High Voltage Direct Current: Pathway to a Sustainable Energy Future with the Plains & Eastern Clean Line

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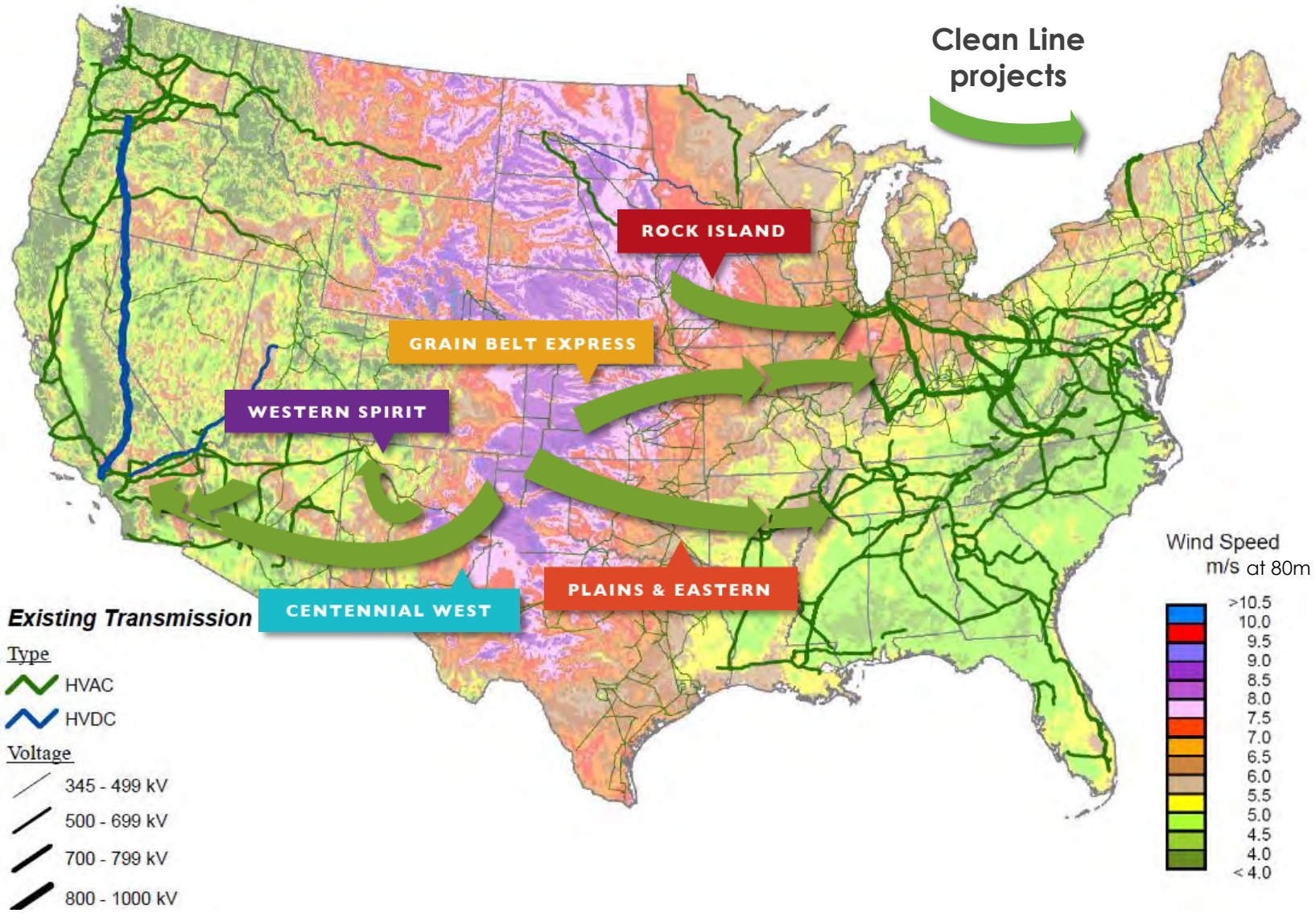
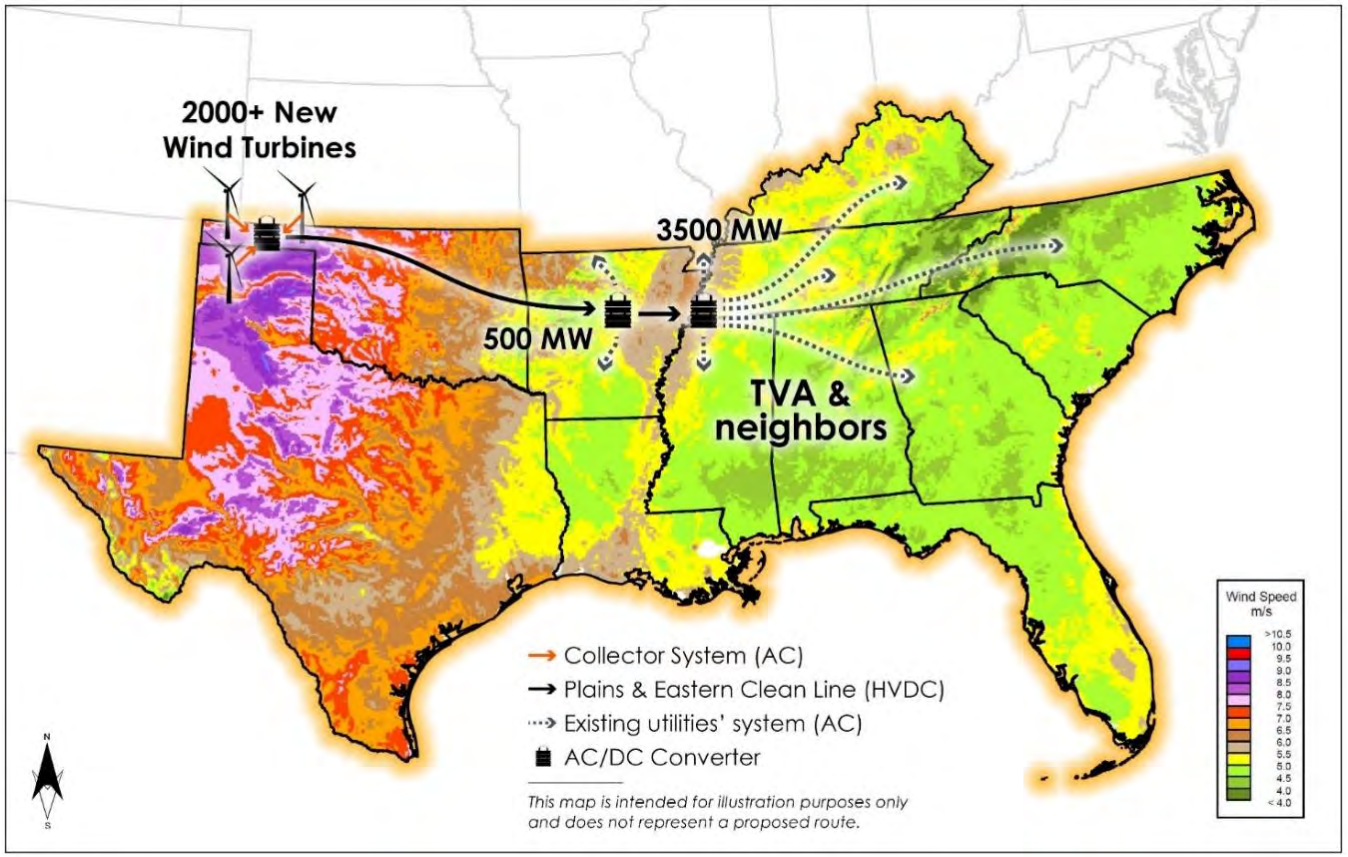
CLEAN LINE
ENERGY PARTNERS

