Materials for Advanced Ultra-supercritical Steam Turbines - Advanced Ultra-supercritical Component Demonstration

DOE Contract Number DE-FE0025064

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What is “Advanced Ultra-Supercritical” ?

Nomenclature	Steam Conditions	Net Plant Efficiency (HHV)
Subcritical	2400psig 1000 to 1050ºF	35%
Supercritical (SC)	>3600psig ~1050ºF (550ºC) and above	38%
Ultrasupercritical (USC)	>3600 psig ~1100ºF (600ºC) and above	>42%
Advanced-UltraSupercritical (A-USC)	4000-5000psig 1300-1400ºF (700-760ºC)	>45%

Higher efficiency fossil fuel cycles
- **Burn less coal**
- **Produce fewer pollutants**
- **Generate less CO2**

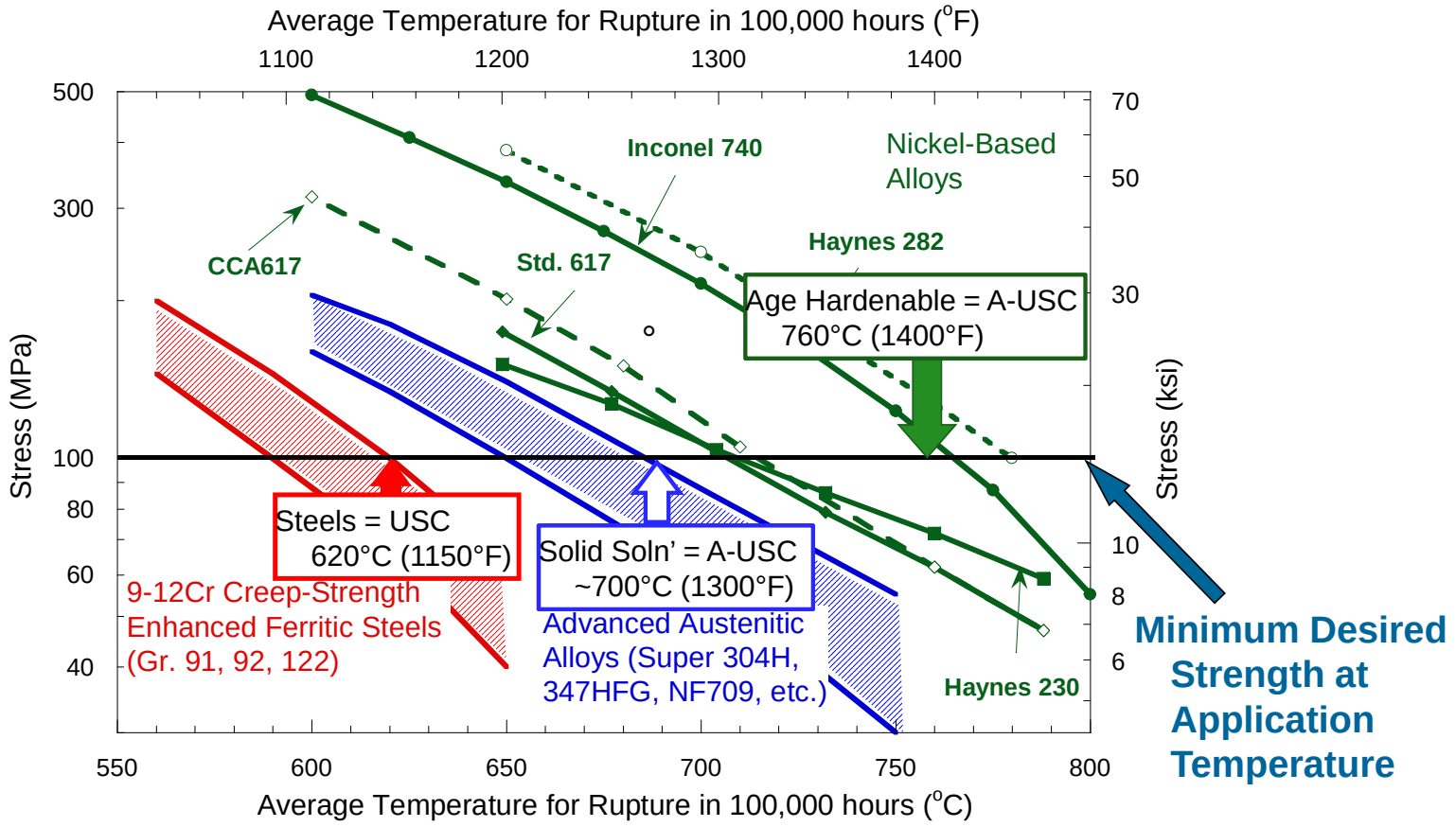
Higher temperatures and pressures
- **Allow higher plant cycle efficiency**
- **Require advanced materials**

