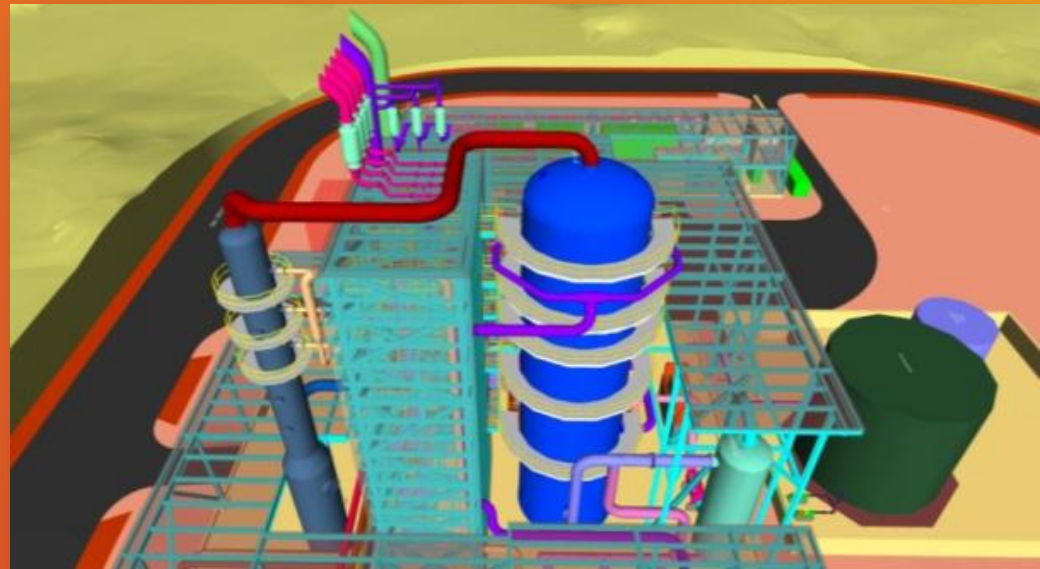


# Design of a Post-Combustion CO<sub>2</sub> Capture Process for a Gas-Fired Plant

Dave Bernier, Senior Principal - Stantec

CSLF Mid-Year Meeting

June 16, 2015



# Agenda

**1** Introduction

**2** Project Overview and Concept Study Details

**3** Summary – How information developed can assist as we look at future projects

# Stantec at a Glance

- Established in 1954
- Publicly traded on two stock exchanges
  - TSX: STN (1994)
  - NYSE: STN (2005)
- Canadian based with over 60 years of secure & stable growth
- More than 250 offices
- ~15,000 employees
- Gross Revenue: ~\$3B



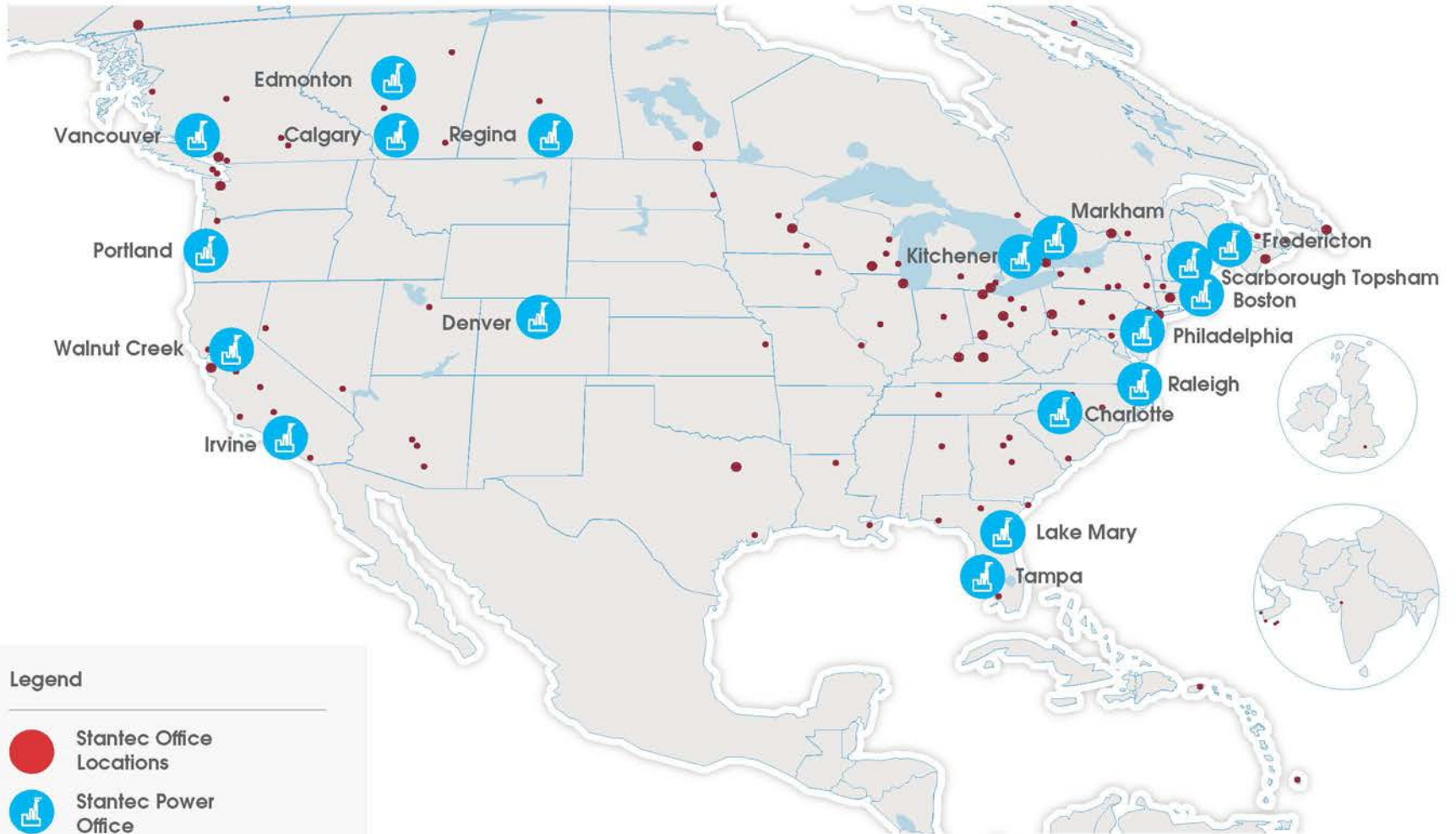
# Stantec Power

- **Conventional Power Generation**
  - Coal
  - Natural Gas
- **Renewable Generation**
  - Wind
  - Solar
  - Geothermal
  - Biomass
  - Landfill Gas
  - Hydro
- **Transmission & Distribution**
- **Substations**
- **Industrial and Chemical Processes**

# Air Quality Control System Experience

- SCR's
- FGD's
  - Dry
  - Wet
- Low Nox Burner Conversion
- SNCR's
- Carbon Capture





### Legend

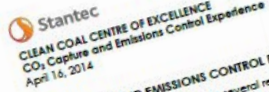
-  Stantec Office Locations
-  Stantec Power Office
-  Locations with more than one office in the area

# CO<sub>2</sub> Capture - Stantec

## Stantec has a long history working in CO<sub>2</sub> capture and clean coal technologies

- Evaluation of Retrofit Emission Control Options (Canadian Clean Power Coalition) 2002
- Emission Control Technology Survey (Confidential Client) 2004
- Power Plant CO<sub>2</sub> Capture using Ceramic Membrane Technology (NRCan) 2004
- Evaluation of Retrofit of Shand 1 Power Plant for CO<sub>2</sub> Capture (SaskPower) 2006
- Owners Engineer for Boundary Dam Integrated Carbon Capture and Sequestration (ICCS) Facility (SaskPower) 2011-2014

# And a lot more...



**CO<sub>2</sub> CAPTURE AND EMISSIONS CONTROL EXPERIENCE**  
 The following paragraphs describe several representative projects completed by Stantec in the areas of CO<sub>2</sub> capture and emissions control technologies.