Clean Line's projects connect the lowest-cost wind resources to major demand centers



Plains & Eastern will connect the robust wind of the Oklahoma Panhandle to the Mid-South and Southeast



The Arkansas converter station interconnects with the Entergy 500 kV system at ANO/Pleasant Hill where the Project will deliver **500 MW**. Enough to power **160,000 Arkansan homes**

The Tennessee converter station interconnects with the TVA 500 kV system at Shelby Substation in western Tennessee where the Project will deliver **3,500 MW**. Or over **850,000 additional homes**

The final major regulatory approval was received in March 2016

NATIONAL ENVIRONMENTAL POLICY ACT PROCESS

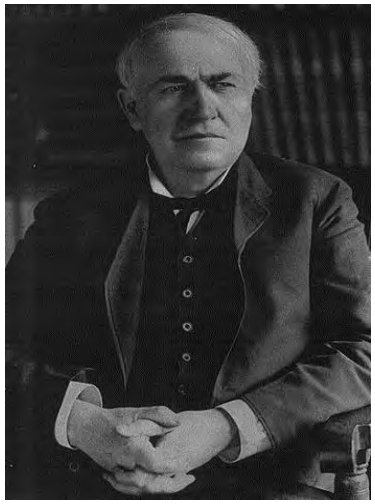
In the Record of Decision issued March 2016, DOE

- Outlined its participation in the project
- Selected the route for the project in Arkansas and Oklahoma
- Confirmed the inclusion of the Arkansas converter station

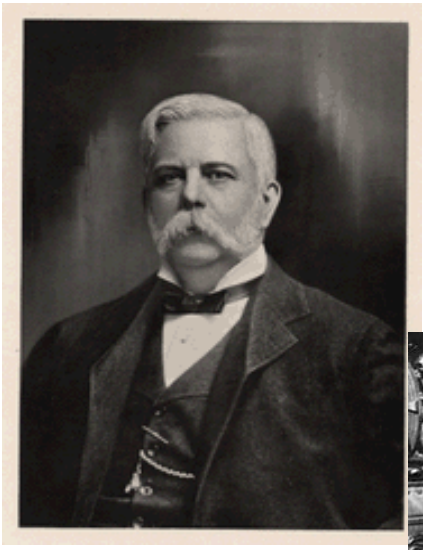
With DOE approval, Clean Line enters the final stages of development: finalizing design and cost estimation, acquiring contiguous rights-of-way for construction, completing interconnection processes and negotiating and executing customer contracts.

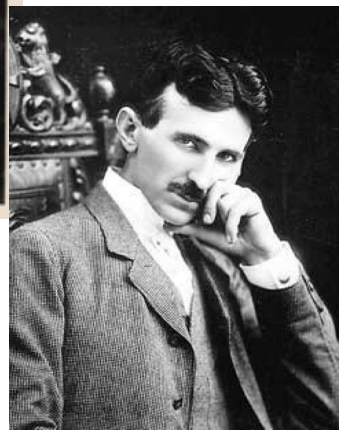
War of the Currents (late 1880s)

Recommended Reading: Empires of Light by Jill Jonnes



- Thomas Edison (1847-1931)
- Advocate of direct current (DC) power system
- Founder of General Electric





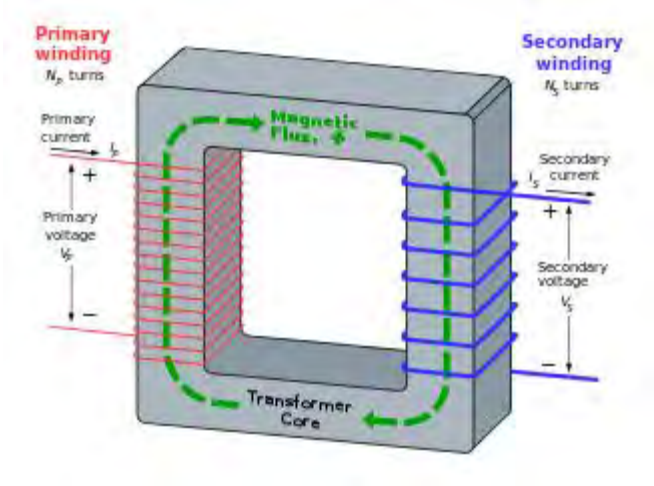
- George Westinghouse(1846-1914)
- Nikola Tesla (1856-1943)
- Advocate of alternating current (AC) power system
- Founder of Westinghouse Electric Corporation
- Licensed polyphase machines from Tesla

Pearl Street Station: 255-257 Pearl Street, Manhattan

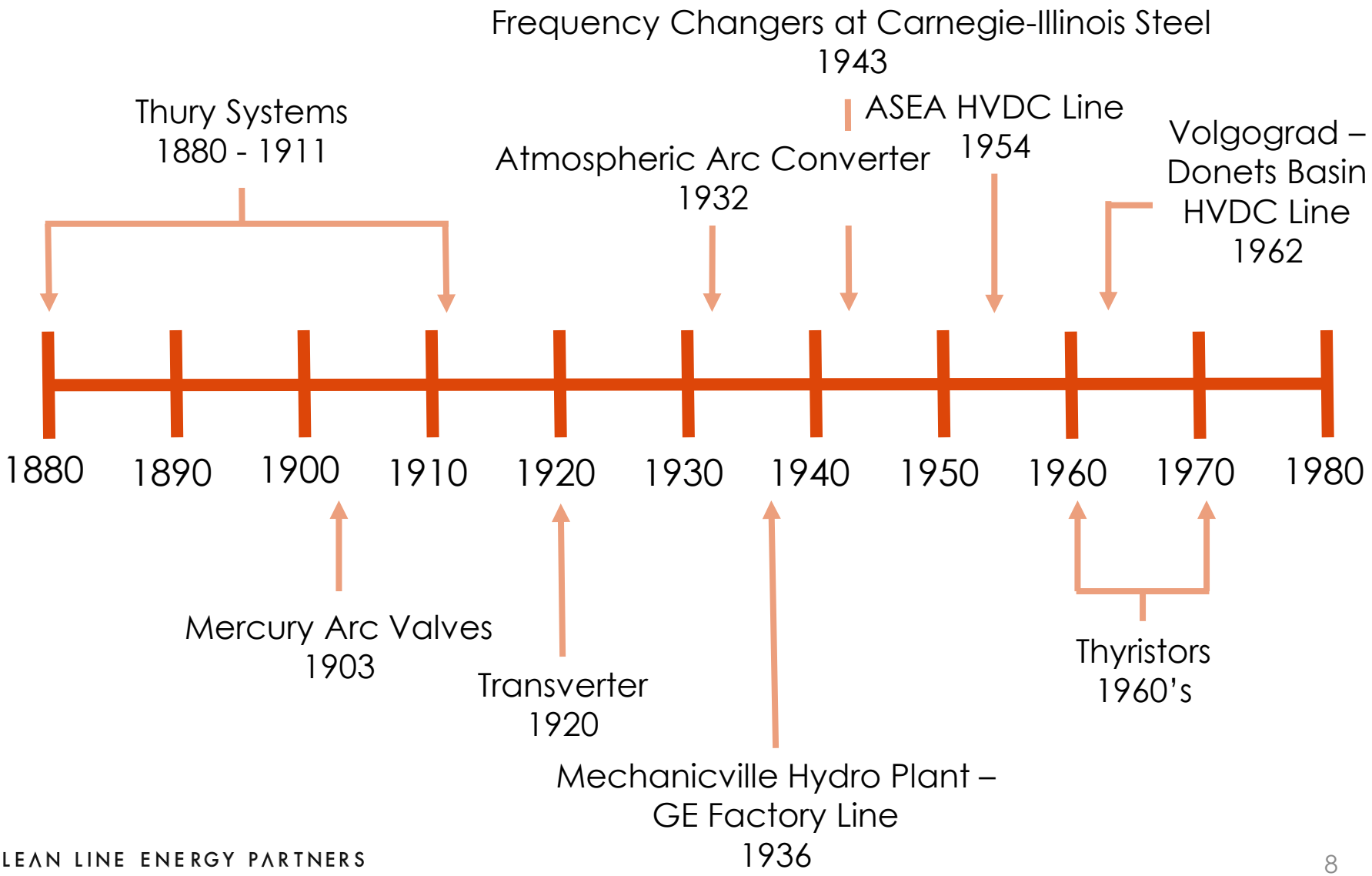
- First central power plant in U.S.
- Edison Illuminating Company
- 1882 – 1890
- 110V Direct Current
- 508 customers
- 10,164 lamps