Background of A-USC Materials Programs

- Present work builds upon 15-year effort supported by U.S. Department of Energy, Ohio Coal Development Office, and industry participants
  - Boiler Materials for Advanced Ultra-supercritical Coal Power Plant
    - DOE Contract: DE-FG26-01NT41175
    - OCDO Grant: CDO-D-05-02(A)
  - Materials for Advanced Ultra-supercritical Steam Turbines
    - DOE Contract: DE-FE0000234
    - OCDO Grant: CDO-D-05-02(B)

Materials Limit the Current Technology:

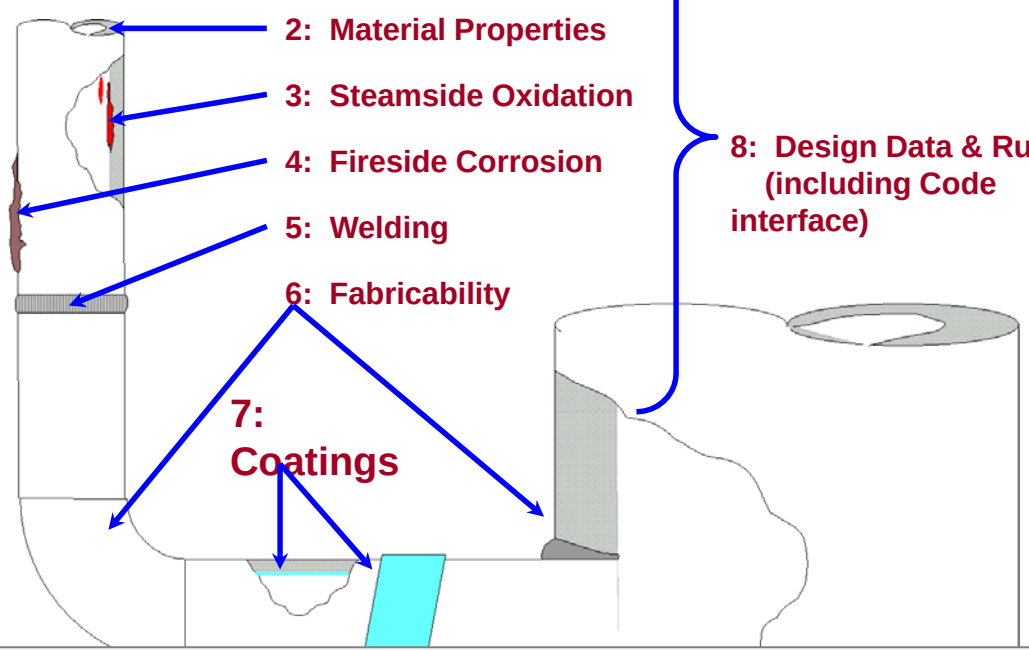
Today's State-of-the-Art (USC) are defined by steel technology



Primary Technical Goals of US A-USC Materials Programs

- Materials technology evaluation
  - Focus on **nickel-based alloys**
  - Development of fabrication and joining technology for new alloys
- Unique conditions for US program considerations
  - Higher-temperatures than other international Programs (760°C versus 700°C) means **additional alloys** evaluated
  - For boiler:
    - Corrosion resistance for **US coals**
    - Data for **ASME code** acceptance of new materials
    - Evaluate the effect of combining technology with other carbon capture technologies such as **Oxycombustion**

U.S. DOE/OCDO: A-USC Steam Boiler Consortium



Develop the materials technology to fabricate and operate an A-USC steam boiler with steam parameters up to 1400°F (760°C)

