CO_2 Mitigation Options, Risks, and Potential Opportunities for Ammonia Manufacturers

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OVERVIEW

- Background
- Managing Economic Risks
- Ammonia Production Technology Options
- Sequestration Technology Options
- Strategic Business Opportunities
- New, “Smart Policies” Required

SFA PACIFIC BACKGROUND

Founded in 1980

Performs technical, economic & market assessments for the major international energy & engineering companies

- over 40% of our work is consistently outside the United States

Principal work involves heavy oil upgrading, syngas (H_2 & CO), electric power generation & emission controls

Niche is objective outside opinion & comparative analysis before companies make major decisions or investments

Unique perspective with no vested interest in engineering, resources, technologies, R&D or project development

SFA PACIFIC CO_2 CAPTURE & STORAGE (CCS) RELATED PROJECTS

1989 – present: CO_2 Capture analysis for EPRI

2001: Private Multi-client Analysis of CO_2 Mitigation Options

2002 – present: Technical Advisory Board (TAB) to the CO_2 Capture Project (CCP)

2003 - 2005: Lead author of the UN IPCC Special Report on CO_2 Capture & Geologic Storage *(published Nov. 2005)*

2007: CO_2 Capture & Storage costs for Canada Government & Industry Expert Economic and Policy Working Group

Most of our CO_2 mitigation work is for private industry

MANAGING ECONOMIC RISKS

Natural Gas Dependence

- Access to Secure, Low-Cost Supplies
- “Nationalization” of Resource Access
- Increasing Dependence on LNG Imports
- Production viability in High-Cost Locations
- Location, Location, Location and Logistics

MANAGING ECONOMIC RISKS

CO_2 Emissions Intensity from Production

- Perceived Future Liabilities
- Potential Market Devaluation of Assets
- Corporate “Brand” Reputation/Image
- Ability to Meet Demand Growth
- Future Carbon Constraint Scenarios
- Compliance Costs
- Innovative Solutions Required

AMMONIA PRODUCTION TECHNOLOGY OPTIONS

Current NG-based Ammonia Plant Designs Are Not CO_2 Capture Friendly

Primary steam methane reformer (SMR) with secondary air-blown secondary autothermal reformer (ATR)

CO_2 from NG feedstock is already recovered via MDEA or Selexol, however, this is only about 60% of total CO_2 and still required large CO_2 compressors for CCS

Other 40% CO_2 from the NG fuel used to fire the SMR ends up as a low pressure, dilute flue gas that is expensive & inefficient to recover CO_2

Firing the SMR with H_2 in place of NG fuel would greatly increase the SMR/ATR size and costs while reducing the efficiency, plus major radiant heat transfer issues of a H_2 fired SMR

AMMONIA PRODUCTION TECHNOLOGY OPTIONS

Many Ways to Improve Ammonia Plant Designs Relative to CO_2 Capture & Storage:

Commercial options that could improve CO_2 capture in H_2 gen

- Just big air-blown only ATR with no primary SMR, however, very costly plus too much N_2 added for NH_3

- Just big oxygen-blown ATR and add N2 from air separation units (ASU), however, high capital and operating costs of ASU

- Heat integrated primary SMR with heat supplied by secondary oxygen blown ATR commercial Kellogg Reforming Exchange System (KRES)

Costs increase due to the added capital and lower efficiency of adding CCS, especially with high NG prices of a carbon-constrained world.

CO_2 Capture Costs for Current NG-Based Ammonia Design

High steam need of the CO_2 MEA scrubber on the SMR furnace flue gas greatly reduce efficiency

Large heat demand of CO_2 MEA scrubber (1,800 Btu/lb CO_2) can be supplied by SMR & ATR, however reduces overall efficiency 15-20%

High power needs of the big CO2 compressors

Increase electricity purchase by a factor of 2 – 3

Greatly increases the NG-based ammonia costs due to added capital costs of MEA CO_2 scrubber & big CO_2 compressors plus added operating costs of both increased electric power needs and the lower efficiency, especially as NG prices increase if a carbon-constrained world develops.

AMMONIA PRODUCTION TECHNOLOGY OPTIONS

Pre-Combustion CO_2 Capture

Overview

- Gasification at high pressure of any carbonaceous fuel with O_2 to make H_2 & CO "syngas" then CO reaction with H_2O to just H_2 & CO_2

Status

- Many commercial gasification based hydrogen and ammonia plants making pure H_2 & CO_2 – with units >3,500 t/d CO_2 capture operating
  - of the >50 GWt (syngas) of commercial plants now operating, **all except** the few IGCC units (<8 GWt or <4 GWe) **already** have CO_2 capture

Attributes

- H_2 or high H_2/CO ratio fuels have many strategic long-term utilization advantages over just making steam in a coal-fired boiler power plant

- Adding CO_2 storage to industrial gasification (like ammonia) is much cheaper than adding CCS to coal-based power generation.

