Achieving Very Large-Scale Wind Development

Emerging Opportunities in New Baseload Coal Technologies and Wind-Compressed Air Energy Storage

Regional Wind Conference

September 13, 2005

Brooking, SD

What is Powering the Plains?

- Public-private coalition dedicated to harnessing full energy potential of our region
- PTP seeks to:
  - Add value to energy and agriculture while mitigating the risks of climate change
  - Help jurisdictions capitalize on their energy strengths

Who is involved in PTP?

- Elected and government officials
- Energy industry executives
- Farm organization representatives and agricultural producers
- Environmental advocates

PTP Funding and Staffing

Funding

- Participating private firms, non-governmental organizations and individuals
- Foundations
- Government agencies

Staffing

- Great Plains Institute, a regional nonprofit organization based in MN and ND

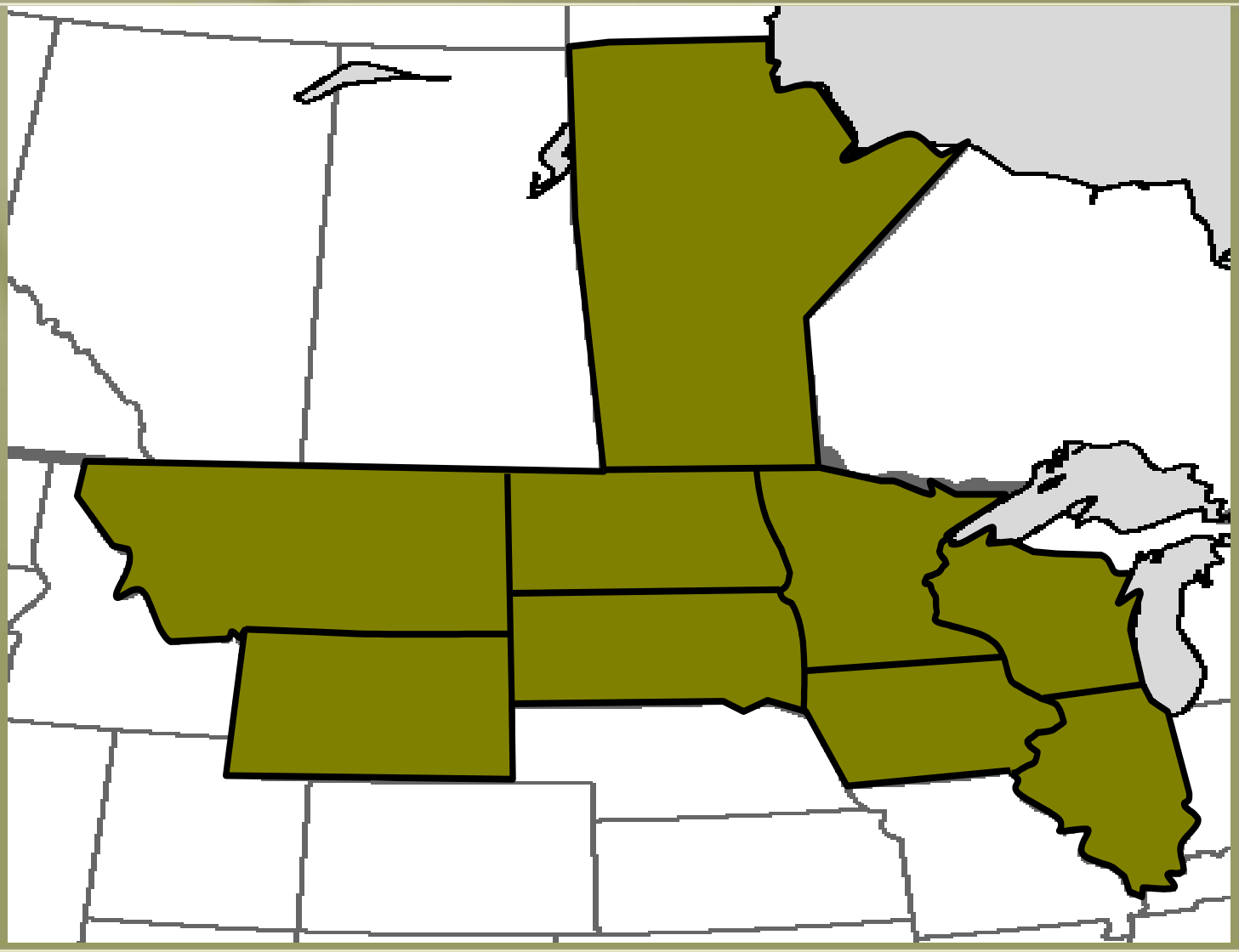
Background: Charting a Regional Energy Transition

