Evaluation of Steam Cycle Upgrades to Improve the Competitiveness of US Coal Power Plants

Grant: DE-FE0031535

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Project Kick-off Meeting
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Project Title:
"Evaluation of Steam Cycle Upgrades to Improve the Competitiveness of U.S. Coal Power Plants"

Submitted Under Funding Opportunity Announcement:

DE-FOA-0001728

Advanced Combustion Systems: Existing Plant Improvements and Transformational Technologies

Area of Interest 1: Advanced Combustion Coal Power Plant Improvement Technologies

Subtopic 1B: Near-Term Opportunities for Existing Coal-Based Units

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Electric Power Research Institute, Inc. (EPRI)

Meeting Topics

- Background
- Technical Approach
- Project Objectives
- Project Structure
- Project Schedule
- Project Budget
- Project Management Plan / Risk Management

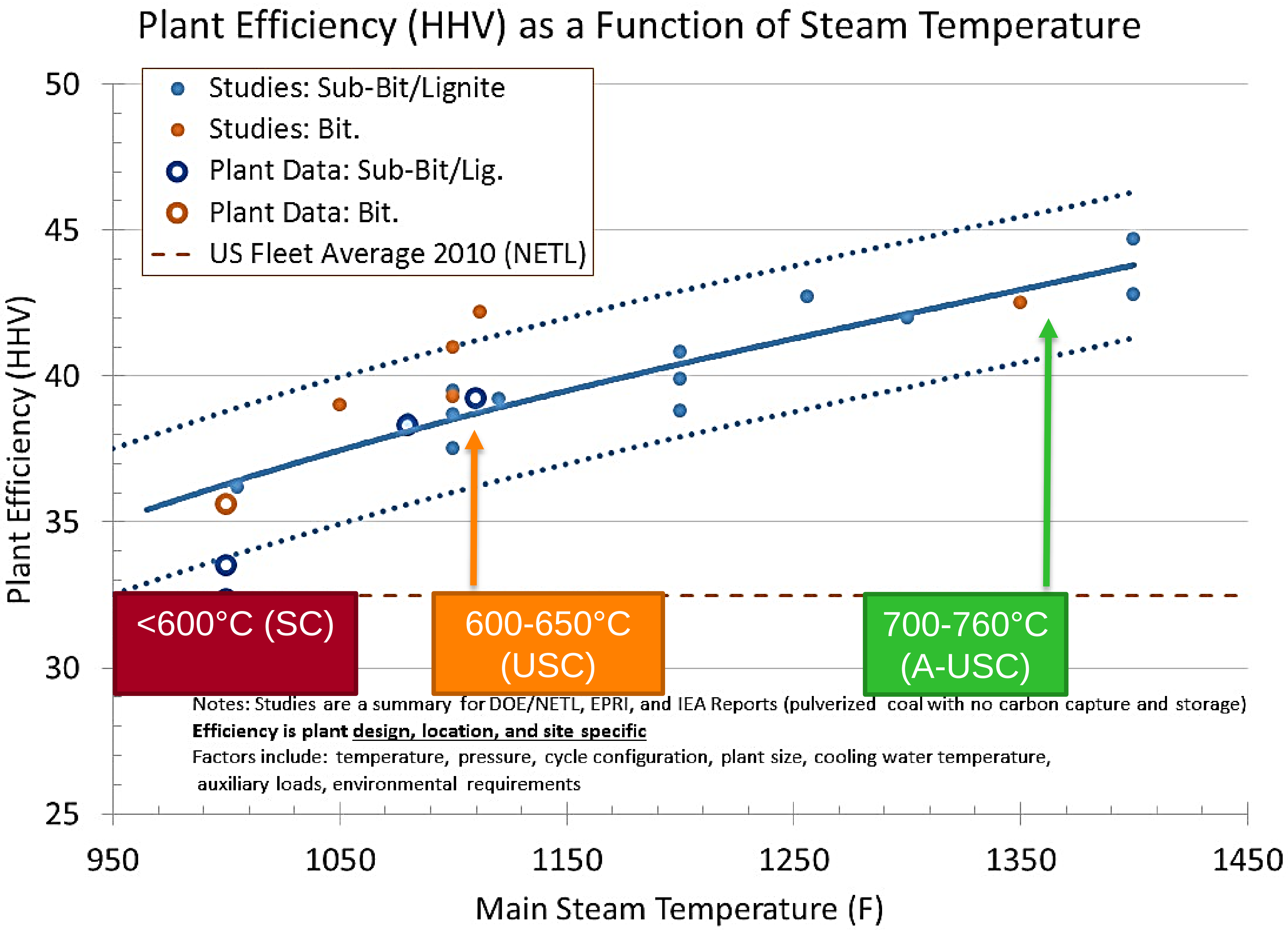
Background – Goals of FOA