CO_2 Capture & Storage (CCS) Overview

Simple concept: recover CO_2 from fossil fuel or waste biomass utilization then geologically store CO_2 deep underground.

HOWEVER, the "Devil is in the details," requires the following:

<u>Locations</u> with specific geologic formations of sedimentation & cap rock – typically oil & NG and/or deep saline aquifers geology

<u>Large "point sources"</u> of CO_2 for essential economy of scale

- Typically coal power plants, cement kilns & other big "smoke stack" industrial complexes: oil refineries, bulk chemicals & iron/steel making

<u>Concentrate & compress</u> to high pressure for geologic CO_2 injection

- Some pure CO_2 vents but usually only 15% CO_2 in coal boiler flue gas thus large costs & energy use to recover or capture CO_2 as pure stream

- Compress the recovered or captured CO_2 to high pressure supercritical conditions for pipeline transport & injection into geologic storage

The CCS Cost Basics

CCS costs can be separated into 3 distinct steps:

- 50% for capture to pure CO_2 stream
- 25% for compression
- 25% for CO_2 pipeline, injection & geologic storage monitoring

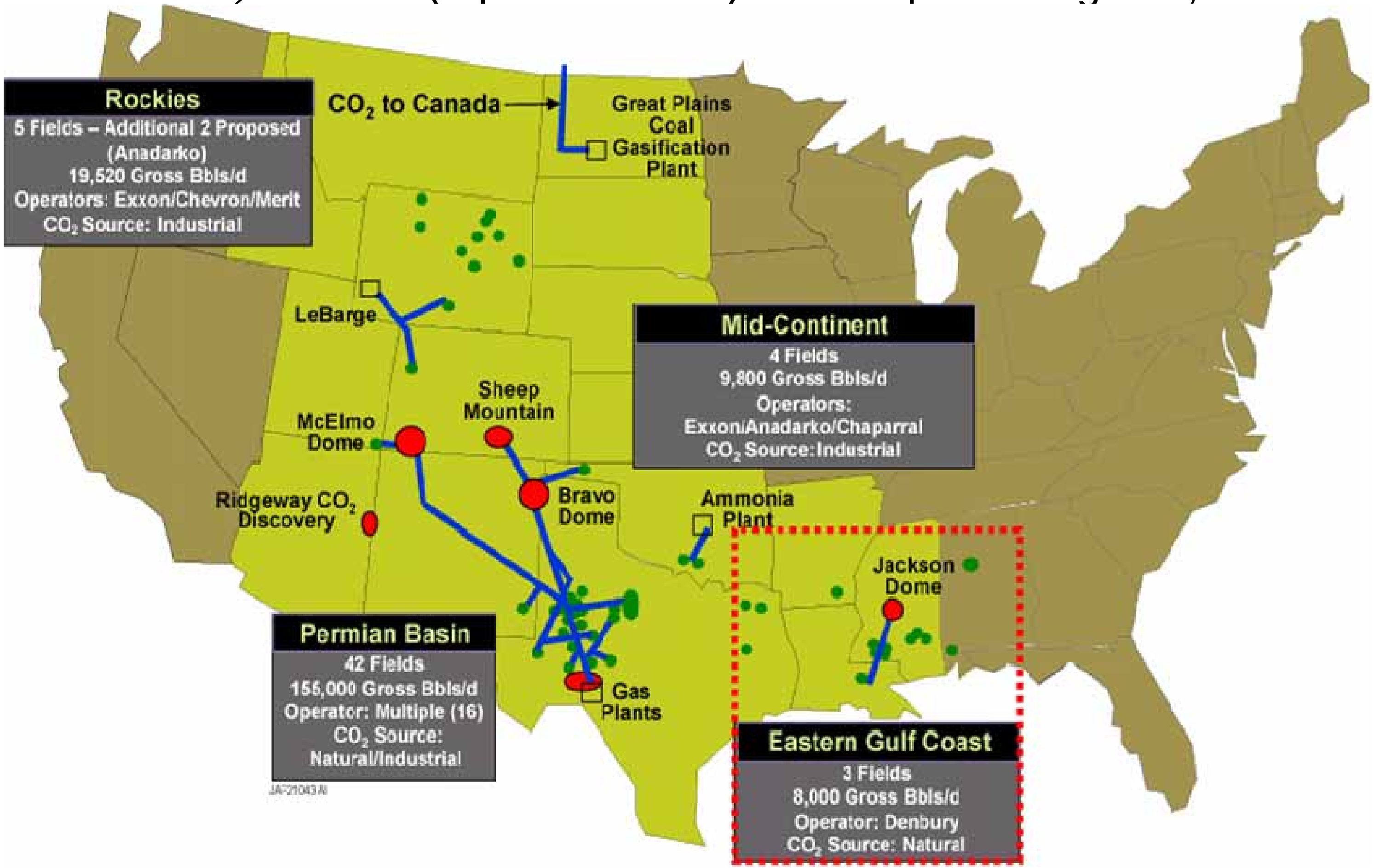
CCS Costs are mostly from added capital & internal energy use

