Painesville Municipal Electric Power Vanadium Redox Battery Demonstration Project

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Briefing Overview

- Painesville Municipal Electric Power Plant Project Synopsis
- Vanadium Redox Flow Battery Technology
- City of Painesville Municipal Electric Plant History
- Project Multiple Objectives and Additional Detail
- Project Risk Analysis presented at previous Peer Review
- Project to date progress
- Cost Distribution
- Summary/Conclusions
- Future Tasks
- Questions

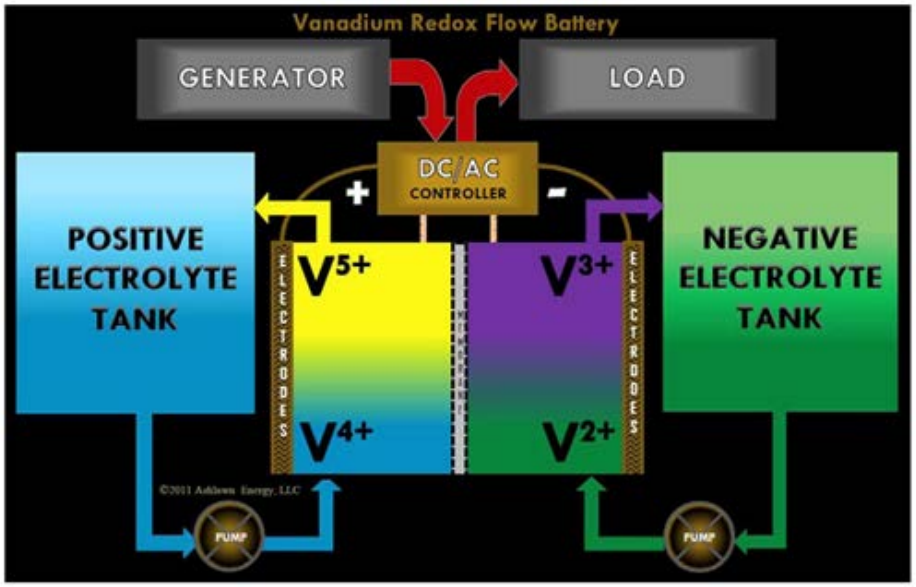
US Produced Vanadium Redox Flow Battery for Bulk Storage, Peak Shaving

- 8 MW Hour redox flow battery (1MW 8 hours)
- To be installed at Painesville Municipal Electric Plant (PMEP), a 32 MW coal fired facility
- Most efficient PMEP operation is steady state at 26 MW (lowest emissions, lowest operating cost)
- Nominal PMEP power demand ranges from 19 MW to 37 MW
- 8 MW Hour battery to demonstrate benefits of energy storage at PMEP

Ashlawn's VanCharg™ Technology

What is VanCharg™?

- Ashlawn Energy's vanadium redox flow battery
- Electricity storage system
- Made in the USA



Advantages:

- Power and Energy Storage are independent
- It is a closed loop system that doesn't need refueling
- Systems last 30 years
- Operationally safe
- Operates in wide temperature ranges
- Low maintenance
- Interfaces with SCADA through software
- FLEXIBLE FOR MANY USES
  - Frequency Regulation
  - < 50 millisecond response
    - Black Start
    - UPS
  - Incorporating wind & solar
  - Peak shaving
- AFFORDABLE

Vanadium Redox Flow Battery

- Power is not tied to energy storage capacity
- Construction is modular
- Safe
- Extended deep cycle life (>5,000 cycles)
- Affordable

Modular Design

Stack Modules-Higher Power

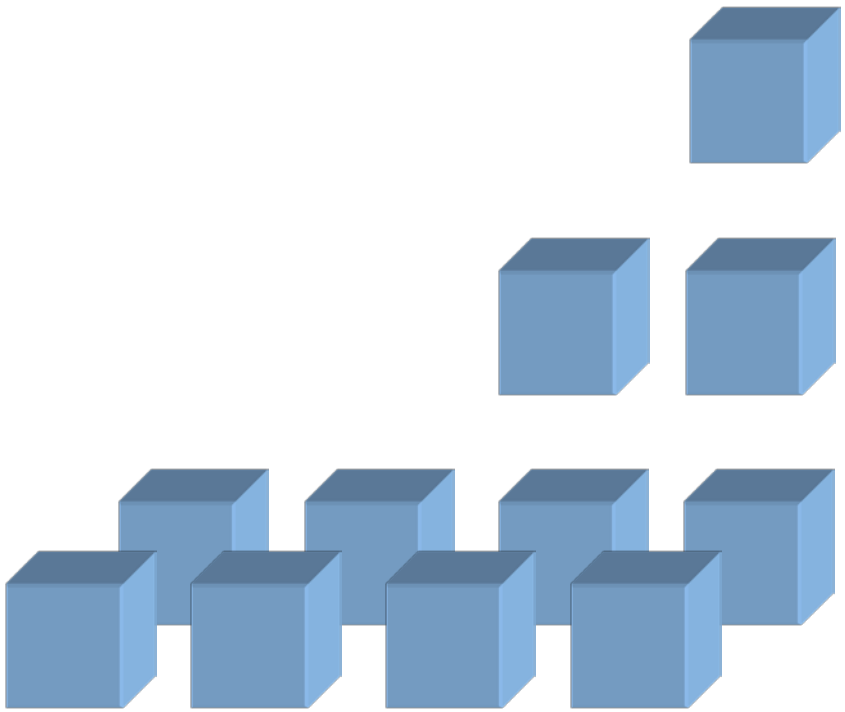
Painesville building block – 10kw stack
1 Module below of 160 kw is made up of 16, 10kw stacks

