Development Of The sCO_2 Allam Cycle

50MWth Demonstration Plant Update

Supercritical CO2 Power Cycles Symposium

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Jeremy Fetvedt

Chief Engineer, 8 Rivers Capital

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sCO2 Cycle Development: A tipping point?

Tremendous growth of interest and support over the last decade

- 2007 sCO2 Symposium: 10 Presentations
- Today: 74 Papers; 24 Posters; 24 Sessions
- sCO_2 Focused Track at ASME
- Increased R&D opportunities across the DOE labs

Knowledge has moved from the theoretical to the experimental

- Subscale components have undergone testing
- Subscale integrated cycles have been demonstrated

The next phase: scaling up to larger demonstrations

- Department of Energy STEP Facility
- NET Power's 50MWth demonstration plant

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The NET Power Demonstration Program Overview

8 Rivers invented the Allam Cycle and has been developing it since 2009.

NET Power was created to commercialize the natural-gas-fueled configuration of the Allam Cycle.

- Owned by 8 Rivers, Exelon Corporation and CB&I.
- Partnered with Toshiba to develop a new turbine for the cycle.
- $140M committed to cycle development, demonstration, and commercialization; demonstration effort is fully-funded.
- Program has demonstrated novel combustion system for the cycle at 5MW.
- Construction has begun on a 50MWth demonstration plant in Texas.
- NET Power in discussions for commercial plants.

8 Rivers continues to advance the development of the Allam Cycle across a variety of configurations and fuel sources.

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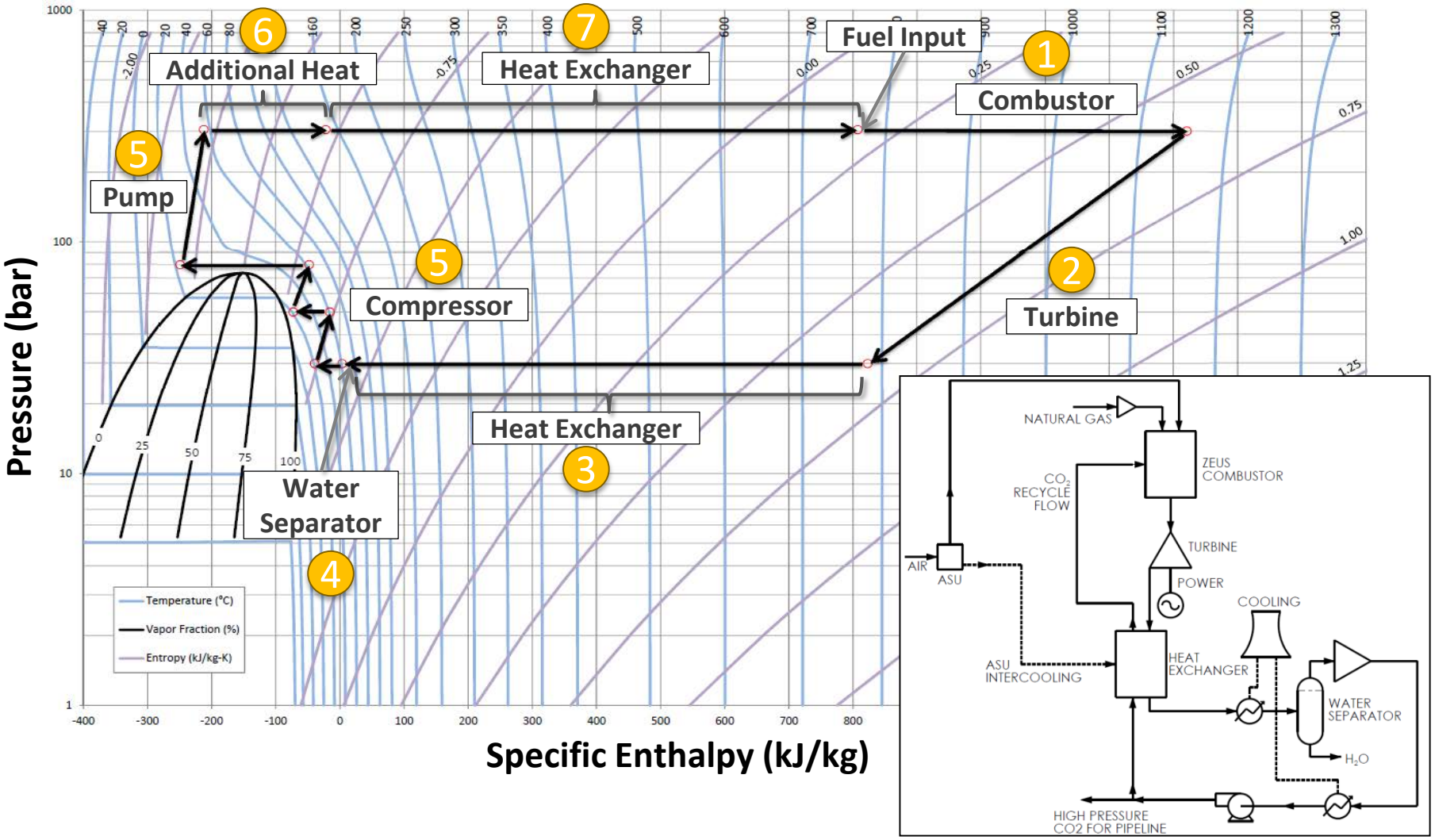
Allam Cycle Overview

