What is Project Tundra?

Project Tundra is a bold initiative to build the world's largest carbon capture facility in North Dakota.
Agenda

- Why CO2 capture
- Project summary
- How to capture CO2
- Plant impact
- Resources
- Current status
Who We Are

- Minnkota Power is a wholesale electric generation and transmission cooperative
- Headquartered in Grand Forks, N.D.
- 11 member-owner cooperatives
- 3 in ND, 8 in MN
- 12 municipals – Northern Municipal Power Agency
- Serve 35,000 square miles in 33 counties
- About 150,000 consumers
- 390 employees
Generation Resources
Why Carbon Capture?

- Demand for carbon-free energy
- Carbon-managed future
- Intermittency of renewable generation requires backup
  - Natural gas
  - Nuclear
  - Hydro
  - Coal
  - Batteries?
- North Dakota coal facilities advantages
  - Nearby Williston-Basin oil formation
  - Unique geology
Why Minnkota?

- Resource planning
  - Young Station with Tundra – lowest cost of reliable electricity
  - Combined Cycle – similar cost, but subject to variable gas prices
  - Simple Cycle – good for back-up, but too expensive for 24/7 power
  - Wind – competitive with combined cycle, but not reliable in extreme cold

- Carbon managed future
  - Young 2 with Tundra – 0.11 tons CO$_2$/MWh
  - Combined Cycle – 0.35 tons CO$_2$/MWh
  - Simple Cycle – 0.54 tons CO$_2$/MWh
  - Ultra Supercritical Lignite – 0.96 tons CO$_2$/MWh
Best firm capacity resource is Young station with Tundra

Also the lowest cost
Why Minnkota?

- **North Dakota jobs**
  - Young Station with Tundra – 400 with mine
  - Combined Cycle – 25

- **Environmentally friendly enhanced oil recovery (EOR)**
  - Pipeline & oilfield jobs
  - Even California recognizes as “green” oil

- **North Dakota Geology**
  - Internationally recognized as excellent storage capacity
  - DOE has funded two phases of storage study and analysis
  - DOE will now consider providing partial funding to development of storage facility
Project Tundra Summary

- Retrofit Milton R. Young Unit 2
  - Capture approximately 90 percent of the CO$_2$

- Permanent storage
  - CO$_2$ injected into deep saline formations beneath the nearby coal mine

- Enhanced Oil Recovery
  - CO$_2$ transported 100+ mile pipeline
  - CO$_2$ substantially increase production in declining fields
  - 45 year history
Permanent Storage
Oil Field Target
Project Tundra

Top 30 Fields in proximity to sources and pipeline showing estimated million tons of CO₂ demand

Incremental oil, STB
- 50,000,001 - 100,000,000
- 25,000,001 - 50,000,000
- 15,000,001 - 25,000,000
- 7,500,001 - 15,000,000
- 4,000,001 - 7,500,000
- < 4,000,000

Carbon Dioxide Pipeline
*Sales of CO₂/EOR Potential not known estimated at 2-12/14 of CO₂
Petra Nova Project

- Texas project that Project Tundra is modeled after
- Operational in December 2016
  - On time and on budget
  - 1,300% increase in oil production
- Enhanced oil recovery only
- Pipeline & oilfield all part of the project
## Project attributes
(with comparison to Petra Nova)

<table>
<thead>
<tr>
<th></th>
<th>Tundra</th>
<th>Petra Nova</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>455 MWe</td>
<td>240 MWe</td>
</tr>
<tr>
<td>Flue gas fuel</td>
<td>Lignite</td>
<td>PRB</td>
</tr>
<tr>
<td>Steam source</td>
<td>Extract from host</td>
<td>Stand-alone CCGT</td>
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<tr>
<td>Host plant owner</td>
<td>Coop – long-term view</td>
<td>IPP – short term view</td>
</tr>
<tr>
<td>CO2 disposition</td>
<td>On-site storage or sold to EOR</td>
<td>Project-owned EOR oilfield</td>
</tr>
<tr>
<td>Financial exposure to oil price</td>
<td>None</td>
<td>Yes – high</td>
</tr>
<tr>
<td>Revenue sources</td>
<td>45Q Tax Credits &amp; CO₂ sales</td>
<td>Crude oil sales</td>
</tr>
<tr>
<td>Host unit dispatch</td>
<td>To serve long-term contracts</td>
<td>Day-to-day decision</td>
</tr>
<tr>
<td>Capture technology provider</td>
<td>Fluor</td>
<td>Mitsubishi</td>
</tr>
</tbody>
</table>
How Does Carbon Capture Work?

