Driving Innovation ♦ Delivering Results

CCPI Update: Texas Clean Energy Project, IGCC Polygen w/ Full Carbon Capture

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Major Projects Division

October 6, 2015

CCPI-3 Texas Clean Energy Project Discussion Topics and References

- **Summit Power Group**
- **The Project and FEED Update**
- **Technologies**
- **Environment and MVA**
- **Status**
- **Observations**

- **A special Thank You to the Co-authors**
  - Jason Crew, Chief Executive Officer, Summit Power Group, LLC
  - Karl Mattes, Senior Vice President, Project Development & Engineering, Summit Power Group, LLC

CCPI-3 Texas Clean Energy Project
Summit Power Group, LLC

- **Summit Power Group, LLC (SPG) is a Seattle-based developer of clean energy projects**
- **Founded in the late 1980's by Don Hodel, former U.S. Secretary of Energy & Secretary of the Interior, and Earl Gjelde, former COO of the U.S. Department of Energy and Under Secretary of the Interior**
- **SPG's Projects**
  - 7,000+ MW completed
  - 2,500+ MW in development
- **SPG's Principal Project Types**
  - Natural Gas-fired Generation
  - Wind Power
  - Solar Power
  - Carbon Dioxide (CO_2) Capture

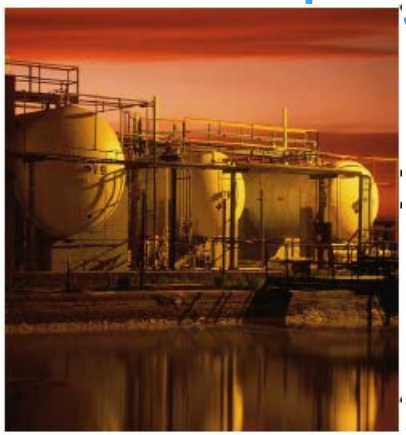
CCPI-3 Texas Clean Energy Project
A Nominal 400MW Polygen IGCC Facility

PRB Sub-bituminous Coal via Railroad

~1.55 MMtpy (~5,000 tpd)

Non-drinkable Water

Water Treated for Process Use and Steam Production



Coal Gasification & Gas Cleanup

Tail Gas (coal drying) ~49 MMBtu/hr

Syngas (89% H_2) ~1,450 MMBtu/hr

High-Hydrogen Gas Turbine (in Combined Cycle)

~190 MW_e low CO_2 power to CPS Energy (San Antonio)

Syngas ~1,280 MMBtu/hr

CO_2 ~0.56 MMtpy (~1,830 tpd)

Ammonia/Urea Plant

~756,000 tpy (~2,480 tpd) Granulated Urea to Agricultural Fertilizer Company

CO_2 ~1.84 MMtpy (~6,100 tpd)

Deep geologic storage w/ concomitant enhanced oil recovery (EOR)

2.5 – 3 barrels of oil per ton CO_2 injected

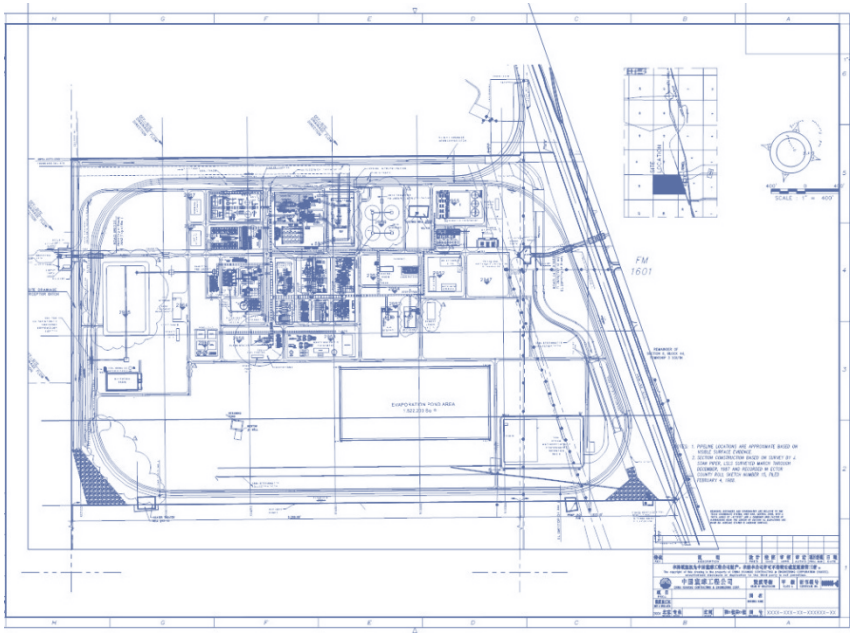
NOTE: All tons are short tons (2,000 lbs)
MMtpy → million tons per year
tpy → tons per year
tpd → tons per day

