Next Generation Durable, Cost Effective, Energy Efficient Tubular SOFC

DE-FE0031674

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Summary

- **Solid Oxide Fuel Cell (SOFC)** - “Powder to Power” all in one 30,000 sq ft facility in Walpole, MA
- Customers include oil and gas, telecommunications, rail, environmental monitoring, mining, construction and US Coast Guard
- Market leader in remote continuously available power
  - ~600 systems sold; 6,000,000+ field operating hours
- Commercial Product - ideally suited for off-grid applications
- Commercial technology suitable for JP8/Diesel fuels as well
- Strong track record of development
- Poised for rapid growth

Commercial Fleet

- **Fleet**
  - 6,000,000+ hours of field operation
  - Installed in major oil & gas, telecom, transportation and mining
- **Distribution & Support**
  - Eleven(11) channel partners to provide sales, commissioning & post-sale support

Project Objectives

- **Low Cost, Reliability, Efficiency are key to wider market acceptance and durable remote power source**
- **Ultimate project aim is for a low degradation and low cost fuel cell system through improved technology and production automation**
  - Reduction in production cost (increase yield by real time shrinkage control, use mass production technique)
  - Reduction in labor cost (co-sintering)
  - Faster ROI (increased efficiency through near direct HC utilization)
  - Increase in reliability and longevity (low temperature operation, performance enhancement, flexible fuel feed quality)
- **2000 hour demonstration of a low cost, low degradation, high performance natural gas fueled 2.5kW stack by September 2020.**

Strategies

I. Cell Technology Innovations

1. High performance and robust interconnect material
2. Enhancement of anode transport and electrical conduction
3. Highly active and durable catalyst for improved ORR (ALD of cathode)
4. Reduction of electrolyte polarization
5. Optimization of tubular cell geometry (area to volume ratio)

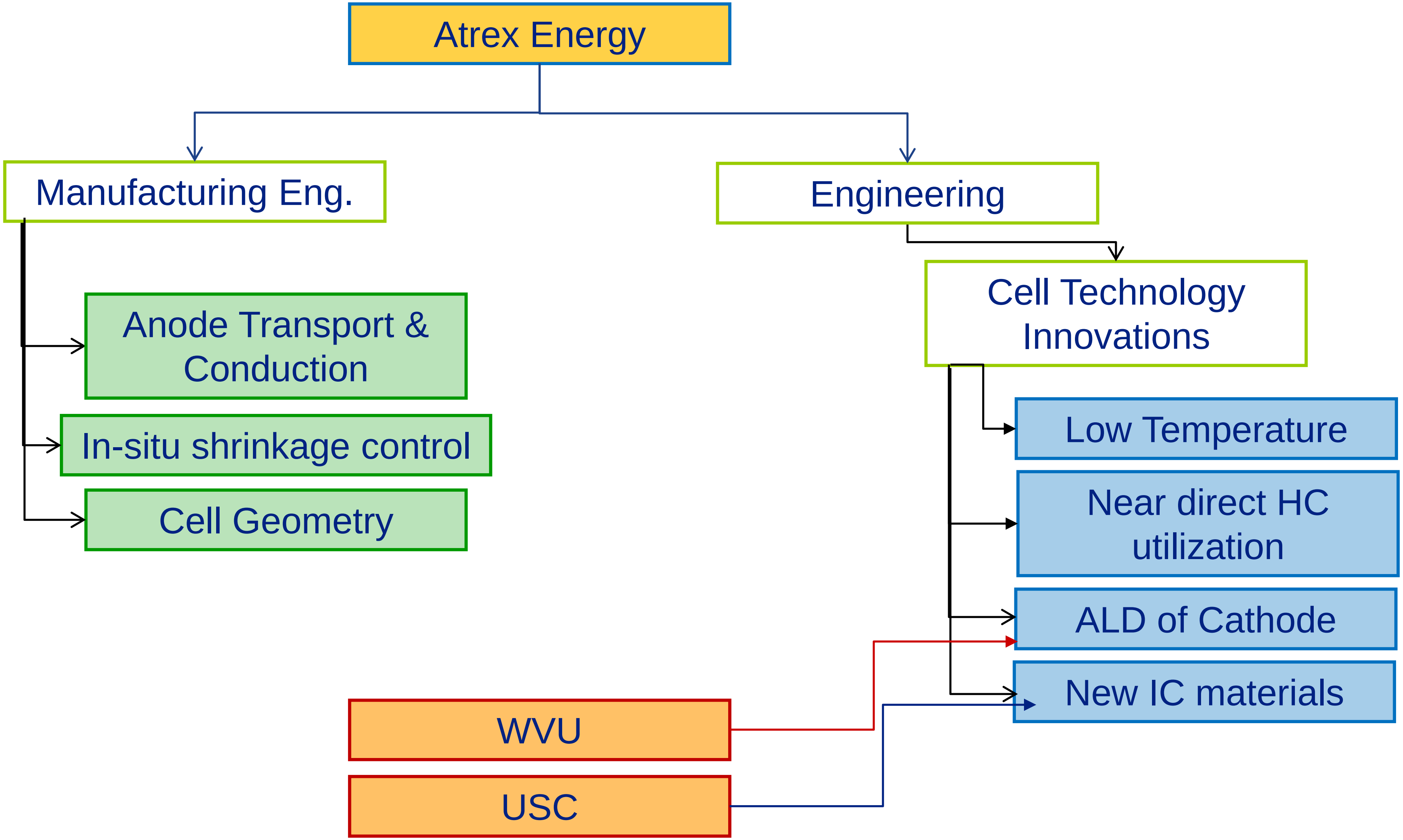
II. Low Cost, High Energy Efficiency Fuel Processing