U.S. DEPARTMENT OF ENERGY

Ohio Coal Development Office

Energy Industries Of Ohio

B&W power generation group

NETL

EPRI ELECTRIC POWER RESEARCH INSTITUTE

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Riley Power

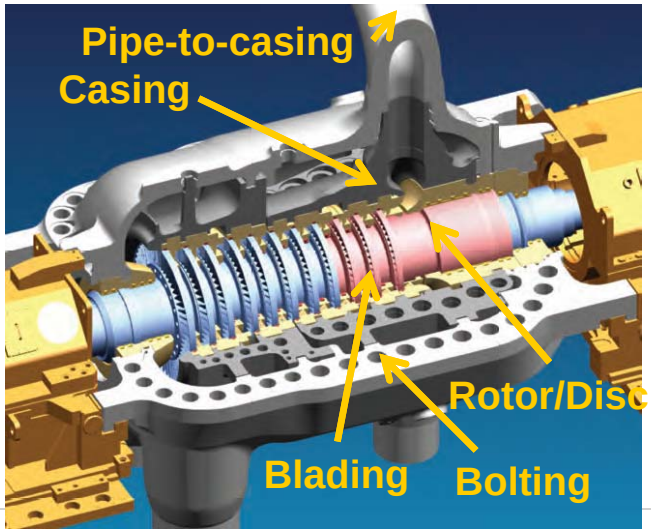
ALSTOM

FOSTER WHEELER

DOE/OCDO A-USC Steam Turbine Consortium

- Selected materials from Phase I
- Rotor/disc testing (full-size forgings, environmental interaction)
- Blade alloy testing (and erosion resistant coatings)
- Cast casing scale-up alloy testing
- Casing welding and repair

1400°F (760°C) Steam turbine conceptual design (HP) – *bolted construction*



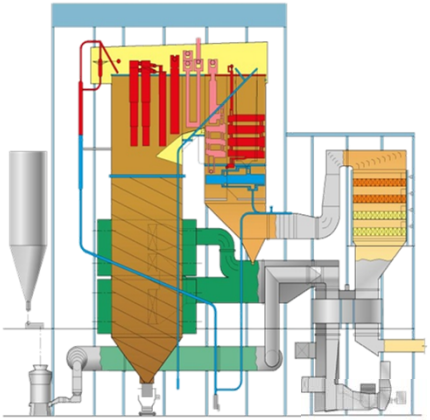
Turbine

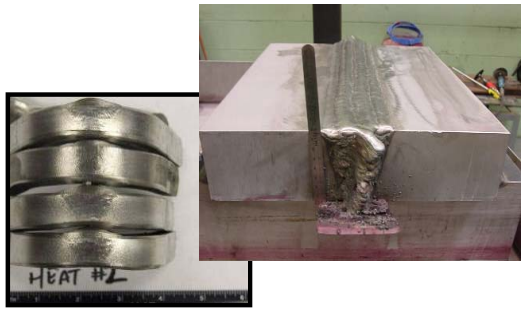
- Final Phase 2 technical report recently published by DOE
  - "Materials for Advanced Ultrasupercritical Steam Turbines"
  - http://www.osti.gov/scitech/biblio/1243058

Consortia Accomplishments Summary
A-USC Fact Book - EPRI 1022770

(download free at: www.epri.com)