Continuous Discharge Rate (kW)

1 Module (160 kW)

2 Modules (320 kW)

8 Modules (1.28 MW)



Modular Design

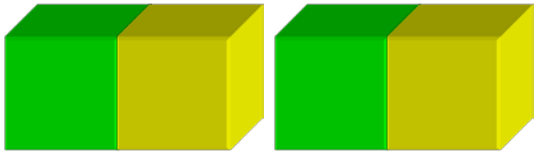
Vanadium Electrolyte Modules-Higher Molarity

Painesville Storage time
The amount of Vanadium Electrolyte dictates storage time in hours

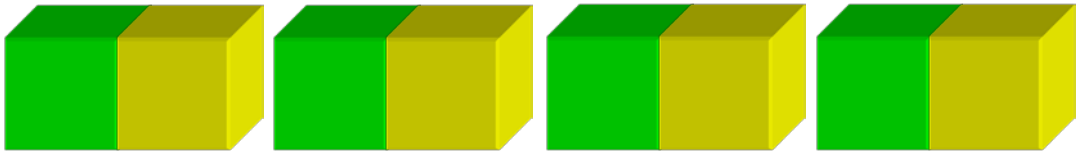
Capacity (kWh)

320 kWh = 3,300 G

640 kWh = 6,600 G



1.28 MWH = 13,200 G



History of Painesville Power

1885 - Established by the Globe Electric Company, the Painesville Council contracted for street lights at $6 per light per month.

1888 - Council sold bonds raising $12,500 to erect an Electric Light Plant on N. St. Clair near Main Street in back of the old Fire and Police Station (now public parking lot). The plant continued in operation until 1908. Municipal Electric Systems in Painesville and was adopted by Resolution 223.

1907 - Painesville Cider and Manufacturing Company property (site of present Light Plant) was purchased for $2,250.

1908 - A new plant was put into operation. The Commercial Electric Company phased itself out of operation around this time.

1923 and again in 1928, large general expansions of the plant facilities created by an increasing demand for electric power in the growing Painesville area.

1923 - a 1500 kilowatt steam turbine generator manufactured by Allis-Chalmers was installed to replace the existing reciprocating engine type generators and continued in operation until the late 1950s. This was the first large steam turbine at the Light Plant.

Additional Coal fired boilers steam turbines generators and allied equipment have been added to the Light Plant over the course of the years.

The American Public Power Association's grouping of Centennial Cities and Towns lists Painesville's system as the 10th oldest in the country of those communities that still operate their systems. In addition, it is one of 14 municipally-owned electric systems in Ohio still generating, and the oldest still in continuous operation.

