Flameless Pressurized Oxy-combustion Large Pilot Design, Construction, and Operation: Phase I

DOE National Energy Technology Laboratory

Project Number: DE-FE0031580

5/23/2018

Principal Investigator:

Joshua Schmitt

Federal Share: $998,862

Cost Share : $249,715

Total : $1,248,577

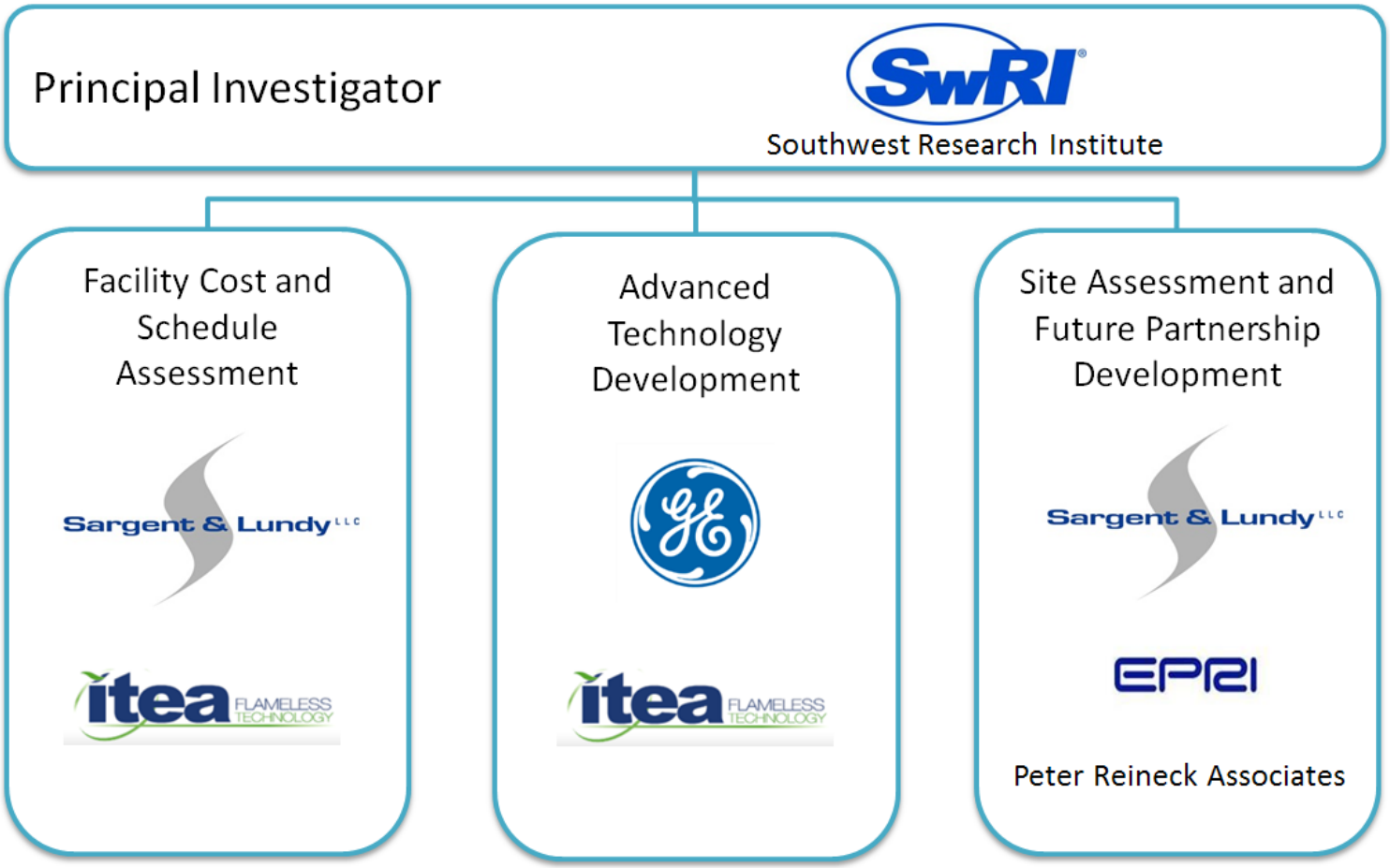
Project Team:

SwRI, Sargent & Lundy, ITEA, EPRI, GE Global Research, Peter Reineck Associates

Overview

- Team, Budget, and Schedule Overview
- Objectives
- Background on the Technology
- Project Tasks
- Project Schedule
- Project Spending
- Reporting, Deliverables, and Risk