General design studies show favorable economics





Welding Technology Developments

Fabrication Processes

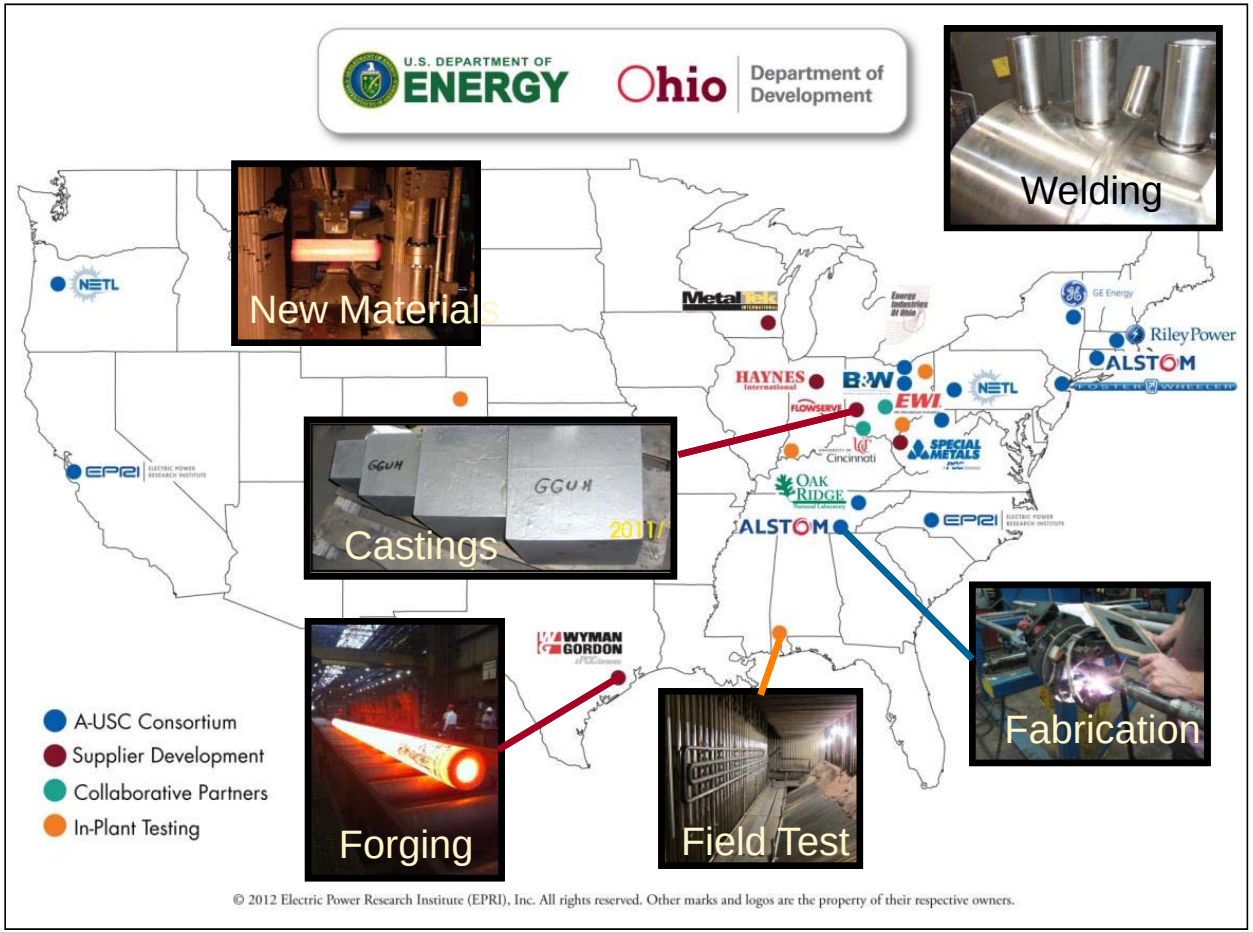
Steam-Side Oxidation

Fireside Corrosion (High-Sulfur Coal & In-Plant Testing)

Turbine Component Scale-up

ComTest is the Next Step for the Highly Successful and Highly Leveraged U.S. Department of Energy (US DOE) / Ohio Coal Development Office (OCDO) A-USC Steam Boiler and Turbine Consortia

Federal – State – National Laboratory
Non Profit – For Profit
Cost Sharing Consortium



Project Objectives of ComTest

- Evaluate advanced materials and components under A-USC service conditions
- Minimize risks
  - For a firm to own and operate an A-USC plant
  - For the OEM to provide commercial guarantees
- Understand manufacturing, cost, and supply chain issues
  - First of a kind
- Validate fabrication, construction, installation and repair of A-USC components

ComTest Project Team

- Energy Industries of Ohio (EIO): prime contractor / administrative lead
- Electric Power Research Institute: technical lead organization
- Team members
  - AECOM EPC contractor
  - Youngstown Thermal (selected host site)
  - Advanced USC ComTest Consortium
    - EPRI
    - Babcock & Wilcox
    - General Electric Power (turbine design group)
    - General Electric Power (former Alstom Power)