A winner…by technology convenience

- AC became the current of choice, largely because of the transformer
  - Transformers could easily increase voltage levels to transmit power from the generator and decrease voltage at the load
    - Allowed for large central generating stations
  - Induction motors
- Also, AC is easier to disconnect because the current is equal to zero twice during each cycle



History of DC technology



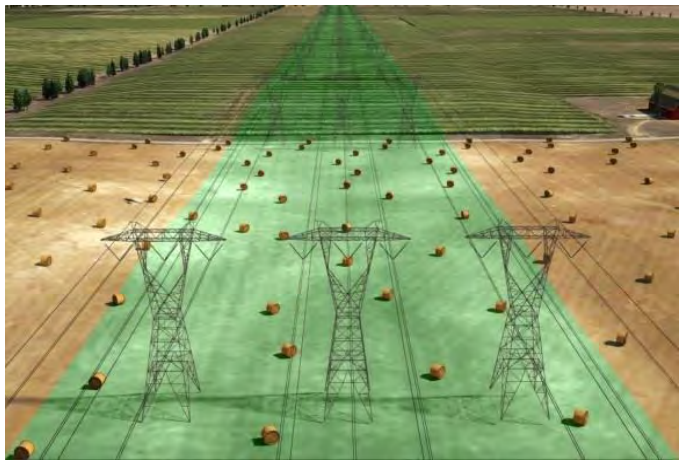
HVDC key advantages in transmitting large amounts of electricity over long distances

More efficient — Transfers power with lower line losses

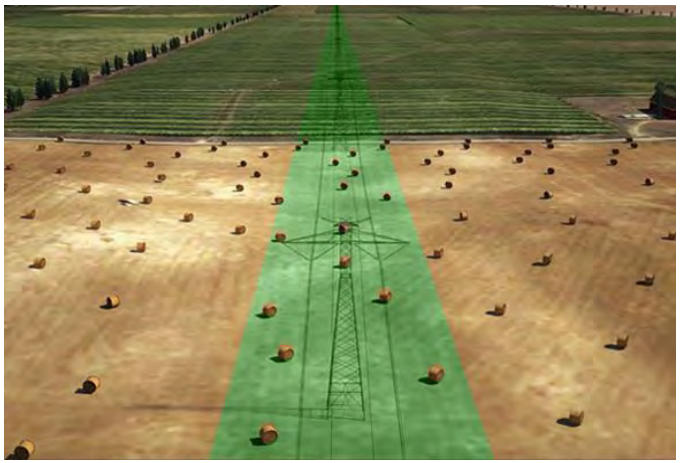
Lower cost — Requires less infrastructure, resulting in lower costs and lower prices for delivered renewable energy

Improved reliability — Provides operator complete control over power flow and facilitates integration of wind energy from different resource areas

Smaller footprint — Uses a narrower right-of-way than alternating current (AC) lines that carry comparable amounts of power