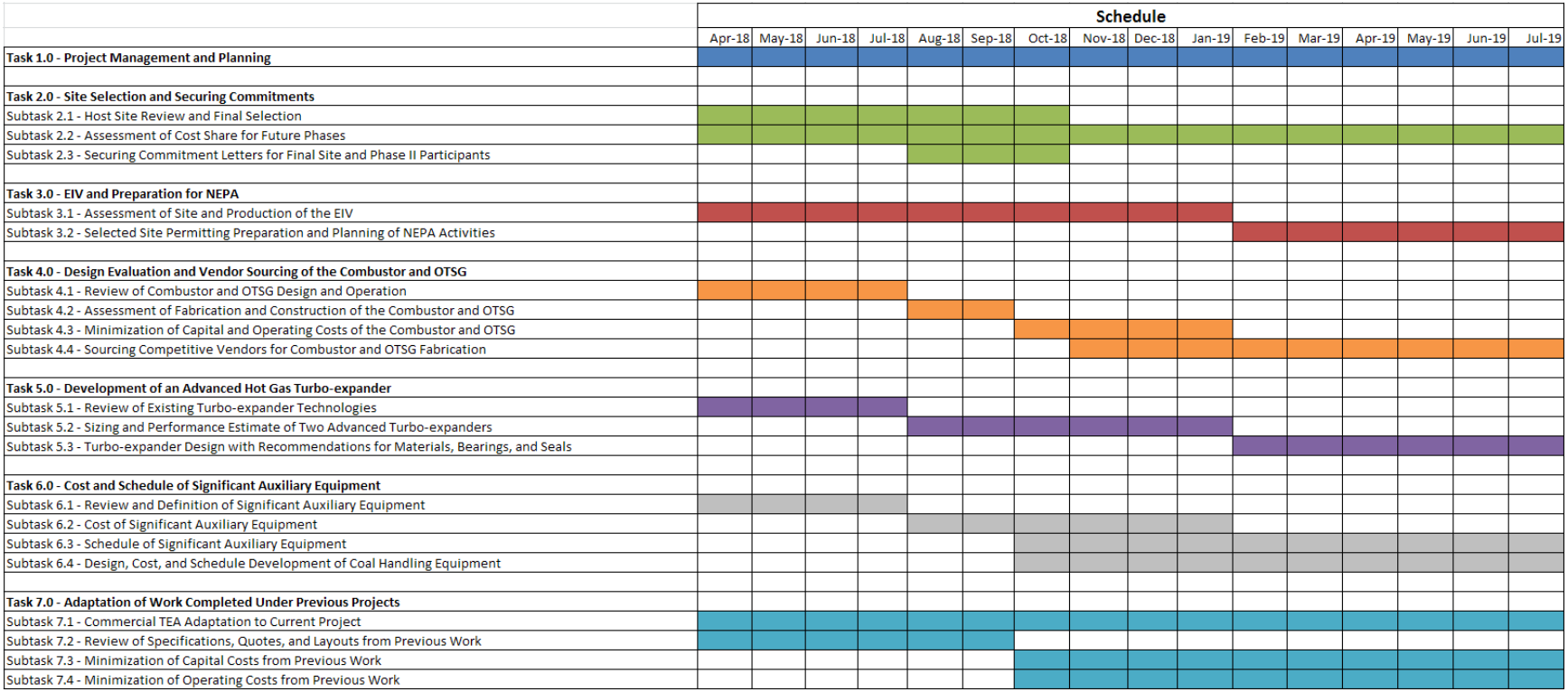
Project Team Overview



Project Budget Overview

	Budget Period 1 4/01/2018 – 3/31/2019		
	Federal Share	Cost Share	Total
SwRI	$419,126	$19,796	$438,922
Sargent & Lundy	$320,000	$80,000	$400,000
ITEA	$90,060	$90,000	$180,060
EPRI	$79,731	$19,933	$99,664
GE Global Research	$39,945	$9,986	$49,931
Peter Reineck Associates	$50,000	$30,000	$80,000
Total	$998,862	$249,715	$1,248,577
Cost Share	80.00%	20.00%	

Schedule Overview



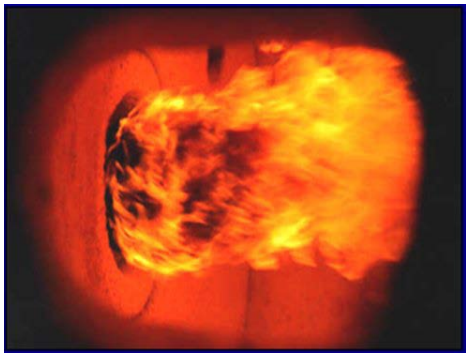
What are the objectives of the proposed project?