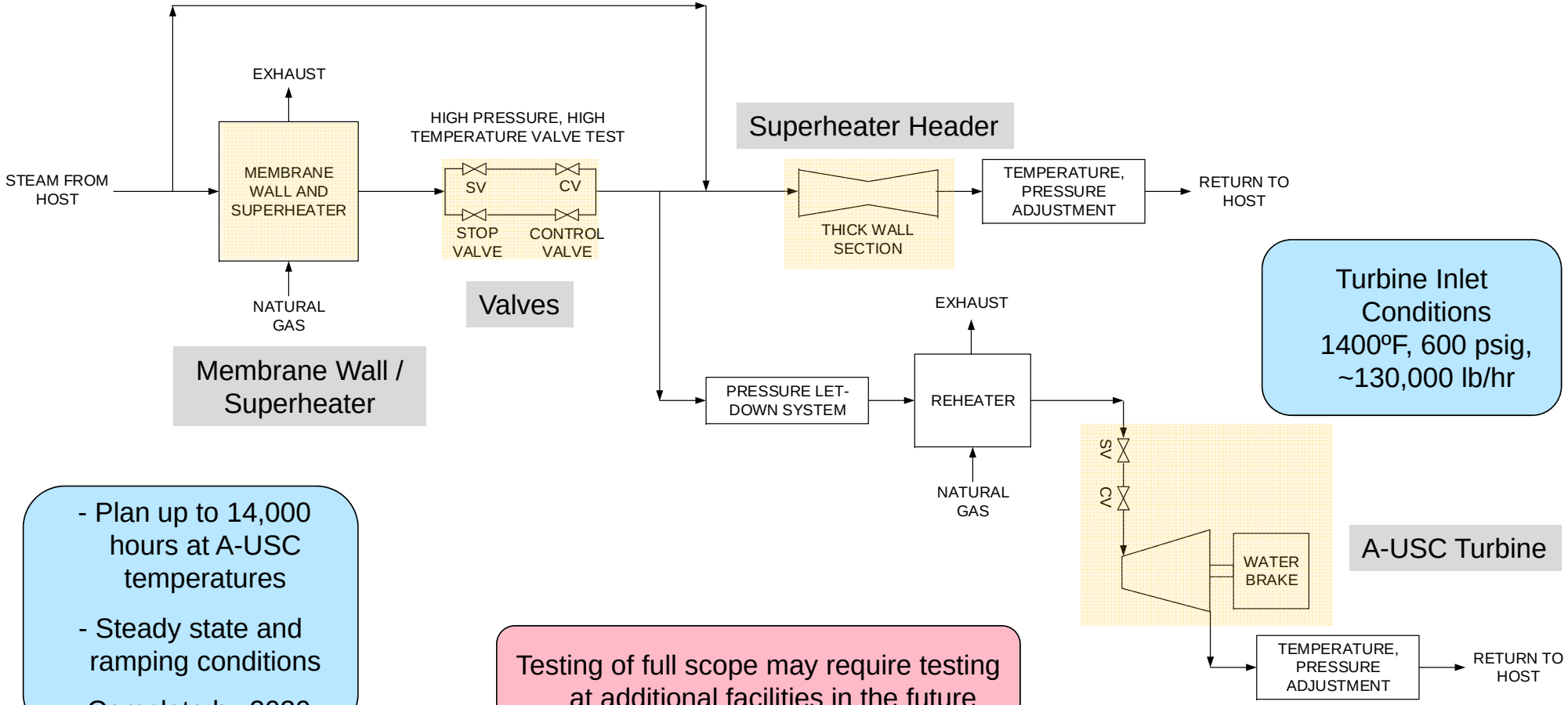
Utility Advisory Committee

- Formed in 2014 to support the development of a U.S. based A-USC Component Test Facility

- Current membership
  - Southern Company
  - AEP
  - Duke
  - FirstEnergy
  - Tri-State

- **Prioritize needs, from utility perspective, and provide critical input to build confidence in using A-USC technology**
- **Ensure A-USC technology is ready when needed by industry**
- **Support project by defining technology needs, justifying technical approach, providing potential host site(s), collaborating with the project team, and informing stakeholders**

ComTest Schematic



Turbine Inlet Conditions
1400ºF, 600 psig, ~130,000 lb/hr

- Plan up to 14,000 hours at A-USC temperatures
- Steady state and ramping conditions
- Complete by 2020

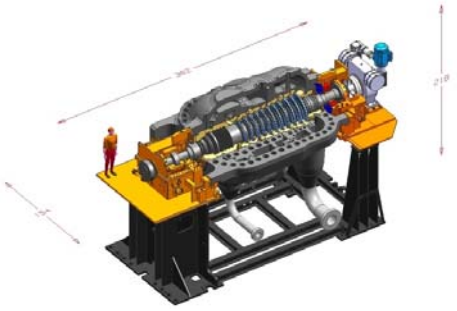
Testing of full scope may require testing at additional facilities in the future

ComTest Technical Project Goals

- Demonstrate high pressure boiler reliability and safety
  - Design, install, start-up, operate and cycle high temperature nickel components (Inconel 740H & others)
  - Large diameter thick-section piping
  - Membrane wall with advanced steels and alloys
  - Cycling header and tubes
  - Superheater materials exposure (at pressure & temperature)