**Invents**

- Owners Engineer for Boundary Dam Integrated Carbon Capture and Sequestration (ICCS) Demonstration (SaskPower) 2011-2014**  
 This project incorporates life extension of the existing Unit 3 facilities; implementation of significant efficiency and criteria air emissions control (SO<sub>x</sub> and NO<sub>x</sub>) upgrades to Unit 3 and installation of a one million tonnes per year, post-combustion, CO<sub>2</sub> capture and compression system that will produce CO<sub>2</sub> at purity suitable for enhanced oil recovery (EOR). Collectively, the project will fully integrate a coal-fired generation unit with carbon capture and a (privately funded and operated) EOR operation, resulting in low-emission electricity and CO<sub>2</sub> for oil extraction. Schedule to come on line in December 2013.
- Owners Engineer for Confidential Client 2011-2012**  
 Stantec is Owners Engineer for front-end engineering for an amine based post-combustion gas-fired combined cycle plant capturing over one million tonnes per year.
- Owners Engineer for Confidential Client 2011-2012**  
 Stantec is the Owners Engineer for front-end engineering for a 150 tonnes of CO<sub>2</sub> per day pilot test facility to test various sorbents on a slipstream from 300MW unit.
- Owners Engineer for Confidential Client 2011-2012**  
 Stantec performed a study and is now carrying out detailed engineering for a 100 tonnes of CO<sub>2</sub> per day pilot test facility to test various sorbents on a slipstream from 300MW unit.
- Owners Engineer for Confidential Client 2011-2012**  
 Stantec is carrying out detailed engineering for a 100 tonnes of CO<sub>2</sub> per year for a 550 MW (net) pulverized coal-fired power plant in order to evaluate the viability of solid sorbents as a retrofit technology for CO<sub>2</sub> capture. Stantec is also responsible for assisting in scaling down the high-level 550 MW concept to a 1 MW pilot system. Stantec also plays a key role in integrating the pilot plant into the live gas and heat cycle path of an actual power plant.
- Evaluation of Solid Sorbents as a Retrofit Technology for CO<sub>2</sub> Capture (Confidential Client) 2010-2012**  
 Stantec was contracted to propose the commercial scale conceptual design of the solid-based CO<sub>2</sub> adsorption process to capture approximately 4.4 million tonnes of CO<sub>2</sub> per year for a 550 MW (net) pulverized coal-fired power plant in order to evaluate the viability of solid sorbents as a retrofit technology for CO<sub>2</sub> capture. Stantec is also responsible for assisting in scaling down the high-level 550 MW concept to a 1 MW pilot system. Stantec also plays a key role in integrating the pilot plant into the live gas and heat cycle path of an actual power plant.
- Consultation on Wet Electrostatic Precipitation Design and Specification (Confidential Client) 2010-2011**  
 Stantec was contracted to provide guidance on the proper selection of five gas pre-treatment options for a confidential client related to carbon capture in a refinery environment. This included wet electrostatic precipitation (WESP) selection and implementation, and the creation of a specification document to be used to secure vendor bids.
- Techno-Economic Study of Pre-combustion Coal Cleaning Technologies (Confidential Client) 2010-2011**  
 Stantec performed a preliminary techno-economic comparative study of three pre-

combustion technologies, Desander Technology, compared for their ability to remove minimum loss of coal heating value. The lower consumption, capital cost, and O&M cost technologies were also studied for power plants.

**(Confidential Client) 2010**  
 This project involved the design and installation of a flue gas clean-up device, the Electron Beam, for controlling SO<sub>2</sub> and HCl emissions. Technology evaluation in three critical performance, as well as high level economic cost testing.

**Carbon Capture and Sequestration (CCS) System for 150 MW Ignite fired boiler. This project involves the design and installation of Unit 3 facilities; implementation of significant (SO<sub>x</sub> and NO<sub>x</sub>) upgrades to Unit 3 and installation of a capture and compression system that will produce CO<sub>2</sub> at purity suitable for enhanced oil recovery (EOR). This phase included design and implementation of various technologies, which had not been used before.**

**2010**  
 Amine based post-combustion capture demonstration

**2007Pd CO<sub>2</sub> capture demonstration**  
 Concepts for post-combustion capture of power plant in the planning stages.

**2007**  
 Concept for coal fired power plant. Work included layout drawings, heat and mass balance, compression / pipeline. Cost estimates

**SaskPower) 2004-2007**  
 Ignite fired power plant. Work included: flue gas clean-up device, the Electron Beam, for controlling SO<sub>2</sub> and HCl emissions. Technology evaluation in three critical performance, as well as high level economic cost testing.

**2006**  
 Concept for coal fired power plant. Work included layout drawings, heat and mass balance, compression / pipeline. Cost estimates

**(Confidential Client) 2008**  
 This conceptual 500 MW net capacity plant would incorporate a novel CO<sub>2</sub> capture technology and incorporate a novel CO<sub>2</sub> capture technology and incorporate a novel CO<sub>2</sub> capture technology and incorporate a novel CO<sub>2</sub> capture technology.

**2007-2008**  
 Concept for coal fired power plant.

**2007**  
 Concept for coal fired power plant.

**2006**  
 Concept for coal fired power plant. Work included layout drawings, heat and mass balance, compression / pipeline. Cost estimates

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# Project Description

## Carbon Capture at StatOil's Mongstad Facility near Bergen, Norway

Large industrial gas-fired combined heat and power (CHP) plant - 280MW electricity, 350MW heat

Five (5) of the world's leading capture technologies were evaluated for application using a rigid format:

- *An Engineering Feasibility Study*
- *A Technology Qualification Program (TQP)*
- *An Engineering Concept (Pre-FEED) Study*

Evaluation was conducted over a period of ~21 months concluding in July 2013

Today's focus: Engineering Concept Study (pre-FEED)