- Secure commitments from the chosen host site
- Create an Environmental Impact Volume (EIV) and prepare for the NEPA process
- Design evaluation and vendor sourcing of the combustor and once-through steam generator (OTSG)
- Cost and schedule of auxiliary equipment
- Adaptation of work under previous projects

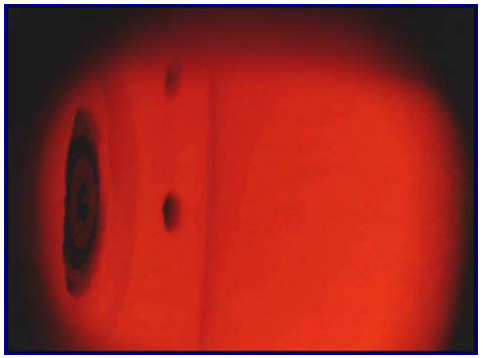
Background on FPO

- Pressurized atmosphere of water and CO_2 under "volume expanded combustion"
  - FPO combustion is more locally controllable with more uniform temperatures
  - Pressurized firing with oxy-combustion also improves cycle efficiency
- Chemical balance in combustion is near stoichiometric
  - Achieved through CO_2 recycle, water, and oxygen balance control
  - Oxidizing environment
- Almost zero carbon content in incombustible products
  - Traditional: flying and falling ash particles
    - Must be filtered and collected from gas stream
  - FPO: slag with near-zero carbon content
    - Drains out the bottom of the combustor
    - Particulate still exists in exhaust but at reduced quantities and sizes

Traditional Combustion with Flame Front

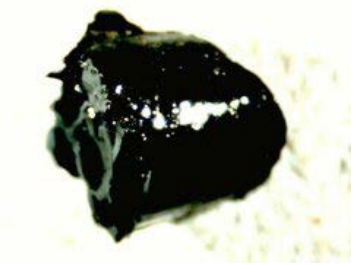


Flameless Pressurized Combustion



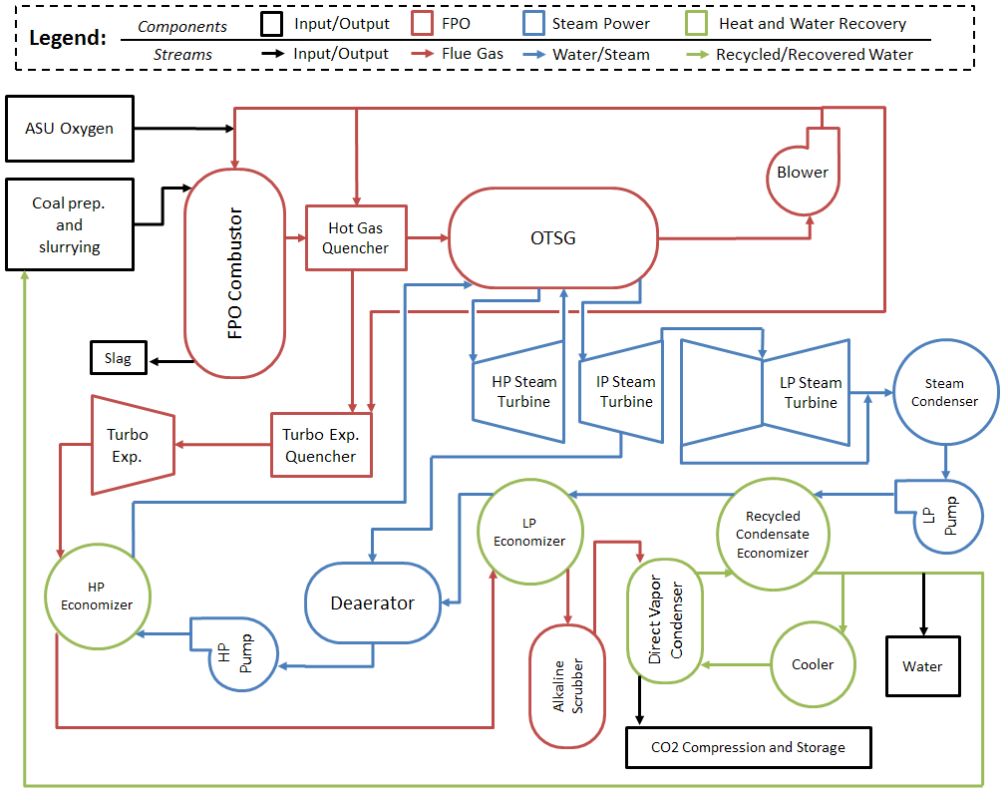
Traditional Combustor Products: Particulate

