Advanced Hybrid Water Heater Using Electrochemical Compressor (ECC)

Xergy Inc
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Project Summary

Timeline:

Start date: 05/2017

Planned end date: 12/2018

Key Milestones

1. Develop Advanced ECC for integration 12 mo.
2. Develop Advanced MHHX for integration 12 mo.
3. Develop Advanced Controls for system 12 mo.

Key Partners:

Xergy Inc
University of Delaware
ORNL
NREL
Haier Group

Budget:

Total Project $ to Date:

- DOE: $ 985,033
- Cost Share: $ 0

Total Project $:

- DOE: $ $954,040.28

Project Outcome:

To simultaneously advance 3 inter-related, transformational, and disruptive heating and cooling technology platforms through delivering functional home appliances: Air Conditioner, and Hybrid Hot water heaters. Technologies are:

1. Electrochemical Compression
2. Metal Hydride Heat Exchangers
3. Ionic Liquid Desiccants

Challenge: Advancing 3 Technology Platforms

Problem:

- **HFCs are up to 10,000 times more potent than carbon dioxide in contributing to climate change. Emissions of HFCs are expected to nearly triple in the U.S. by 2030. <u>US is a partner in global action to phase down HFCs.</u>**
- **HVAC, water heating, and refrigeration systems are the largest energy consuming appliances in buildings, using nearly <u>50% of all energy in U.S. buildings.</u>**

Challenge:

Xergy has proposed 3 major 'platform' technologies, each of which has the potential to transform Heating and Colling systems. Xergy is delivering the following prototype appliances: **Hybrid Hot Water Heater (under SBIR), and Window Air Conditioner for residential use & a Multi-Ton HVAC Unit for commercial buildings (under BENEFIT).** These units will showcase the following t**echnologies: (1) Electrochemical Compressors, (2) Metal Hydride Heat Exchangers and (3) Ionic Liquid Desiccants**

Together with its partners Xergy will not only develop demonstrate units, but put in place a commercialization plan in support of DOE program goals of phasing out HFCs and reducing energy use in commercial and residential buildings.

Team

Xergy Inc. :
Dr. William Parmalee – P.I. – Director of R&D
Mark Golben – (MHHX) Metal Hydride Heat Exchangers
Scott Fackler – (ECC) Electrochemical Compressors
Harish Opadrishta – (ILD) Membrane Pervaporation Systems

University of Delaware: Dr. Ajay Prasad – Center for Fuel Cell Research
Core Technology Development (CO2 & NH3 Compressor)

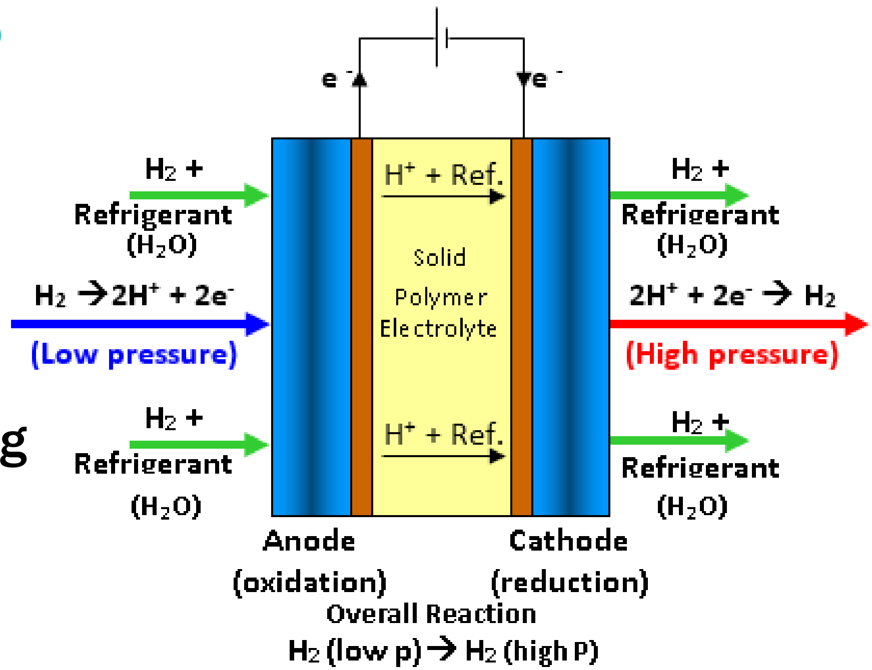
Haier Group: Wei Wei: Haier System Integration

NREL: Jason Woods: ILD System Consulting (and Testing)

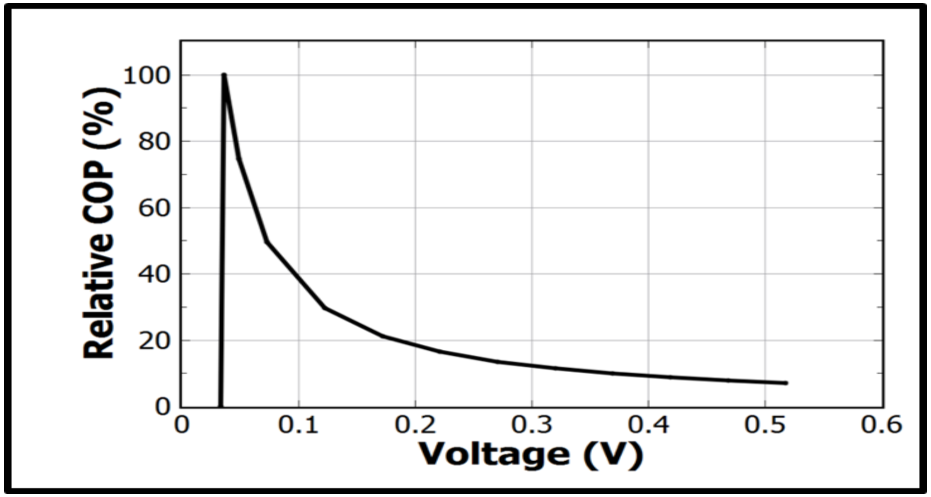
ORNL: Shen Bo: ILD System Testing, Appliance Testing (at end of the program)