CCPI-3 Texas Clean Energy Project 2014-2015 Update

- **2013 result: plant too expensive; contract structure needed enhancement; and, returns were too low**
- **Reduce Cost**
  - Replace two SFG-500 gasifiers with one SFG-850
  - Change Siemens F-class turbine to H-class
  - Input lessons learned
  - Reduce redundancy
  - Optimize, modularize, and value engineer in FEED
- **Change Contracting Plan**
  - "Single" EPC with HQC on Chemical Block and Siemens on Power Block
  - Single constructor
  - Address labor
  - Reset Siemens O&M (negotiating 20-year term)

CCPI-3 Texas Clean Energy Project
Plot Plan Improvements

- **Cost Savings**
  - Terraced landscape using natural elevation of site, reducing soil processing
  - Reduced coal pile by 15-days
  - Re-oriented buildings and process units
    - ASU, AMM/UREA, H_2SO_4, Cooling Tower, Aux Equipment, and Raw Water and Wastewater processing
    - Building placement optimized results in pipe, steel, concrete, and construction savings
  - Coal handling optimized, saving conveyance
  - Rail; deleted one shoofly track and double track throughout
  - Work around an existing well
  - Evaporation pond sizing and use
  - Road routing at south entrance
  - Drainage ditch sizing



CCPI-3 Texas Clean Energy Project
FEED Update Goals and Objectives

- Update 2010-2011 FEED using new plant configuration and verify assumptions of cost, schedule, and performance
- Optimize design compared to prior FEED in regard to value engineering, modularization, and overall size of the project
- Complete licensor PDP's and leverage more engineering to sharpen cost estimates
- Identify all commodities with certainty, including soil, concrete, steel, pipe, etc., and construction manhours
- Prepare a FEED Update cost estimate for input/conversion to lump sum turnkey price, with provision to manage construction volatility

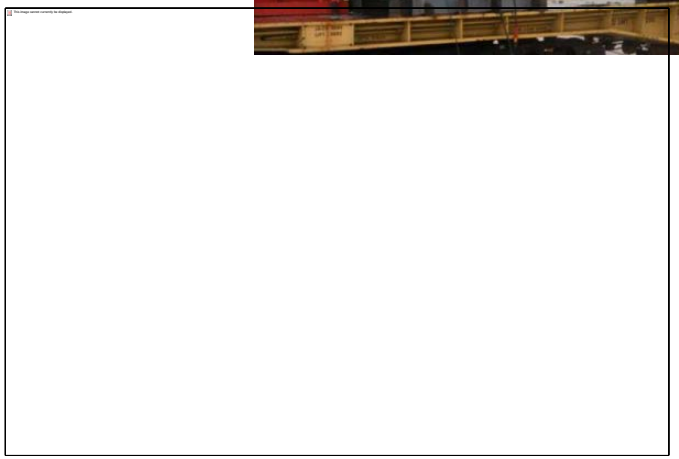
CCPI-3 Texas Clean Energy Project FEED Update Results

- **Cost estimate results in lower CAPEX**
- **Feedstock savings due to using less coal and higher power block efficiency**
  - Single SFG-850 gasifier vs two SFG-500
  - H-class turbine vs F-class
- **Revenue streams to off-takers maintained**
- **Overall plant economics enhanced relative to 2013**

CCPI-3 Texas Clean Energy Project Gasification Technology

- **1 x 100% Siemens SFG-850 (2 x 50% SFG-500 prior to 2014)**
  - 850 MW_{th} coal heat input LHV basis
  - ~9000 ft^3 reactor/quench vessel
  - Operates at >600 psig & >2,600 ^oF
- **~229,500 Nm^3/hr Raw Synthesis Gas (Syngas)**
- **Syngas Composition (after cleanup) is 89% H_2 Gas, 6% N_2 Gas, ~3% CO, and ~2% Other**
- **~2,800 MMBtu/hr (HHV) Total Clean Syngas**
  - ~1,450 MMBtu/hr or ~52% to Combined Cycle Gas Turbine, blended w/Natural Gas at 56% Syngas and 44% Natural Gas
  - ~1,280 MMBtu/hr or ~46% to Ammonia/ Urea Plant
  - ~49 MMBtu/hr tail gas or ~2% to coal milling and drying

A Siemens SFG™-500 Gasifier is shown (left) with matching Feeder Vessel (below).