Painesville Municipal Electric Power Plant

Battery Building Site

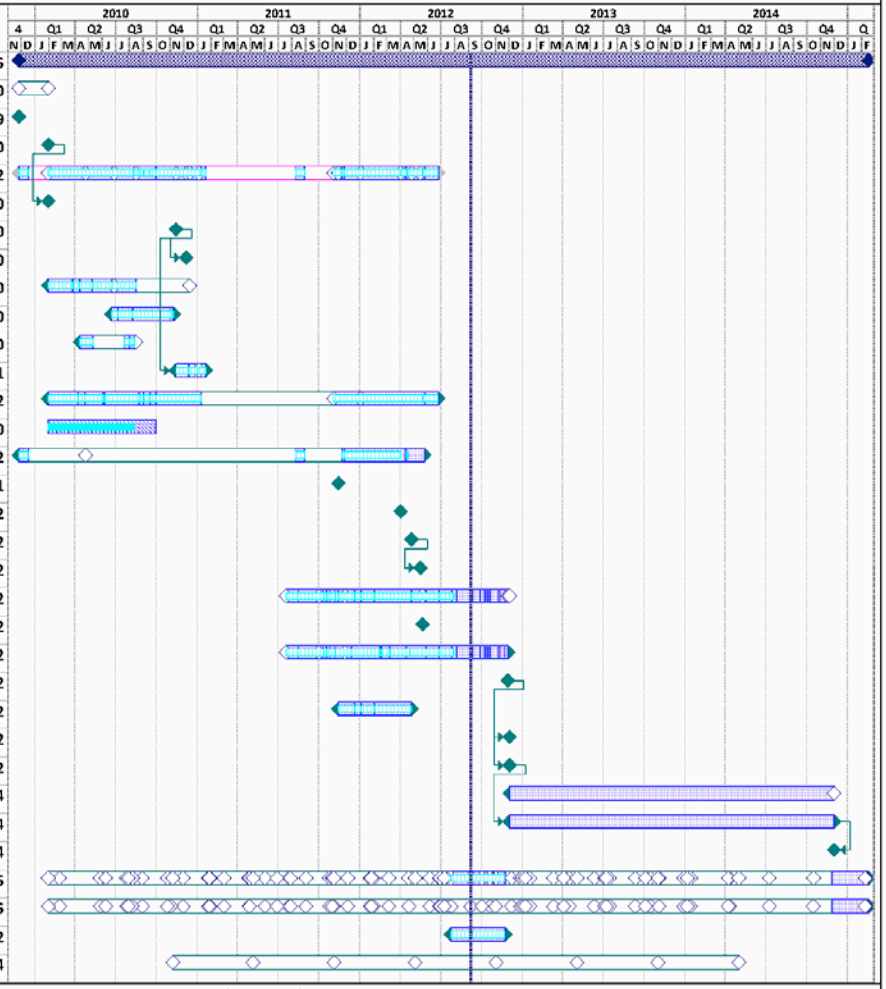
Project has Multiple Objectives

- **Establish/Use US Manufacturing Base**
  - Stack components/stack fabrication
  - Electrolyte
  - Power Conditioning System
- **Demonstrate Efficacy/Reliability of latest Vanadium Redox Flow Battery Design**
- **Cost Reduction**
- **Platform for Commercially Viable Product**

Current Overall Schedule

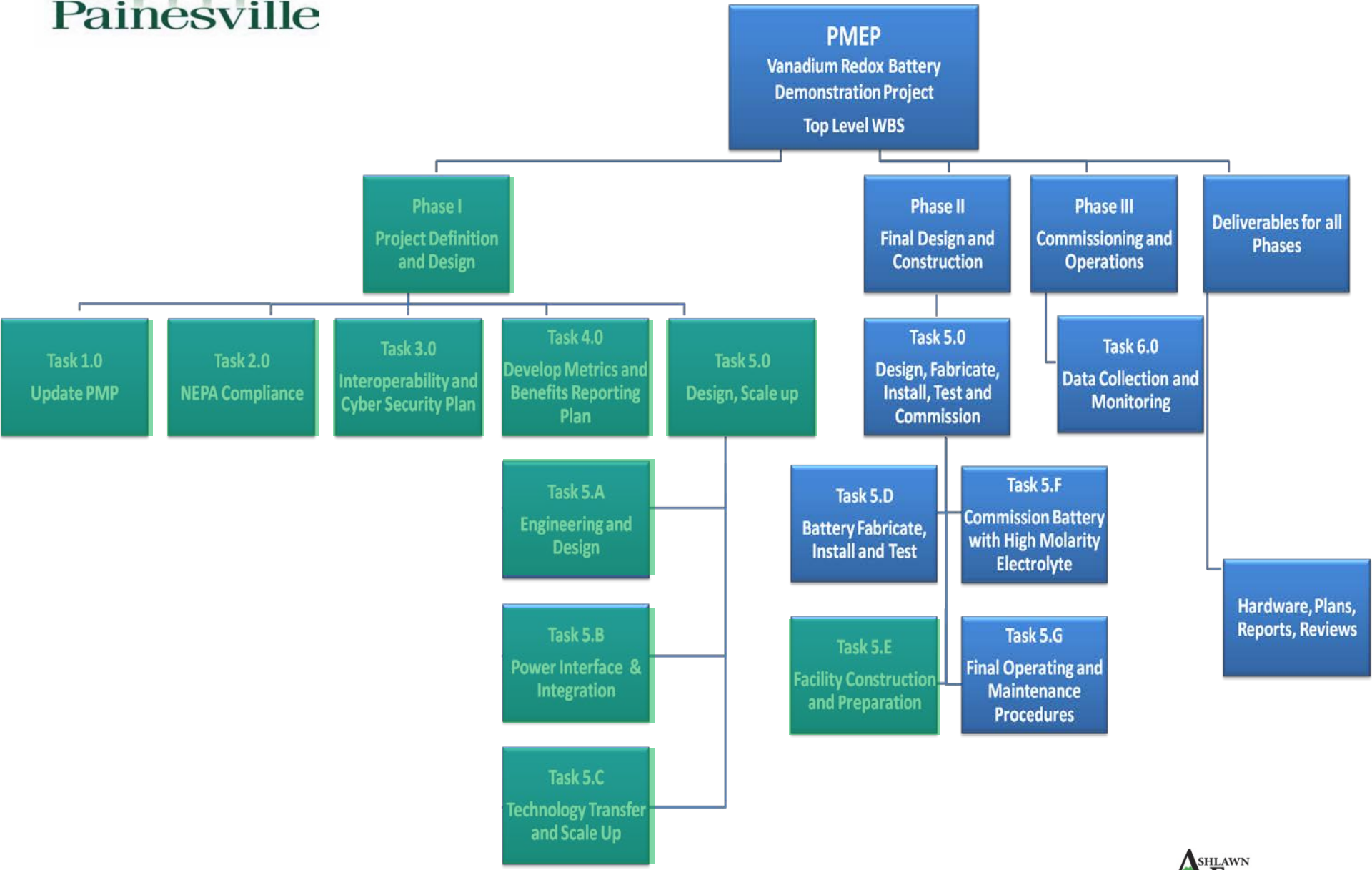
Project: 1 Battery Group with 20 kW Stacks-Painesville Ohio-Schedule
Date: 9/5/12