- Subtopic 1B called for “R&D to improve the performance and economics of existing coal fueled plants leading to **reduced cost of operation** for coal-fired utilities and industrial scale coal-fired boilers.”
- Overall objective of the FOA was to fund “research projects to develop advanced combustion systems that will make substantial progress toward **enabling cost-competitive, coal-based power generation** systems to remain in operation and to expand coal use while meeting the goal of achieving near-zero pollutant emissions.”

Background – Strategy

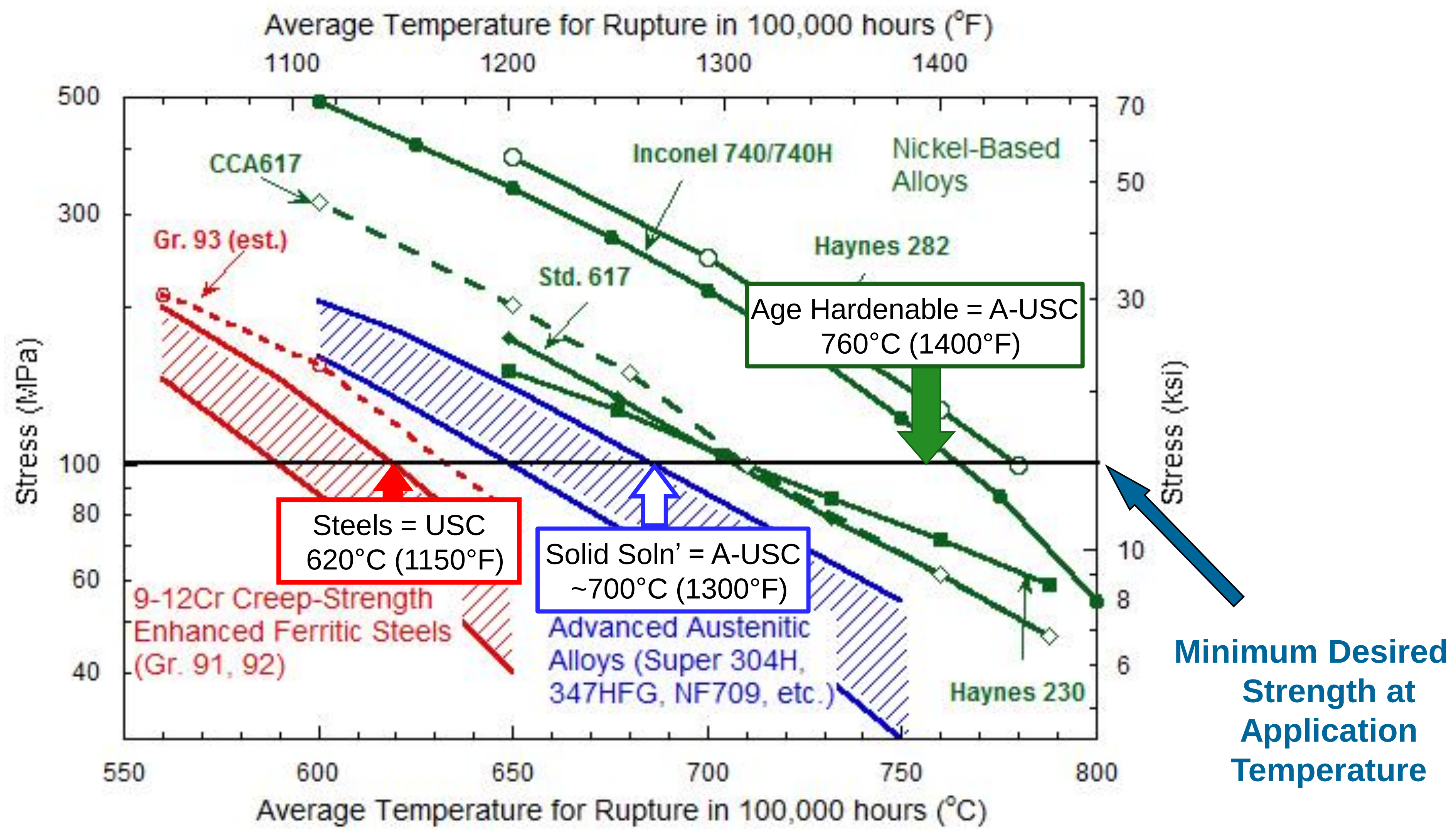
- Reduce coal consumption by decreasing heat rate, via increase in steam cycle efficiency
- Upgrade steam temperature
  - Average efficiency of US coal-fired fleet = 33% HHV
  - Efficiency increases to 41.4% HHV at 1,350°F steam temperature
- Employ advanced high-temperature materials
  - Result of DOE-funded materials R&D
- Expect higher capacity factor from increased plant efficiency