- All amine based systems very similar
  - Quencher – Cools flue gas prior to entering Absorber Tower, remove additional SO$_2$ emissions
  - Absorber Tower – Lean amine mixed with flue gas, captures CO$_2$ in solution (rich amine)
  - Regenerator – Rich amine is stripped of CO$_2$, amine returns to absorber, CO$_2$ is “pure” for compression.
  - Lots of heat exchangers
Process Requirements

- 100% Flue Gas Capture – ≈90% CO₂ Recovery
  - 11,000 to 12,000 tons/day of CO₂ captured
  - 60-85 MW of auxiliary power
  - Large consumer of low pressure steam
  - Increase plant CW needs by 60%

- Options for BOP steam and power
  - Natural Gas Cogeneration Unit (Petra Nova)
  - Integrate existing plant
  - Natural gas pas package boilers (steam only)
One pre-FEED study looked at natural gas boilers

- Feasible
- Preserve project economics
- Possible additional CO₂ source
- No impact to existing turbine

NG challenges

- Lack of natural gas infrastructure
- Permitting of new emissions source
- Commingling gas streams
- Increase capital cost
Plant Impact – Steam Integration

- LP steam supplied from IP/LP crossover
  - 35-50% of crossover steam flow extracted
  - Lower capital cost

- Integration challenges
  - Low crossover pressure
  - Increased expansion over HP and IP blades
  - Low LP flow during reduced load cases
  - Steam conditioning control
  - Condensate return location
  - Loss of unit capacity
Heat Recovery Optimization

- Significant loss in energy production due to steam integration
- Possible cycle optimization
  - Replace existing steam drive boiler feedwater pumps
  - Condensate heat recovery
    - Heat recovery from CO₂ compressor intercoolers
    - Heat recovery from flue gas cooling
  - Back-pressure Steam Turbine
Heat Recovery Optimization

- All options were un-economical over facility ITC life cycle
  - Replace steam driven boiler feedwater pump
    - Did not raise crossover pressure enough
  - Heat recovery from CO\textsubscript{2} Compressor Intercoolers
    - Small increase in plant power output, but too costly
  - Heat Recovery from Flue Gas Cooling
    - Small increase in plant power output, but too costly, & possible AQCS issues
  - Back-pressure Steam Turbine
    - Costly and space constraints
Water Resources

- Increase of plant cooling capacity by 60%
- Existing cooling system at thermal capacity
  - Hot months – cooling water exceeds desired temperature
- Install new Cooling Tower
  - Make-up from Process Condensate (Quencher)
  - Increase river water take-off
- Cooling tower blowdown
  - Possible deep well injection
Our People are the Experts

- Initial research led by the Energy & Environmental Research Center (EERC) at the University of North Dakota
  - Recognized as leading experts in carbon capture and utilization projects

- David Greeson
  - Former Vice President of Development for NRG Energy, Inc.
  - Petra Nova was his vision and he led the project from inception through design, financing, construction, and commissioning
Cost Recovery

- 45Q Federal Income Tax Credits
  - Start construction prior to end of 2023
  - 12 year eligibility

- $50 per tonne of CO₂ permanently stored underground

- $35 per tonne of CO₂ used for enhanced oil recovery

- Represents approximately $2 billion to Project Tundra

- Minnkota cannot monetize these credits
  - We will need a partner
Project Schedule

## Tundra Development Schedule

- **Pre-FEED**
  - NDIC Grant
  - DOE Grant
  - Form ProjectCo
  - Outside Law Firm
  - Financial Advisor

- **Apply/receive permits**
- **FEED Study**
- **Project Documents**
- **Storage/EOR Deals**
- **Financing**

### Timeline:
- **2018**
- **2019**
- **2020**
- **2021**
- **2022**
- **2023**
- **2024**
- **2025**

#### Construction:
- **Construction – complete in Q3 2024**
- **Construction – complete in Q4 2025**

#### Key Dates:
- **Early Start Construction**
Next Steps

- **Tax Guidance on 45Q**
  - Comments submitted

- **Front-End Engineering & Design and Costing**
  - CO2 Capture System (Fluor Enterprises)
  - Geologic Storage (EERC-CarbonSAFE)
  - Pipeline/EOR

- **Permitting (2020-2022)**
  - Longest schedule is permit for geologic storage facility
  - CCS air and water permits to be initiated during the FEED

- **Financial investment decision & commence construction before the 2023 deadline for 45Q tax credits**
Questions?