III. Manufacturing Innovations

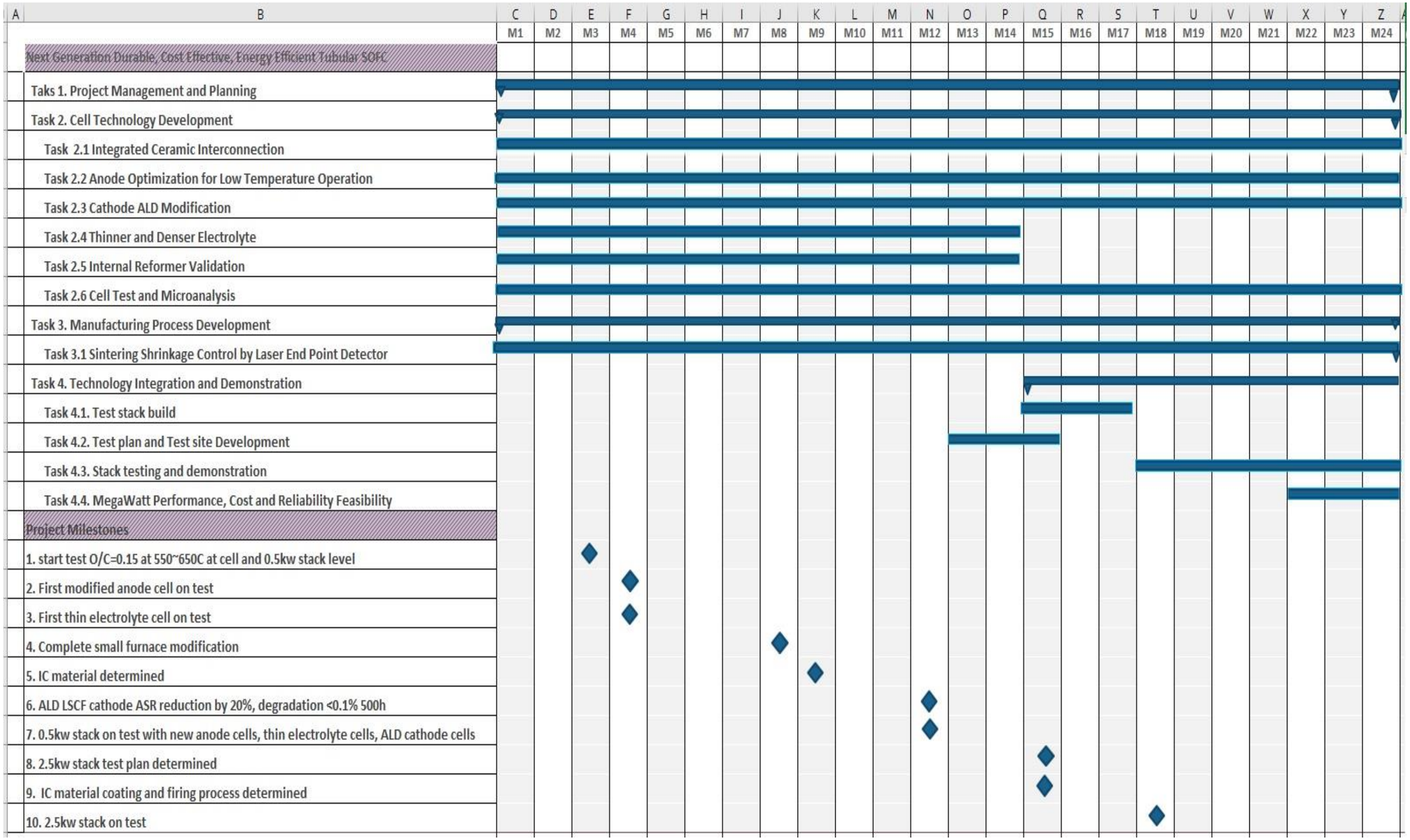
Technological Approach to Low Cost Reliable SOFC Systems