Motivation for A-USC Coal-Fired Power Plants



Advanced Materials Enable Plant Improvements

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



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Background – Challenges for AUSC Technology

- Greenfield AUSC steam plants may not be cost effective
  - Conventional USC (1100°F or 593°C) power plants use lower cost materials
- Proposed AUSC retrofits may be more cost effective option
  - Significant reuse of existing equipment – decreased capital cost
  - Increase only steam temperature – not steam pressure
    - Limit the scope of equipment replacement
      - Superheater and reheater panels
      - Steam turbine
      - Piping between the superheater/reheater and steam turbine

Technical Approach - Summary

- Maximize the applicability of the study results to existing fleet
  - 300+ units with 2,400 psia (16.6 MPa) main steam (subcritical)
  - 100+ unit with 3,500 psia (24.1 MPa) main steam (supercritical)
- Insure that results reflect actual situations in US fleet
  - Data from existing operating units supplied by Southern Company
- Employ an experienced technical team that has worked together on prior DOE-funded AUSC project (ComTest)

Technical Approach – Upgrade Cases Planned

Case Name	Main Steam Pressure	Main Steam Temp.	Reheat Steam Temp.
Subcritical Base Case	2400 psia (16.6 MPa)	1000°F (538°C)	1000°F (538°C)
Subcritical USC Option	2400 psia (16.6 MPa)	1100°F (593°C)	1100°F (593°C)
Subcritical A-USC Option 1	2400 psia (16.6 MPa)	1200°F (649°C)	1200°F (649°C)
Subcritical A-USC Option 2	2400 psia (16.6 MPa)	1000°F (538°C)	1350°F (732°C)
Subcritical A-USC Option 3	2400 psi (16.6 MPa)	1350°F (732°C)	1350°F (732°C)
Supercritical Base Case	3500 psi (24.1 MPa)	1000°F (538°C)	1000°F (538°C)
Supercritical USC Option	3500 psi (24.1 MPa)	1100°F (593°C)	1100°F (593°C)
Supercritical A-USC Option 1	3500 psi (24.1 MPa)	1200°F (649°C)	1200°F (649°C)
Supercritical A-USC Option 2	3500 psi (24.1 MPa)	1000°F (538°C)	1350°F (732°C)
Supercritical A-USC Option 3	3500 psi (24.1 MPa)	1350°F (732°C)	1350°F (732°C)
Supercritical A-USC Molten Salt	3500 psi (24.1 MPa)	1350°F (732°C)	1350°F (732°C)

Project Objectives

- Technical and economic feasibility of steam cycle upgrades to typical U.S. pulverized coal power plants
  - Subcritical: 2300–2600 psi (16.6–17.9 MPa)
  - Supercritical: 3400–3600 psi (23.4–24.8 MPa)
- Maintain steam pressures at their original values, and increase main and reheat temperatures from 1000°F (538°C)
  - USC (i.e., 1100°F or 593°C)
  - A-USC conditions (≥1300° or 704°C)