Approach – Technology - Electrochemical Compressor (ECC) Platform

- ECC uses an external voltage to **pump hydrogen, water or other refrigerants.**
- The driving force is an **electric potential gradient** governed by the Nernst equation and Ohm's Law
- Multiple **small cells are combined** to create units with the required pumping capability and efficiency for **different refrigeration cycles**
- **Many Fluids Feasible:**
  - H2, Water, CO2, NH3, O2
  - Vapor Compression or Absorption
- **Most Efficient system,** No Moving Parts, Reliable, Scalable, Modular, noiseless, vibration free. – wide temp range!

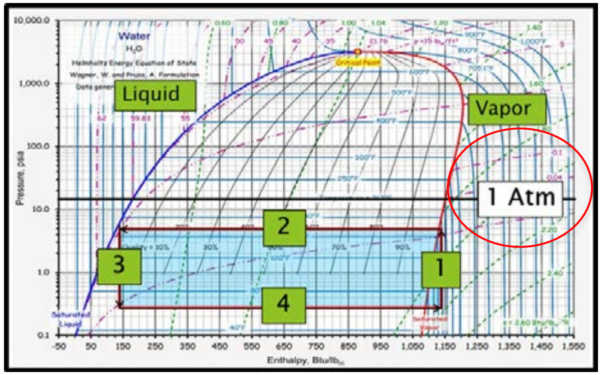


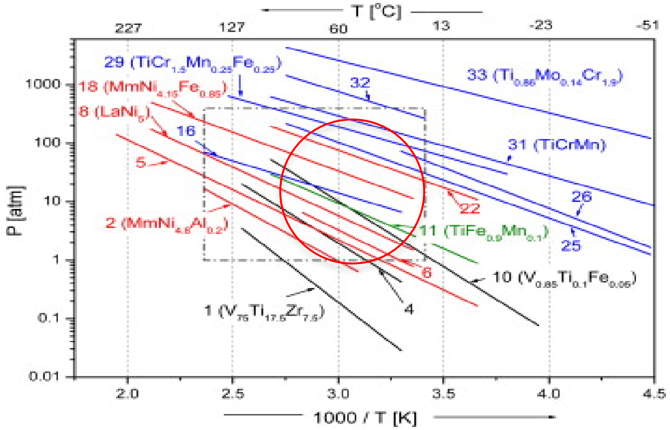
Xergy, Inc. is the world leader in ECC technology
55+ Patents (103 Total)

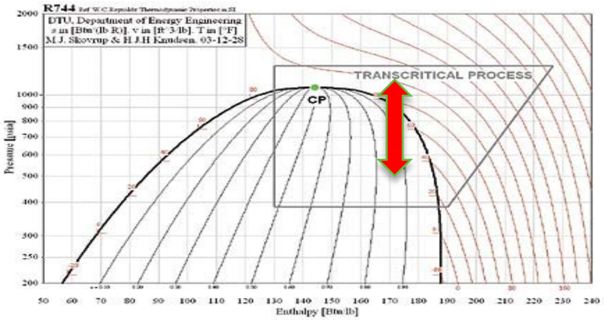


Approach – Technology – ECC Driven Cycles

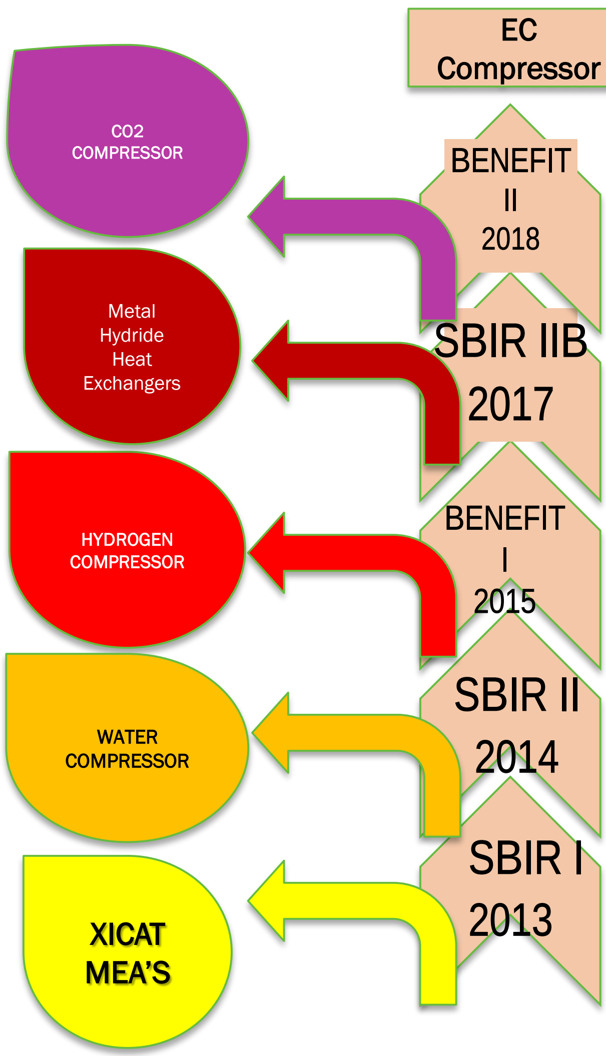
- Water VC: ECC water compressor requires **low pressure** operation (~2 kPa to 26 kPa) which is impractical using traditional compressors.
- Hydrogen (ECC) + Metal Hydride heat exchanger, requires ultra dry compressed hydrogen, at **controlled pressure** operation.
- CO2 VC: requires **low compression ratio**, but large pressure differential (hard to do with mechanical systems).