No.	Innovation	Degradation	Reliability	Low temperature performance	Cost	Energy Efficiency	Risk
1	New IC materials		✓		✓		Med.
2	New IC coating method		✓		✓		Med.
3	ALD of cathode	✓	✓	✓		✓	Med
4	Thin electrolyte	✓		✓	✓		Low
5	Anode transport and conduction	✓	✓	✓		✓	Low
7	Optimization of cell geometry		✓	✓	✓	✓	Low
8	Real time shrinkage control		✓		✓		Low
9	Near direct HC utilization operation		✓	✓	✓	✓	Low

Project Structure: Company and University Effort



Schedule (October2016–September 2018)



Project Milestones

Milestone No (SOPO Task No.)	Milestone Description	Verification Method	Planned Completion
1 (2.5)	start test O/C=0.25 at 550~650C at cell and 0.5kw stack level	Testing data	12/31/2018
2 (2.2)	First modified anode cell on test	Cell performance (550~650C)	1/31/2018
3 (2.4)	First thin electrolyte cell on test	Cell performance (550~650C)	3/31/2019
4 (3.1)	Complete small furnace modification	Sintering piece size measurement data	7/31/2019
5 (2.1)	Interconnection material determined		7/31/2019
6 (2.3)	ALD LSCF cathode ASR reduction by 20%, degradation <0.1% 500h	Performance data	7/31/2019
7 (2.2.1)	0.5kw stack on test with new anode cells, thin electrolyte cells, ALD cathode cells	Performance data	11/30/2019
8 (2.2/2.3/2.4)	2.5kw stack test plan determined		12/31/2019
9 (2.1)	IC material coating and firing process determined		12/31/2019
10 (4.3)	2.5kw stack on test	Performance data	2/28/2020

Current Progress

- **Program Management**
  - DOE contract has been signed
  - NDAs with USC and WVU have been signed
  - Sub contracts with USC and WVU imminent: expected to be signed soon
  - Technical teams and meeting schedules are in planning
- **Technical**