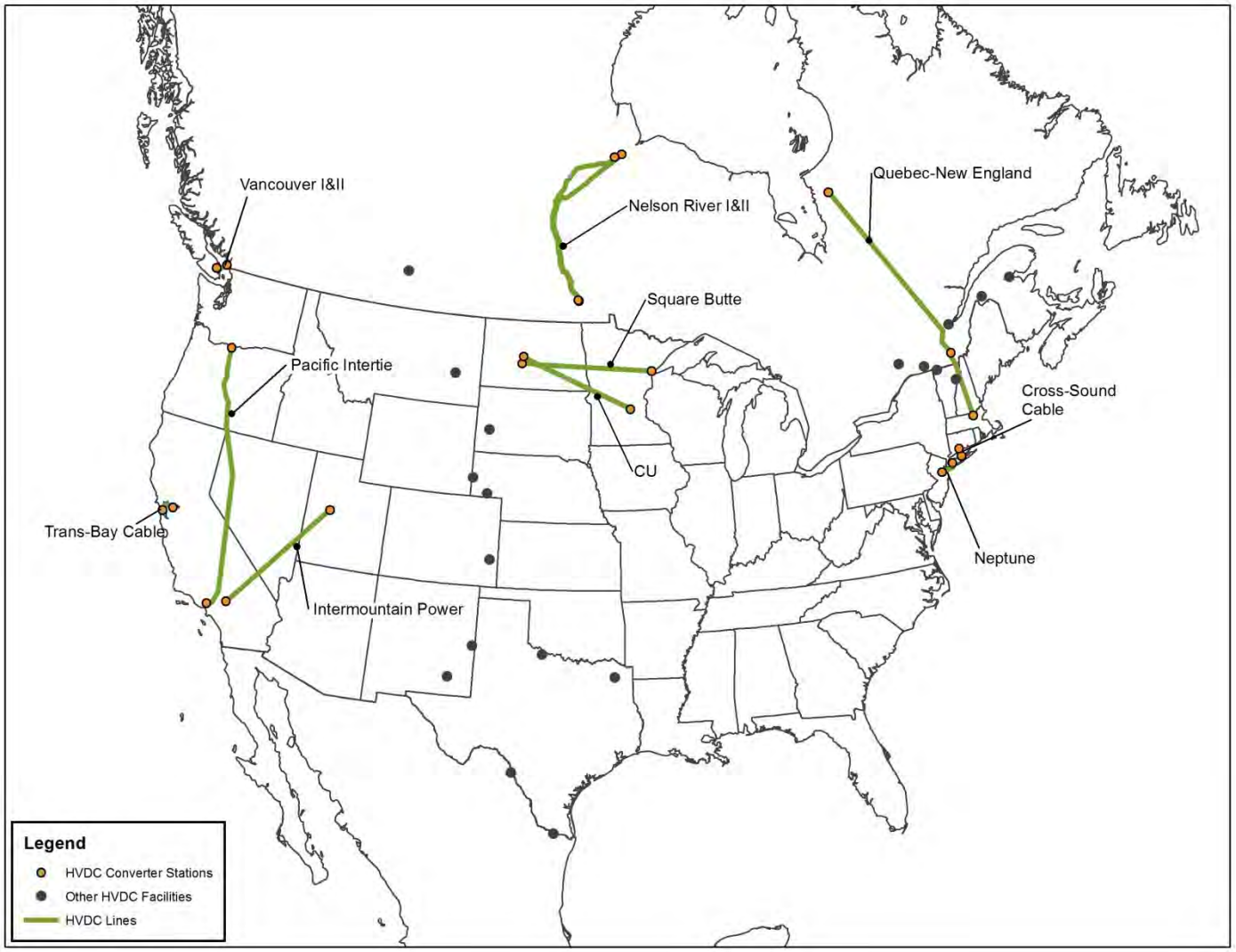


AC footprint

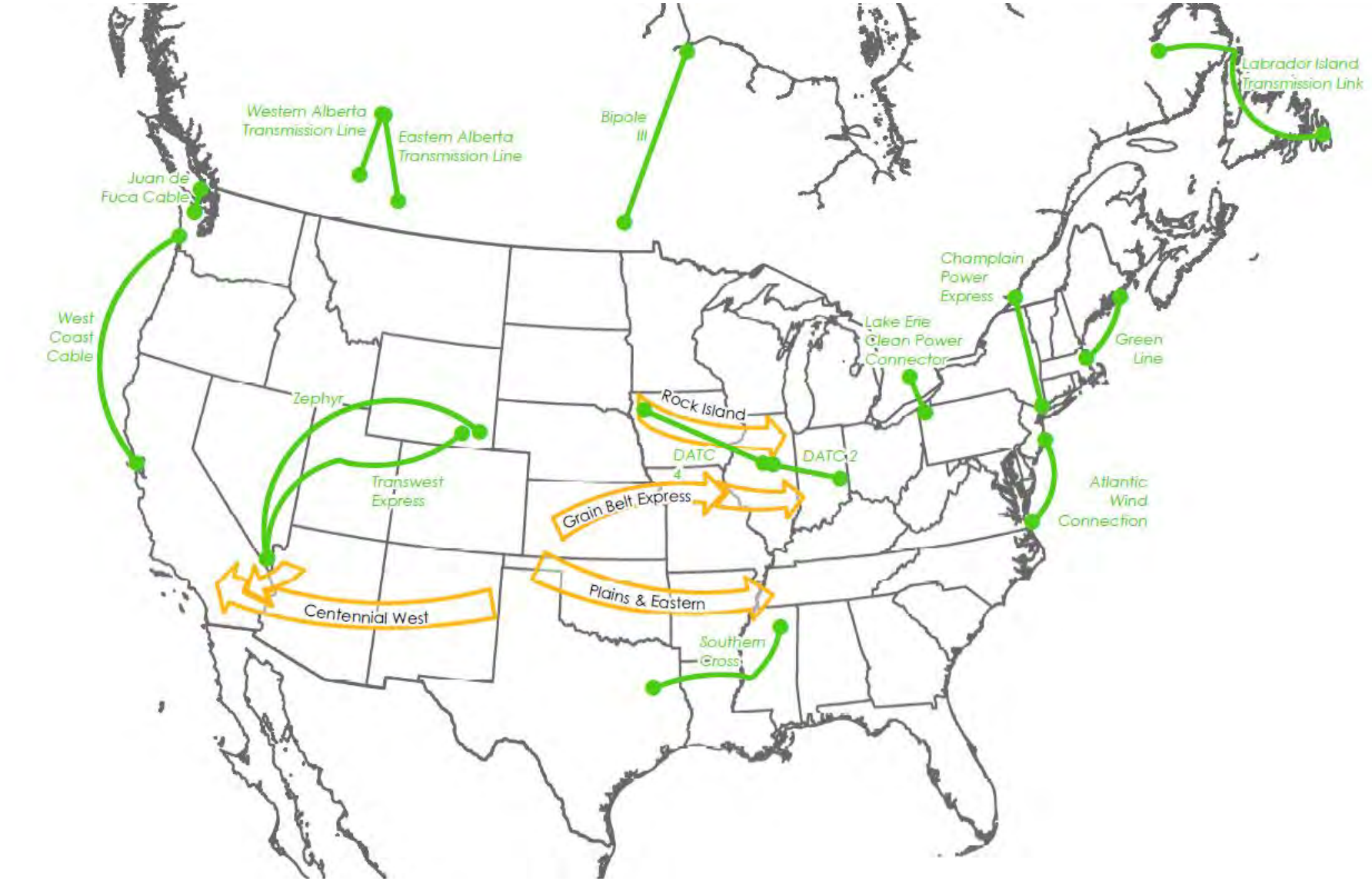


DC footprint

Over time DC applications have gained popularity across North America for appropriate applications…



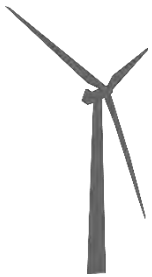
Though the grid is mostly AC, there are many recently proposed North American HVDC projects



The Plains & Eastern Clean Line is responding to market trends and economic demand

Market Trends

Arkansas companies have adopted strong energy sustainability goals



Consumer Demand

85% of Arkansans are supportive of increasing renewable energy in Arkansas[1]

The Plains & Eastern Solution

3-4¢ per kilowatt-hour renewable energy delivered to Arkansas

[1]Poll by Impact Management Group, April 2015.

Large commercial and industrial companies in Arkansas are demanding renewable energy supply

Commercial users in Arkansas with established clean energy supply goals:

Walmart

"Finding cleaner and more affordable energy is vital to everyday low cost. Scaling renewable energy while accelerating energy efficiency is our vision for a more sustainable world and is the right direction for our business." ***Bentonville, AR***

LOCKHEED MARTIN

Promotes "efforts to manage energy and GHG emissions associated with company operations, including efforts to promote energy efficiency, use of renewable energy, and the offset of emissions." ***Camden, AR***

hp

"Our new goals: commit to 100% renewable electricity in our global operations with 40% by 2020…" ***Conway, AR***

Unilever

"In November 2015, we announced that we will become carbon positive in our operations by 2030. We will source 100% of the energy used within our operations from renewable sources by 2030, and generate more renewable energy than we consume." ***Jonesboro, AR***

L'ORÉAL

"L'Oréal firmly believes that increasing the use of renewable energy is one of the principle levers for reaching its target for reduced CO2 emissions. To this end, major projects are underway in several sites." ***Little Rock, AR***

J.B. HUNT

"At J.B. Hunt, we're doing the right thing for our society and environment by making our operations more efficient and less dependent on carbon-based fossil fuel." Corporate headquarters in ***Lowell, AR***

Kimberly-Clark

"Our 150-year anniversary in 2022 is a major milestone for us. We're looking forward with a strong focus on increasing our energy efficiency and use of alternate energy sources each year." ***Conway, AR***

Over a half-billion dollar investment will result in jobs and low-cost energy for Arkansas