Five Siemens gasifiers on-line in China

Source: Summit Power Group, LLC
Presentation to the 29th Annual Spring Conference of the Gulf Coast Power Association, Jason Crew, CEO Summit Power Group, April 1, 2015
Top two photos courtesy of Siemens Fuel Gasification Technology GmbH & Co. KG (Germany)

CCPI-3 Texas Clean Energy Project
Gas Cleanup Technologies

- **Particulate Matter, Chlorides and Char Removal**
  - Jet Scrubber for large particles
  - Two Venturi Water Scrubbers for mid-sized and fine particles
- **CO Shift Unit**
  - 1 x 100% with three shift stages
  - Water-gas shift reaction in the presence of cobalt and molybdenum oxides catalyst

$$CO + H_2O \rightarrow CO_2 + H_2$$

  - Provides for increased CO_2 capture efficiency & increased mass flow of H_2
- **Mercury Removal Unit**
  - Pre-sulfided activated carbon bed adsorber
  - >95% Hg removal
- **NO_x Control**
  - Saturation & N_2 Dilution
  - >90% NO_x elimination

CCPI-3 Texas Clean Energy Project
Rectisol® Wash Unit (RWU)

- **Acid Gas Removal (AGR) System**
- **Well-commercialized chilled methanol process with warranted availability**
- **Operates at about -40 ºF**
- **>99% sulfur removal or <0.1 ppmv**
  - Sulfur sent to Sulfuric Acid Plant
- **CO_2 removal >90% from syngas or to <1.6 vol.-%**
  - ~2.40 MMtpy captured
    - ~1.84 MMtpy to EOR
    - ~0.56 MMtpy to ammonia/urea plant
  - Purification and Compressor Systems for product CO_2