# Project Team

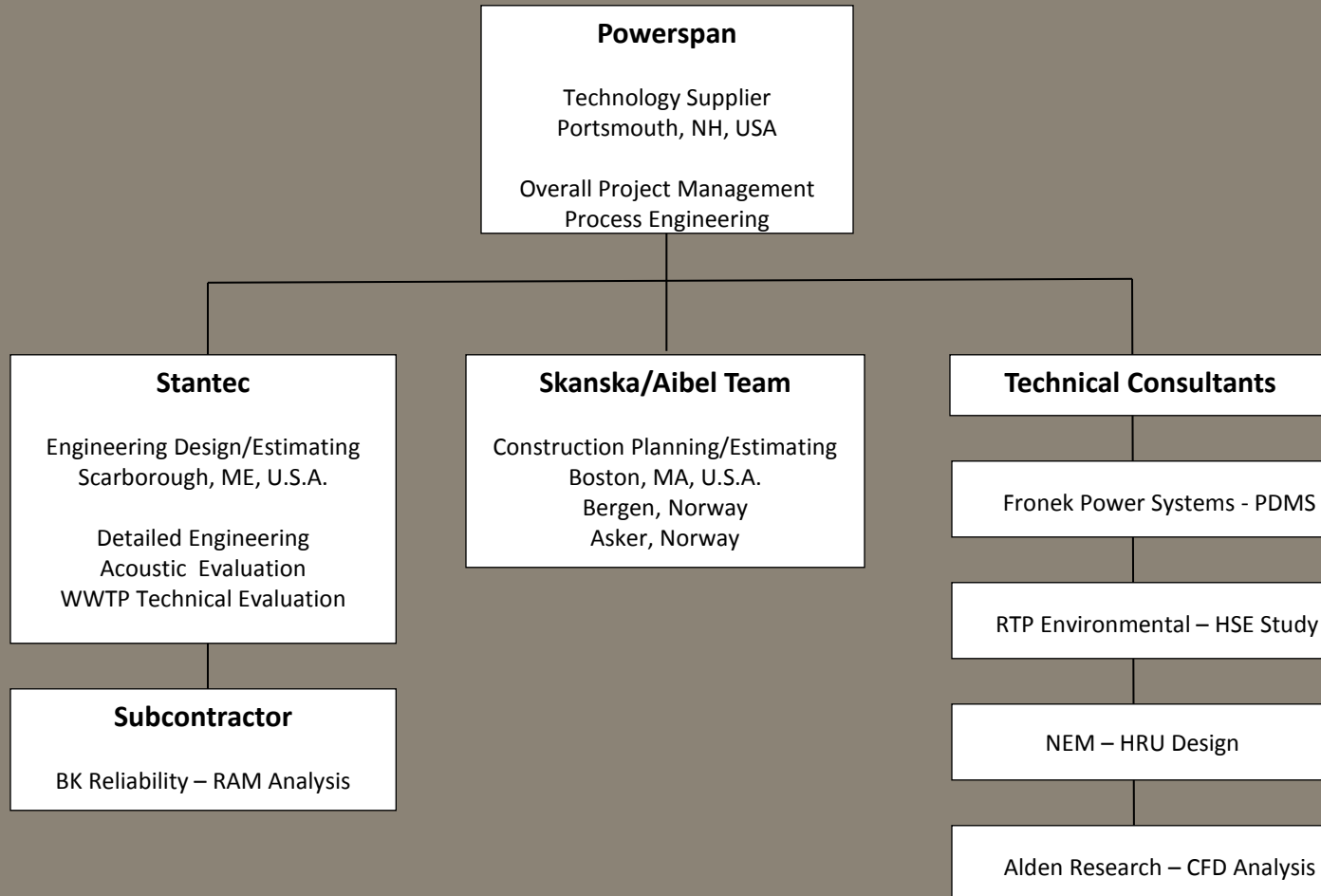
## Powerspan – Portsmouth, NH

- Developer of CO<sub>2</sub> capture (ECO<sub>2</sub><sup>®</sup>) technology
- Has been operating laboratory and pilot plants on actual and simulated flue gas streams since 2005, including its most recent pilot plant near Beijing, China.

## Stantec – Scarborough, ME

- A world leader in engineering large carbon capture projects, e.g., as Owner's Engineer at SaskPower's Boundary Dam plant and Shand Power Station Test Center, and as design engineer on numerous applications

# Project Team



# Engineering Scope

## Concept Study scope:

- Flue gas handling (blower, extraction control, transport, heat recovery and cooling)
- Design and supply of the CO<sub>2</sub> removal system, solvent handling, and reclaim
- CO<sub>2</sub> desorption, drying, and compression (~900psi)
- HP steam let-down and steam condensate return/treatment
- Waste water treatment and waste handling
- Power distribution system
- Solvent storage
- Cooling water system

# Technical Approach

## Establishing confidence:

- Focused on critical equipment - advanced designs for confidence in performance, sizing, and pricing
- 3D modeling – modeled all piping 8" and larger to ensure MTOs and craft labor were highly accurate
- Ensured realistic design – conducted detailed RAM analysis, noise evaluation, and CFD analysis
- Involved constructor contractor throughout process
- Considered safety throughout - reviews conducted and recommendations incorporated in design
- Operations - Equipment arranged on site with maintenance alleys and lifting beams, evacuation routes, etc.

# Health & Safety

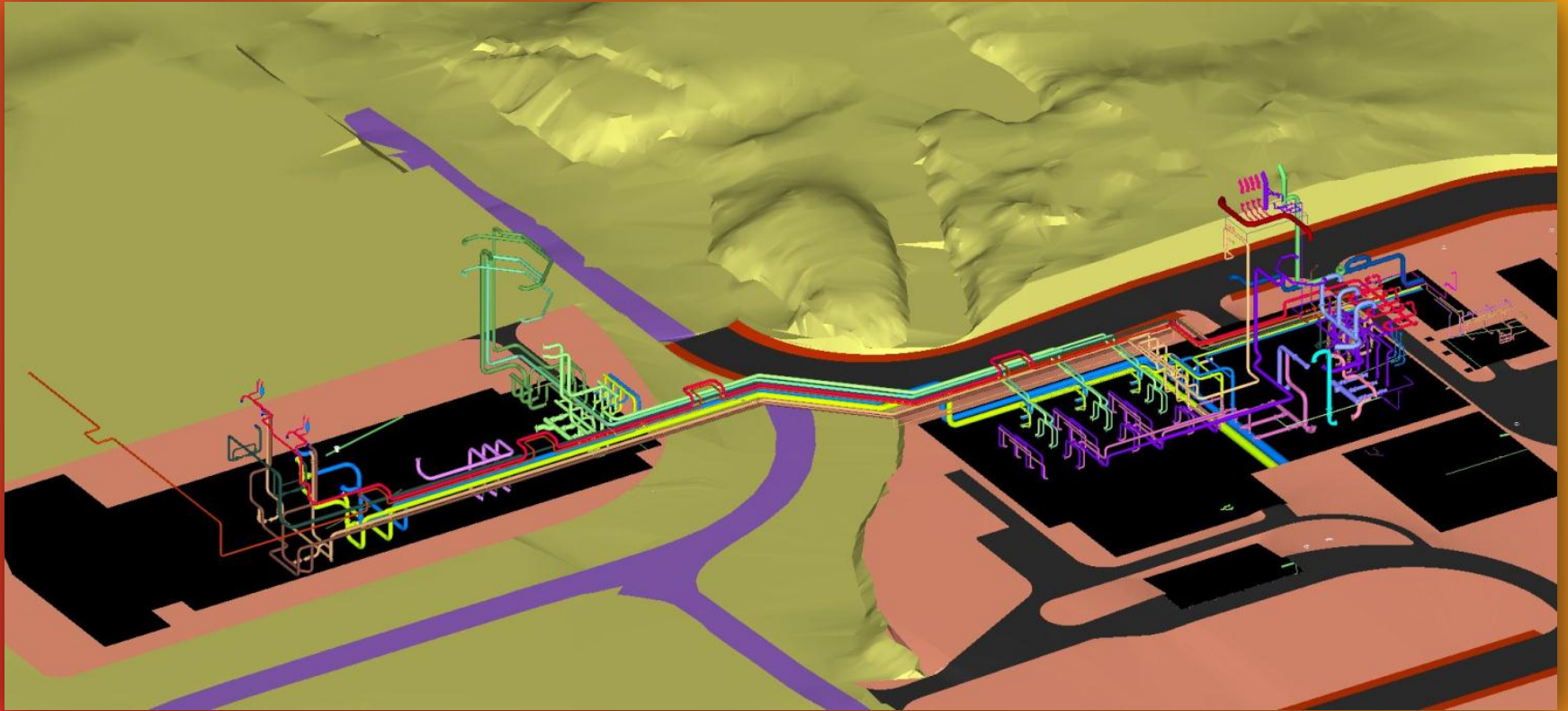
## Process, Environmental and Operational Hazard Reviews Conducted

- HAZOP, ENVID and WEHRA reviews conducted
- Concept level acoustical analysis performed for near and far field
- CO<sub>2</sub> operational and relief venting analysis performed
- Completed safety risk analysis and supplied input to site safety plan

# Overview – 3D Model



# 3D Model – Piping Layout/MTOs





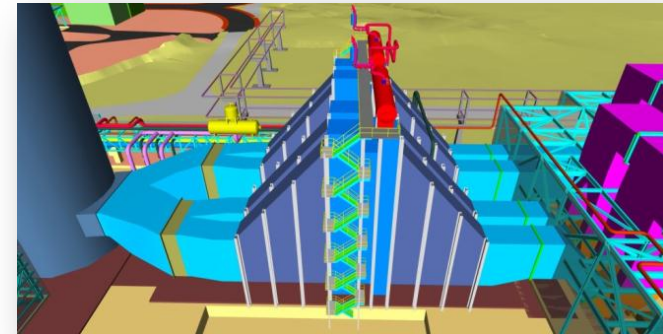
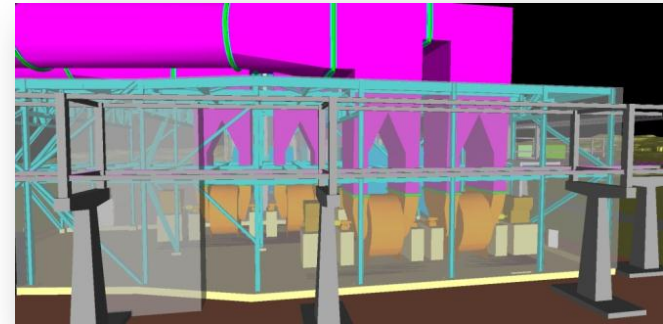
# Process Equipment Highlights