OVER A HALF BILLION DOLLARS IN NEW INFRASTRUCTURE INVESTMENT

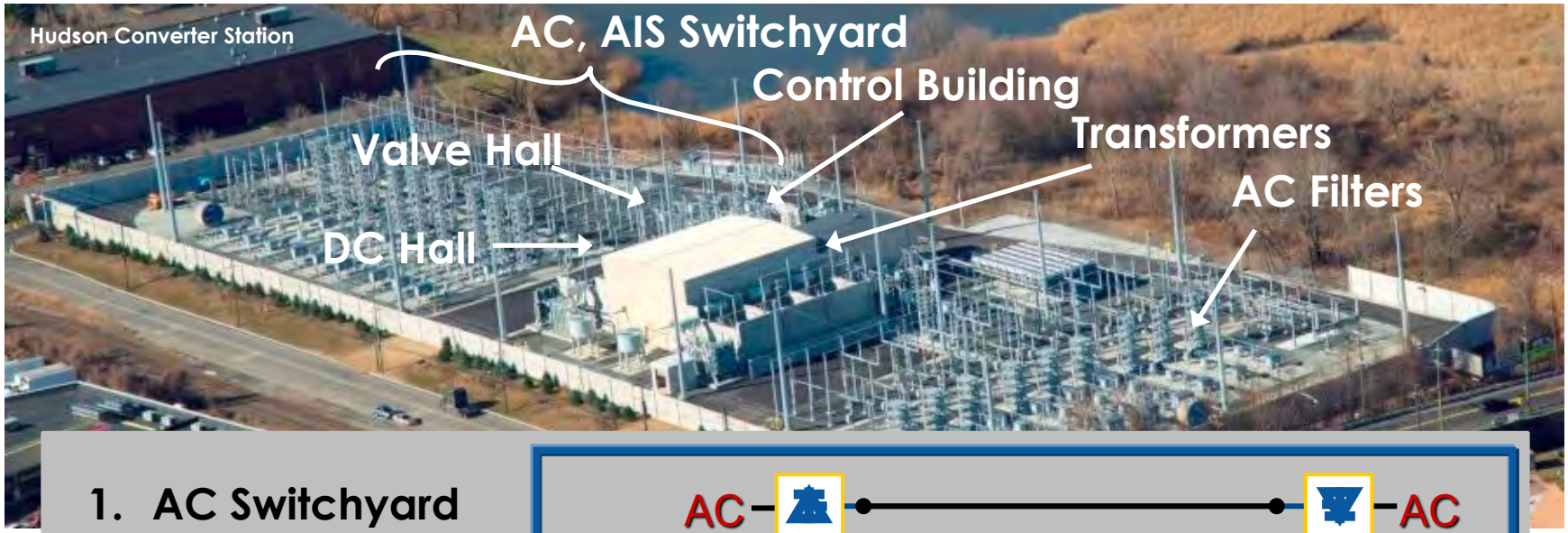
HUNDREDS OF CONSTRUCTION AND MANUFACTURING JOBS IN ARKANSAS

MORE THAN 10 WIND ENERGY SUPPLY CHAIN COMPANIES LOCATED IN ARKANSAS

Schools

MILLIONS IN ANNUAL REVENUES BENEFITING LOCAL COMMUNITIES

Key Components of a typical HVDC Converter Station



1. AC Switchyard
2. AC Filters
3. Transformers
4. Converter Valves / Valve Hall
5. Smoothing Reactors and DC Filters
6. DC Switchyard
7. Control and Protection
8. Auxiliary Systems

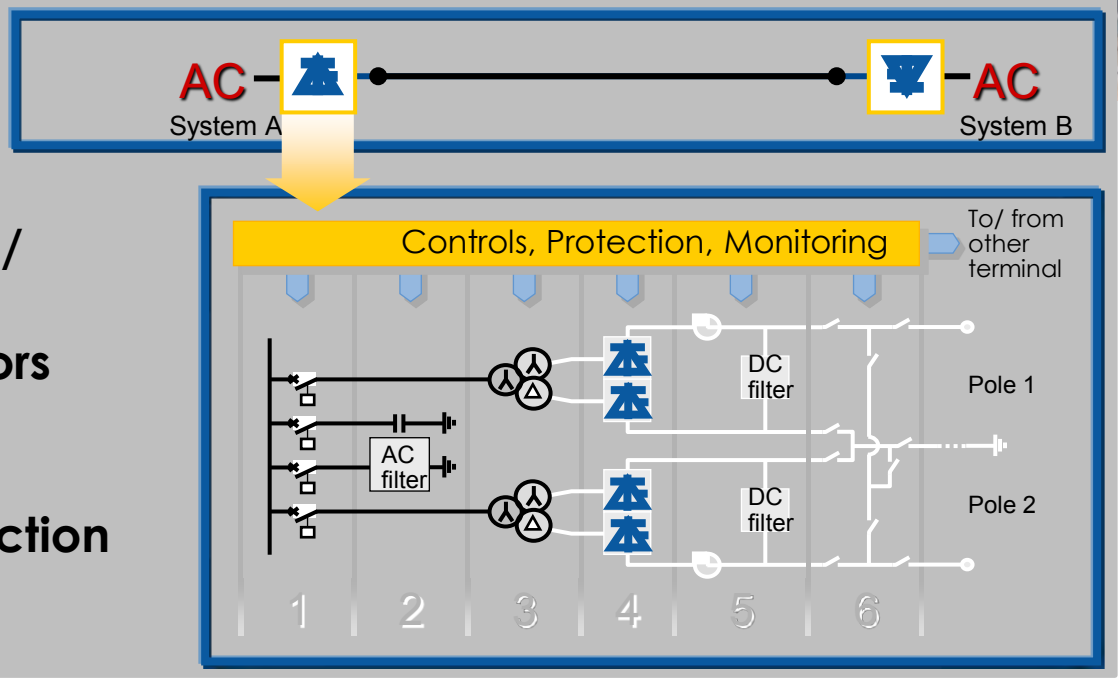
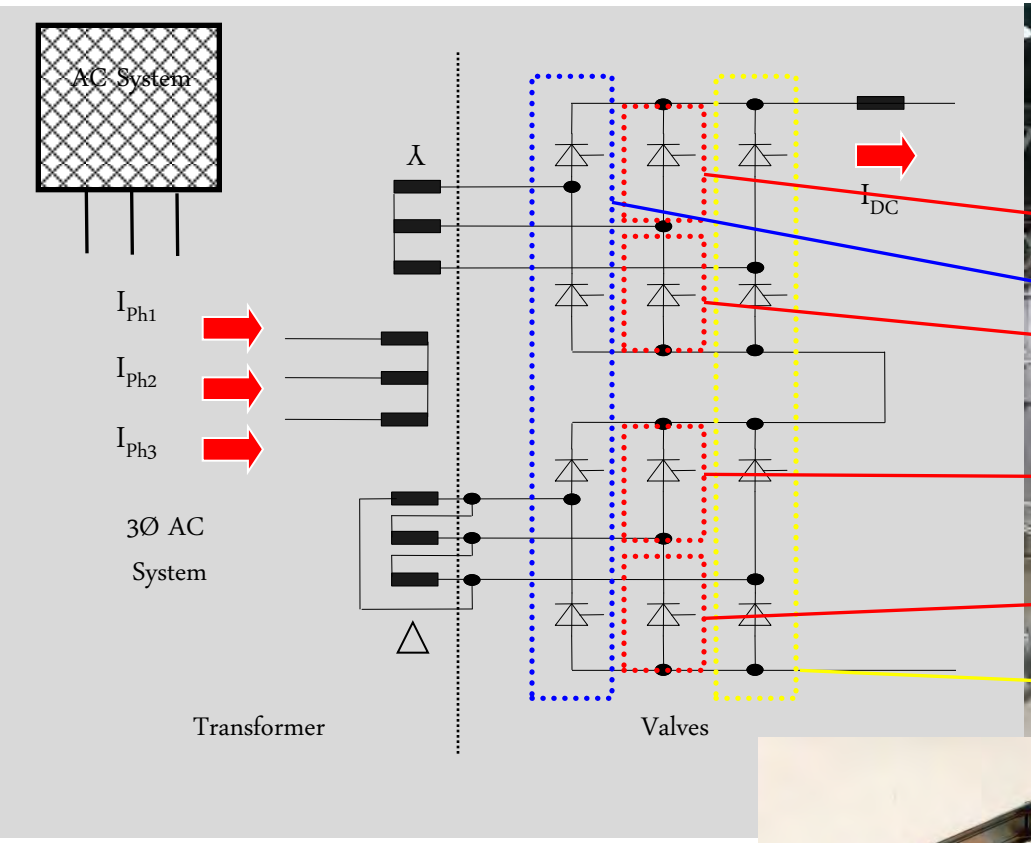