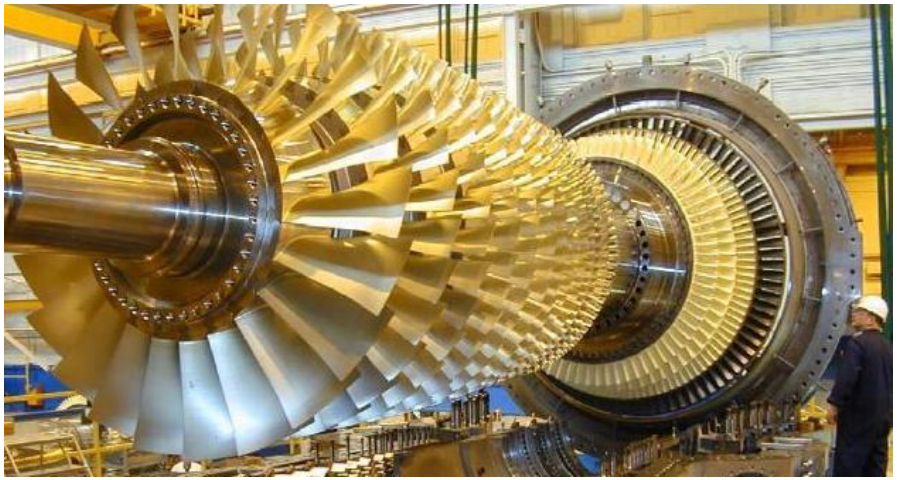
Linde Rectisol® Wash Unit

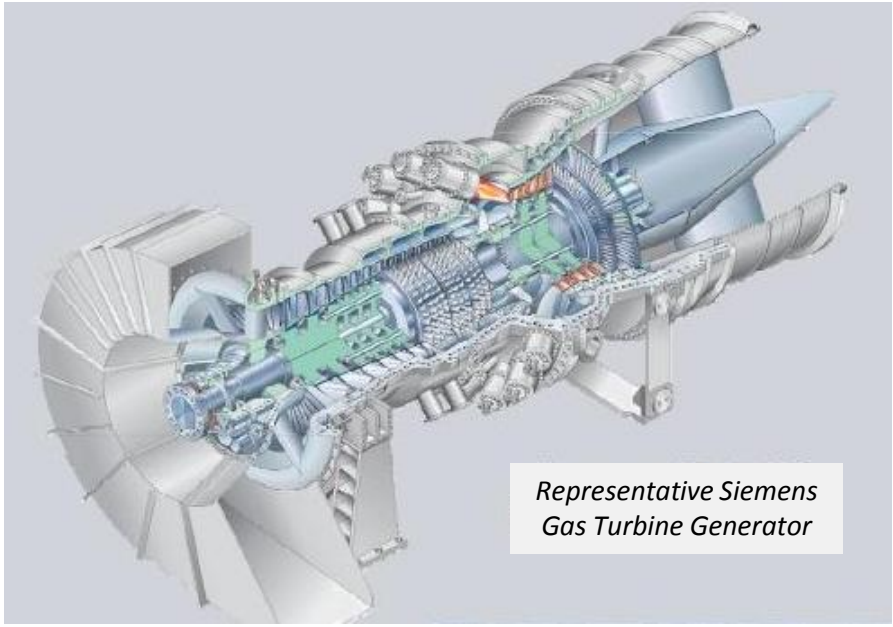
NOTE: All tons are short tons (2,000 lbs)
MMtpy → million tons per year

Source: Summit Power Group, LLC
Photo courtesy Linde Engineering North America Inc. a.k.a. Linde AG (Germany)

CCPI-3 Texas Clean Energy Project
1 x 1 Combined Cycle Power (CC) Plant

- **Siemens 60-Hz SGT6-8000H Gas Turbine up to 296 MW_e**
  - High-Hydrogen (H_2) capable
  - (SGT6-5000F3 prior to 2014)
- **Siemens SST-900RH Steam Turbine up to 250 MW_e**
  - Full by-pass capability
  - Air-cooled condensor
- **TCEP CC Plant ~405 MW_e (gross) at site conditions**
- **Heat Recovery Steam Generator (HRSG)**
  - Three pressure, reheat drum type
  - With SCR and CO catalysts
- **30% reduction in water consumption by substituting air-cooling for the Power Block**



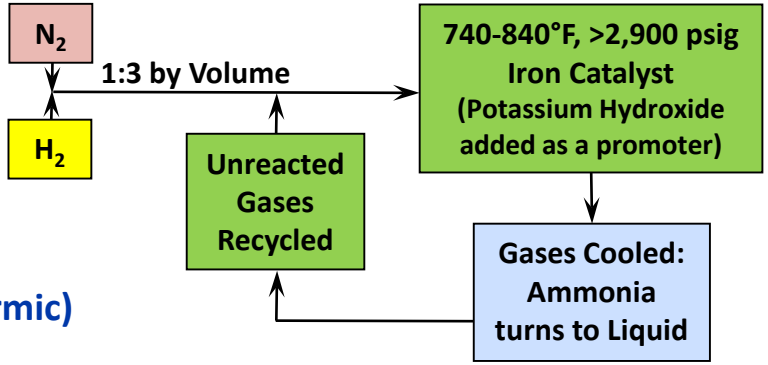


Representative Siemens Gas Turbine Generator

Source: Summit Power Group, LLC and Siemens http://www.siemens.com/about/en/businesses/power-and-gas.htm
Presentation to the 29th Annual Spring Conference of the Gulf Coast Power Association, Jason Crew, CEO Summit Power Group, April 1, 2015
Photos/illustrations courtesy Siemens Energy (USA)

CCPI-3 Texas Clean Energy Project Ammonia/Urea Plant

- **Ammonia Synthesis**
  - 1 x 100% Haber Process
  - ~1,280 MMBtu/hr syngas
  - 99.9 weight percent NH_3 (anhydrous)



$N_2 + 3H_2 \leftrightarrow 2NH_3$ (exothermic)

- **Urea Synthesis and Granulation**
  - 1 x 100% Bosch-Meiser Process to produce urea from ammonia and CO_2 with two main equilibrium reactions
  - ~0.56 MMtpy CO_2
  - Liquid ammonia with CO_2 ice to form ammonium carbamate

    $2NH_3 + CO_2 \leftrightarrow H_2N\text{-}CO\text{-}ONH_4$ (exothermic)
  - Decomposition of ammonium carbamate into urea and water

    $H_2N\text{-}CO\text{-}ONH_4 \leftrightarrow (NH_2)_2CO + H_2O$ (endothermic)
  - Process reactions taken in combination is net exothermic
- **~50 MW used to produce ~2,480 tpd (~756,000 tpy) urea for agricultural use**