Improve heat rate while minimizing power plant modifications

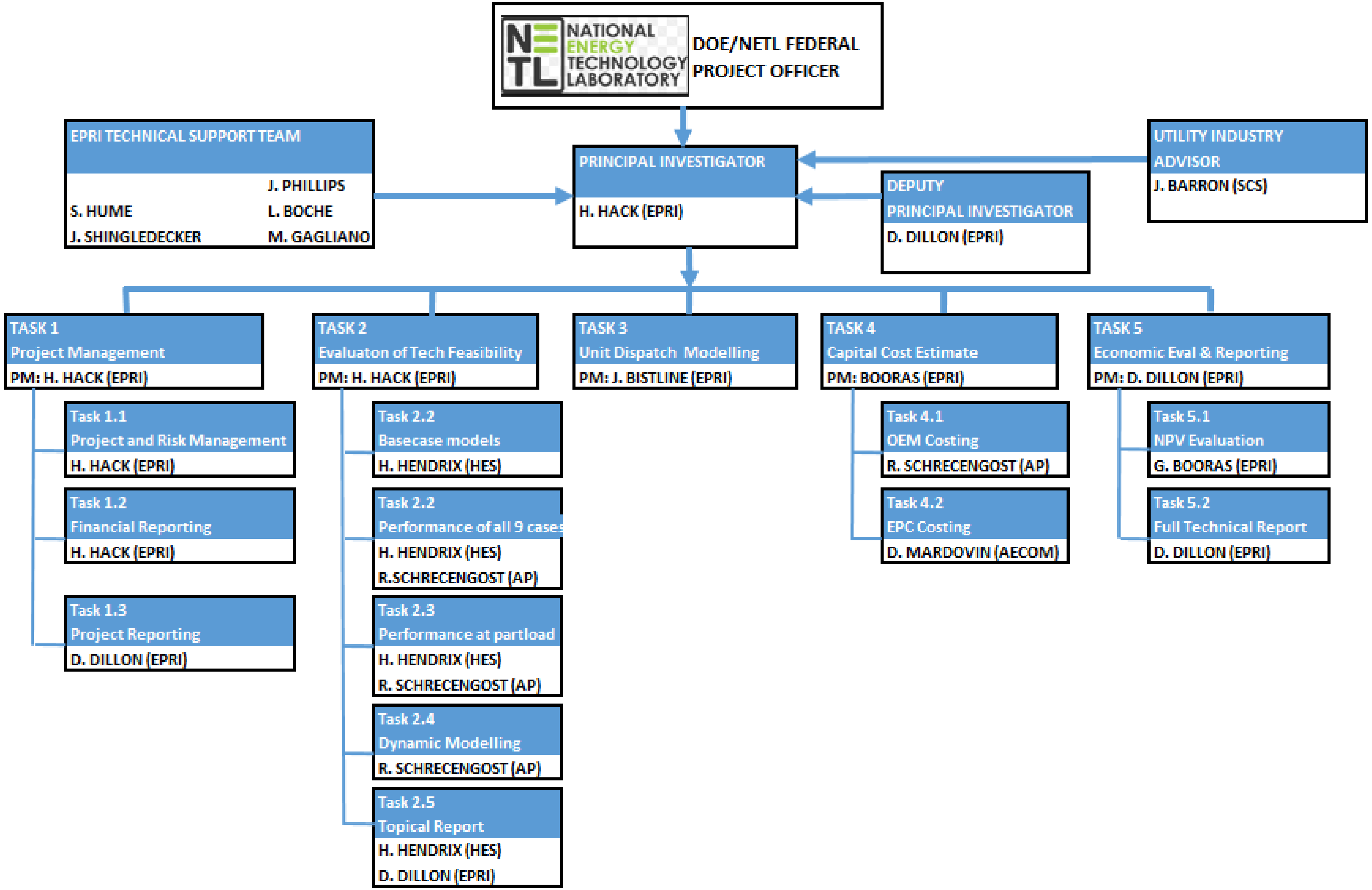
Project Structure - Tasks

- 1 Project management and planning
- 2 Evaluation of technical feasibility
  - 2.1 Thermodynamic performance models of base case at full load
  - 2.2 Impact of upgrades to base cases at full load
  - 2.3 Part load performance for flexible operation scenarios
  - 2.4 Dynamic modeling of system for fluid circulation
- 3 Unit dispatch modeling (EPRI's US-REGEN model) to 2050
- 4 Capital cost estimation to AACE Class III (+/-30%)
- 5 Overall economic evaluation

Project Structure – Team

Team Member	Funder	Role
US DOE NETL	✓	Funder
EPRI	✓	Lead Organization, Ecomomic Evaluation, Unit Dispatch Model
GE / Alstom Power	✓	Boiler and Steam Turbine Costs, Dynamic Modeling
AECOM (EPC)		Blance of Plant Costs
Hendrix Engineering		Thermodynamic Performance, Modeling & Analysis Calculations

Organizational Chart



Project Schedule – 24 Months – Starting 1/1/2018

Task No.	Milestone Description	Planned Completion
1	Kickoff meeting	2/21/18
2.1	Base case models	3/31/18
2.2	Full-load modeling of upgrade options	8/31/18
3	Unit dispatch analysis	3/31/19
4	Capital cost estimates	9/30/19
5	Economic evaluation	12/31/19
1	Final report and closeout meeting	12/31/19

Project Budget

Federal	Non-Federal	Total
$1,179,839	$302,157	$1,481,996

Project Management Plan / Risk Management

- Evaluation and technical feasibility first
- Unit dispatch modeling and capital cost estimates in parallel
- Overall economic evaluation at the end
- The milestone status and any anticipated deviation from the planned milestone schedule will be routinely reported to DOE/NETL as part of the required quarterly progress reports.