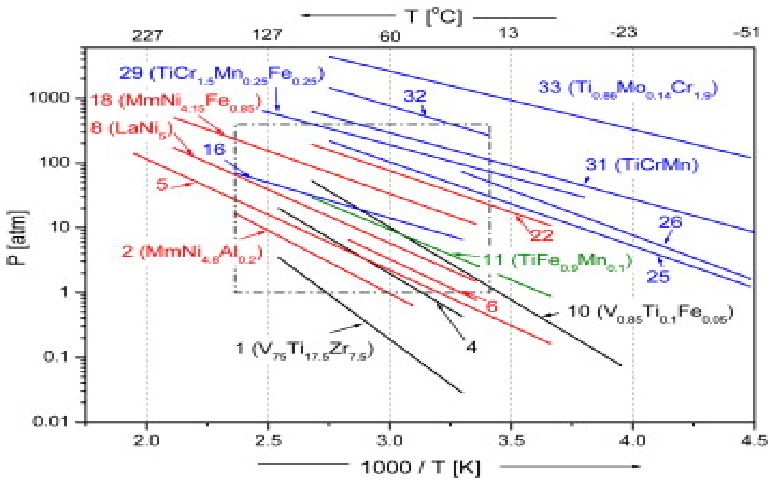




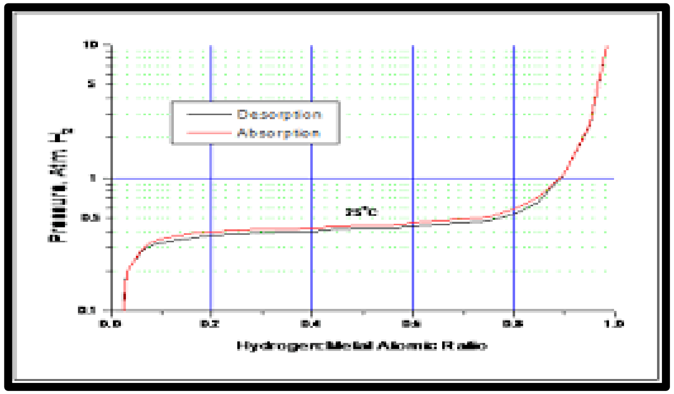
ECC Technology Advancement



(ECC +) Metal Hydride Heat Exchangers Systems

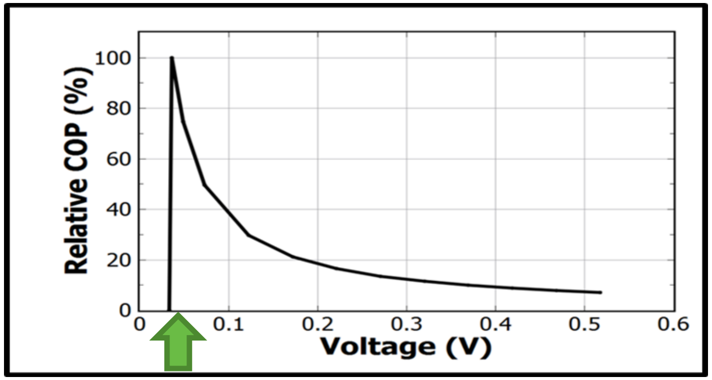


MHHX Heat Exchanger

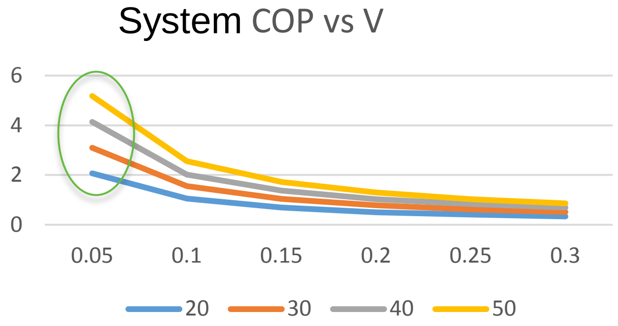


Almost Reversible Reaction
Difference Between Curves is called Hysteresis
< 5% Loss For "Right Hydrides"

Hydrogen Compressor

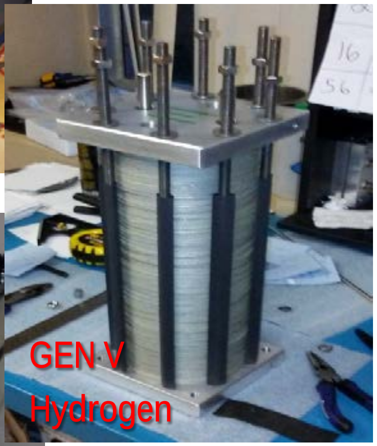


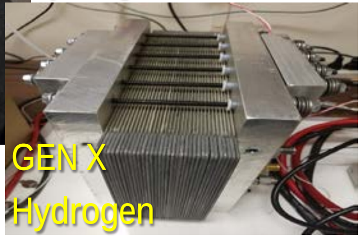
Operating Point (0.05 V)



Progress and accomplishments (2018): EC Compressors

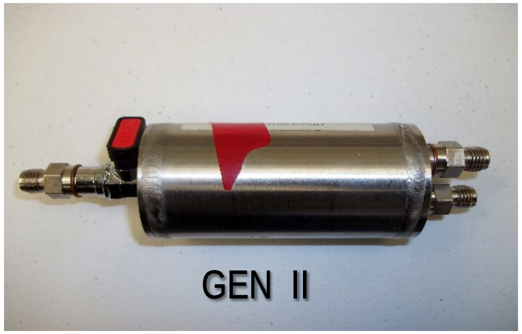
- **Water:**
  - Gen III system built (under SBIR program)
  - Compressor Performance
- **Hydrogen:**
  - Gen IV and Gen V systems built (under SBIR program)
  - Gen IV & Gen V stacks integrated with Metal Hydride Heat Exchangers, for 150W Cooling
  - Gen VI & Gen VII ECC small prototype stacks designed and tested
  - **Gen VIII & Gen X Built and now being integrated into HHWH, and Air Conditioner**
    - **Gen X is 3x smaller than Gen VIII, which was 3 x smaller than Gen V …**