NOTE: All tons are short tons (2,000 lbs)
tpy → tons per year
tpd → tons per day

CCPI-3 Texas Clean Energy Project Environmental

- **Lowest air emissions of any coal-based facility permitted in the State of Texas**
- **Permit No. 92350 & PSDTX1218**
  - 0.008 lbs/MMBtu Particulate Matter
  - 0.005 lbs/MMBtu SO_2 (>99% removal)
  - 0.012 tpy Hg (>95% removal)
  - 0.0112 lbs/MMBtu NO_x (>90% eliminated)
- **585,000 tpy of CO_2 emitted to the atmosphere**
  - ~50% of the CO_2 emissions on a MWhr basis of an equivalent-sized natural gas combined cycle (NGCC) power plant
- **Zero liquid discharge (ZLD)**

Department of Energy environmental manager Mark McKoy, center, talks about the Summit Power coal gasification plant as Odessa Chamber of Commerce economic development director Gary Vest, left, and federal project manger Jason Lewis, right, look on Thursday afternoon, May 20, 2010, in Penwell, Texas. The $1.73 billion plant is designed to capture 90 percent of the carbon dioxide it emits. The plant will then sell it to oil companies for injection into wells to aid in the oil recovery process.
Kevin Buehler|Odessa American

NOTE: All tons are short tons (2,000 lbs)
tpy → tons per year

Source: Summit Power Group, LLC Air Permit, issued 12/28/10

CCPI-3 Texas Clean Energy Project
CO_2 MVA – Baseline Monitoring

- **MVA planning and implementation supported by the University of Texas Bureau of Economic Geology**
- **Mechanical Integrity Testing**
  - Conducted by the operator in compliance with Texas Railroad Commission (RRC) regulations prior to initial injection of CO_2
- **Pressure Monitoring**
  - Pressure histories above the confining system monitored for 1-year prior to injection to determine trends from production and water disposal pre-injection
- **Pressure Testing**
  - As required per RRC regulations prior to initial injection
- **Geochemical Sampling**
  - Sampling of nearest aquifers and underground sources of drinking water zones conducted at least monthly for 1-year prior to CO_2 injection; more frequently if required by future regulations. Sensitivity analysis would determine which constituents will be sampled, sampling method, and frequency

Source: Summit Power Group, LLC Air Permit, issued 12/28/10

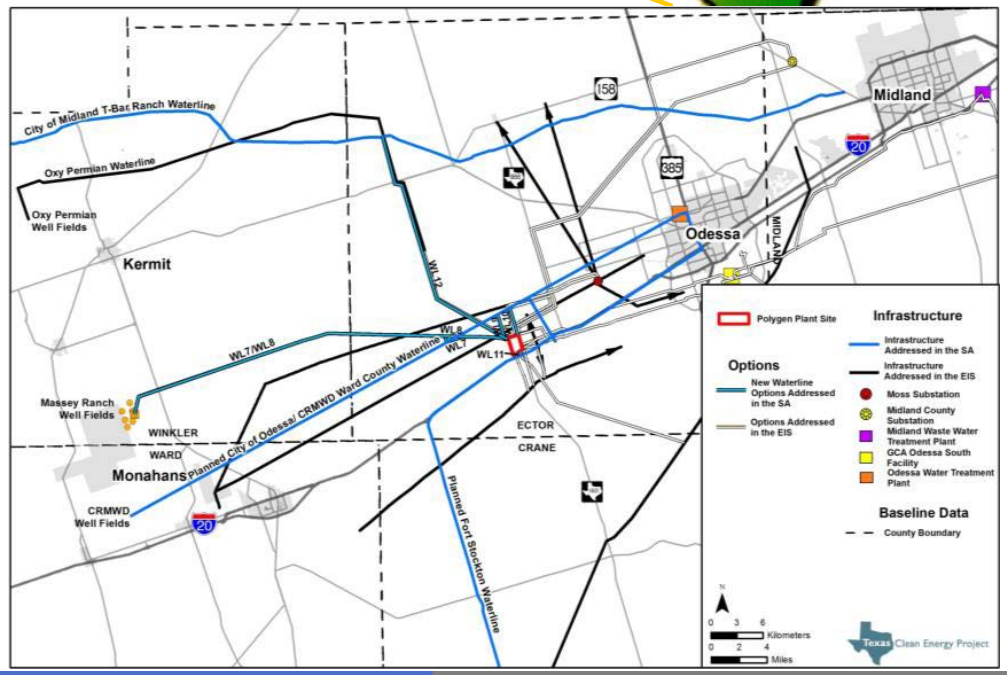
CCPI-3 Texas Clean Energy Project
CO_2 MVA – Operational Monitoring