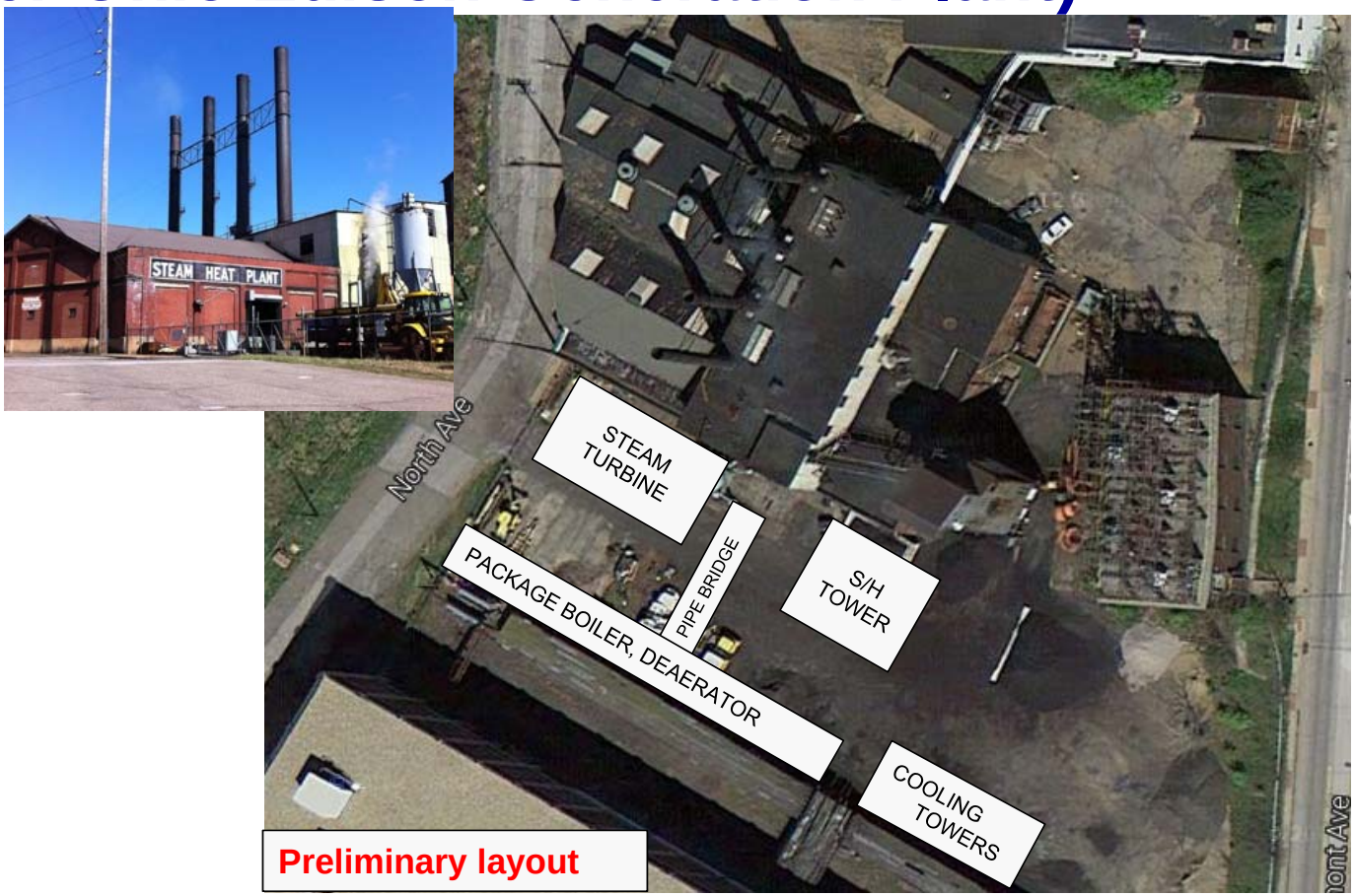
- Demonstrate high temperature turbine and components in operation
  - Design, install, start-up, operate and cycle full size steam valves & ComTest steam turbine at 760^{0}C
  - High temperature steam valves
  - Materials & coatings
  - Turbine architecture
  - Oxidation, deposits, solid particle erosion (SPE)
  - NDE/NDT