FPO Combustor Products: Near-zero carbon, neutral slag



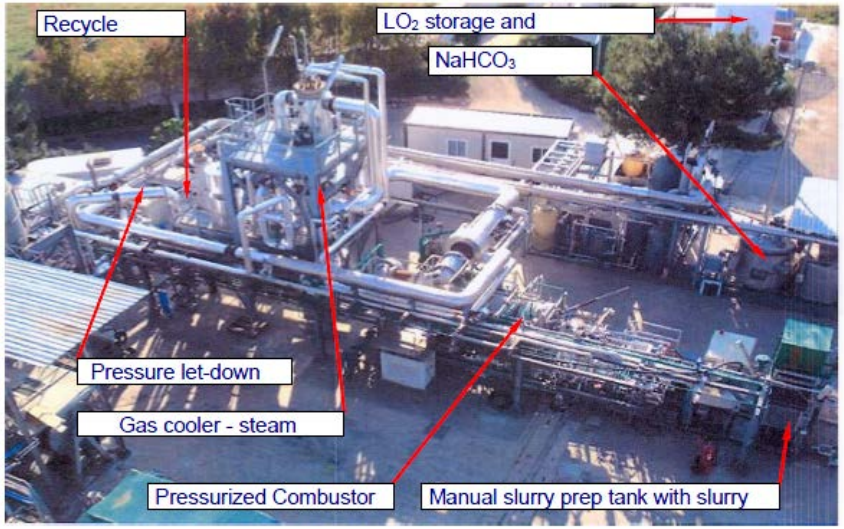
What is the FPO Cycle?

- Slurry of milled coal and water combusted under pressure
- Hot combustor gas is quenched through mixing
- Recycling flow enters OTSG
- Portion of flow leaves the process with before the OTSG with heat and pressure and is expanded
- A large percentage of combustion products are recycled
  - Some recycled flow used for quenching
  - The remainder of recycled flow is mixed with pressurized oxygen and injected into the combustor



What is the State of the Technology?

- 5 MWth plant in Italy
  - Capable of 4 bar (58 psi) pressure
  - Over 18,000 hours of testing experience
  - Technology proven with high and low rank coals
- 15 MWth plant in Singapore
  - 2 years of operation
- Components that need large pilot demonstration: Combustor, OTSG, and turbo-expander



Commercial Case for FPO

- 350 MWe commercialization study already performed by ITEA with ENEL
  - Costed out earlier version of the system
  - Provided commercial scale material and energy balances
- Update existing commercial economic assessment with results from 50 MWth design efforts
  - Targeting a 500 MWe output to match DOE baseline studies
  - Add features and components not included in the 50 MWth pilot
  - Demonstrate a path to cost reduction goals

Parameter	**Unit**	**SCPC no CC Base Line**	**ITEA FPO / Integral CCS Estimate**	**ITEA FPO / No CCS (Retrofitable)**
Power in LHV	MWth	1,345	1,410	1,410
Gross Power	MWe	580	695	695
Parasitic Power	MWe	30	145	113
Net Power	MWe	550	550	582
Efficiency % LHV	%	40.9%	39.0%	41.3%
Capital	$M	$869	$1,281	$1,243
CAPEX	$/kWe	$1,579	$2,328	$2,136
LCOE – **Bit. Coal**	$/MWh	$68	$78	$73
LCOE compared to Base Line			116%	108%
LCOE – **PRB Coal**	$/MWh	NA	$73	$68
LCOE compared to Base Line			108%	100%

Other Project (DE-FE0027771): Technical Development

- Aspen Plus Model of FPO cycle at 50 MWth and commercial scale 500 MWe
- ITEA one-dimensional modeling and CFD of OTSG and combustor
- Specification of major equipment
- Preliminary definition of pilot figures of merit
- Outline of a pilot test plan