ID	Phase/Task	WBS	Task Name	Start	Finish
0	Painesville		Painesville Vanadium Redox Battery Energy Storage Project	11/27/09	2/18/15
1		1	Pre-Award Activities	11/27/09	2/1/10
2		1.1	Contract Announcement	11/27/09	11/27/09
3		1.2	Contract Agreement Award with Stipulations	2/1/10	2/1/10
4		2	Phase I Project Definition and Design	11/27/09	6/26/12
5		2.1	Phase I Release	2/1/10	2/1/10
6		2.2	Project Definitization Complete	11/15/10	11/15/10
7		2.3	Kick Off Meeting	12/7/10	12/7/10
8	Task 1	2.4	Update Project Management Plan	2/1/10	12/15/10
16	Task 2	2.5	National Environmental Protection Act (NEPA) Compliance	6/23/10	11/9/10
22	Task 3	2.6	Develop Interoperability and Cyber Security Plan	4/13/10	8/16/10
27	Task 4	2.7	Develop Metrics and Benefits Reporting Plan	11/15/10	1/20/11
32	Task 5.A	2.8	Engineering for this Specific Application at PMPP	2/1/10	6/26/12
92	Task 5.B	2.9	Power system interface and integration	2/1/10	9/30/10
93	Task 5.C	2.10	Technology Transfer and Scale Up-CTC Test Matrix	11/27/09	5/25/12
110		2.11	Phase II Release	11/15/11	11/15/11
111		2.12	Freeze Flow Frame Design for 10 kW Stack Frame	4/3/12	4/3/12
112		2.13	10 kW Stack Go/No Go Decision	4/27/12	4/27/12
113		2.14	Mixed Acid Go/No Go	5/16/12	5/16/12
114		3	Phase II Final Design and Construction	7/20/11	12/3/12
115		3.1	20 kW Split Stack Go/No Go Decision	5/22/12	5/22/12
116	Task 5.D	3.2	Battery Fabrication, Installation and Testing (1.12 MW)	7/20/11	11/30/12
186		3.3	Release 8 MW hour Battery For Operations	11/29/12	11/29/12
187	Task 5.E	3.4	Facility Construction and Preparation	11/15/11	4/26/12
196	Task 5.G	3.5	Release Final Operating and Maintenance Procedures	12/3/12	12/3/12
197		3.6	Go/NO GO Decision for Data Collection and Monitoring	12/3/12	12/3/12
198	Task 6	4	Phase III Commissioning and Operations	12/3/12	12/2/14
199		4.1	Data Collection and Monitoring	12/3/12	12/2/14
202		4.2	Release Final Data Collection Information to Publishing	12/2/14	12/2/14
203		5	Deliverables	2/1/10	2/18/15
204		5.1	DOE Required Reports	2/1/10	2/18/15
334		5.2	Phase II Deliverable Hardware	7/25/12	11/23/12
336		5.3	Conference Papers Proceedings and Reviews	11/8/10	5/2/14



Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Top Level WBS



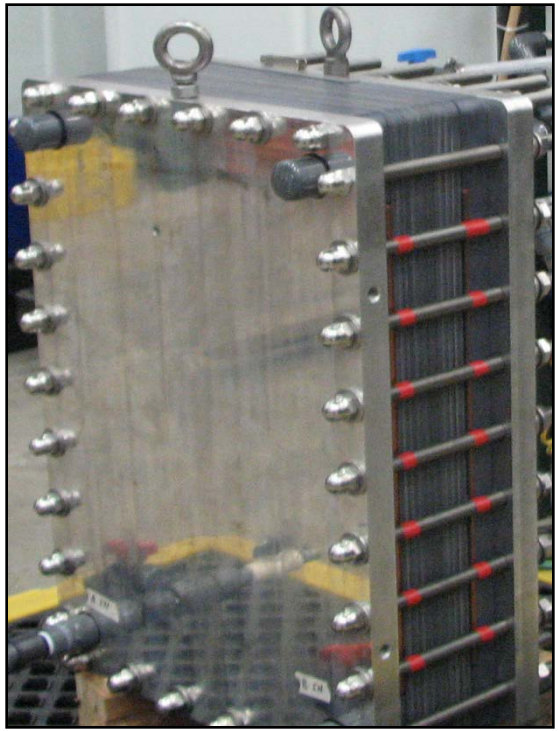
Green shading denotes complete

Project Risk Analysis Reported at Previous Peer Review

- 10 kW stack prove out and electrolyte pricing are key to meeting cost targets
- Process design schedule confirmation is key to meeting building schedule
- Higher molarity electrolyte is key to storage time target
- Process design changes will demonstrate round trip efficiency improvements