- Bi-partisan coalition of legislators has called for a regional energy transition that "relies on clean energy production and carbon sequestration"
  - Resolution asked PTP to:
    - "prepare preliminary scenarios, goals and measurable targets outlining a potential regional energy transition; and
    - identify legislative measures and institutional arrangements needed to implement such a transition roadmap inter-jurisdictionally over time."

Regional Energy Advantages Identified by Legislators

- **Renewable energy development**;
- **Hydrogen production**;
- **Coal gasification with geologic sequestration**;
- **Terrestrial carbon sequestration**; and
- **Renewable energy/carbon credit marketing**.

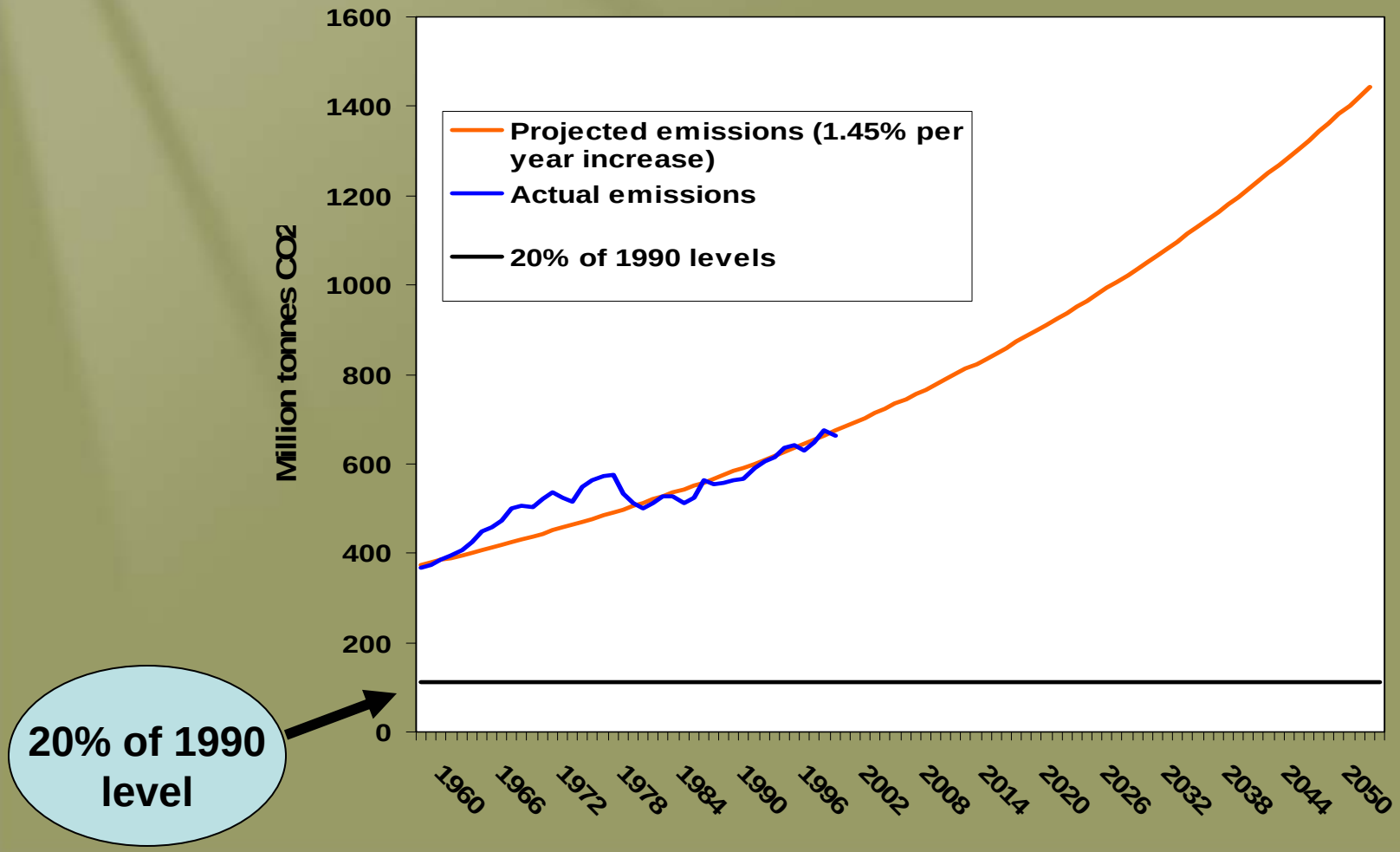
Establishing a Regional Roadmap



Regional CO^2 Scenario Analysis

- How might region reduce CO^2 emissions 80% from 1990 levels by 2050?
- Everything on the table for analysis:
  - Efficiency, renewables, fossil and carbon sequestration, and nuclear
- U of MN research team partnering with PTP
  - Analysis near completion

The Challenge: Current and Projected Emissions



20% of 1990 level

Scenario Modeling

1. Aggressive renewable power and fuels deployment
2. Aggressive coal gasification with sequestration and ag-based sequestration
3. Maximum energy efficiency and conservation

Long-Term Vision for Roadmap

The Upper Midwest transitions as rapidly as possible to an energy system that relies on energy efficiency, renewable energy, and carbon-neutral production of hydrogen and electricity.

The region's energy supply remains affordable, reliable and secure during this 25 to 50-year transition.

Wind Energy's Role in the Transition

- Large-scale wind: greater than normally contemplated today
  - Probably in excess of 20% grid penetration routinely already achieved in Northern Europe
  - Likely to approximate scale of region's resource over time
  - Use of wind beyond electric power generation
    - e.g. Hydrogen and energy-intensive products such as fertilizer

What Will It Take to Achieve Large-Scale Wind?