Risk Management – Technical Risks (1/3)

Description of Risk	Probability	Impact	Mitigation and Response Strategies
Project team has difficulty reaching consensus on technical direction and technology choices	Low	High	The key personnel from EPRI, Hendrix Engineering Solutions (HES), GE and AECOM have worked well together during the Pre-FEED, FEED and Detailed Engineering phases of the AUSC ComTest project and have shown they can reach consensus using fact-based analysis. Consequently, this is rated as a low risk. Nevertheless, should consensus not be reached, EPRI will serve as the final decision maker based on its position as prime along with its understanding of the needs of the power industry.
Nature and maturity of some technologies make it difficult to produce a Class-III cost estimate	Low	Moderate	Previous work on the design of the AUSC ComTest has strengthened the team's knowledge of the technology supply chain. An independent study conducted by Southern Company on integrating a molten salt heat transfer loop into an existing coal power plant has been offered to the project as a starting point for that portion of the analysis. This justifies the ranking as a low probability.

Risk Management – Technical Risks (2/3)

Description of Risk	Probability	Impact	Mitigation and Response Strategies
Performance calculations show only modest improvements in thermal efficiency before technical constraints are reached	Low	Moderate	The teams involved have significant experience in examining modifications to existing coal-fired power plants. Prior independent calculations have shown that pinch points will be encountered as the steam temperature reaches 1150-1200°F (621-649°C); however, these can be mitigated by removing heat transfer surfaces in the cold end of the boiler.
Unit Dispatch Modeling reveals only a small increase in capacity factor from the upgrades	Low	Moderate	The current electricity markets are very close to parity between natural gas combined cycles and coal power plants. Consequently, even a modest improvement in coal power plant heat rate should result in meaningful increases (>5%) in capacity factor.

Risk Management – Technical Risks (3/3)

Description of Risk	Probability	Impact	Mitigation and Response Strategies
The reduced fuel cost and increased capacity factors from the upgrades is not sufficient to offset the high capital cost	Moderate	High	The project will examine a wide range of upgrade options from modest (1100°F or 593°C) to aggressive (1350°F or 732°C). In this manner we hope to find one or more options which do offer an attractive cost/benefit ratio. Some even more aggressive options such as increasing the main steam pressure have been ruled out due to the concerns over high capital cost.

Risk Management – Resource Risks

Description of Risk	Probability	Impact	Mitigation and Response Strategies
Available DOE/NETL funding to support this work is reduced	Low	High	EPRI will work with DOE/NETL to determine if appropriate funding exists to conduct some fraction of the originally-proposed program. If so, the project team will negotiate an appropriate project scope to fit the available budget. EPRI will also seek additional cost share contributions from its utility members to allow the work to continue.
Planned project staff are not available to support project at time of award due to staff attrition or deployment on other projects	Moderate	Low	All teams have obtained commitments to ensure that proposed staffing levels can be met. For instances where staff attrition occurs, appropriate (experienced) replacements will be identified from existing staff or hired, and provided with proper training to enable them to effectively assume the vacated project responsibility. EPRI, AECOM and GE have significant bench strength to minimize this risk. While HES has only one principal, if he is unable to complete HES's proposed role, EPRI has staff which can conduct HES's tasks, albeit at a higher cost.

Risk Management – Management Risks

Description of Risk	Probability	Impact	Mitigation and Response Strategies
Negotiations associated with contracting and acceptance of project startup documents requires excessive time to complete, subsequently delaying start of the program	Low	Low	EPRI, HES, GE, and AECOM have all conducted work for DOE/NETL and with EPRI in various projects. All four organizations are familiar with EPRI's contracting requirements as well as DOE/NETL's. To minimize time, negotiations with the sub-contractors will begin as soon as DOE/NETL releases the award to EPRI. After contracts are in place, EPRI will work with its subcontractors to enable prompt startup of the project, including updating the PMP.
Project expenditures exceed the plan, resulting in a budget overrun	Low	Moderate	Because this project only involves engineering calculations and not procurement of equipment, the risk of cost overruns is low. EPRI has a good track record in conducting similar projects for DOE within budget. EPRI will employ project controls, including financial tracking and recurring meetings on schedule and budget, to monitor the project financial performance and prevent cost overruns.

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