Other Project (DE-FE0027771): Economic Development

- Preliminary selection of University of Wyoming as host, with Coal Creek, ND as backup
- Pilot plant layout, cost and schedule
- Commercial scale techno-economic assessment
- Preliminary permit plan

Project Tasks Overview

- Task 1.0 – Project Management and Planning
- Task 2.0 – Site Selection and Securing Commitments
- Task 3.0 – EIV and Preparation for NEPA
- Task 4.0 – Design Evaluation and Vendor Sourcing of the Combustor and OTSG
- Task 5.0 – Development of an Advanced Hot Gas Turbo-expander
- Task 6.0 – Cost and Schedule of Significant Auxiliary Equipment
- Task 7.0 – Adaptation of Work Completed Under Previous Projects

Task 1.0 - Project Management and Planning

- Manage project according to Project Management Plan (PMP) to meet all technical, schedule, and budget objectives and requirements
- Documentation of project plans, results, and decisions, and project reporting and briefing requirements are satisfied
- Update the PMP 30 days after award and as necessary
  - Changes to the technical basis, cost, and/or schedule for the project
  - Significant changes in scope, methods, or approaches
  - As otherwise required to ensure that the plan is the appropriate governing document for the work required to accomplish the project objectives
- Management of project risks
  - Identify, assess, monitor, and mitigate technical uncertainties and schedule, budgetary, and environmental risks
  - Document and report updates to major risk factors

Task 2.0 – Site Selection and Securing Commitments

- Subtask 2.1 – Host Site Review and Final Selection
  - Assessment of sites from previously developed work under new contractor
    - Assessment of available space, existing infrastructure, accessibility, environmental considerations, cost-share potential, and other factors
  - The final site recommendation will be delivered in the Phase I Topical Report
- Subtask 2.2 – Assessment of Cost Share for Future Phases
  - Interview the power industry
    - Solicit feedback on the proposed technology, the pilot-plant project, and their potential for providing cost
    - Up to 15 total organizations to be selected in consultation with the team
    - A set of questions will be developed and the feedback will be included in the Phase I Topical Report

Task 2.0 – Site Selection and Securing Commitments

- Subtask 2.3 – Securing Commitment Letters for Final Site and Phase II Participants
  - Negotiations with sites and other interested parties that have the potential of adding third-party cost share to the project
  - By mid-way through Phase I, commitment letters will be delivered to the DOE
    - The host site
    - Any parties deemed necessary in Phase II

Task 3.0 – EIV and Preparation for NEPA

- Subtask 3.1 – Assessment of Site and Production of the EIV
  - An EIV will be developed for the primary candidate site
    - The EIV will follow DOE guidelines and describe characteristics of the site that will assist in completing the NEPA process
- Subtask 3.2 – Selected Site Permitting Preparation and Planning of NEPA Activities
  - Any additional arrangements or permits needed with the site
    - Approaching or securing a NEPA contractor

Task 4.0 – Design Evaluation and Vendor Sourcing of the Combustor and OTSG

- Subtask 4.1 – Review of Combustor and OTSG Design and Operation
  - A review of the combustor and OTSG technology
  - Assess the design for capabilities, limitations, and potential for cost reduction
- Subtask 4.2 – Assessment of Fabrication and Construction of the Combustor and OTSG
  - The steps needed to fabricate and construct the combustor and OTSG in the U.S. will be produced and analyzed for feasibility
  - Requirements for quality control, tolerances, and other concerns in fabrication will be addressed under this subtask

Task 4.0 – Design Evaluation and Vendor Sourcing of the Combustor and OTSG

- Subtask 4.3 – Minimization of Capital and Operating Costs of the Combustor and OTSG
  - Design of the combustor and OTSG will undergo minor revision to improve capital costs
    - Assessment of materials and other cost drivers will also help improve the cost of these components
    - A review will be made of the operating requirements of the combustor and OTSG and this analysis will target areas of potential operating cost reduction
- Subtask 4.4 – Sourcing Competitive Vendors for Combustor and OTSG Fabrication
  - In an effort to minimize cost, the team will solicit multiple bids from vendors for the combustor and OTSG fabrication
    - These bids will be selected for cost, capability, and quality control

Task 5.0 – Development of an Advanced Hot Gas Turbo-expander

- Subtask 5.1 – Review of Existing Turbo-expander Technologies
  - Assessment of current technologies used for expansion of hot flue gas from coal fuel sources
  - Select two candidate turbo-expander designs for assessment
    - Design criteria and a weighted decision matrix
- Subtask 5.2 – Sizing and Performance Estimate of Two Advanced Turbo-expanders
  - Two candidate advanced turbo-expander designs will be evaluated with one-dimensional performance models
  - Preliminary sizing of the turbo-expander with performance estimate