## Booster Fans

- 4 fans @ 5,250kw each with Variable Speed Control
- Noise attenuation included

## Heat Recovery Units

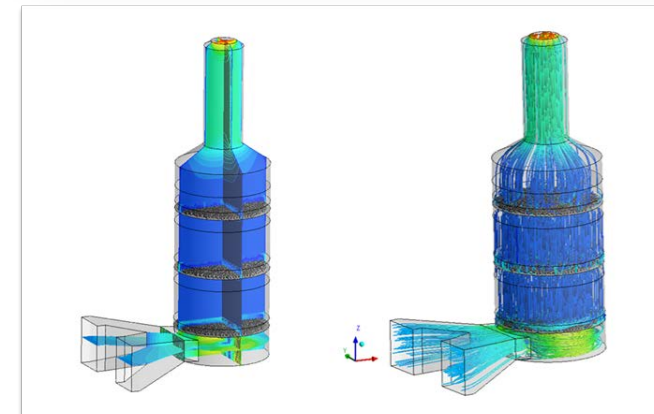
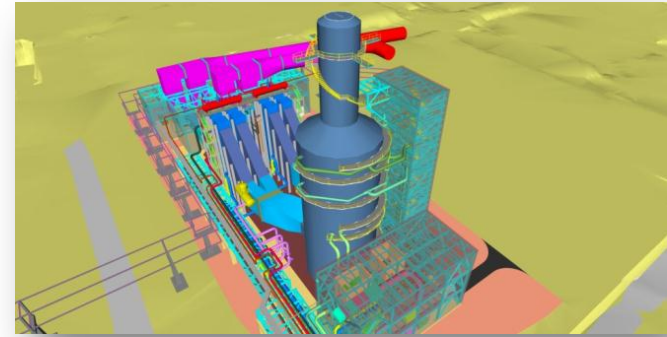
- Worked closely with EU vendor for design and pre-assembly plan (8 modules)
- Flue gas latent heat used for steam and hot water generation



# Process Equipment Highlights

## Absorber Vessel

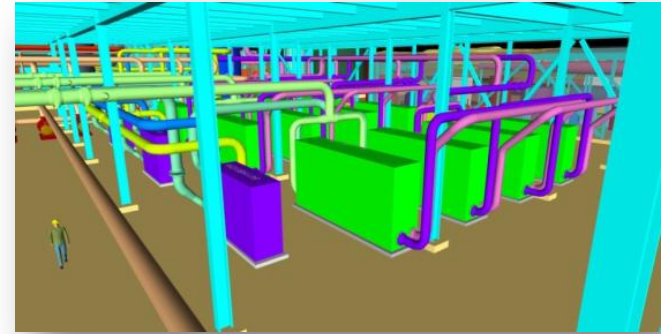
- Vent and exit cap optimized for dispersion after modeling
- Worked closely with EU vendor for fabrication plan (shipping in preassembled sections)
- CFD modeling completed to ensure acceptable distribution at inlet to the mass transfer sections and flow for isokinetic sampling



# Process Equipment Highlights

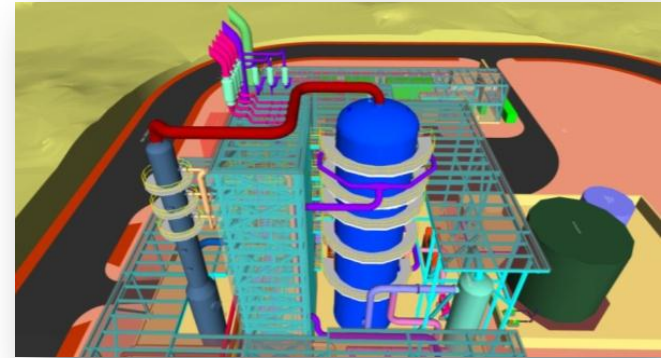
## Cross Heat Exchangers

- 3 x 50% heat exchanger trains to facilitate maintenance during operations
- Maintenance access and lifting beams to pull units included



## Regenerator Unit

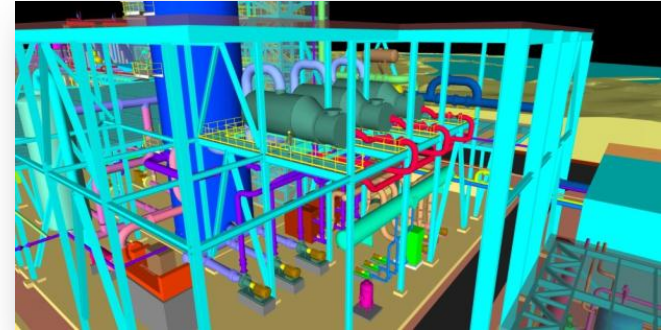
- Proposal from EU vendor
- Each column to be hydro tested and shipped as single units