- For coal power plants these efficiency losses and added capital costs are high because
  - the generation process does not separate the carbon as an inherent step in producing the product.
- Industrial Gasification processes producing fuels and chemical feedstocks include processing steps to remove some or all the carbon
  - Hence, the additional costs for CCS are about 1/3 of the cost from a power plant
  - And the efficiency of CO-produced electricity is from 50 – 70% vs. less than 40% for a power plant.

Commercial Coke Gasification to Pure Hydrogen for Ammonia Plus Pure CO_2 Capture for Urea

SEQUESTRATION TECHNOLOGY OPTIONS

25 Years of CO_2 Experience – about 35 million t/y CO_2 storage with 25% man-made CO_2 sources (squares below) used in producing 250,00 bbl/d of



CO_2 EOR CCS Using Anthropogenic CO_2

State/Prov.	Plant type	CO_2 mil. Mt/yr	EOR Fields	Operator
Michigan	NG Processing	0.1	Dover	Core Energy
Alberta	Ethylene Plant	0.5	Joffre Viking	Numac Energy
Oklahoma	Fertilizer	0.6	Purdy & Sho-Vel-Tum	Anadarko &Chaparral
Colorado	NG Processing	1.2	Rangely	Chevron
Texas	NG Processing	2.0	Sharon Ridge Sacroc	ExxonMobil & Kinder Morgan
No. Dakota	Coal Gasification	2.9	Weyburn (Sask.)	EnCana & Apache
Wyoming	NG Processing	3.4	Lost Soldier & Others	Anadarko

North American Total: 10.7 million metric tons per year CO_2

Already 30% of total North American EOR use of about 35 million mt/y CO_2

For comparison, North Sea Sleipner Aquifer CO_2 injects only 1.0 million t/y

SEQUESTRATION TECHNOLOGY OPTIONS

Large CO_2 EOR Opportunity While Also Reducing CO_2

Current 0.25 million bbl/d EOR while storing 35 million t/y CO_2 with total USA domestic oil production at only 5 million bbl/d and total USA proven reserves of only 21.9 billion bbl

Feb. 2006 DOE Report by ARI estimate of U.S. EOR potential:

582 billion barrels OOIP & 389 billion barrels ROIP (67% of original IP)

<u>47 billion barrels</u> (economic potential, current technology)

89 billion barrels (technical potential, current technology)

129 billion barrels (technical potential, advanced technology)

Exploitable U.S. CO_2-EOR potential up to 3 million bbl/d by 2030

CO_2 requirements – about 0.5 billion t/yr CO_2or 9% of U.S. total

EOR is currently limited by CO_2 supplies – must develop cost-effective, man-made CO_2 supplies as this is a big "win-win."

STRATEGIC BUSINESS OPPORTUNITIES

Production of Ammonia/Urea via Industrial Gasification (IG)

- Dedicated facility co-producing “sequestration-ready” CO_2 at a “sequestration-accessible” site.
- Sequester in oil reservoirs for initial plants.
- Use petroleum coke/coke-coal blend feedstocks in initial plants.
- Collaborate with “CO_2 Aggregators” or directly with CO_2 user.
- Industrial gasification (IG) plant construction and operation expertise must be acquired.