- Many things, surely, but two areas deserve more focus:
  - New baseload coal technologies to provide a better transmission partner for wind power
  - Wind-compressed air energy storage technologies to enable wind power to capture higher-value markets

Regional Context of Coal

- Three-fourths of current power generation and centuries' worth of supply
- High-paying jobs and significant tax revenue
- Important advantages and experience
  - Suitable geologic reservoirs for CO2 storage
  - Dakota Gasification: world's only coal gasification plant that currently captures, markets and geologically sequesters CO2

The Transition to Advanced Coal Baseload Technologies

- PTP strategy: build broad agreement on a long-term transition path for coal
  - Shift from pulverized coal combustion to integrated gasification-combined cycle technologies (IGCC)
  - 25-50 year transition as generation assets turn over
    - New plants and repowering of older facilitities
  - Linkages to large-scale wind and hydrogen development

History of Coal Gasification

- Production of “town gas” in early 20th century
- Germany gasified coal to produce diesel fuel during WWII
- Worldwide deployment and commercialization in petroleum refining, hydrogen and chemical industries

Benefits of Next Generation IGCC Technologies

- Potential near-total CO2 and mercury capture
- Order of magnitude reductions in other pollutants
- Large-scale, carbon-neutral hydrogen production via gasification
- Polygeneration: production of syngas, liquid fuels, fertilizer and other energy-intensive products from coal
- Avoidance of future carbon liability and potential to export carbon credits

Potential Benefits of IGCC for Wind Energy

- Reduce barriers to transmission expansion for export that large-scale wind will require:
  - Overcome likely future economic constraints from carbon regulation
  - Increase political support by tailoring wind-coal export projects to growing market preference for renewable/zero-carbon energy
  - Win-win proposition: a pro-development and pro-environmental strategy