# Process Equipment Highlights

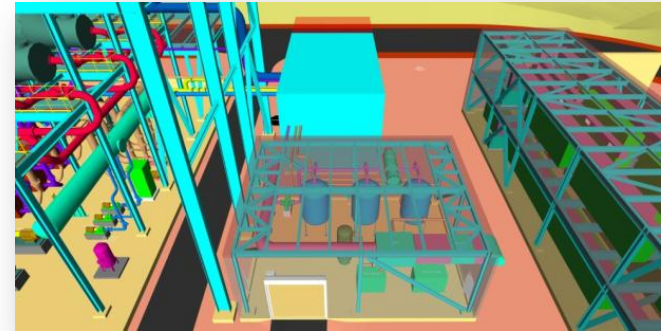
## Reboilers and Preheaters

- 3 x 50% arrangement for process turndown and maintenance

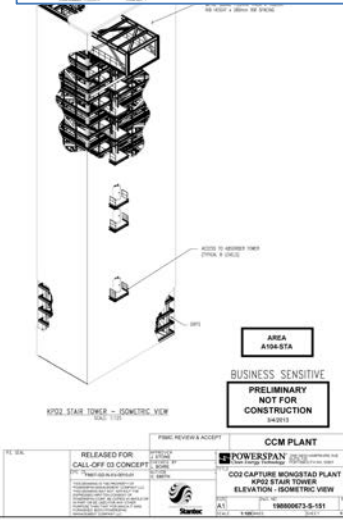
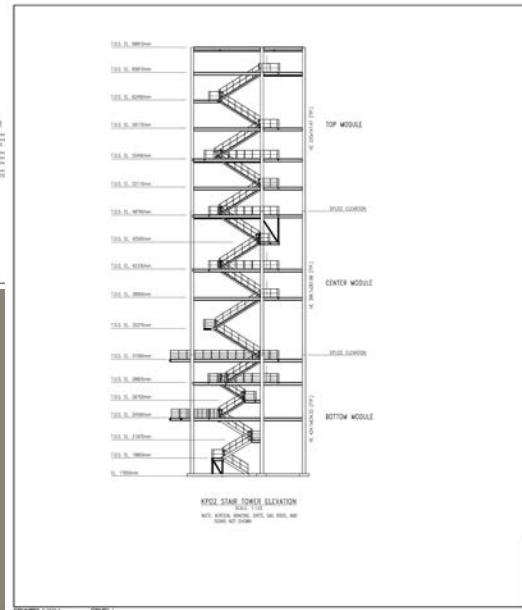
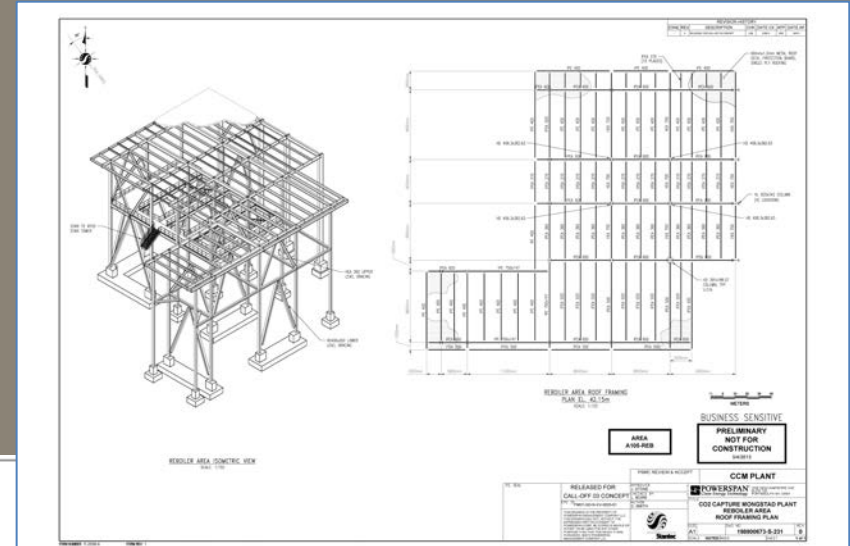
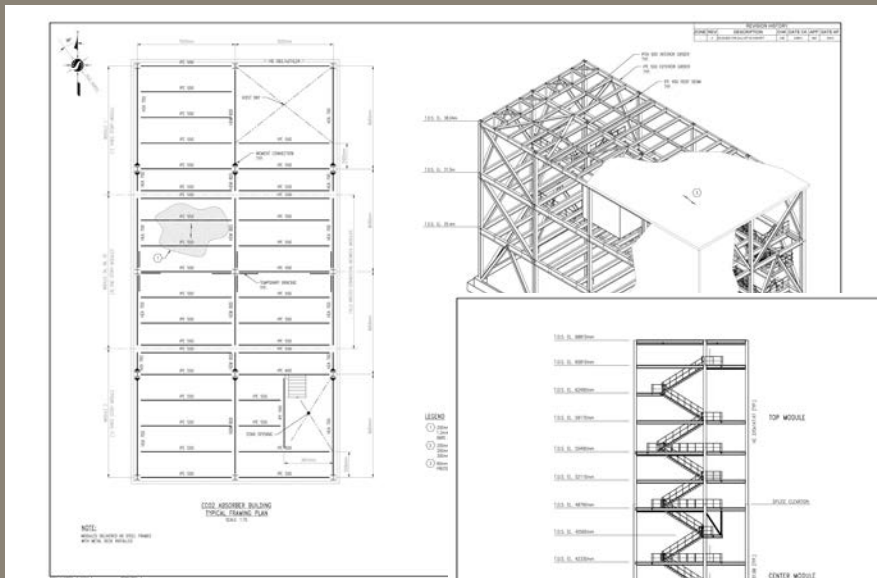


## CO<sub>2</sub> Drying and Compression

- Layout based on single unit multi stage compressor
- CO<sub>2</sub> dryers included