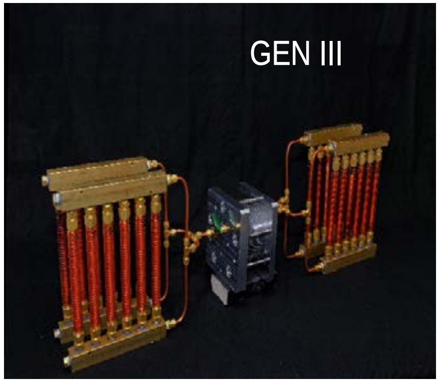


Progress and accomplishments (2018): MHHX Development

- **GEN II MHHX systems purchased**
  - Tested with a wide range of MH formulations

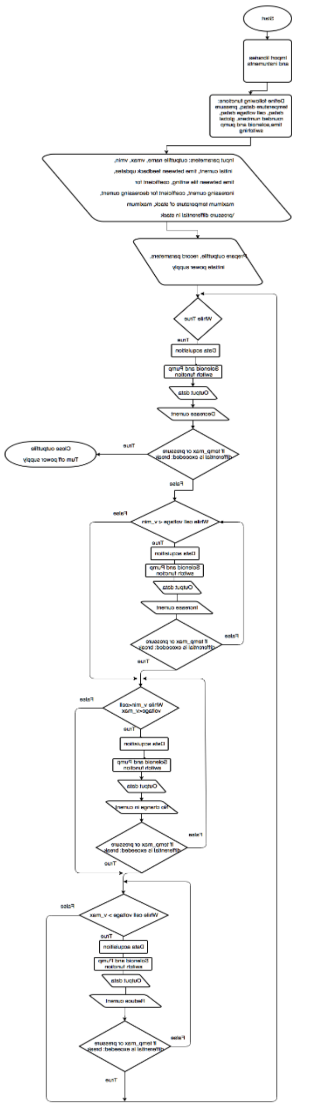


- **GEN III & GEN IV MHHX Built in house**
  - Air & Liquid exchange
  - Started with one formulation of MH
  - Alternate formulations analyzed



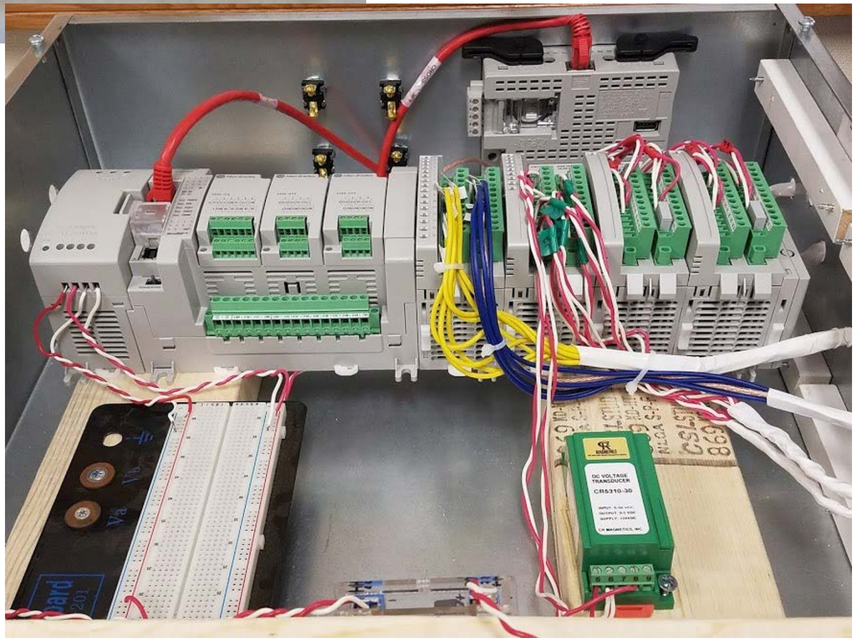
- **GEN V MHHX Built and Integrated**
  - Liquid Exchange System
  - Narrow Diameter System
    - Faster Heat Exchange, Lower Material Cost
  - Advanced Formulations Developed For Each Application