Current Progress

- **Stack Design**
  - Performance Capability of 10 kW Milestone Stack Verified
  - New, All Composite Stack (not shown) being tested
    - Lower Weight/Lower Cost/Improved Sealing/Faster Assembly Time



  - 20 kW Stack Design Concept Confirmed

Current Progress

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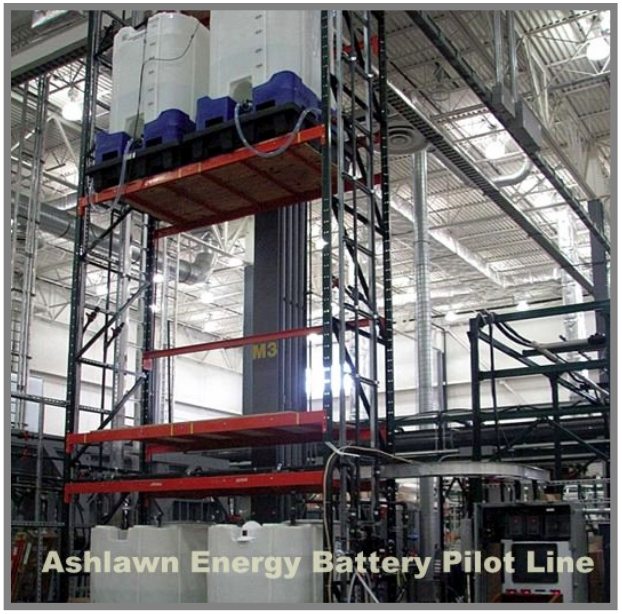
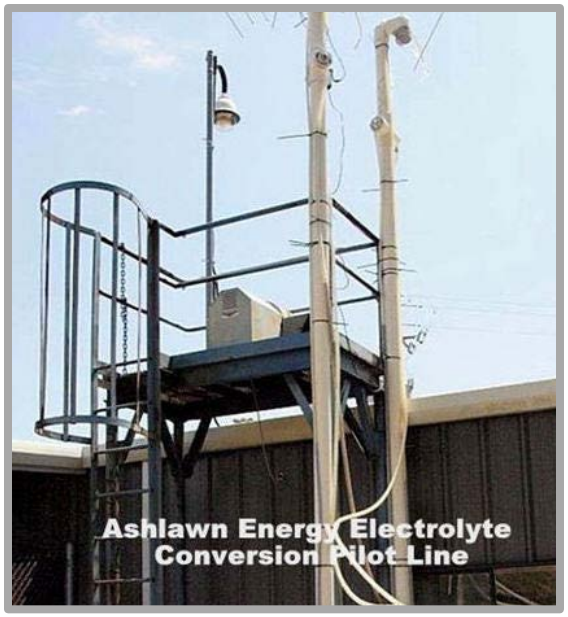
- **Domestic Production and Testing Capability**
  - Battery Test Bed System upgraded to confirm full scale pumping rates, shunt current levels, new SOC measurement methodology





  - Electrolyte from 2 producers validated thereby establishing US production capability (two additional producers products in test)
  - Various Low Cost Membranes, Bi-Polar Plates and Felt Approved for use
  - Flow Frame Mold Steel at Mold Supplier, awaiting final flow frame design

Current Progress

(Continued)

- Dedication of Ashlawn Battery Stack Assembly Building in Painesville

Current Progress

(Continued)

- Ashlawn Battery Stack Assembly Building in Painesville

Current Progress

(Continued)