- **Mechanical Integrity Testing**
  - Conducted by the operator prior to initial injection of CO_2 and once every 5-years as required by the RRC; more frequently if required by future regulations (EPA has proposed annual)
- **Pressure Monitoring**
  - Continuous measurement inside the injection tubing string and the annulus of the well. Monitoring would also be performed periodically in the nearest underground sources of drinking water zones
- **Pressure Testing**
  - Prior to initial injection and once every 5-years thereafter; frequency would conform to any change in regulations
- **Geochemical Sampling**
  - Of nearest aquifers & underground sources of drinking water zones conducted semiannually; more frequently if required by future regulations
- **Injection Rate Monitoring**
  - Measured continuously and reported monthly
- **CO_2 Mass Balance Accounting**
  - Material balances performed monthly on each injection pattern, comparing total injected CO_2 and CO_2 being recovered from oil production; results compared to reservoir models for injection pattern under review.

Source: Summit Power Group, LLC Air Permit, issued 12/28/10

CCPI-3 Texas Clean Energy Project
Status: Location

- 600-acre site at Penwell in Ector County, TX, just north of I-20 and ~15 miles west of Odessa
- Adjacent to Union Pacific Railroad line
- Kinder Morgan regional CO_2 pipeline just offsite to the northeast
- Nearby access to water, natural gas, and transmission lines



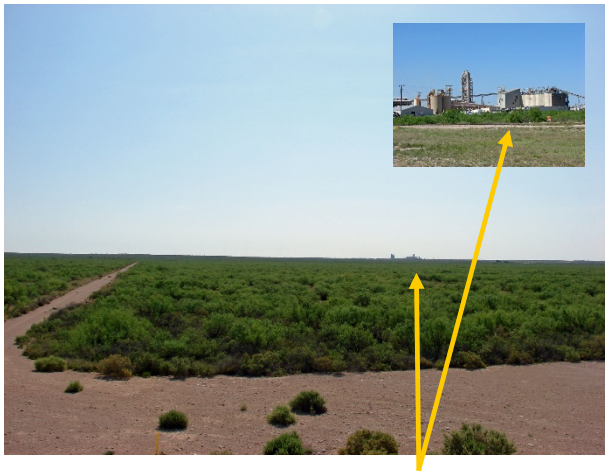
CCPI-3 Texas Clean Energy Project Status: Site Photos (after a rain)

Wind Power Facility to Northwest

Penwell, TX, from I-20 Escarpment East of Town Looking West

Kinder-Morgan CO_2 Pipeline Interconnect to Northeast

Union Pacific Rail Line on Southern Boarder



Cemex Plant to Southeast

CCPI-3 Texas Clean Energy Project Status: The Major Players

Summit Power Group, LLC

Large Business

Energy Project Development

China Huanqiu Contracting & Engineering Corp. (HQC)

Large Business

Global Contracting & Engineering

SNC-Lavalin

Large Business

Engineering and Construction

Siemens AG

Large Business

Siemens Fuel Gasification - Gasifier

Siemens Energy – Power Block

CH2M

Large Business

Owner's Engineer

CCPI-3 Texas Clean Energy Project
Status: Process Licensors

The Linde Group

Large Business

Air Separations Unit (ASU)

Acid Gas Removal (AGR)