Progress and Accomplishments (2018): System Controls

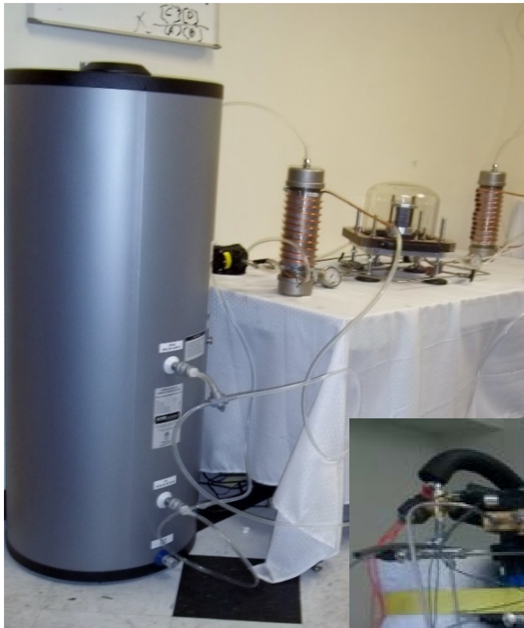


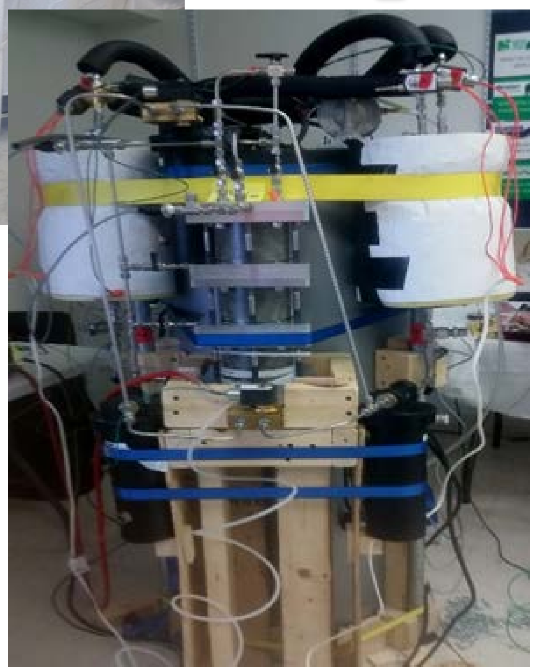
Basic On/Off switching

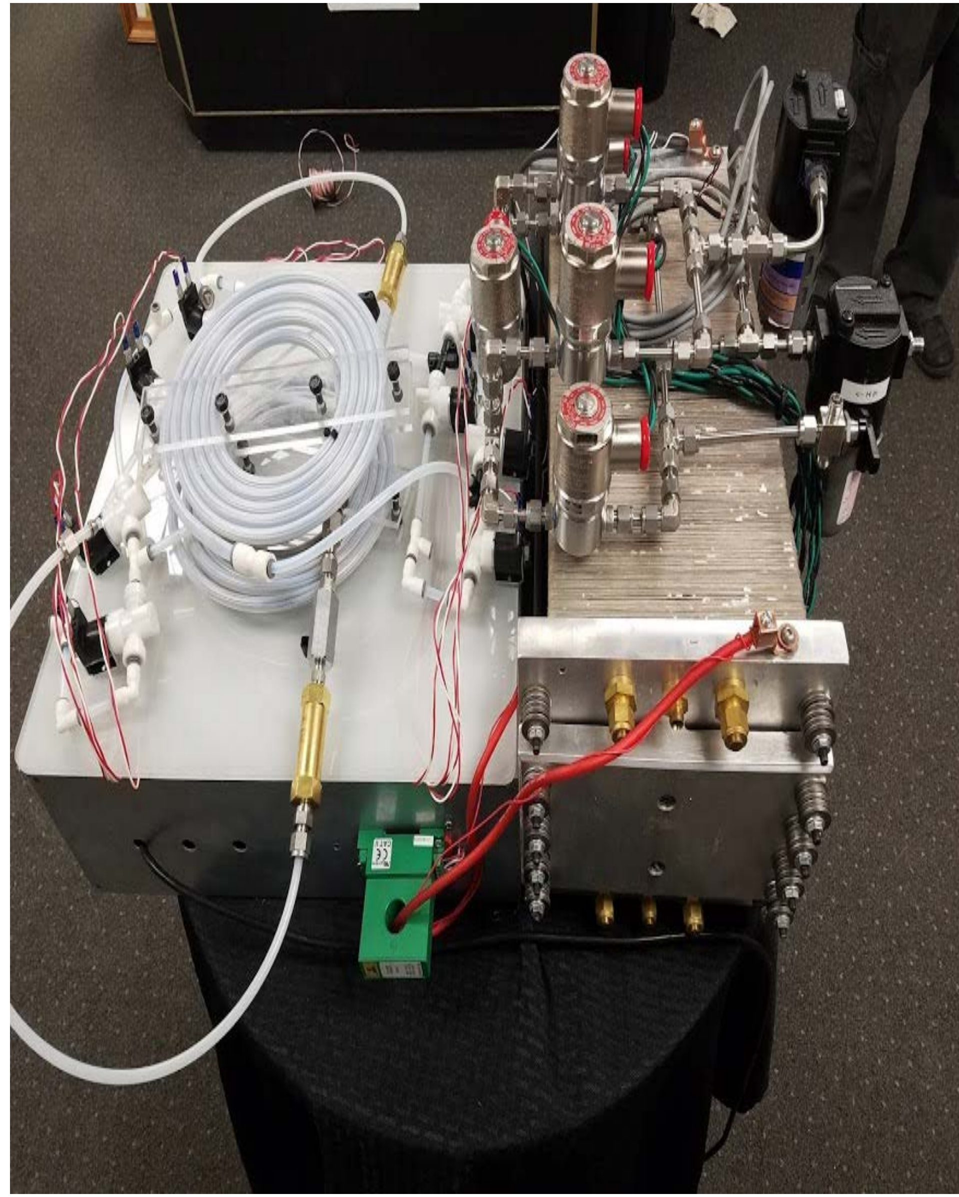
PLC Controls



Progress and Accomplishments (2018): Hybrid Hot Water Heater

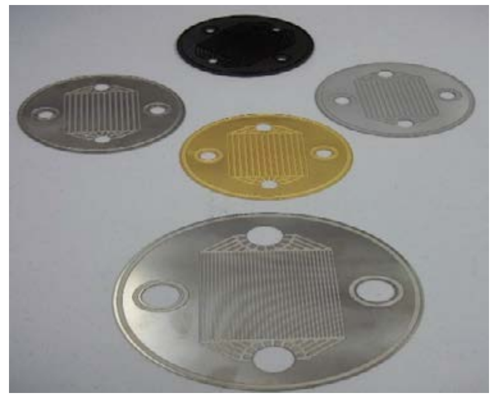


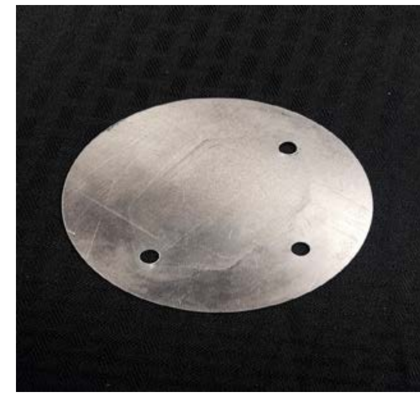


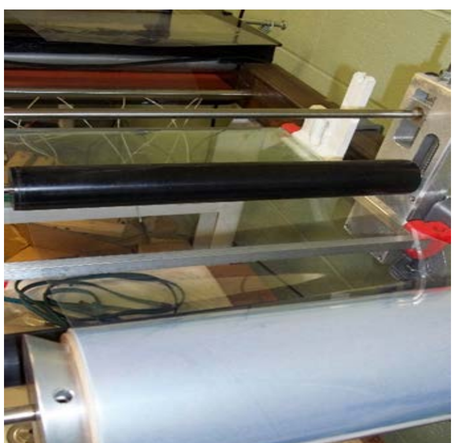


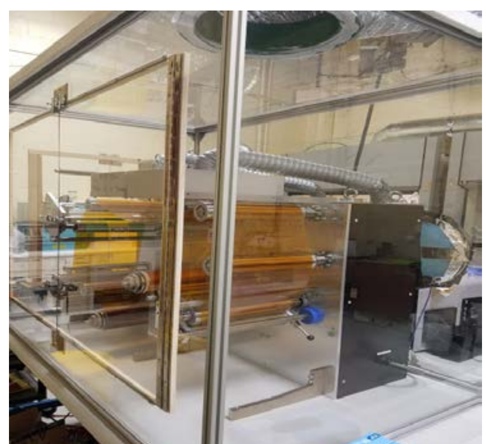
Progress and accomplishments (2018): Components