Task 5.0 – Development of an Advanced Hot Gas Turbo-expander

- Subtask 5.3 – Turbo-expander Design with Recommendations for Materials, Bearings, and Seals
  - A turbo-expander design will be chosen
    - Basis of performance results and stress and material requirements
    - Preliminary design will be used to develop the high temperature turbo-expander in Phase II

Task 6.0 – Cost and Schedule of Significant Auxiliary Equipment

- Subtask 6.1 – Review and Definition of Significant Auxiliary Equipment
  - Further development of valves, piping, balance of plant equipment, and other equipment
  - Not addressed in previous development efforts
  - Auxiliary equipment must contribute significantly to the pilot cost or schedule to merit early design development
- Subtask 6.2 – Cost of Significant Auxiliary Equipment
  - The cost of the significant auxiliary equipment will be incorporated into an overall project cost estimate

Task 6.0 – Cost and Schedule of Significant Auxiliary Equipment

- Subtask 6.3 – Schedule of Significant Auxiliary Equipment
  - A schedule for fabrication and construction or procurement of significant auxiliary equipment
  - Integrated into an overall project schedule adapted from previous work
- Subtask 6.4 – Design, Cost, and Schedule Development of Coal Handling Equipment
  - A coal handling system will be designed
  - The team will go into further detail of the coal handling equipment required for FPO
  - The cost and schedule of the necessary equipment will be added to the estimations from previous work

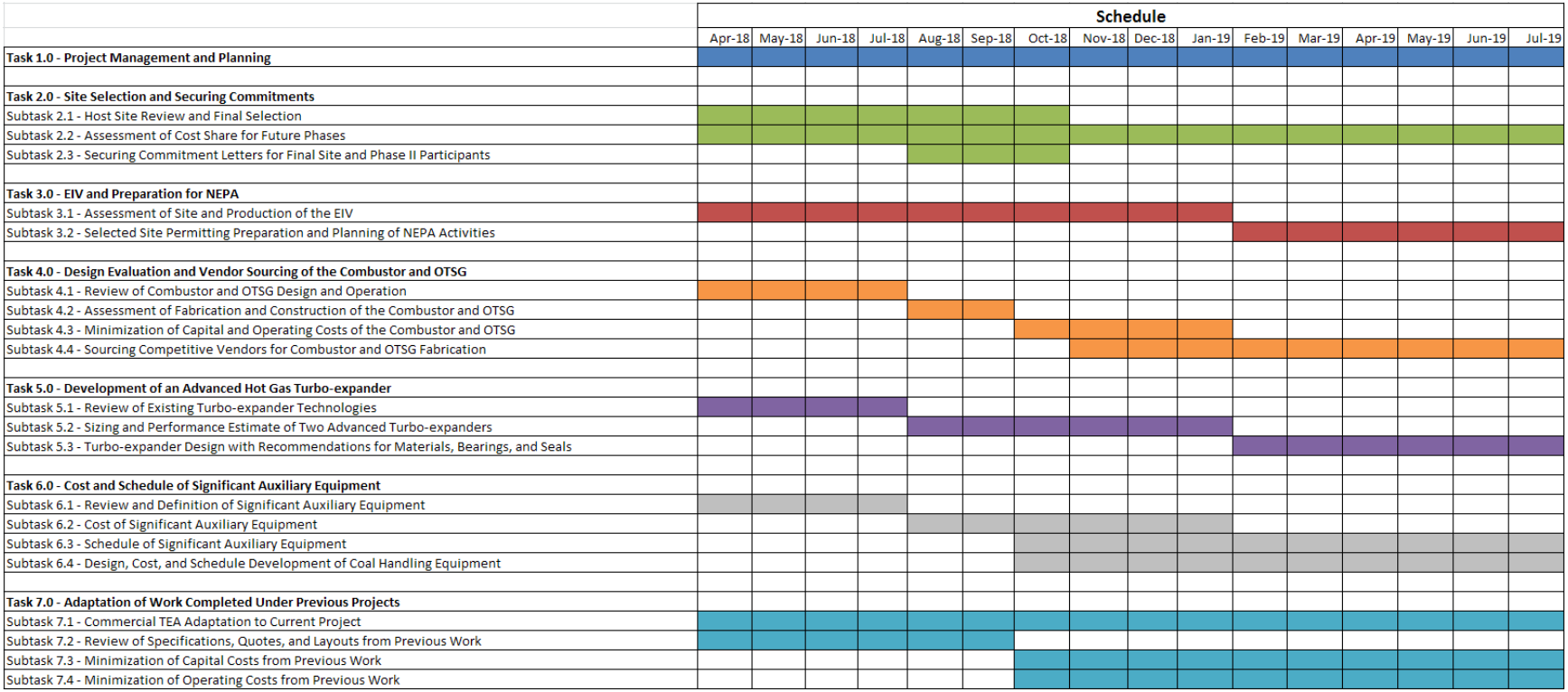
Task 7.0 – Adaptation of Work Completed Under Previous Projects