# Detailed Engineering

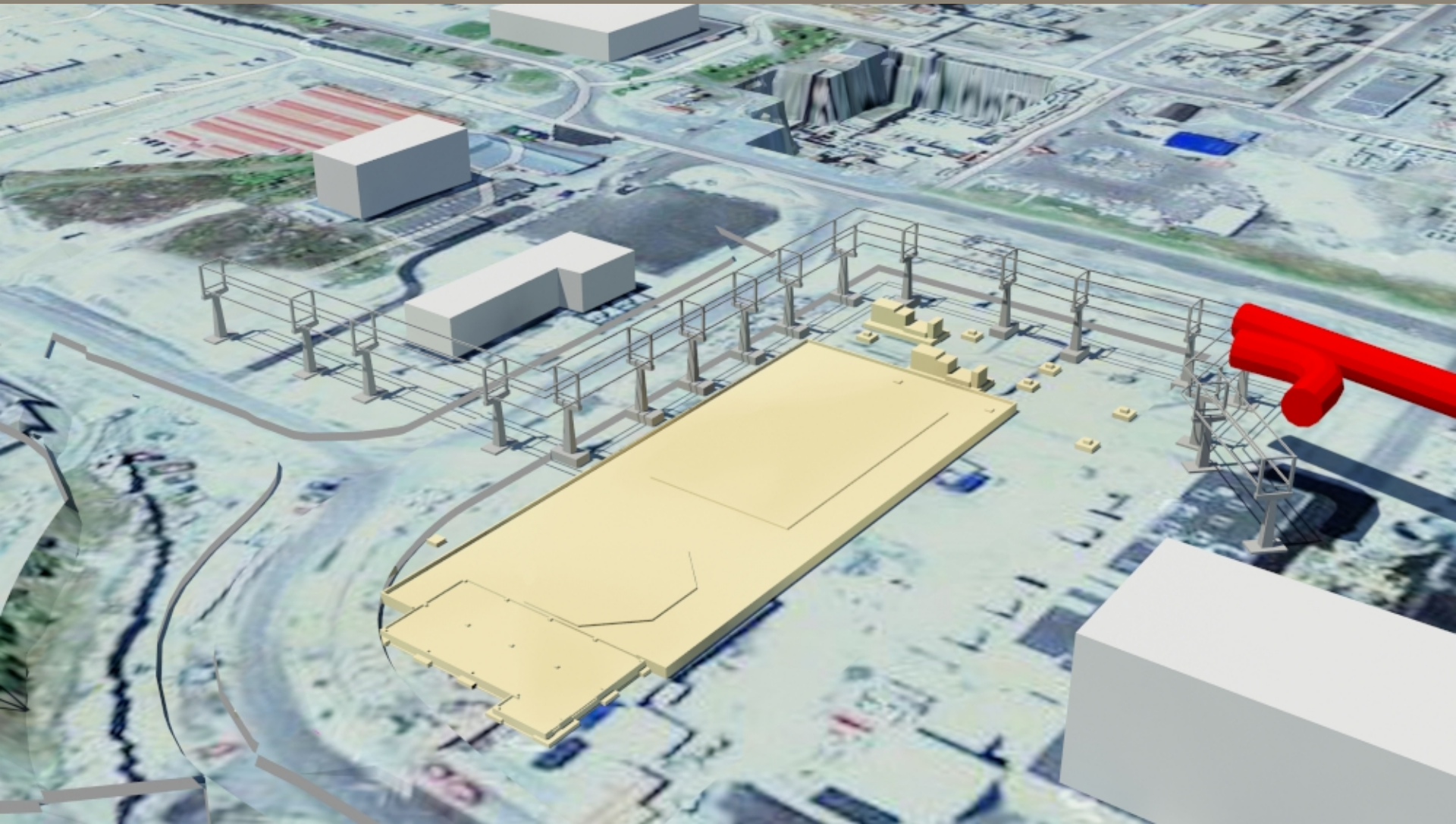


# Construction Planning

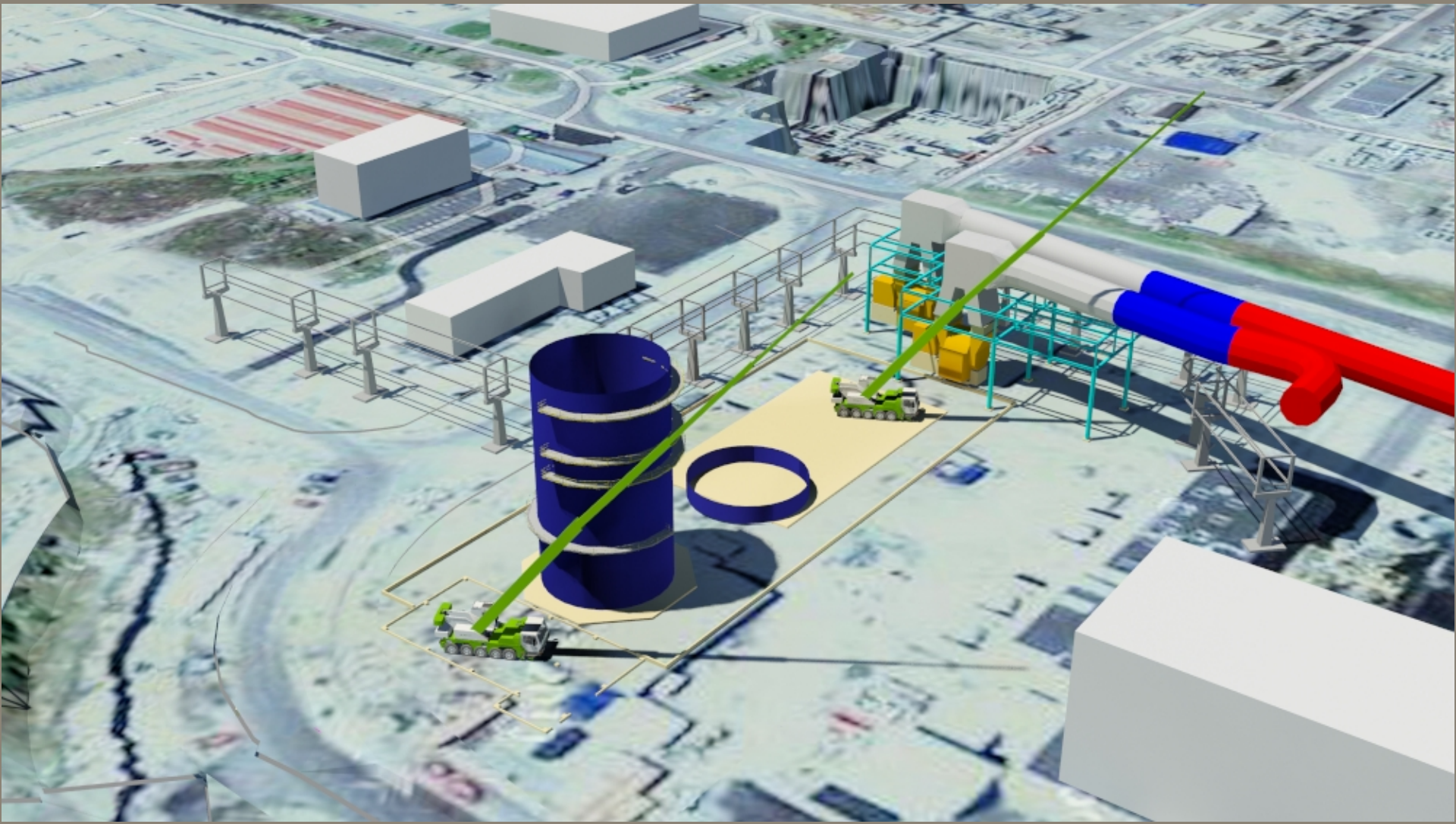
## Active Participation of Constructor during design work

- Constructability considered throughout the design.
- Prefabrication, preassembly, and use of skid mounted systems used extensively to lower congestion during construction, and reduce safety issues and field erection.
- Labor requirements researched by Skanska and Aibel, both familiar with Norwegian labor practices and the experienced working at the site
- Completed a constructability review with client, owner's engineer, and constructor