Low Cost Plate Design & Low Cost Membrane Production Infrastructure

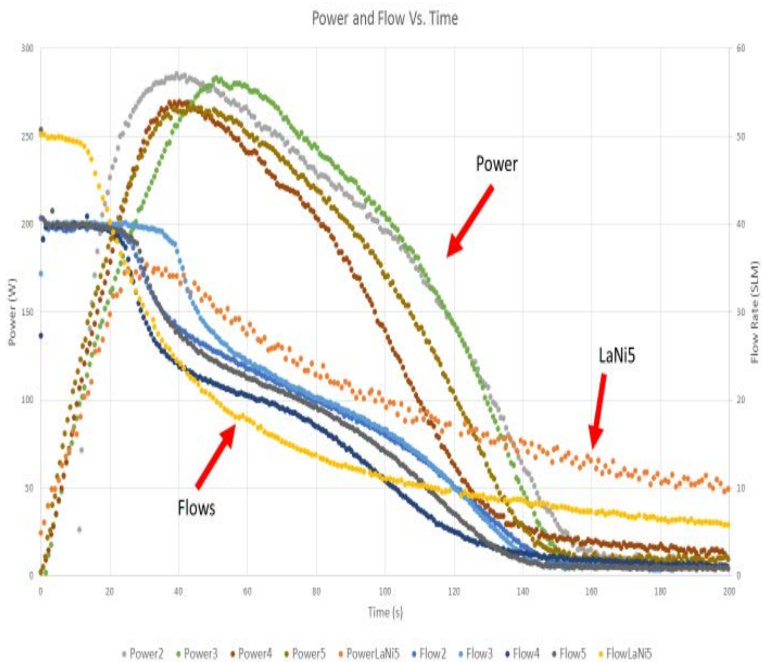


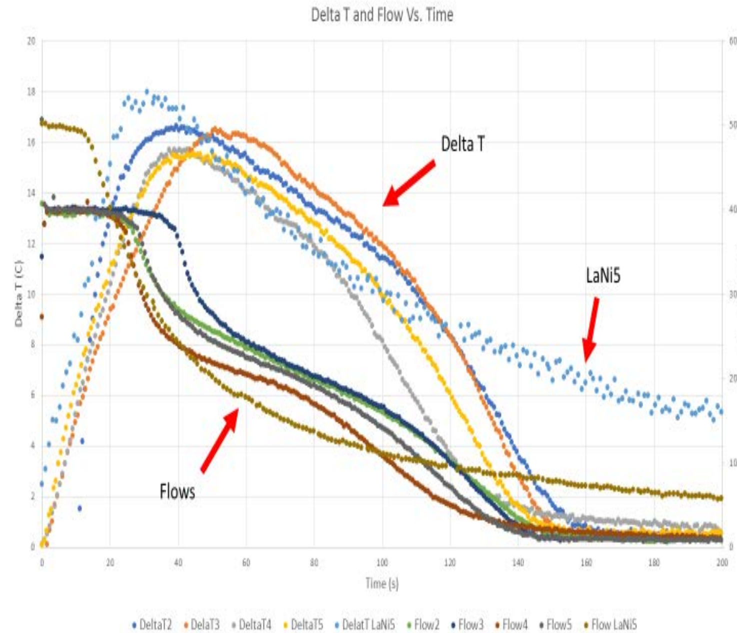






Heat Pump: System Performance Data

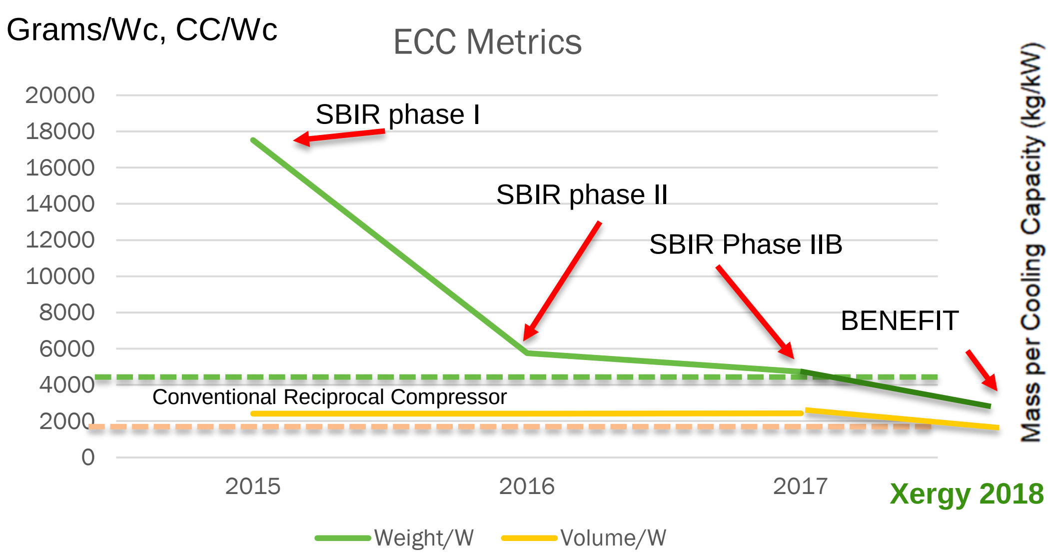


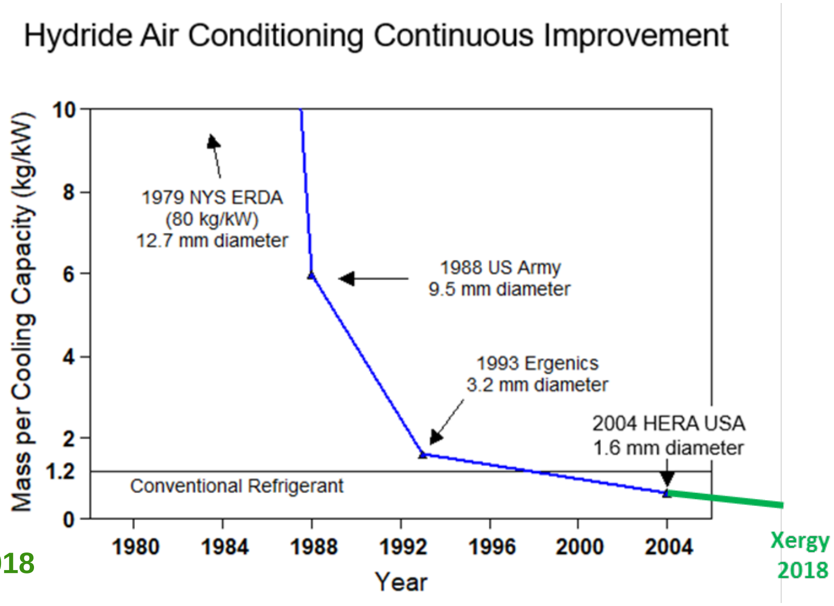


- Hydrogen flow: 40 SLM and 150 PSI
- Compared to Gen 3 MHHX System (LaNi)
- Heat Exchange Fluid (Water): 4.1 ml/second

Heat Pump: System Metrics (2018)

- ECC: Substantial Reduction in both Weight and Volume per Watt of Cooling; very close to meeting Reciprocal Vapor Compressors (still some distance from Rotary Vapor Compressors)
- MHHX: Currently Exceeding Size and Weight for Conventional refrigerant systems