Proposed ComTest Superheater

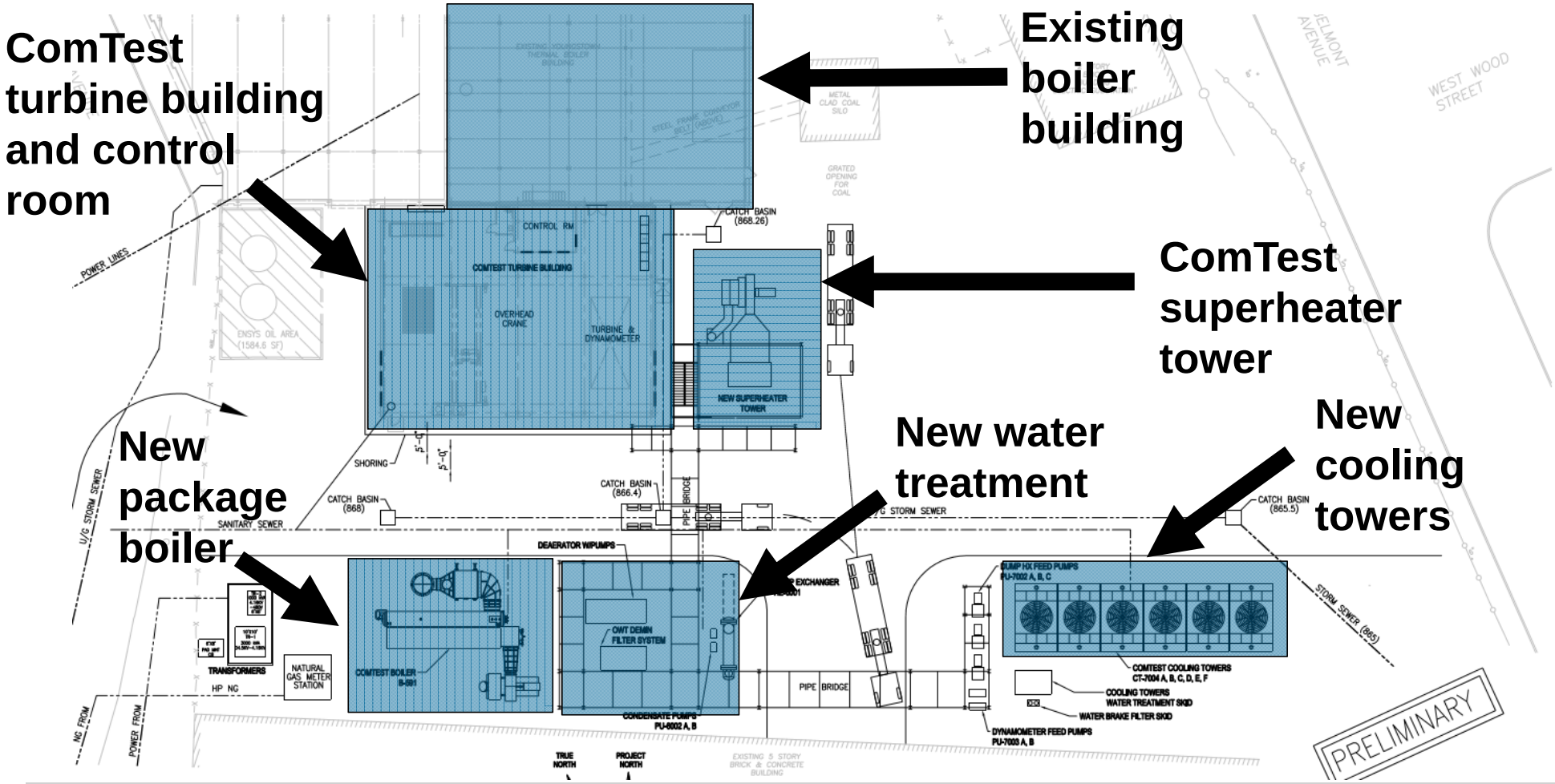


Proposed ComTest Turbine

Primary A-USC ComTest Site Youngstown, Ohio (Former Ohio Edison Generation Plant)