# Construction Review Absorber Island - 90 Days

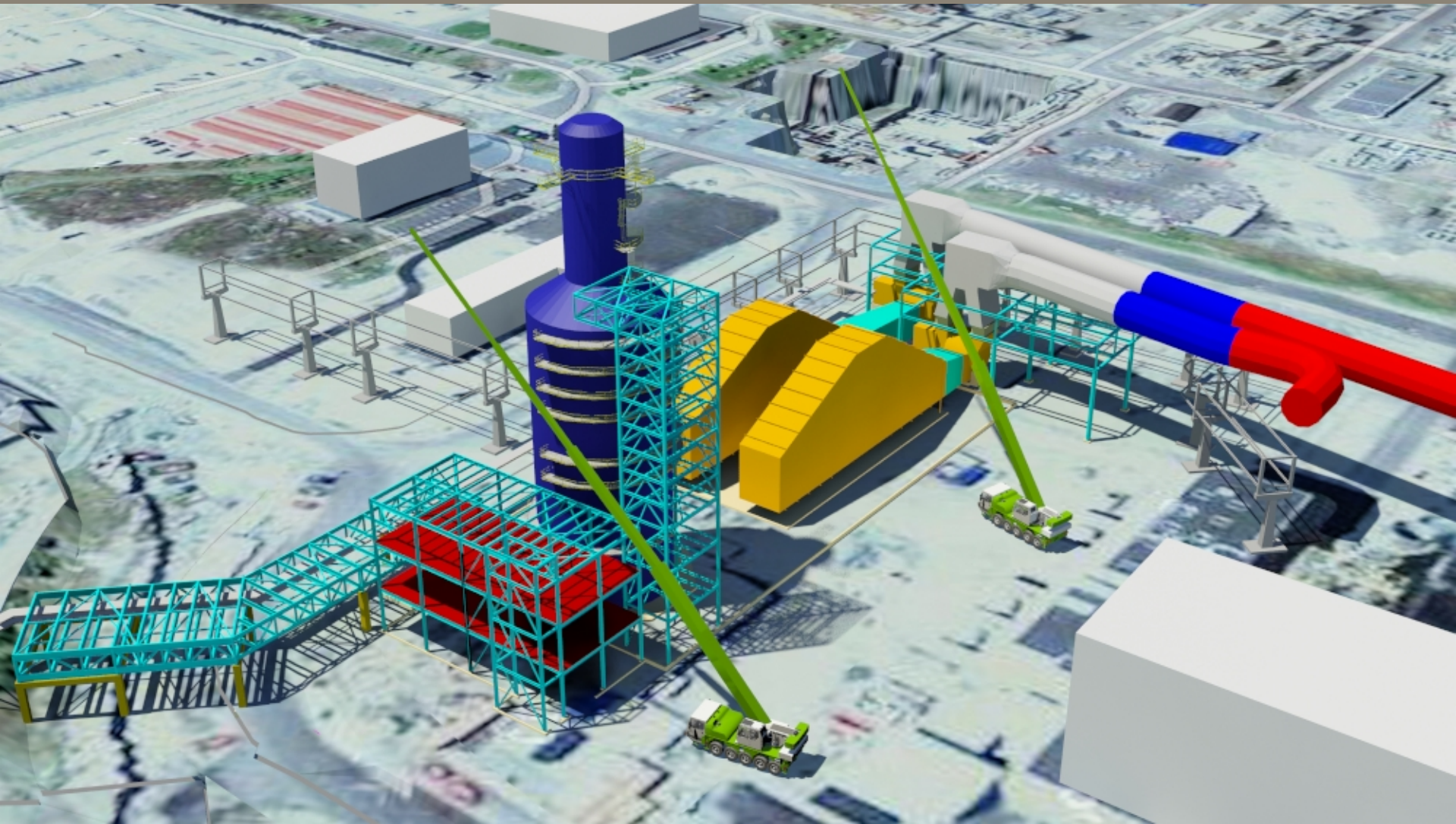


# Construction Review Absorber Island - 270 Days

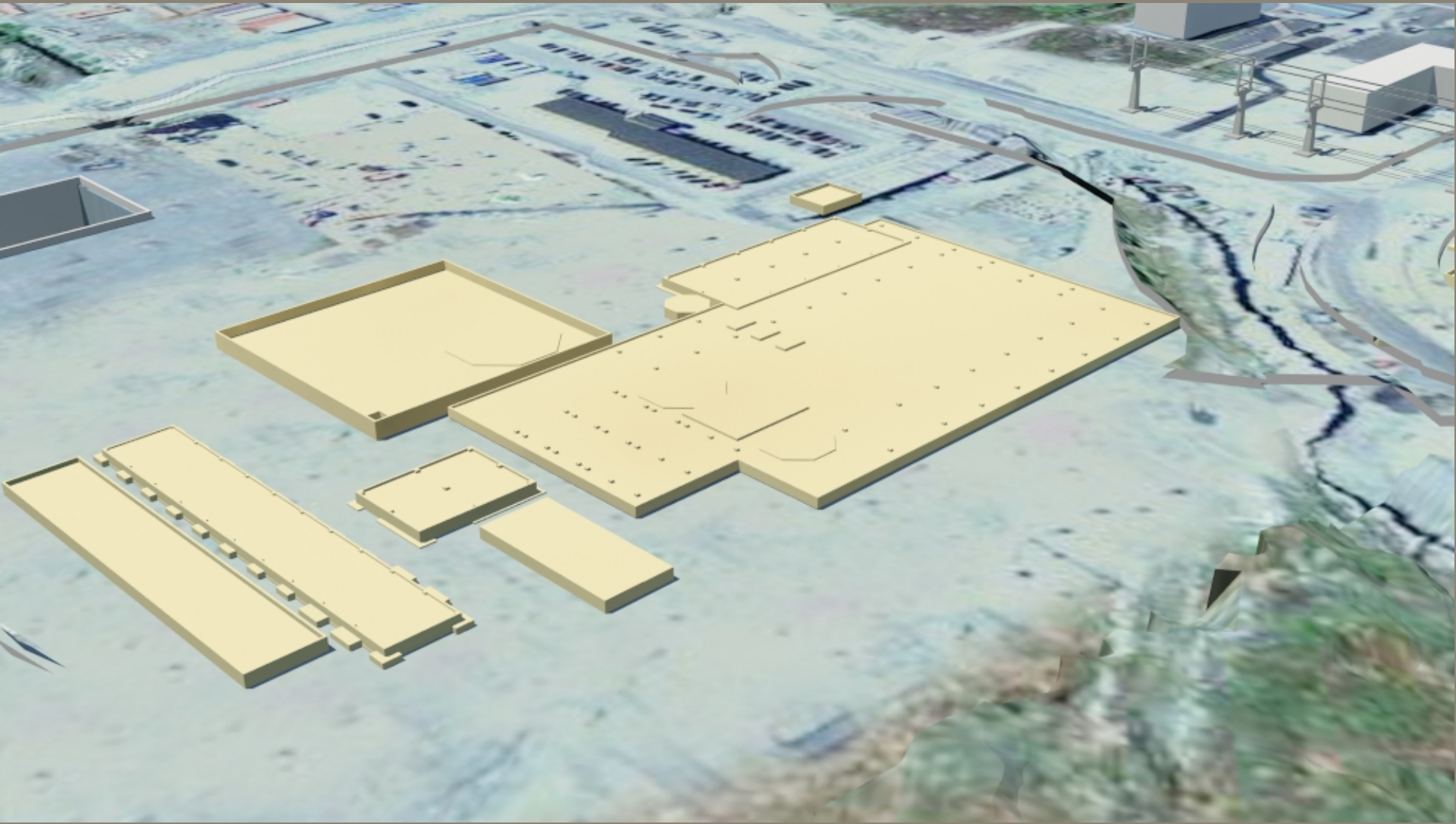




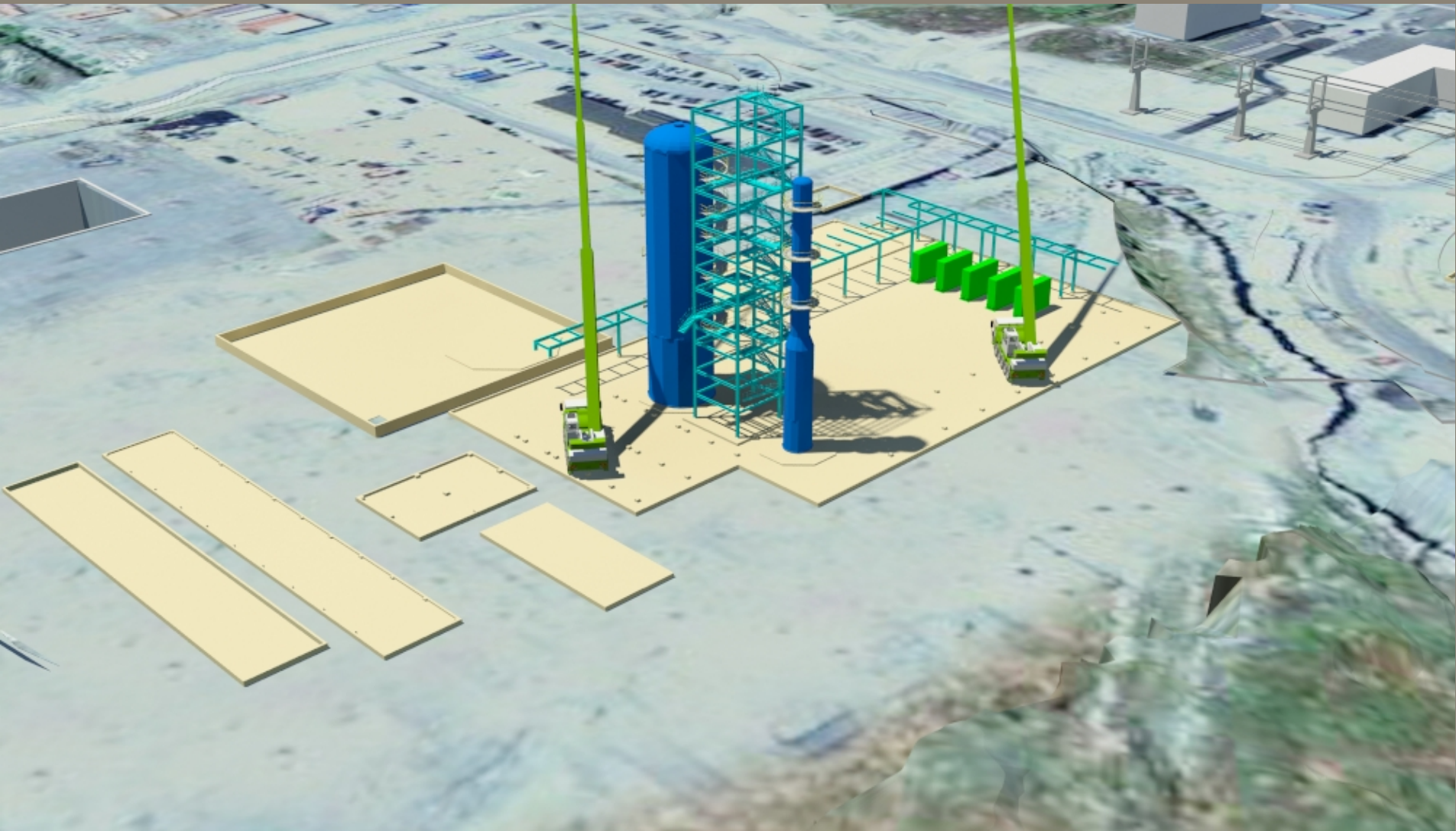
# Construction Review Absorber Island - 630 Days



