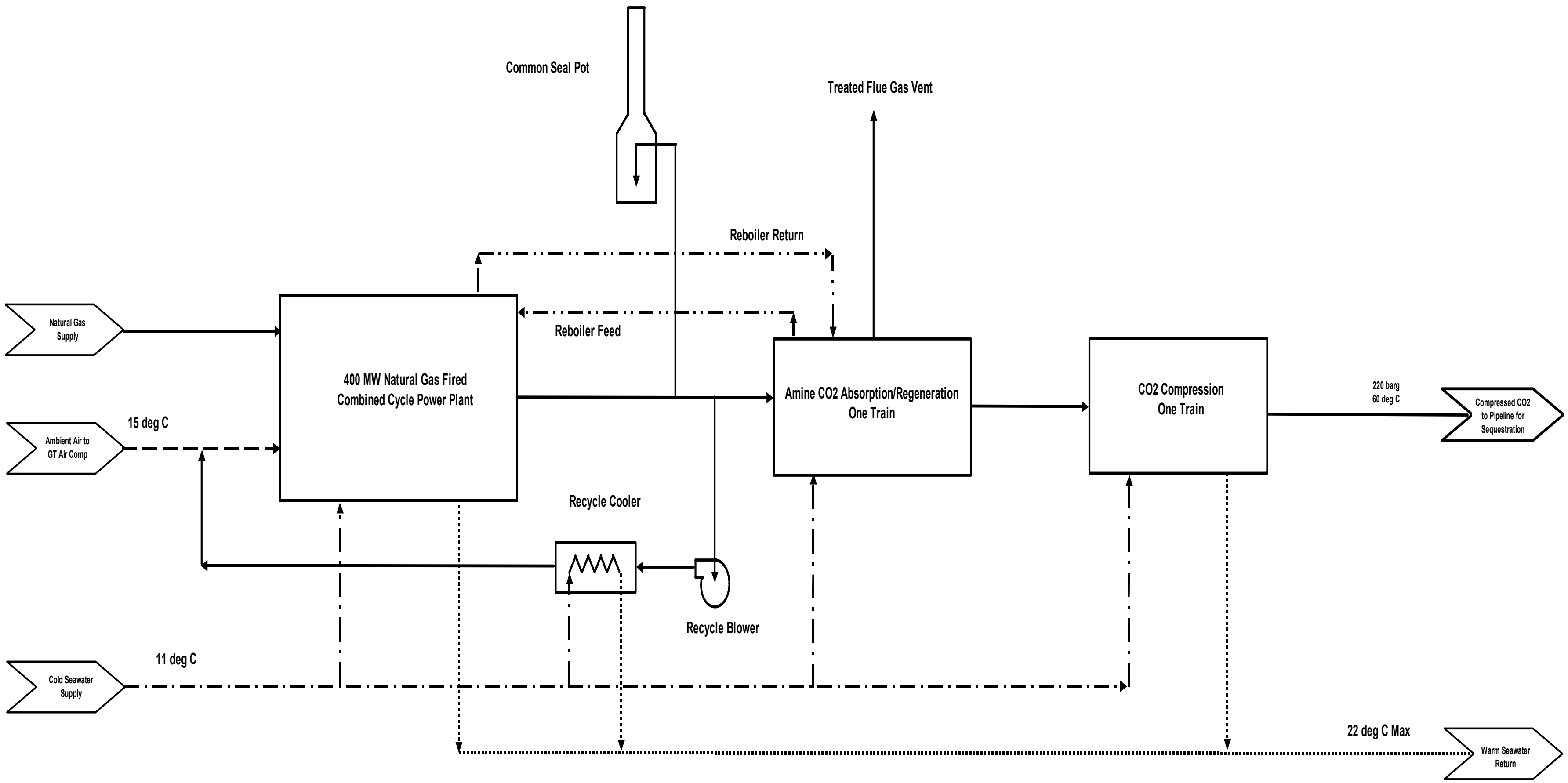
Integrated Scheme Selection

- 5 of the 7 integration ideas judged to be infeasible.
- 2 were implemented in the Integrated NGCC/Low-Cost Alternate Design:
  - Recycle portion of the HRSG flue gas to the GT Air Compressor.
  - Insert Amine Reboiler tube bundles directly in the HRSG.

Integrated NGCC/Low-Cost Alternative Design

- 30 wt% MEA based CO_2 removal process.
- Recycled no more than 50% of the HRSG flue gas to maintain minimum 13 vol% O_2 in combustion air mixture.
- Cooled recycle flue gas to 27 ^{o}C before return to air compressor.
- NGCC Power Plant HRSG, STG, and surface condenser sizes and costs were reduced to match the smaller power plant loads.

Integrated Design Block Flow Diagram



Integrated Scheme – CO_2 Removal Plant Utility Demands

	Low-Cost	Integrated Design
CO_2 Removal Utility Demands:		
Steam Import, mT/h	201	77
Power Import, MW	19	19
Condensate Export, m^3/h	147	32
SW Cooling Duty, 10^6 KJ/h	550	501
CO_2 Recovered, mT/D	2,850	2,838

NGCC Performance

	Design	Low-Cost	Integrated
Power Export, MW:			
To CO2 Removal	0	19	19
To Grid	385	323	325
Steam Export, mT/h	0	201	77
Condensate Import, m^3/h	0	147	32
SW Cooling Duty, 10^6 KJ/h	824	432	621
Nat Gas Burned, MW(LHV)	687	687	684
CO_2 Generated, mT/D	3,314	3,314	3,300

Integrated Design – Performance Verification Needed

- Confirm with Gas Turbine vendors on the feasibility of recycling flue gas back to the air compressor, and of operating the combustor continuously at 13% oxygen.
- Verify with HRSG vendor that the amine reboiler tube skin temperature can be kept below 145 ^{o}C to avoid excess amine degradation.
- Verify regulatory and insurance requirement regarding to heat amine solutions in HRSG.

Conclusions

- Add-On MEA-based CO_2 Removal plants capital cost can be reduced by:
  - utilizing P&F exchangers, structure packing, and ANSI pumps.
  - by integrating the NGCC and the CO_2 Removal plants
- Operating cost can be reduced.
- Further reduction in costs would require solvent changes.

Nexant