- Subtask 7.1 – Commercial Techno-Economic Analysis (TEA) Adaptation to Current Project
  - A review of the pilot-plant cost estimation and the commercial TEA,
    - Supporting and validating that the costing properly uses the NETL QGESS report procedures and complies with required AACE estimate class
- Subtask 7.2 – Review of Specifications, Quotes, and Layouts from Previous Work
  - Conduct an assessment of the work that has already been completed
    - Team members not involved in previous work
    - Help assess the equipment that requires further development or are under-defined in specifications from previous work

Task 7.0 – Adaptation of Work Completed Under Previous Projects

- Subtask 7.3 – Minimization of Capital Costs from Previous Work
  - An assessment of the capital costs of the large pilot
    - Review of vendor quotes
    - Target areas of high capital cost and seek methods to reduce the costs
    - Effort to optimize overall system costs and minimize pilot funding requirements
- Subtask 7.4 – Minimization of Operating Costs from Previous Work
  - An assessment of the operating costs of the large pilot
    - A review start-up, shutdown, and operating procedure
    - Staffing and personnel requirements will be analyzed for excess in cost
    - Safety and operational standards will be checked
    - Minimize pilot-plant cost share and funding requirements
- Subtask 7.5 – Cost and schedule estimates
  - Revised design information to update the cost and schedule estimates for Phases II and III.