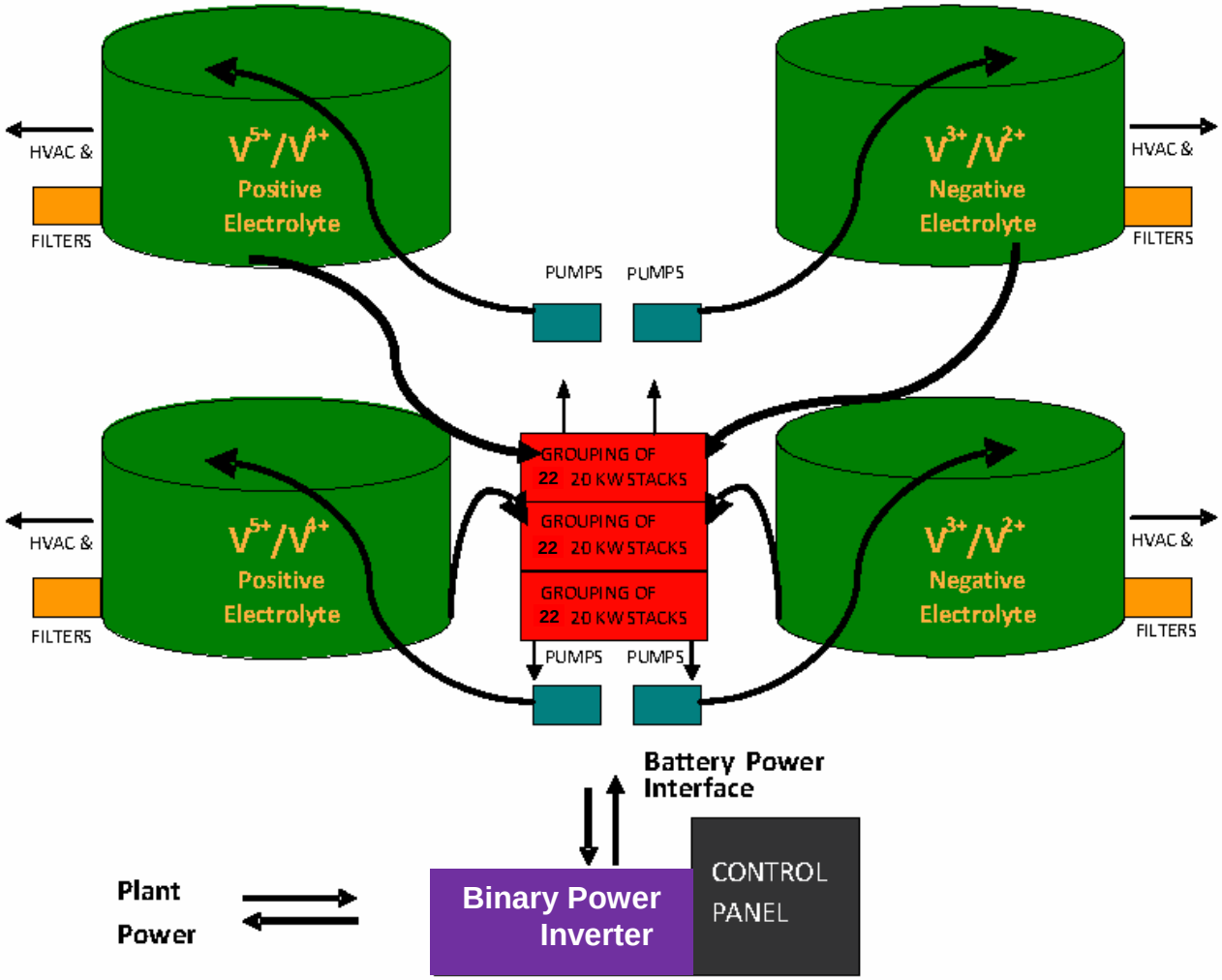
- Battery Building Completed at Painesville Municipal Electric Plant

Current Progress

(Continued)

- Battery Building Motor Control Center at Painesville Municipal Electric Plant

Current Battery Layout



Current Progress

(Continued)

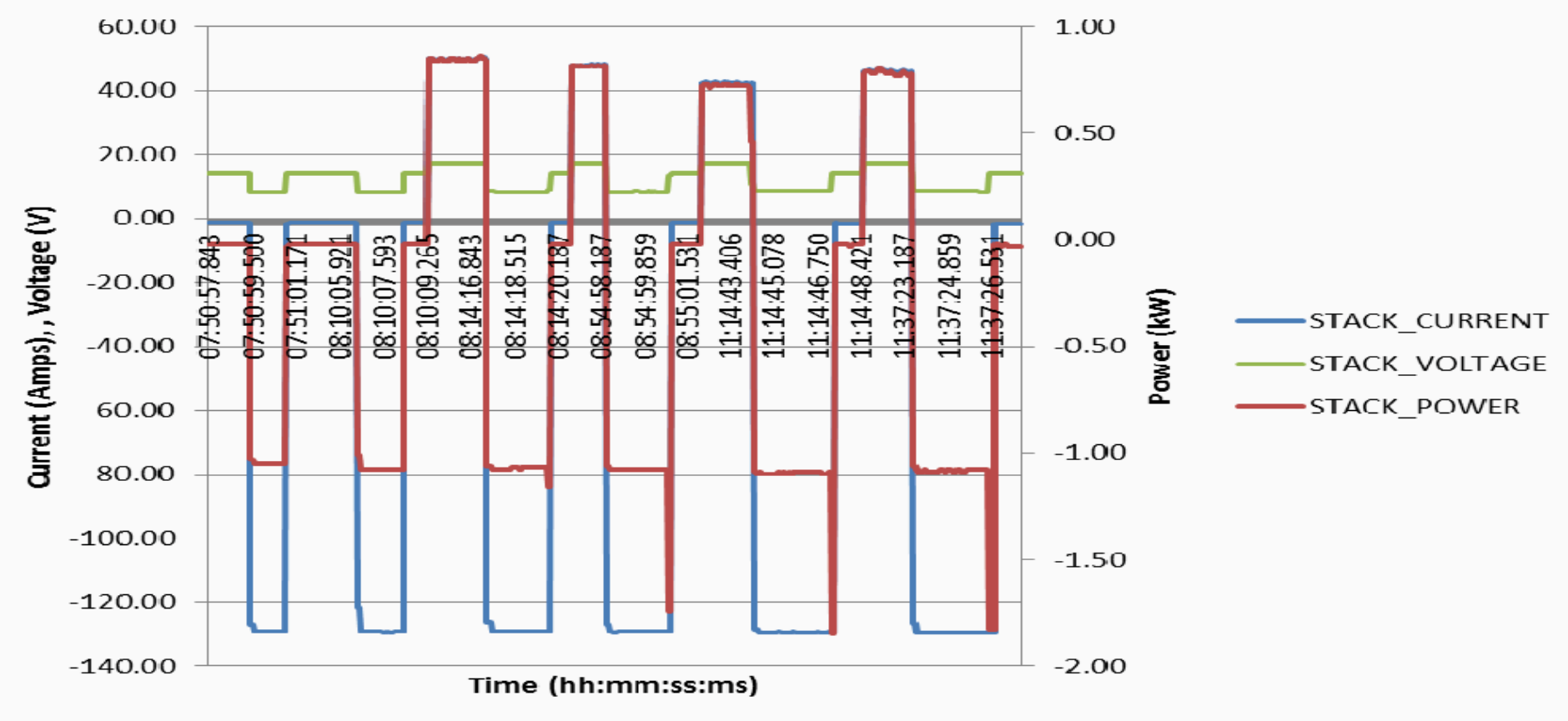
- **Round Trip Efficiency**
  - Flow Frame design parameters undergoing testing/optimization to provide highest AC/AC round trip efficiency
    - Shunt Currents
    - Parasitic Losses
    - Electrical Efficiency
- **Intellectual Property**
  - 10 Potential Patents Identified/2 in Process