STRATEGIC BUSINESS OPPORTUNITIES

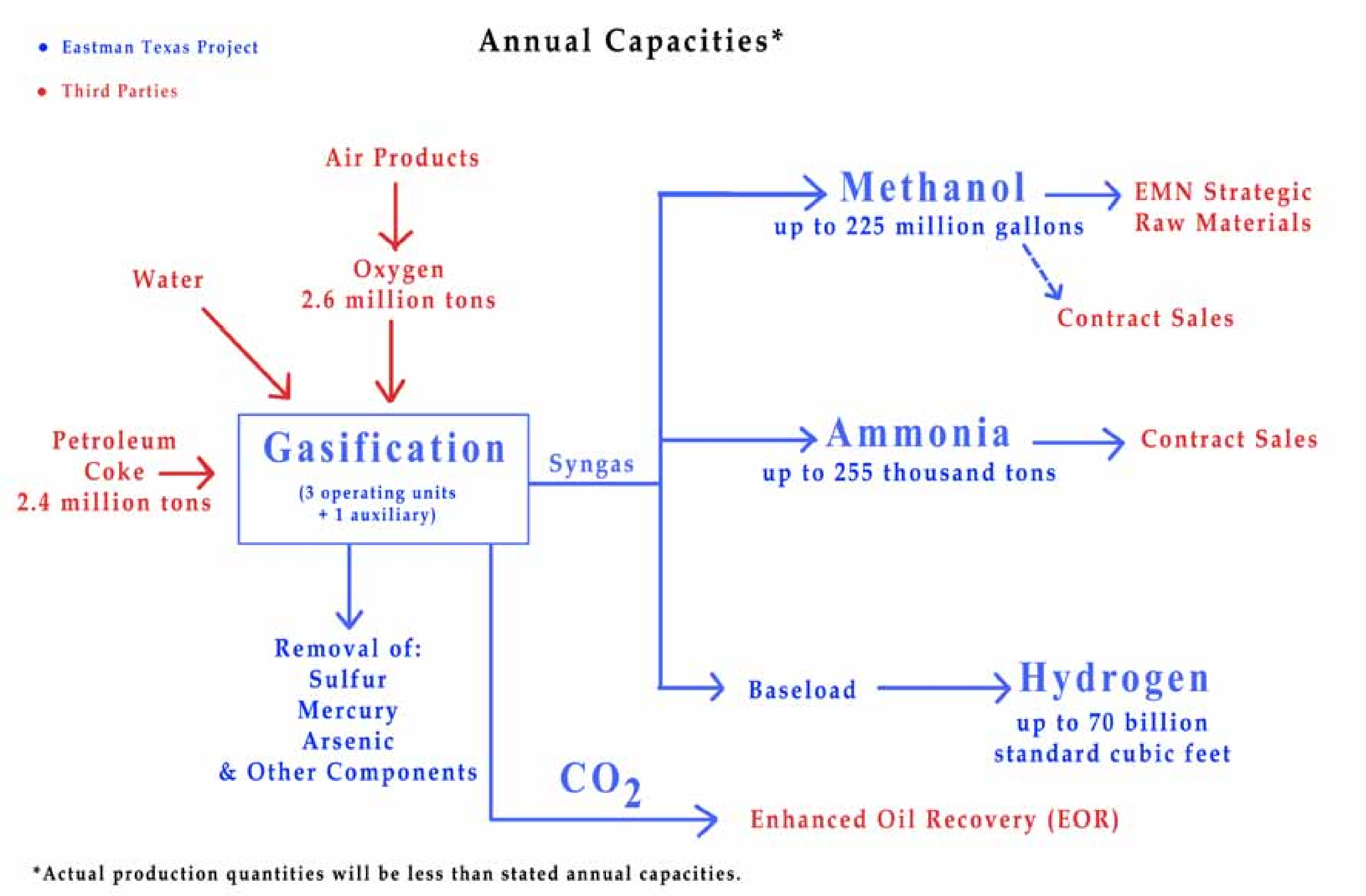
Co-production via IG in a Polygeneration Facility

- Economies of scale and operational flexibility available.
- Participate as off-taker, equity partner, or both.
- Wide range of co-production options include:
  - Hydrogen or Synthetic Natural Gas (SNG)
  - Methanol, other liquid fuel or chemical feedstocks
  - Electricity
- Co-produced electricity would be highest efficiency, lowest-emission fossil-based electricity, for industrial use, or sale to the grid.
- More complex business arrangements and partnering

Trifecta Potential

- Avoid natural gas dependence; CO_2 emissions costs; and vulnerability to high purchased electricity prices

EASTMAN TEXAS GASIFICATION PROJECT



ANOTHER EXAMPLE

Faustina Hydrogen Products LLC Coal-Based Fertilizer Plant

- St. James Parish, LA adjacent to Mosaic Fertilizer LLC
- GreenRock LLC developer
- Mosiac and Agrium ammonia offtakers
- Denbury Resources CO_2 offtaker
- Operator planned as Eastman. Now unclear as Eastman withdrew to focus on 100% interest in TX plant.
- Project has approval for $1 B in GOZ Bonds from LA

NEW "SMART POLICIES" ARE REQUIRED

- Stimulate domestic production of low-emission fossil-based fuels, feedstocks, and electricity from abundant domestic sources
- Industrial Gasification (IG) of coal, petroleum coke, and waste biomass uses commercially proven technologies
- Scale and capital intensity of initial projects entail business risks well beyond "business-as-usual." (BAU)
- No incentives currently to incorporate CCS
- Significant "First-mover" incentives are needed for the first wave of commercial project deployments
- Large economic, national security, carbon intensity reduction, and jobs benefits.

FOR MORE INFORMATION

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