Example of the Opportunity

- Tondu IGCC Plant in Indiana: cleanest coal plant proposed in world today
  - Carbon sequestration capable
  - Dramatic reductions in other pollutants:
    - If Indiana replaced its 29 coal plants with this technology, total SOx and NOx emissions would equal only one large existing conventional coal plant

Major Barriers to IGCC Adoption

- Greater up-front capital costs
- Increased financial risk
- Uncertain performance with low-rank coals
  - MT, ND, and WY have majority of U.S. coal reserves in the form of low rank lignite and sub-bituminous
- Stakeholder resistance
  - Utilities are risk averse and unfamiliar with technology
  - Key constituency groups oppose coal-based power production

PTP Approach

Launched Coal Gasification Work Group in June

- Coal/utility industry executives
- State officials and legislators
- Environmental advocates
- Congressional staff

Work Group will:

- Develop coal component of energy transition roadmap
- Identify policies and demonstration projects to accelerate transition to advanced coal technologies and carbon sequestration
- Link new coal-based technologies to transmission and wind energy development

Unshackling Wind from Fossil Baseload: Wind-Compressed Air Energy Storage

- Wind currently depends heavily on two drivers:
  - Unpredictable and inadequate federal incentives
  - Substitution for expensive natural gas limited in coal-dependent regions
- Ability to schedule wind for higher-value intermediate and peak markets would accelerate market adoption
  - Short-term storage technologies could make this possible

Promising Option: Mechanology's New Compressor Platform

- Compressor operates with completely new geometry
- Highly efficient, provides high pressure and high flow, and operates at variable speeds
- Over 15 years in development
- Funded by U.S. DOE and private investors
- Worldwide patents issued