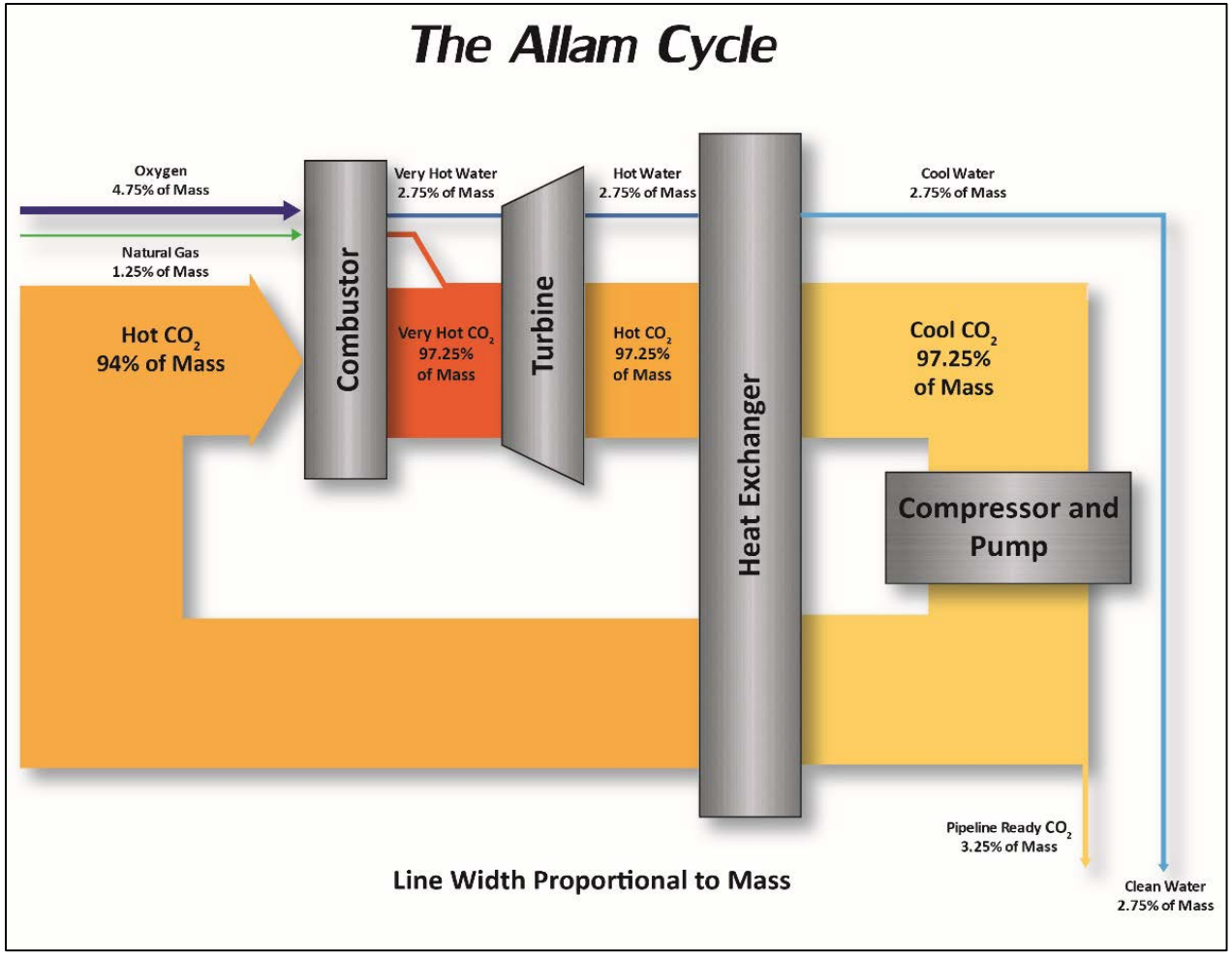
Key Considerations for New CO_2 Cycle Design