Casale

Large Business

Ammonia Byproduct Plant

Saipem / UHDE

Large Businesses

Urea Synthesis & Granulation

Haldor Topsoe

Large Business

Sulfuric Acid Plant

Veolia Water Technologies

Large Business

Water/ZLD Treatment & Recycle

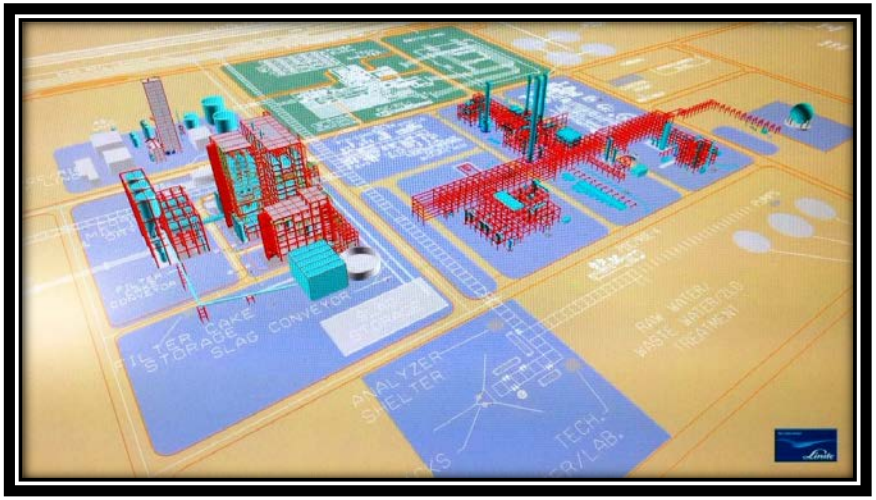
CCPI-3 Texas Clean Energy Project Status: Marketable Products

- **All Primary Products are under signed Off-Take Agreements**
  - Granulated Urea, $(NH_2)_2CO$, to agricultural fertilizer provider (20-year term)
    - Offset annual foreign imports of urea by about 10 percent
  - CO_2 contracts signed with 2 investment-grade entities (30-year term)
    - For deep geologic storage with concomitant enhanced oil recovery (EOR)
    - A portion of captured CO_2 is used as on-site feedstock for urea production
  - Power Purchase Agreement (PPA) signed with CPS Energy of San Antonio, the nation's largest municipal power company (25-year term)
- **Other (Minor) Products**
  - Inert, nonleachable slag for sale to local cement, concrete, and roofing tile manufacturing, or for road construction (~665 tpd, no recycle case)
  - Argon (~85 tpd) & Liquid Nitrogen (~75 tpd) for sale to various industries such as oil and gas, food, auto, semiconductor, and welding
  - Sulfuric acid, H_2SO_4, as on-site feedstock to the ammonia/urea plant and for sale to chemicals or other industry (~46 tpd at 93 weight %)
  - Ammonium sulfate, $(NH_4)_2SO_4$, for sale as agricultural fertilizer to local farming industry (~5 tpd, dry basis)

NOTE: All tons are short tons (2,000 lbs)
tpd → tons per day

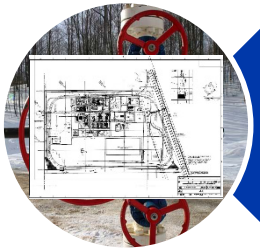
CCPI-3 Texas Clean Energy Project Status: In Final Stage of Development

- **Permits**
  - Air Permit issued December 28, 2010
    - No opposition/requests for hearing
  - DOE NEPA Record of Decision issued September 2011
- **Financial Close and Groundbreaking anticipated late 2015**
  - Project Team is finalizing requirements needed for closing on construction financing
    - EPC contracts based on reconfigured plant of 1st Qtr 2015 FEED Update
    - Equity Agreements
  - All debt to be provided by the China Export-Import Bank
- **Commercial Operations Date (COD) late 2018/early 2019 (estimate)**



CCPI-3 Texas Clean Energy Project Observations (1 of 3)

- **TCEP as a prime example supporting the need for Government assistance in commercialization of 1st-of-a-kind advanced energy technology projects**
- **Disclaimer: Views expressed are the professional opinion of the presenter and do not necessarily reflect the views and opinions of the U.S. Federal Government**



1. Completion of front-end engineering design (FEED) and some post-FEED work does not assure successful closing on construction financing in the capital markets

2. Neither does having off-take agreements for all major products assure successful closing on construction financing

Why?

Interdependencies across the requirements for closing

CCPI-3 Texas Clean Energy Project Observations (2 of 3)

3. Soft activities (e.g., seeking market financing) introduce significant schedule risk during the project development phase

Why?
Unpredictable

4. Managing the disparate interests and expectations of debt and equity investors is a challenge that requires real savvy

5. For an n^{th}-of-a-kind facility, changing contractors or project site, or altering the configuration or scope (size), may be signs of a "failed" project; BUT, may just be part of the "normal" challenges facing a 1^{st}-of-a-kind commercial demonstration

CCPI-3 Texas Clean Energy Project Observations (3 of 3)