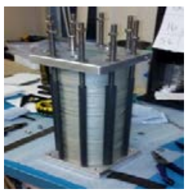
Project Plan and Schedule

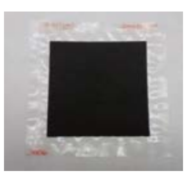
Future Work:

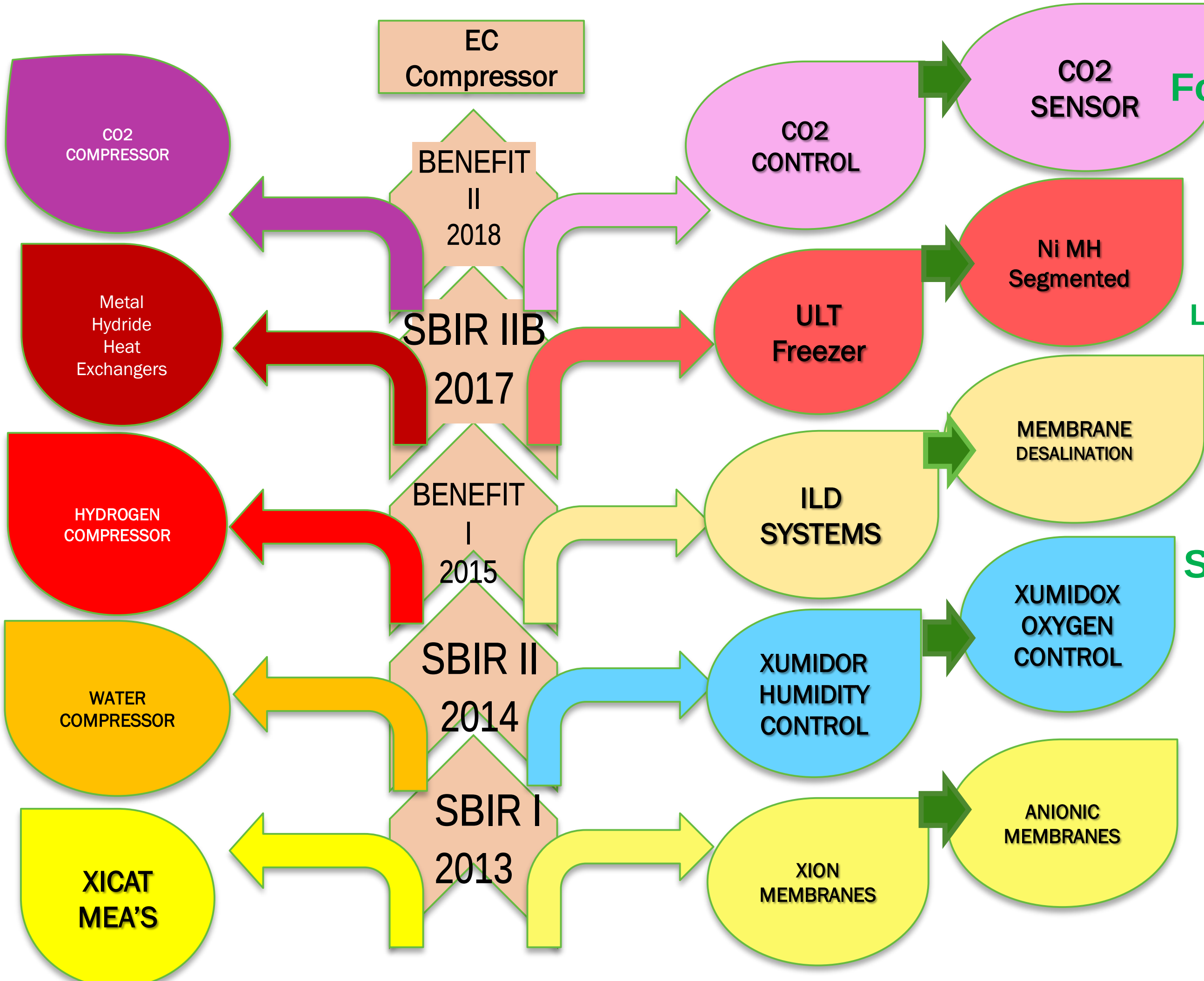
- On track with all work. Go/No Go requirements met.
- Xergy will deliver a Hybrid Hot Water Unit to ORNL at the end of the program for testing and evaluation (3Q2018)
- Also, to provide a ‘commercially’ viable ECC/MHHX/ILD system prototype in this program (TRL8), which derived from Market Research performed under SBIR T2M commercialization program
- Asking for a 6 month extension – ONLY to address commercialization program (not main deliverable)