- Direct-fired oxy-fuel approach helps generate a CO_2 working fluid
- A higher concentration of CO_2 enables more efficient use of the working fluid and requires less cleanup for pipeline transport
- Recuperation keeps heat available in turbine exhaust within the system and increases CO_2 concentration
- CO_2 has large thermodynamic property differences as the pressure difference increases between the streams, extra heat is needed if the critical pressure is crossed.
- The “ASU Problem” has to be adequately addressed and overcome

Natural Gas Cycle P-h Diagram



Simplified Mass-flow Diagram



Cycle Performance

The Allam Cycle Natural Gas vs. Combined Cycle: Efficiency Comparison

	HHV		LHV	
Energy Components	**F-Class US NGCC Plant (0% CC)***	**Allam Cycle NG Plant (100% CC)**	**F-Class US NGCC Plant (0% CC)***	**Allam Cycle NG Plant (100% CC)**
Gross Turbine Output	51.06% (Compressors mechanically coupled)	74.65%	58.7% (Compressors mechanically coupled)	82.7%
CO_2 Compressor Power		-10.47%		-11.6%
Plant Parasitic Auxiliary Power	-0.86%	-11.01%	-1.2%	-12.2%
Net Efficiency	**50.20%**	**53.17%**	**57.5%**	**58.9%**

Parasitic Load Breakdown	
ASU	91.8%
NG Compressor	8.2%

*Performance data from NETL Cost and Performance Baseline Report, 2013.