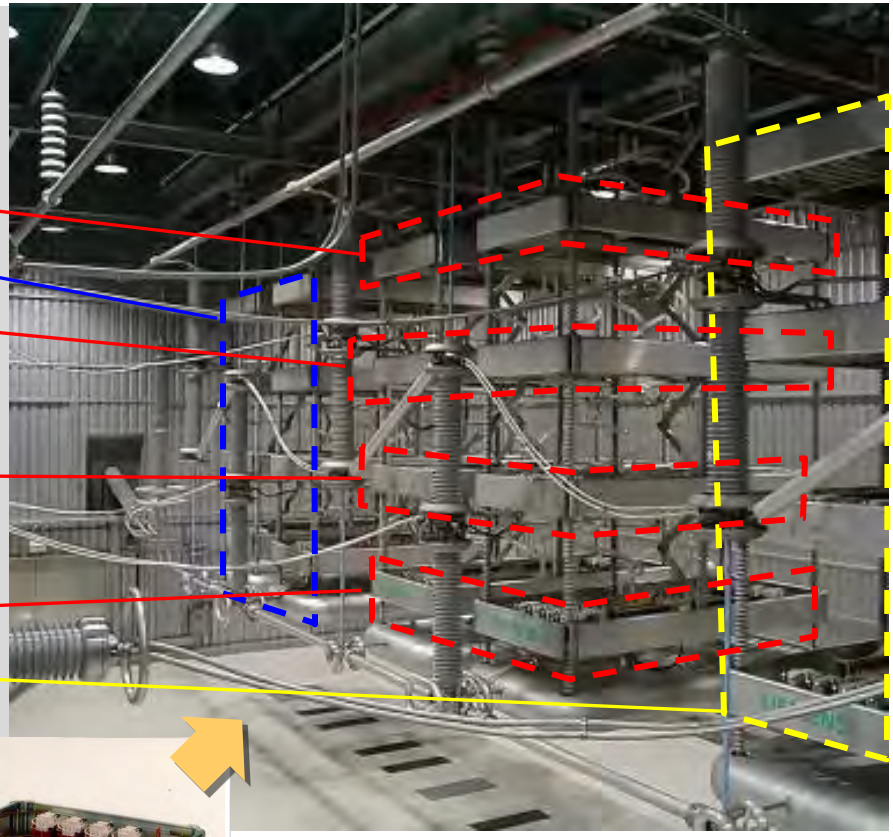
Photo Credit: Siemens

Gui-Guang II, Bipole 3000 MW, ± 500 kVdc

Photo Credit: Siemens

Principles of HVDC Operation
Core Components: Transformer and Valves





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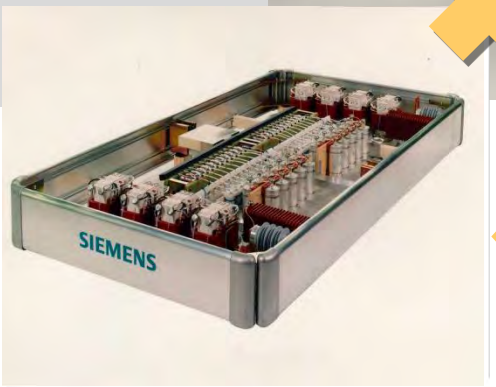
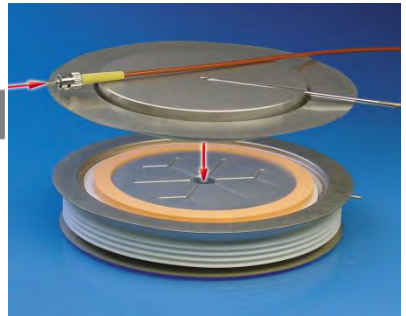




Thyristor Valves in the Valve Hall – Converter Transformer Bushings to Right, Valves to Left

Photo Credit: Siemens

Thyristor Valves in the Valve Hall – Converter Transformer Bushings to Right, Valves to Left

Photo Credit: GE Grid Solutions

Converter Transformers

'Snapshots' from DC Transformer Testing
… at Transformer Factory Test Lab –
Nuremberg, Germany

Photo Credit: Siemens

600 kV Transformers Similar to Plains & Eastern

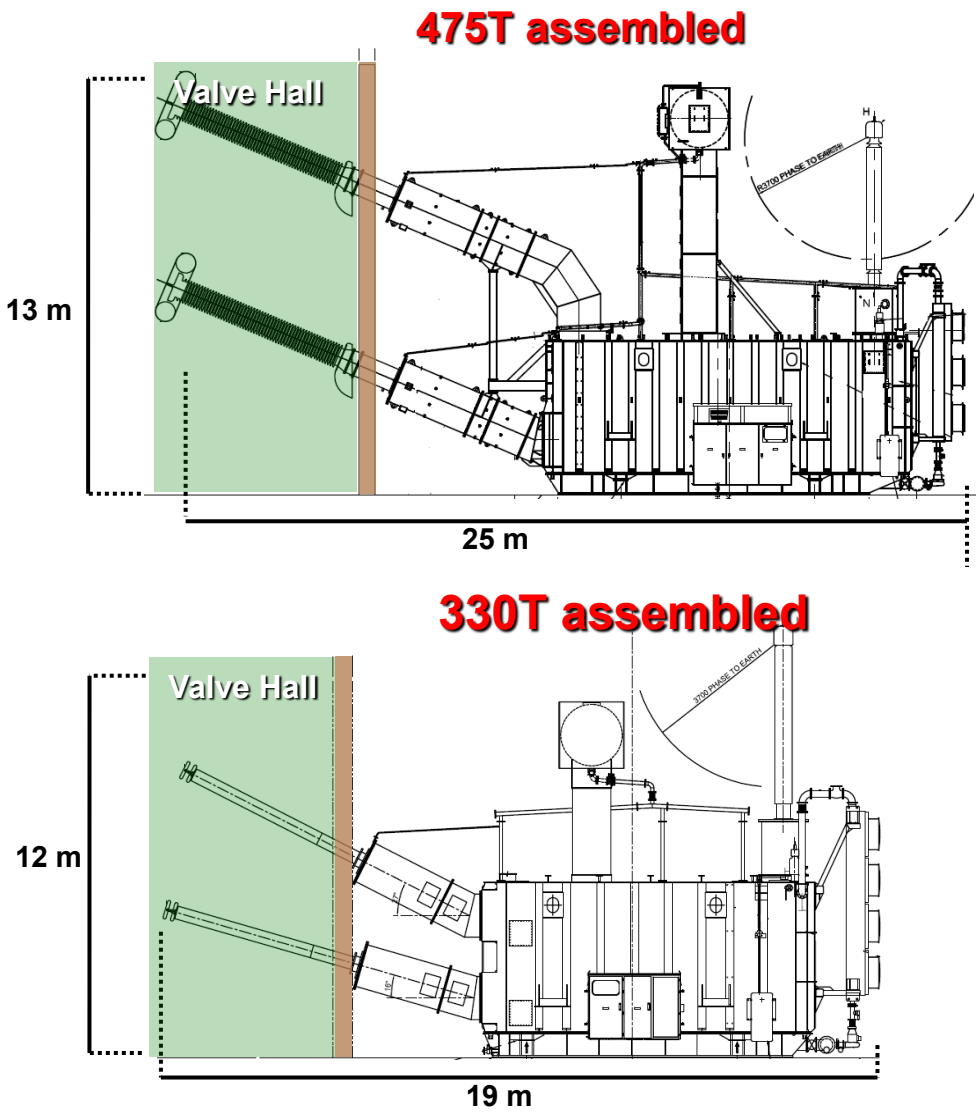


Photo Credit: GE Grid Solutions

Plains & Eastern has selected qualified local vendors like Sediver to supply project components