Schedule Review



Milestone Log

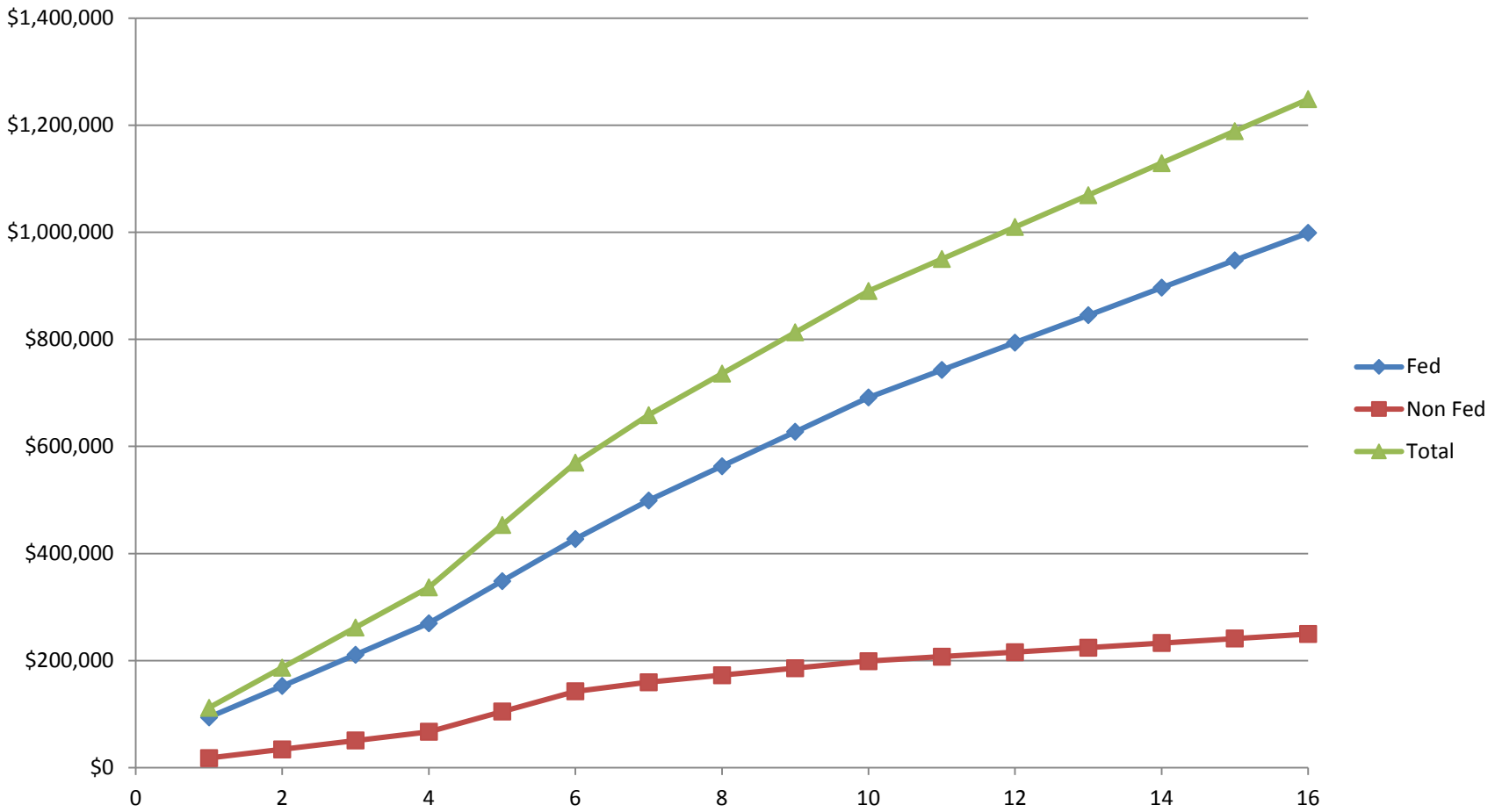
Number	Budget Period	Task/Sub-task No.	Milestone Description	Planned Completion	Actual Completion	Verification Method
M1	1	1.0	Updated PMP, DMP, TMP	04/30/2018		PMP, DMP, and TMP file
M2	1	1.0	Kickoff Meeting	04/30/2018		Presentation file
M3	1	2.1	Selection of final host site	10/31/2018		Commitment letter from host site
M4	1	3.1	Completion of the Environmental Impact Volume	01/31/2018		Phase I Topical Report
M5	1	7.0	Preliminary cost, schedule, and economic analysis	03/31/2019		Phase I Topical Report
M6	1	5.0	Advanced hot gas turbo-expander initial development complete	07/31/2019		Phase I Final Report
M7	1	6.0	Complete cost and schedule update of significant auxiliary equipment	07/31/2019		Phase I Final Report

Risk and Mitigation

Description of Risk	Probability (Low, Moderate, High)	Impact (Low, Moderate, High)	Risk Management (Mitigation and Response Strategies)
Technical Risks:			
Site selected back out of commitment	Moderate	High	Pursue secondary site based on the top three selected sites from previous work
Turbo-expander cannot be designed to survive flue gases	Low	Moderate	Use commercially available turbo-expander at reduced temperature specified in previous work
Vendors unavailable for domestic sourcing of Combustor and OTSG	Moderate	High	Return to more costly international sources for exotic parts unavailable in the United States
Resource Risks:			
Personnel unavailable to complete tasks	Low	Moderate	Develop contingency plan. Seek resources from other partner organizations that can meet the workload
Management Risks:			
Geographically separated groups do not coordinate efforts	Moderate	High	Utilize regular meetings to coordinate efforts; use regular status reports to gauge results and document milestones

- **Miscommunication and duplication of work** - Regular meetings and reports
- **Overspending** – Real time tracking with project management system, competitive quotes
- **Shortage of resources** – SwRI has over two million square feet of lab space and over 3,000 employees

Projected Spending



Reporting and Deliverables

- Additional Reports
  - Final Site and Phase II Participant Commitment Letters (Subtask 2.3)
  - Phase I Topical Report (Task 2.0-7.0)
- Quarterly Reporting (within 30 days)
  - Research Performance Progress Report (RPPR)
  - SF-425 Federal Financial Report
- Final Scientific/Technical Report (within 90 days)
  - Final SF-425, Invention Certification (within 90 days)
  - Subject Invention Reporting, Invention Utilization Reporting
  - Final Property Report (SF-428, SF-428B)
- Reports within 5 days of event
  - Special Status
  - Journal Article-Accepted Manuscript
  - Scientific/Technical Conference Paper/Presentation or Proceedings

Thank You