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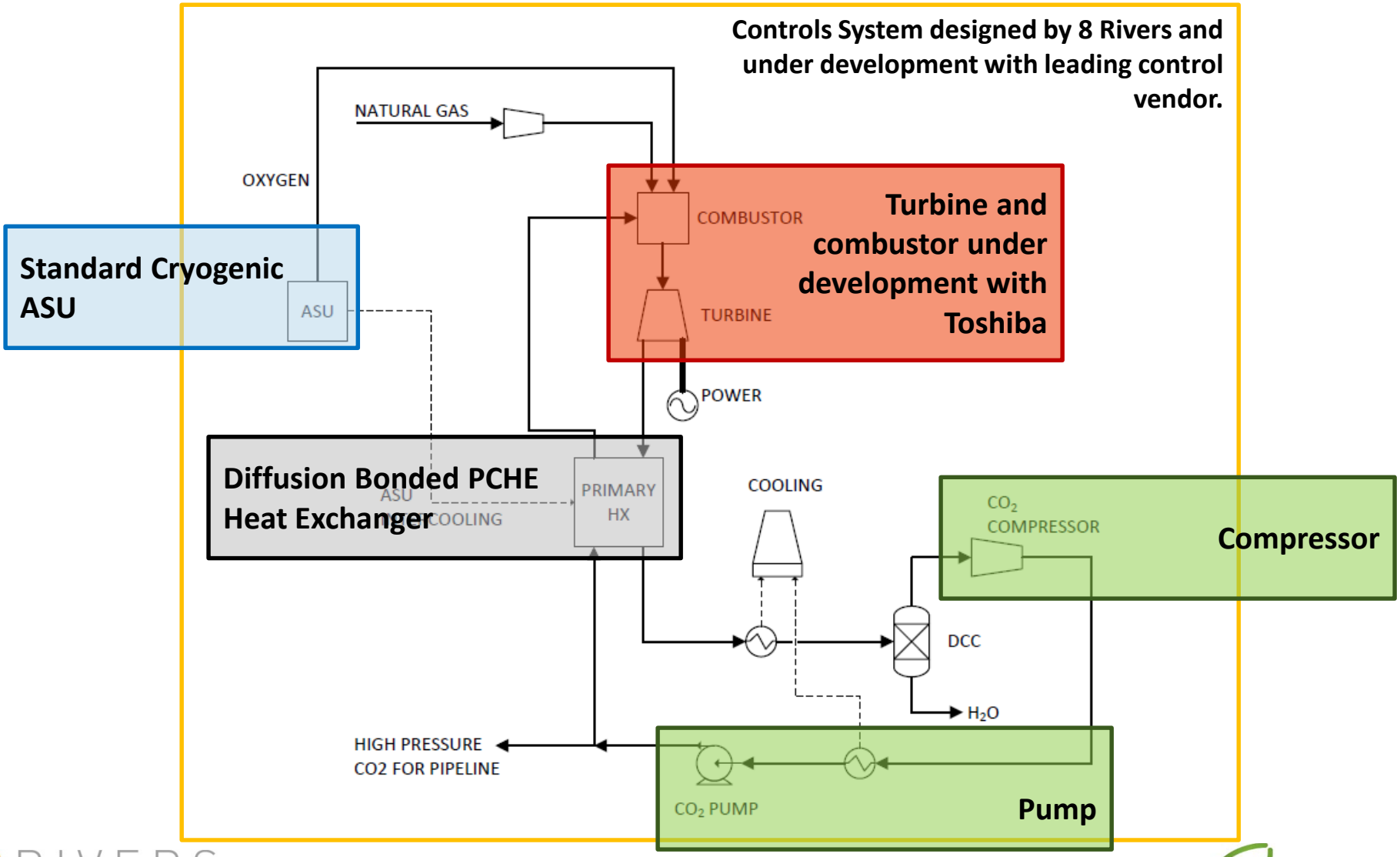
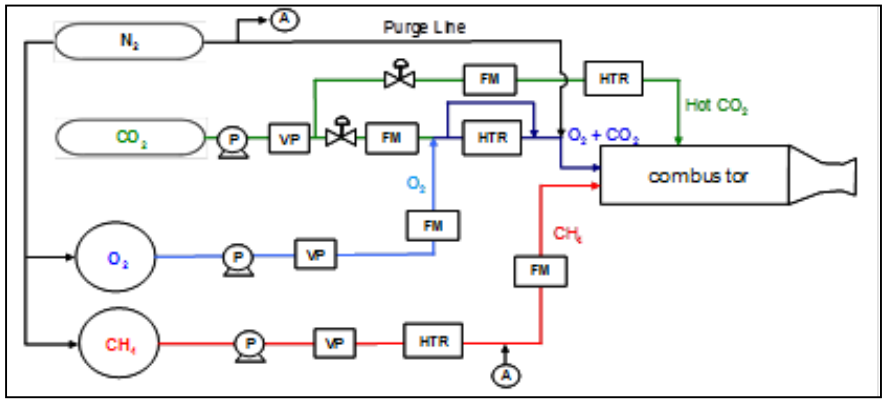
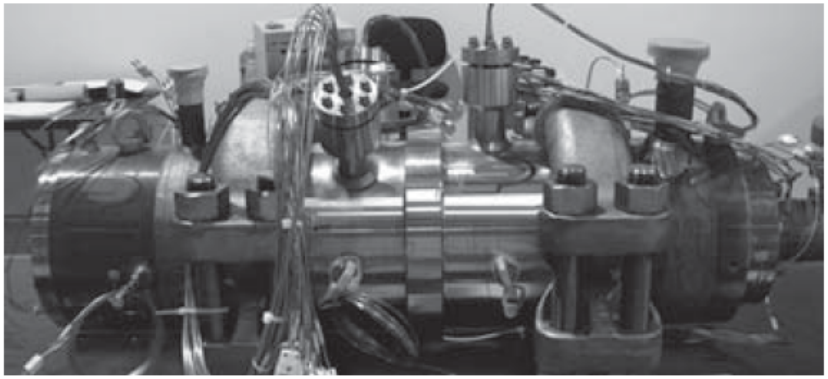
Allam Cycle Development Status