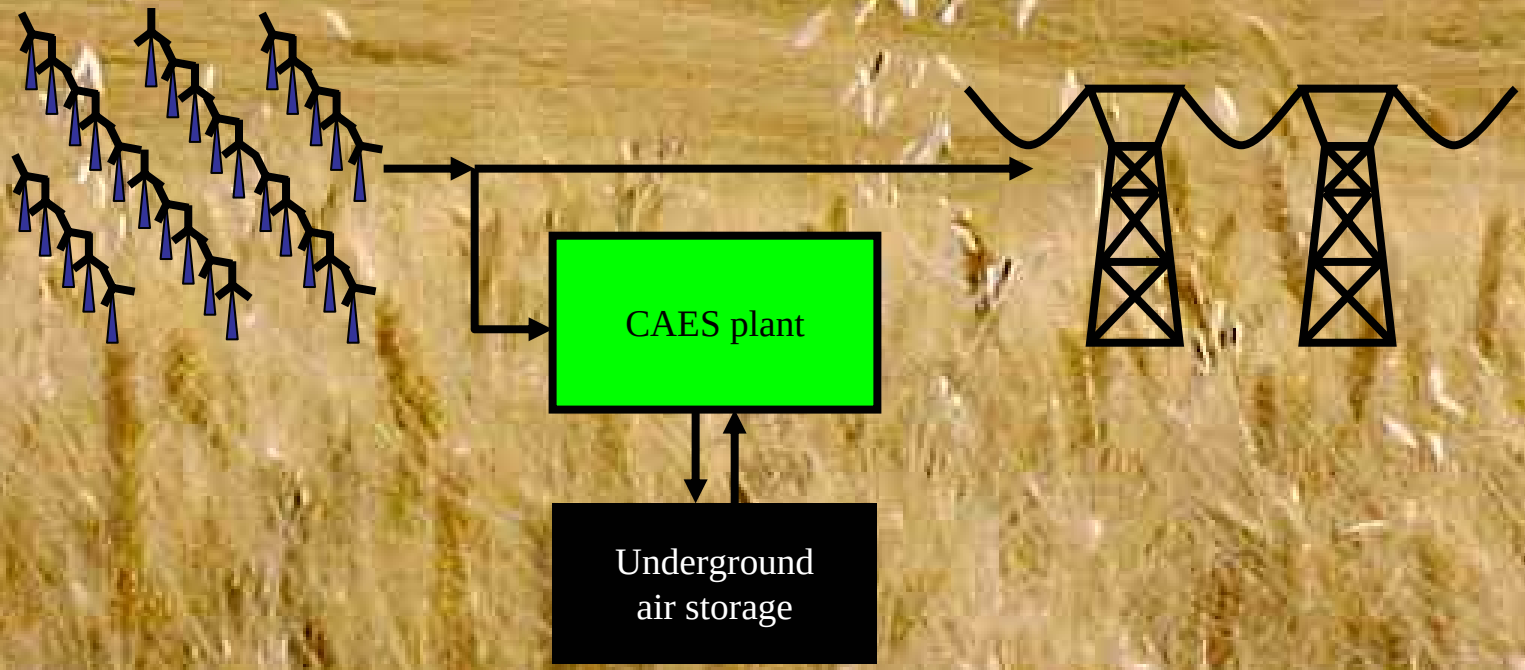
A New Approach

Highly efficient compression enables cost effective compressed air energy storage

Turbines are interconnected by linepipe which also provides storage

Expander/generators at the end of the pipeline convert heated compressed air electricity

The Traditional Approach



Disadvantages:

Expensive-CAES plant is 100% incremental to wind project cost

Restricted application- Sites depend on underground air storage in caverns

The dispatchable wind system

Wind compressor farm

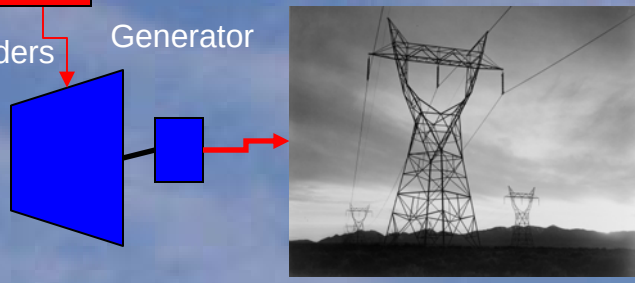
High pressure pipeline

Heat source
(natural gas, biomass, or thermal plant)

Grid connection

Expanders

Generator



Pipeline provides interconnection of wind turbines,
connection to grid, and storage
(A typical design would store a full day's output—8-10 hours)

Each wind turbine is directly driving a large compressor
which compresses air into the high pressure pipeline
(no electrical components on the turbine)

For example 1,500MW (1,000 1.5MW turbines over here…

… Produces 2,250MW of firm capacity over here (due to heat addition)

Benefits

- Sell at times of day when prices are best
- Transforms least responsive into most responsive resource
- Capacity payments
- 2-3x more energy through any given transmission window
- Lower transmission costs
- Significant reduction in component costs of convential turbines

Independent Feasibility Analysis of Concept

Conclusion:

- Viable in northern MISO region without federal production tax credit
  - Intermediate market: 13.5% internal rate of return
    - 17.3% with PTC
  - Peak market: 11.4% IRR
    - 17.3% with PTC
  - Baseload market 11.6% IRR with PTC

Feasibility Analysis (cont.)

Study assumptions

- Prototype compressor meets anticipated design specifications
- No project debt
- Does not include major performance improvements related to wind turbine-compressor application:
  - Accommodates variable speed without efficiency loss, lighter faster rotor, and taller tower for same cost

Status of Technology

- Mechanology has two products in advanced testing:
  - industrial compressor
  - compressor/expander for automotive fuel cells
- Licensing agreement with major industrial compressor manufacturer in place
- Wind-compressed air application would draw on existing prototypes under testing

Next Steps

- PTP participants expressed interest in potential applications in our region
  - Pending feasibility analysis and completion of prototype testing
- PTP and Mechanology to explore options for wind-compressed air prototype development and wind farm scale demonstration

Thank You

Powering the Plains

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