Current Progress

(Continued)

Battery Response Time

- Rapid (<50 millisecond) response time from charge to discharge with no operator interaction



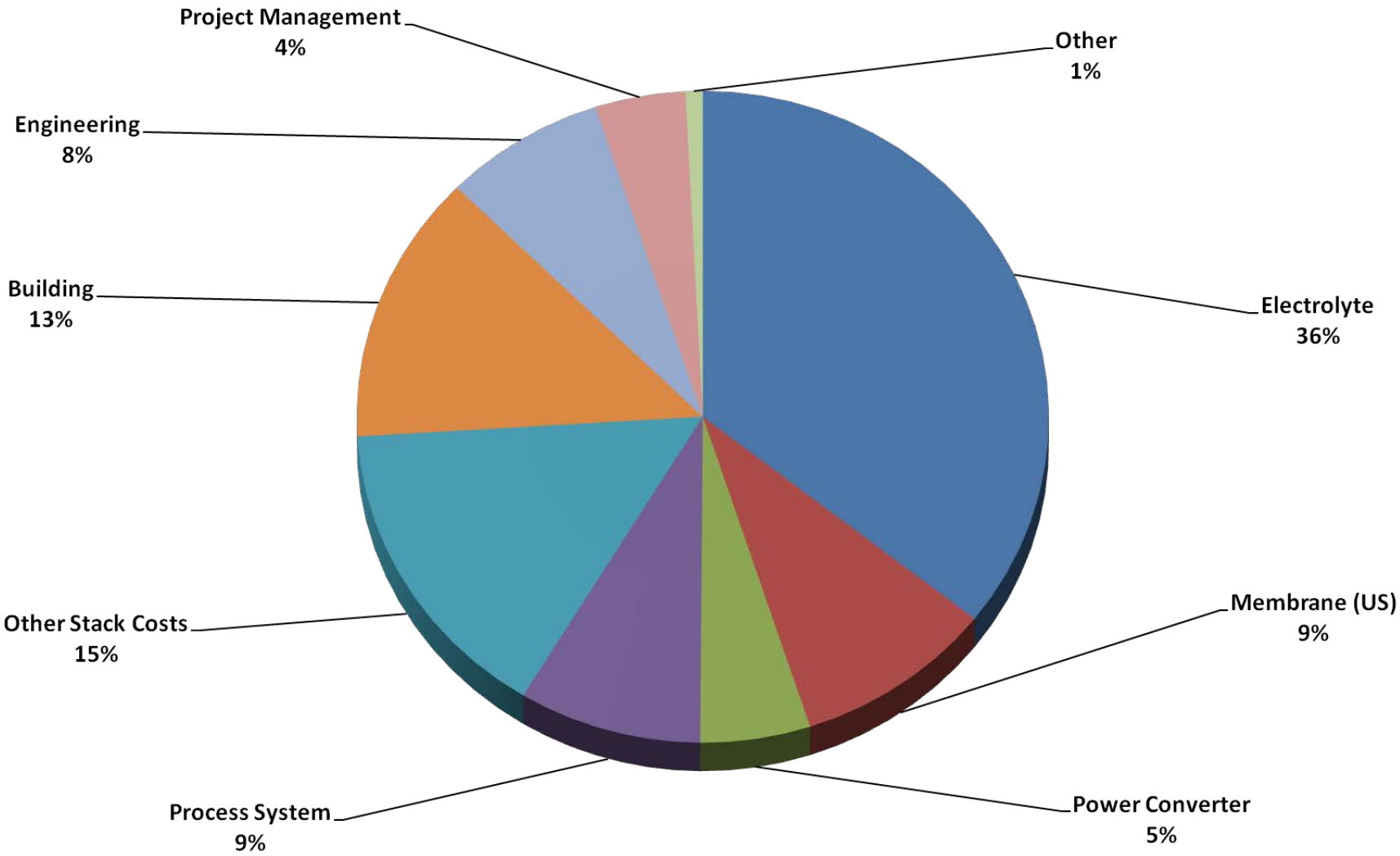
Current Progress

(Continued)