SEVES

SEDIVER

New Manufacturing and Technology Center

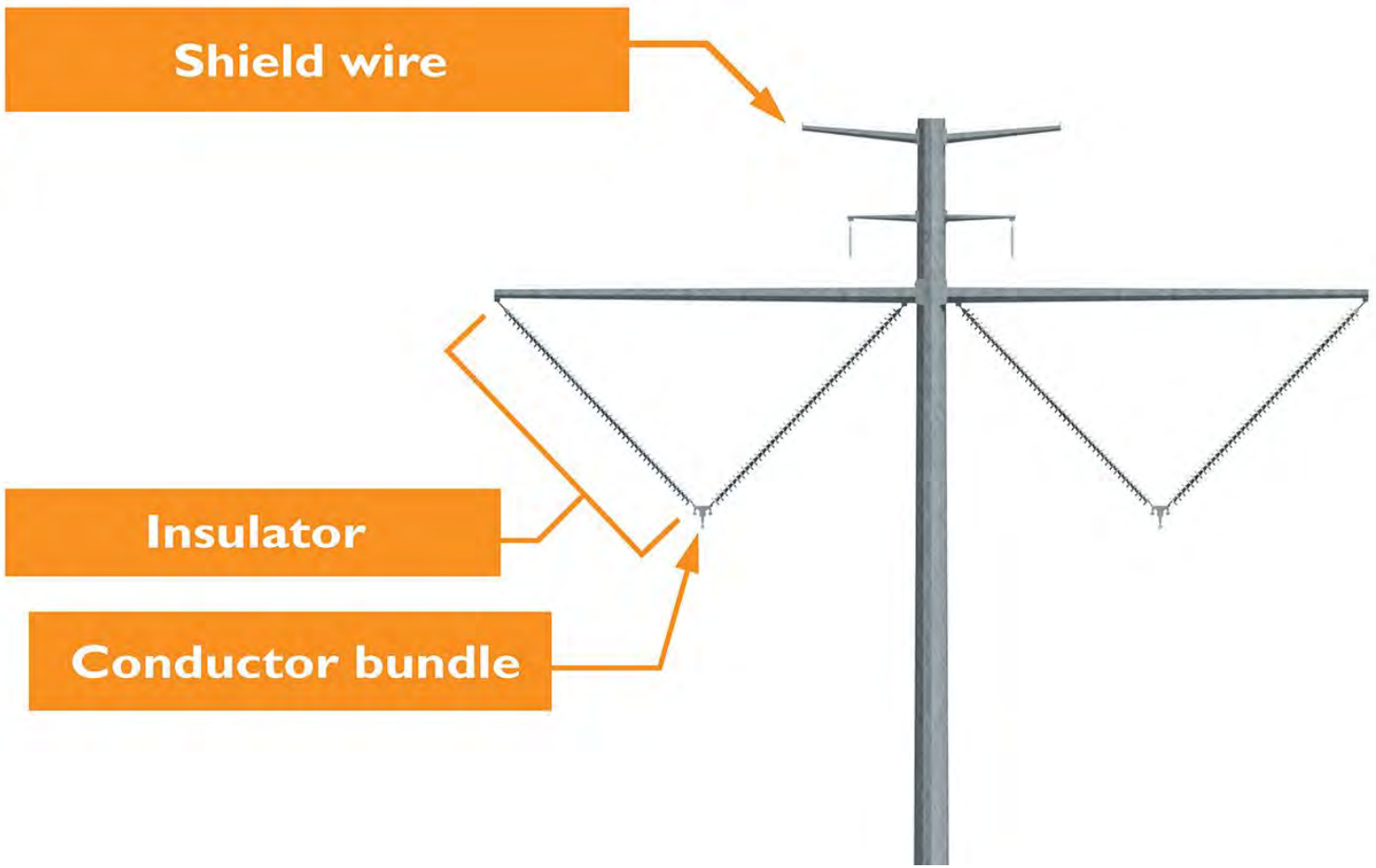
West Memphis, AR

Only US manufacturing center for Sediver

Creates over **70** Jobs
Signed: 12/15/2014

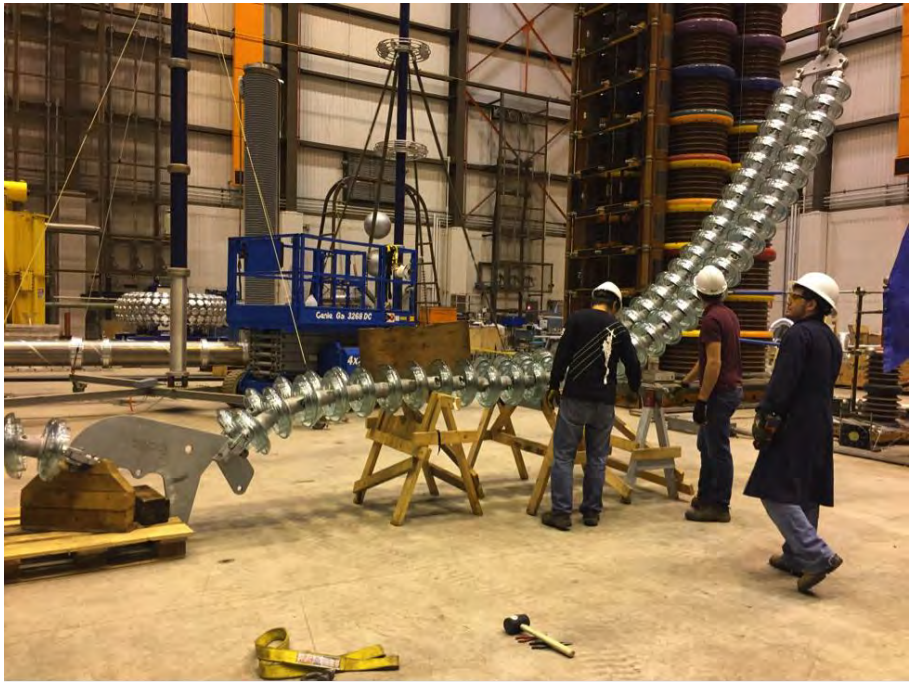
New West Memphis facility to be operational Q1 2017

Insulator functions: (1) mechanical strength (2) electrical isolation of conductors