Equipment Arrangement Plan at Youngstown Site



Alternate A-USC High Pressure Test Site Mobile, Alabama

Accomplishments

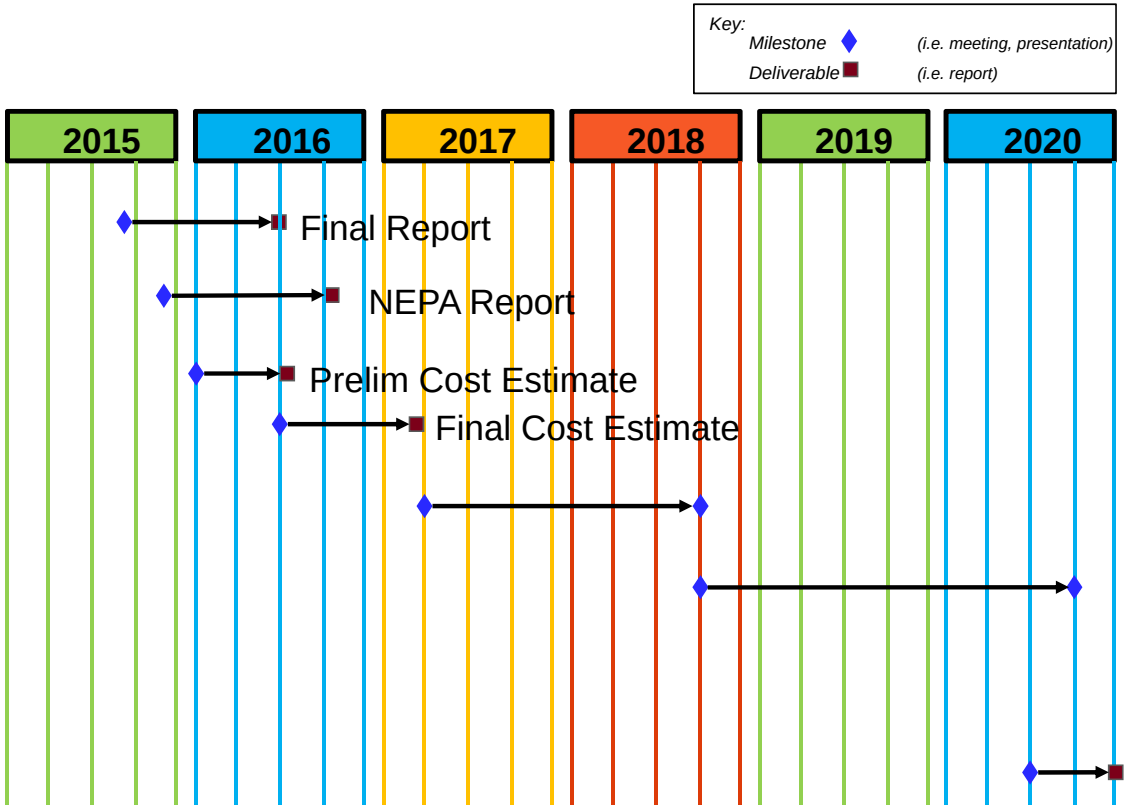
- Multiple potential host sites evaluated
- Primary and alternate host sites identified
- Pre-FEED and FEED tasks completed
  - Preliminary capital cost estimate prepared
  - PFD and P&ID documents developed
  - Interface conditions defined for scope boundaries
  - Equipment arrangement defined for host site
- US-based supply chain development ongoing
- NEPA for primary host site proceeding

Next Steps

- Proceed with Detailed Engineering effort
- Complete NEPA procedure in support of environmental assessment for host site
- Finalize testing operating plans
- Develop procurement specifications for equipment
- Construct ComTest facility
- Operate for two years (ending in 2020)

A-USC ComTest Preliminary Schedule

- Pre-FEED
- NEPA
- FEED
- Detailed Engineering
- Procurement & Construction
- Operation
  a. Membrane Wall & SH
  b. Cycling Header & Valves
  c. Steam Turbine
- Evaluation & Reporting



Transformational technologies will need the A-USC materials and components demonstrated in ComTest

A-USC Materials R&D Consortium (Boiler and Turbine)

sCO2 R&D

A-USC ComTest

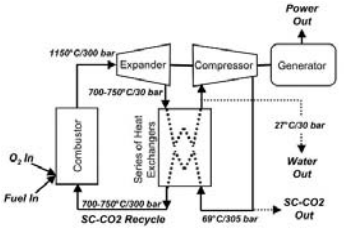
sCO2 PILOT

A-USC DEMO Plant

A-USC DEMO Topping/Retrofit/Repowering

sCO2 DEMO

ComTest provides options to enable transformational technologies



Together…Shaping the Future of Electricity