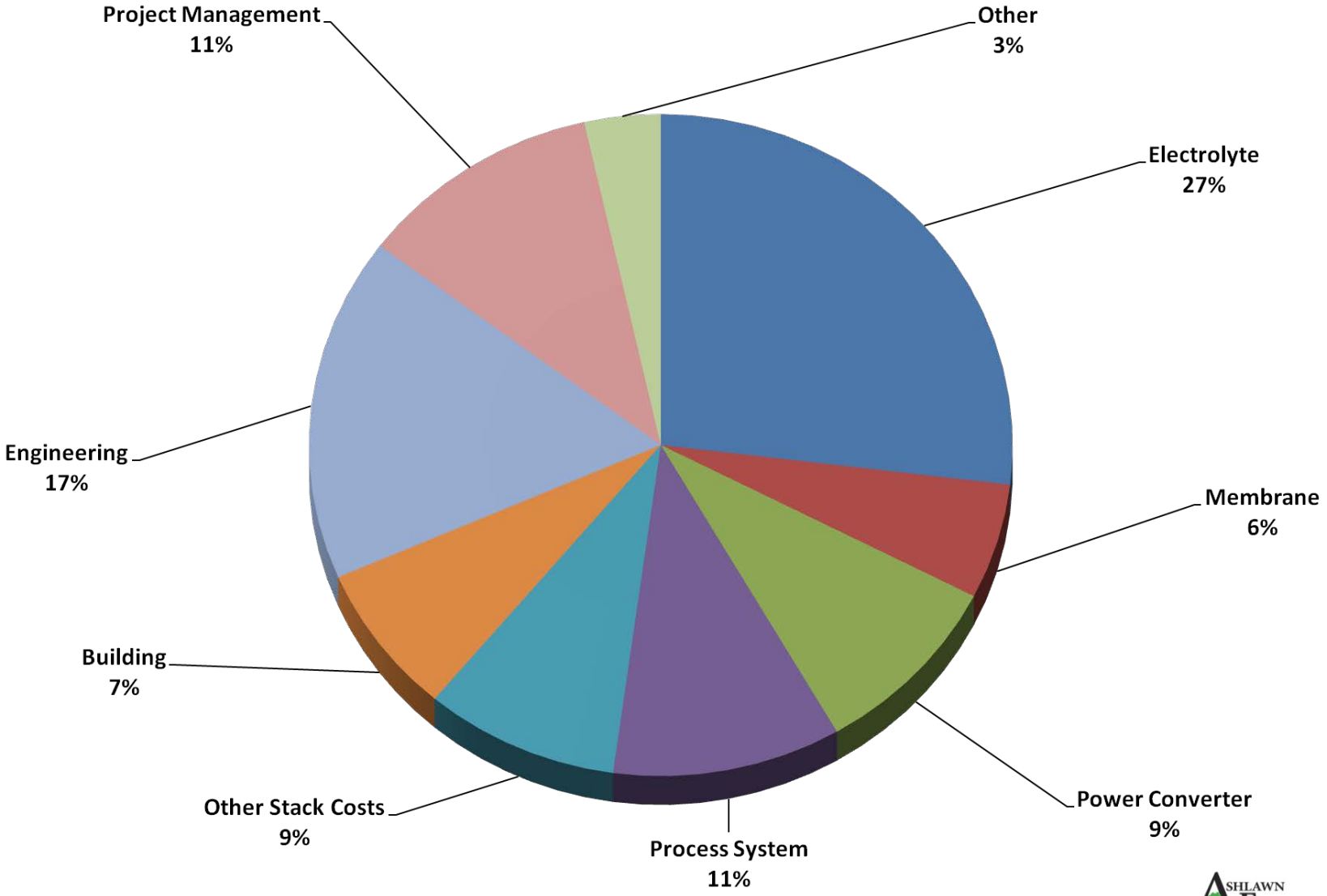
Cyber Security and Interoperability

- Threat Reduction / Risk Analysis
  - Project will be air-gapped from plant SCADA (No Remote Data Communications)
  - Not enough current to cause ripple electrical disturbance at PMEP
  - Battery Control System will be locked and secured per applicable NERC standards
  - DOE-approved security policies will be in effect for all information systems

Major Cost Drivers at Start



Major Cost Drivers at Present



Summary/Conclusions

- Project will complete 3 months behind original schedule and is currently over budget
- Component/Process design improvements, inventions and competition have reduced costs
- Test bed confirmation of process design changes have demonstrated/are demonstrating round trip efficiency improvements

Future Tasks

- Complete trade off analysis between AC/AC round trip efficiency, component cost, shunt current loss and pumping efficiency
- Update Competitive Bids on Components
- Release Long Lead Orders on Manufacturing Equipment/Components
- Optimize Balance of Plant Final Design
- Complete Operational Testing of Improvements
  - 20 kW stack prototype
  - 50% increase in active area
  - Mixed acid scale up
- Install Battery/Initiate Grid Scale Demonstration Phase

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Questions?