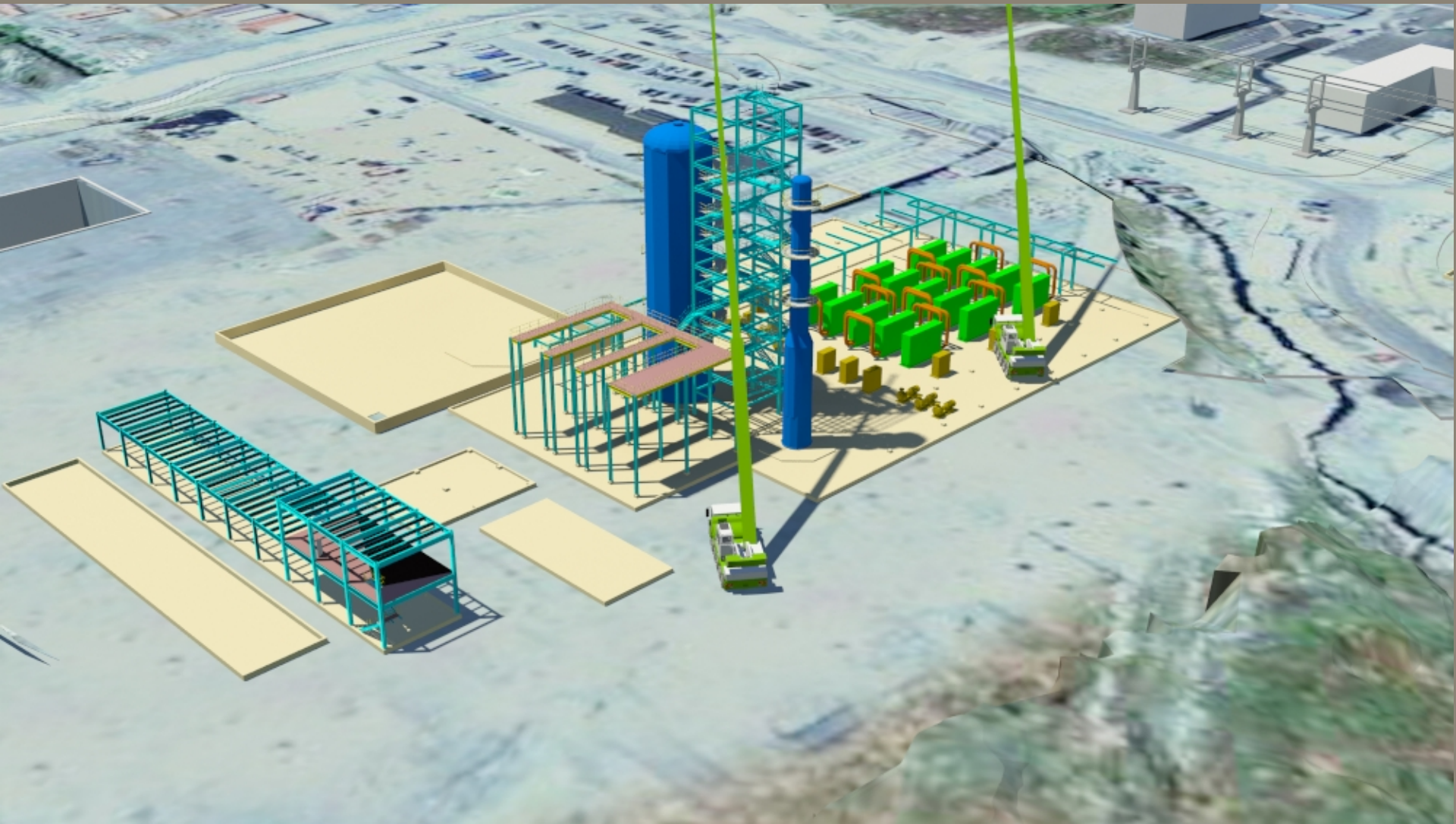
# Construction Review Regenerator Island - 90 Days



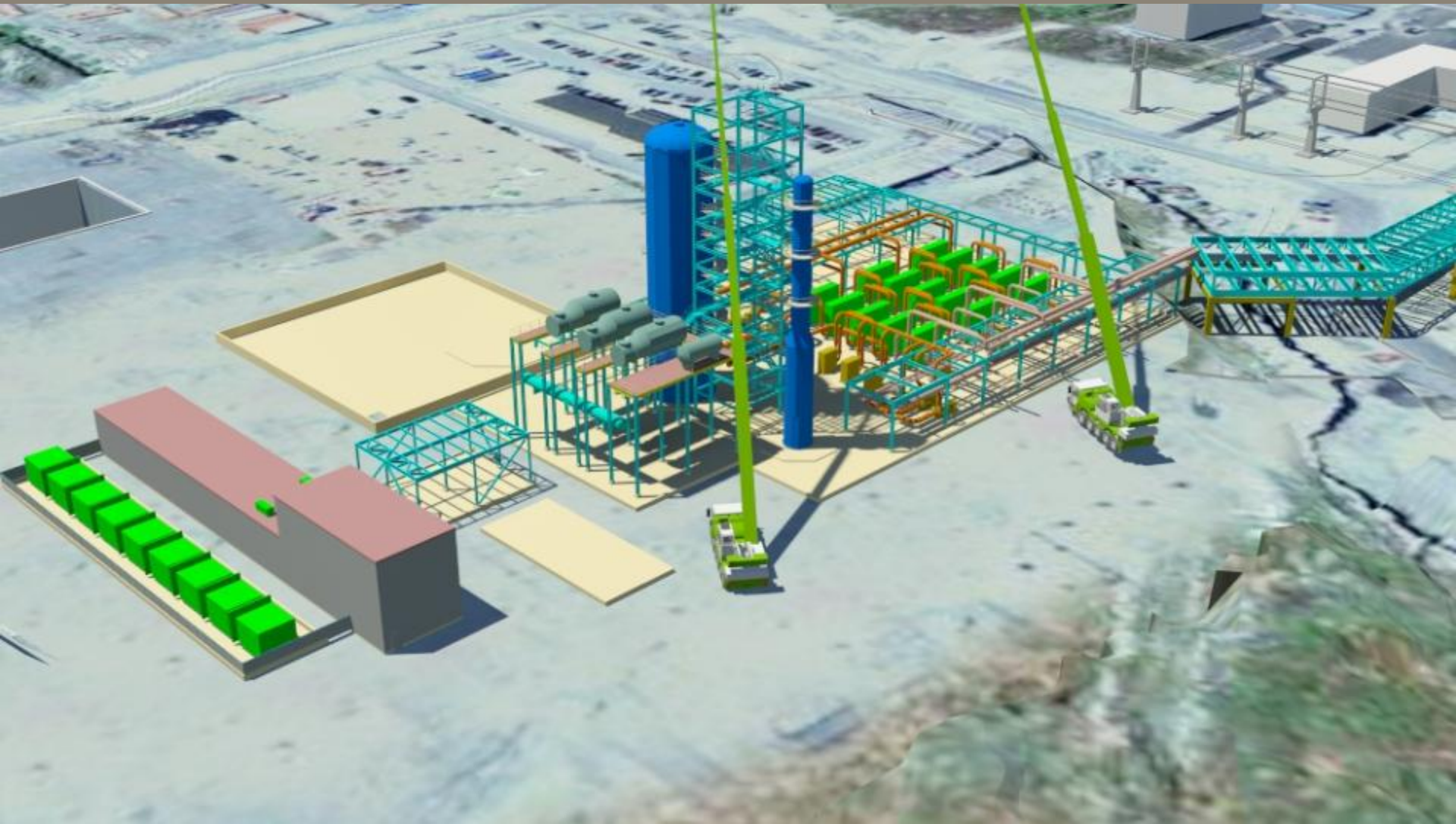
# Construction Review Regenerator Island - 270 Days



# Construction Review Regenerator Island - 450 Days



# Construction Review Regenerator Island - 630 Days



# Cost

## Basis for Estimating Cost

- Major equipment list (MEL) with over 300 items
- Developed Construction MTOs using 3D model, detailed design drawings & hand sketches, etc.
  - >14,000 feet of large bore and 40,000 feet of small bore piping
  - ~25,000 cubic yards of concrete
  - ~3,500 Tons of structural steel
  - >500,000 Linear feet of cable
- Provided confidence factors for every line item in both the MEL and MTOs.

# Summary

## Extrapolating Data

- Information and data generated for the CCM project and others like it, provide tools to develop early capital cost estimates for similar sized systems
- Work products like MEL, MTOs, etc., can be scaled and adjusted for plant-specific estimates and planning
- Data can be scaled using comparison of flue gas flows, CO<sub>2</sub> intensity, and labor factors
- Extrapolated data provides opportunity to generate early capital cost estimates for both coal and gas plants

# Questions?

- **Contact Information**

David Bernier  
Senior Principal – Stantec  
Auburn, NH USA  
603.203.0471

Bob Drever  
Senior Principal – Stantec  
Regina, Saskatchewan  
306.515.0425 (Cell)  
306.781.6605 (Office)

Frank Alix  
President – Powerspan  
Portsmouth, NH USA  
603.661.4827