Most Components are Commercially Available



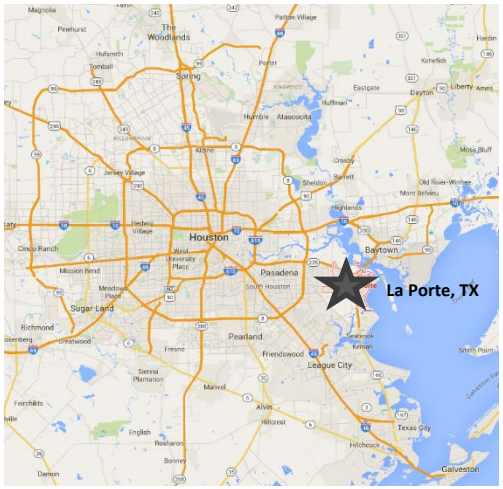
5MWth Natural Gas Combustor Testing was Successful

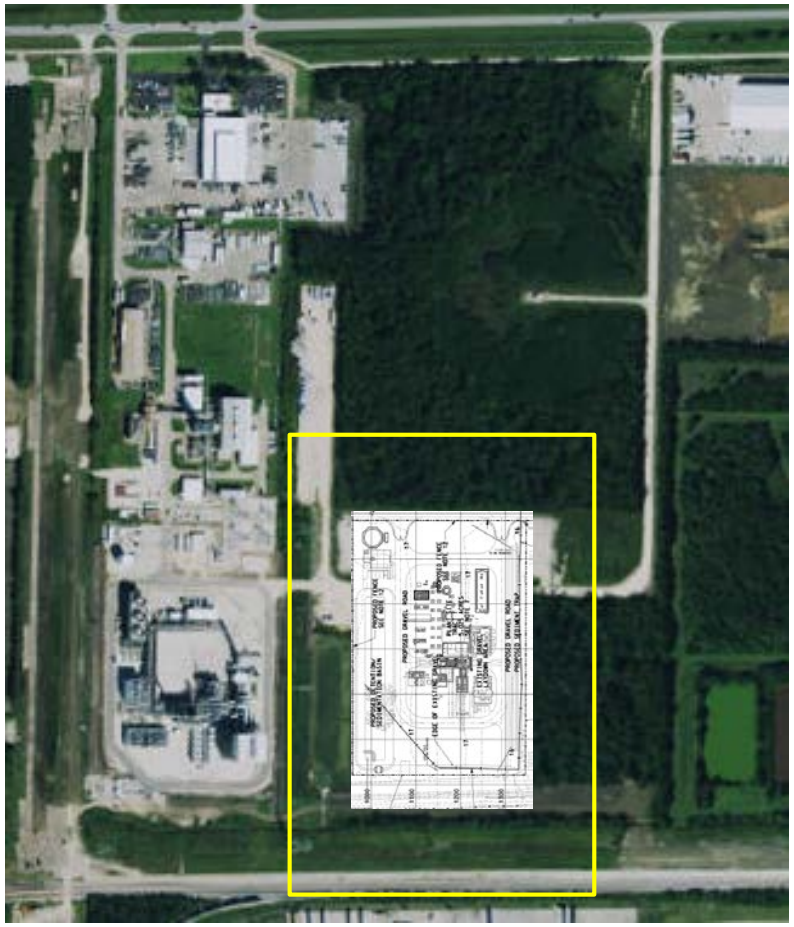




The Next Step is a 50MWth Demonstration Plant

- Construction is underway
- Commissioning expected to begin in Q4 2016
- First fire expected in early 2017
- Site leased from Air Liquide in La Porte, TX
- All major equipment has been ordered
- A full plant simulator is currently in development