Funding Profile

	Fiscal Year 2019			Fiscal Year 2020		
	Federal Share	Non-Federal Share	TOTAL	Federal Share	Non-Federal Share	TOTAL
October	$65,035	$16,330	$81,366	$71,803	$18,017	$89,821
November	$65,035	$16,330	$81,366	$71,803	$18,017	$89,821
December	$65,035	$16,330	$81,366	$71,803	$18,017	$89,821
January	$93,388	$23,450	$116,838	$103,106	$25,873	$128,979
February	$93,388	$23,450	$116,838	$103,106	$25,873	$128,979
March	$93,388	$23,450	$116,838	$103,106	$25,873	$128,979
April	$93,388	$23,450	$116,838	$103,106	$25,873	$128,979
May	$93,388	$23,450	$116,838	$103,106	$25,873	$128,979
June	$72,124	$18,111	$90,234	$79,629	$19,982	$99,611
July	$72,124	$18,111	$90,234	$79,629	$19,982	$99,611
August	$72,124	$18,111	$90,234	$79,629	$19,982	$99,611
September	$72,124	$18,111	$90,234	$79,629	$19,982	$99,611
TOTAL	$950,539	$238,686	1,189,225	$1,049,459	$263,342	1,312,801

	Budget Period 1 10/01/2018-09/30/2019		**Budget Period 2 10/01/2019-03/30/2020**		**Total Project**	
	Gov’t Share	Cost Share	Gov’t Share	Cost Share	Gov't Share	Cost Share
Atrex	$1,067,245	$180,554	1,138,996	$204,444	$1,539,998	$384,998
Univ.of South Carolina	$99,306	$24,778	$100,694	$25,365	$200,000	$50,143
West Virginia University	$129,015	$33,354	$130,985	$33,533	$260,000	$66,887

Program Risk- Technical

Table 1: Risk Assessment Chart: Technology

Description of Risk	Probability	Impact	Overall Degree of Risk	Risk management and mitigation strategy
High resistance of new interconnection material	Moderate	Moderate	Moderate	•Double doping will be exploited to increase electronic conductivity in dual atmospheres • Bilayer option will be explored in parallel in case single materials do not work •The demonstration of other innovations does not depend on the implementation of new interconnection
Reliability of modified anode	Low	Low	Low	•Cell testing will start very early in this project so that modifications can be tested often and as necessary • This is not prerequired for the implementation of other innovations
Long term stability of cathode catalyst by ALD	Low	High	Moderate	•The preliminary experiment will be continued to collect long term degradation data in order to identify the issue and exercise mitigation measures in time. • Evaluation will be conducted in parallel at WVU and Atrex.
Reliability of thin electrolyte	Low	Moderate	Moderate	•We will start single cell testing in early stage of project to evaluate thin electrolyte to identify the potential issue and exercise mitigations as early as possible •If 4~6um has reliability issues, we will target 8~10um.
Laser guided anode shrinkage control	High	Low	Moderate	• Design work will be started early in the project • Experiment will be started with small furnace, and go no-go evaluation will be conducted so that unnecessary capital investment in robotics does not take place • The 2.5kW demonstration and any of the performance and degradation metrics does not depend on the laser guided shrinkage control

Program Risk- Resources and Management

Description of Risk	Probability	Impact	Overall Degree of Risk	Risk management and mitigation strategy
Resource Risk				
Atrex personnel diverted to other projects	Low	High	Moderate	• The goal of this proposed project is in line with our mission. The manufacturing tasks selected for the project are from an internal review for mass production. • The PIs for the project have been selected from the management and executive level and will re-address resources as needed.
Staff Attrition	Low	High	Moderate	•If staff leave Atrex or USC or WVU, resources from within the company will be reallocated and new personnel will be hired as soon as possible. • Atrex' plan in general is to maintain a redundancy of expertise to avoid such problems
Insufficient funding	Low	Low	Low	•The tasks in this .project can be highly leveraged against current awards or external research contracts if supplementary funds are required to complete a task.
Management Risks				
Poor management	Low	Moderate	Moderate	The project will be reviewed by the Director biweekly. Insufficient progress will be escalated to the executive level and weekly reviews will commence from that point.
2.5kW demonstration schedule delays	Low	High	Moderate	Atrex has accumulated experience in delivering 3 and 10kW SOFC projects. Atrex will use all resources possible to stay on schedule, however delays outside Atrex' control will be reported to the DOE project manager.