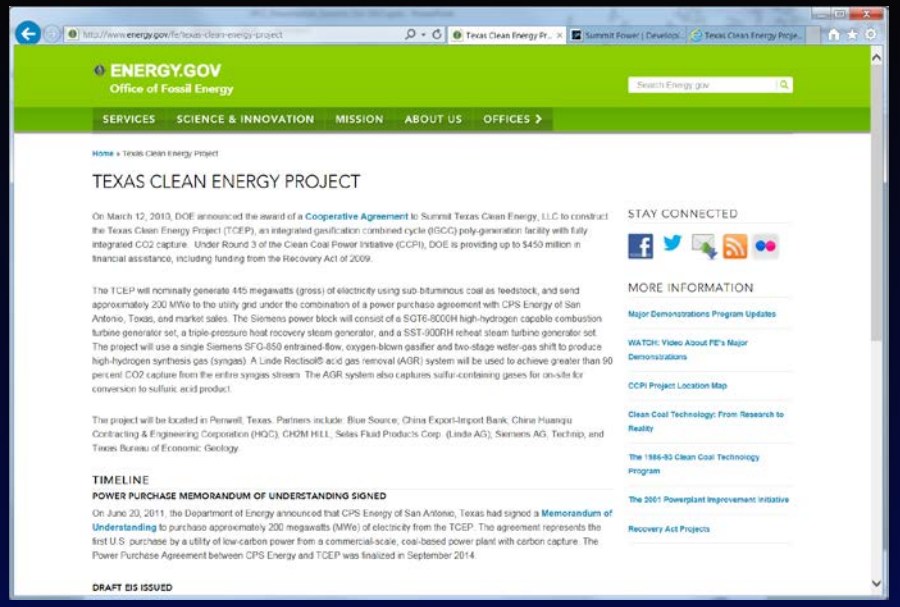
6. International collaboration and partnerships may add complication and nuance; this may be magnified when Government-to-Government interactions are involved

May bring strategic advantages as well

7. In today's economy are Government technology development and other incentive programs adequate for their intended purpose or do they need re-evaluated to ensure successful outcomes and national goals/objectives are achieved

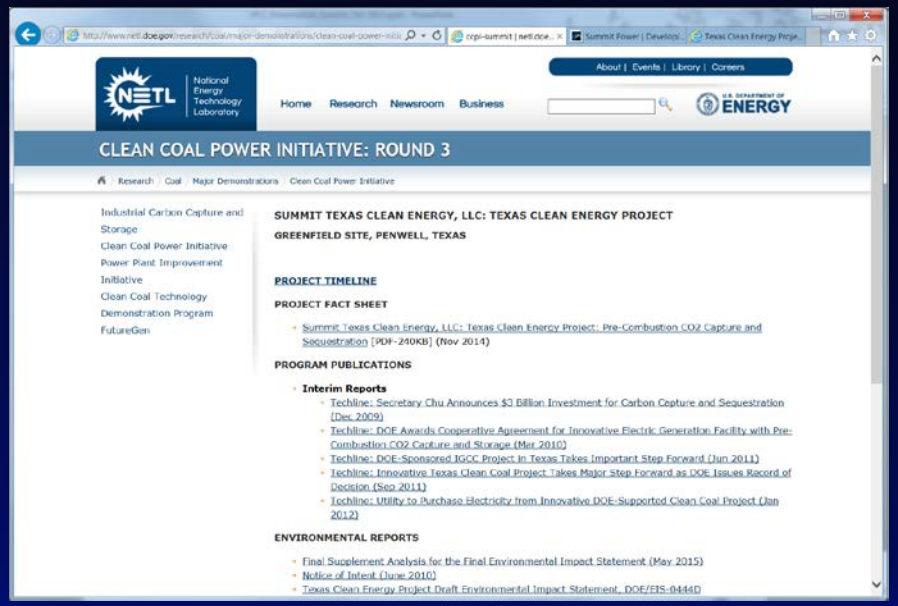
8. Patience and hard work are essential for riding out the "hills and valleys" toward success

CCPI-3 Texas Clean Energy Project Government Information Sources



Office of Fossil Energy

http://www.energy.gov/fe/texas-clean-energy-project



National Energy Technology Laboratory

http://www.netl.doe.gov/research/coal/major-demonstrations/clean-coal-power-initiative/ccpi-summit

Customer Service 1-800-553-7681

CCPI-3 Texas Clean Energy Project Information from Summit Power

Summit Power Group

http://www.summitpower.com/

Texas Clean Energy Project

http://www.texascleanenergyproject.com/

Some Things Just Lend Themselves to a Pie Chart…