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Plant Overview

- **Plant design scaled down from 500MWth pre-FEED design to ensure scalability to commercial size**
- **Plant includes all core components of the Allam Cycle**
  - Combustor/turbine, heat exchangers, pumps and compressors, control system, and ancillary equipment
  - Plant will undergo full performance evaluation (startup, shutdown, ramping, hot/warm/cold starts, emergency operations)
  - Oxygen will be pulled from a pipeline as opposed to a dedicated ASU
  - CO_2 will be generated at high pressure and quality, but will be emitted
    - CO_2 off-take found to be impractical for variable testing operation period
    - CO_2 quality will be confirmed and monitored to ensure viability for commercial facility

Demonstration Plant Rendering

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Construction of the Plant is Underway

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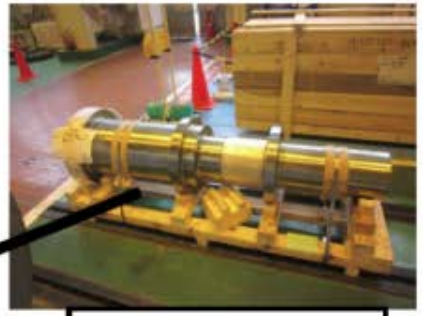
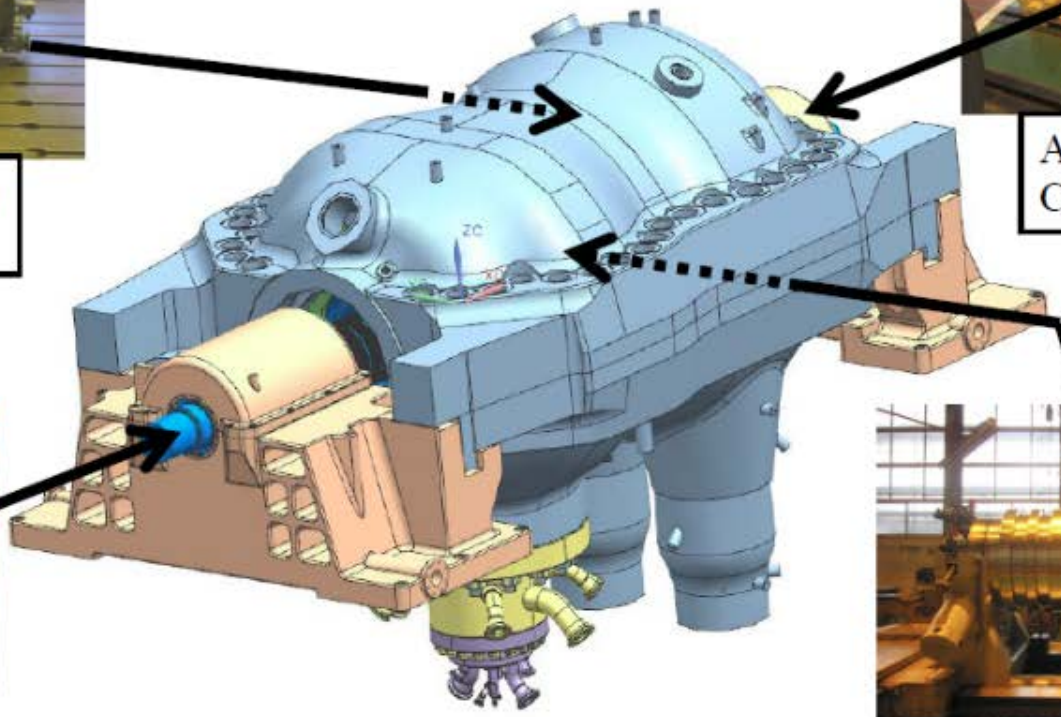
The Turbine is Being Manufactured

Inner Casing; Ni base casting



Aft rotor; CrMoV Forging



Forward rotor; CrMoV Forging

Center Rotor; Ni base Forging

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Development has Begun on the Commercial System

- **Pre-FEED has been completed on a 500MWth natural gas commercial design**
  - Proceeding to FEED as next step
- **NET Power is engaged with power generators around the world on development work**
  - Working with customers on development needs in the 2019-2025 timeframe
  - Some customers have already purchased sites
- **Targeting Plant Completion by late 2019.**

THANK YOU

Jeremy Fetvedt

Jeremy.Fetvedt@8Rivers.com

919-667-1800