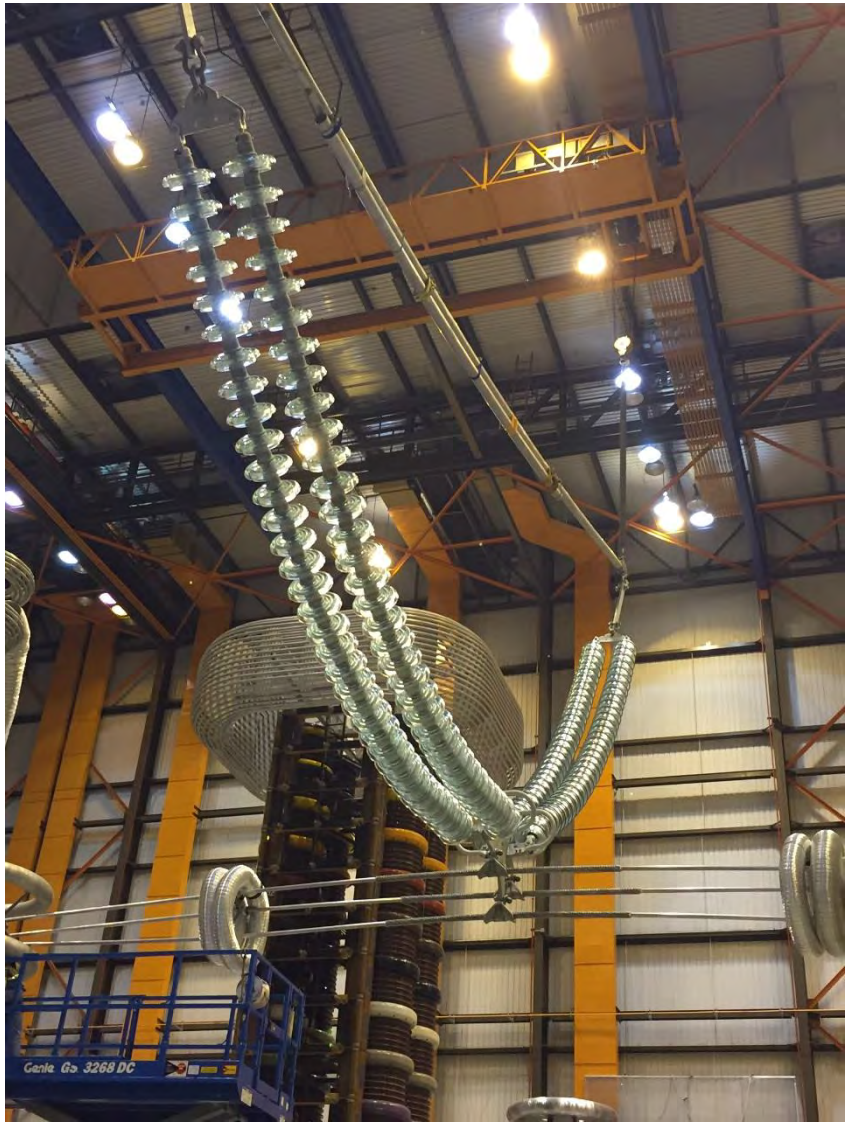


High Resistivity Toughened Glass Insulators for HVDC

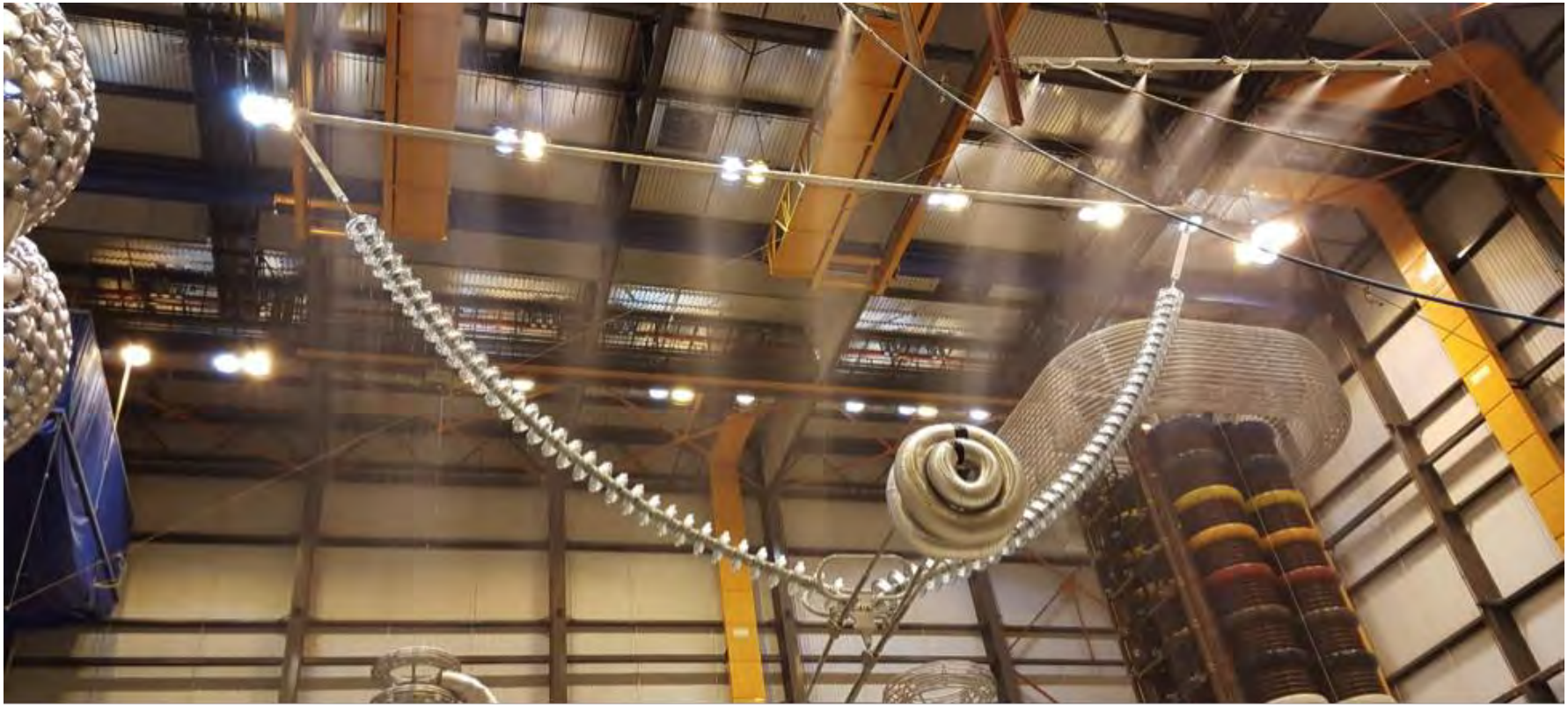
Toughened glass insulators being assembled for testing



Insulators suspended for RIV, Corona, and Noise testing



Toughened glass insulators: Wet Withstand Test



High Voltage labs are just plain cool…but safety first!

Insulator tests a success and I'm still in one piece!

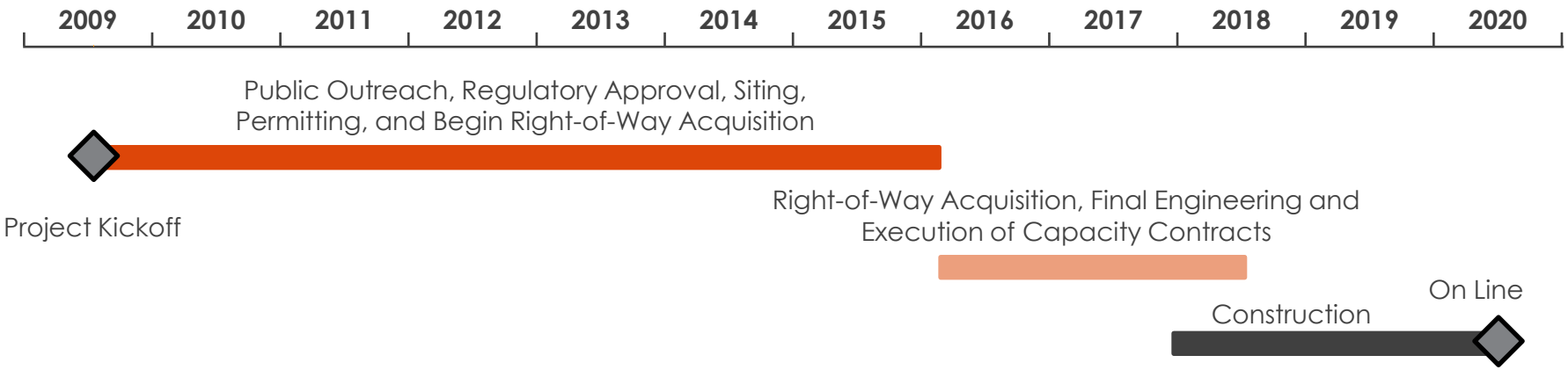
The Plains & Eastern Clean Line is expected to be online by 2020

Construction on the Plains & Eastern Clean Line is anticipated to begin as early as late 2017

Final stages of development include:

- finalizing design and cost estimation
- acquiring contiguous rights-of-way for construction
- completing interconnection processes
- negotiating and executing customer contracts

Current Schedule



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