main	Sub	Task	Month	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	11	11	12	12	13	13	14	14
A1		Down select metal hydride system for operation at hot water heater temperature envelope																													
	1	Specify two customized calorimetric hydride/heat exchanger characterization systems																													
	2	Specify system requirements (H2 sorption & desorption pressure, flow (L/min), heat capacity																													
	3	Design test systems																													
	4	Fabricate test systems																													
	5	Assemble and validate test systems																													
	6	Release test systems for development activity																													
	7	Study the performance of the 5 identified candidate hydride systems																													
		Milestone go-nogo decision-1 select best commercially available hydride system																													
	8	change alloying components; and rerun van hoff curves (ones the best candidate(s) are selected) i.e. alloy optimization.																													
	9	Select hydride systems for appropriate temperature/ pressure operating envelopes																													

Impact: 1st , 2nd , 3rd & 4th Order Derivatives …







Forecast Sales 2019
ULT Heat Pump

LED TO NEW SBIR 2017
Breakthrough in Desalination

Started Sales 2018
Revolution in Food Preservation

Started Sales 2017
LED TO ARPA-E Ionics Program

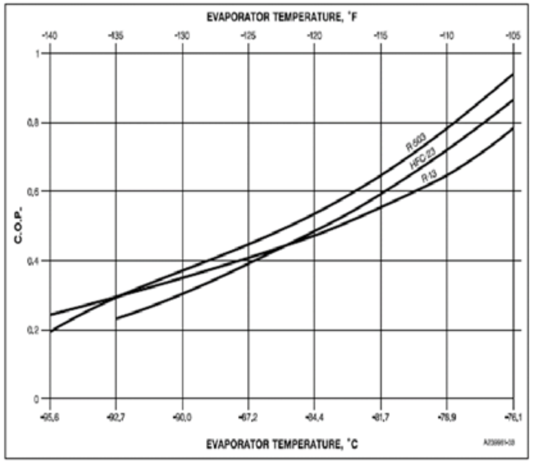
Developed many strategic relationships with each derivative

T2M : Entry @ Low Volume - High Value Application

If you want to cool to - 80 C what are your options?

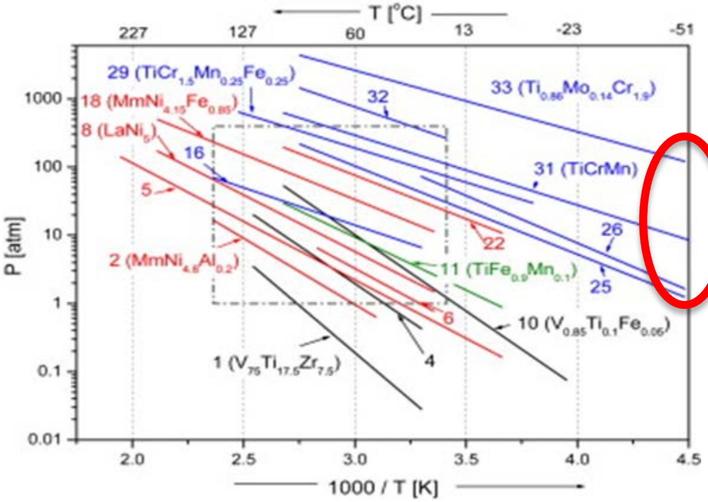
- **Vapor Compression**
  - R410A: –30 C
  - CO2: –40 C
  - Ammonia: –60 C
  - R503 and R13: -82 C, but they deplete Ozone; phased out due to Montreal protocol
  - R 23: - 82 C, Replacement for R503 and R13
- **Stirling Heat Pumps using Helium as the working fluid**
  - Many limitations (logistics, etc.)
- **Emissions of these ULT VC Refrigerants are not only addressed in Montreal protocol but also singled out in Kyoto**
  - R23: (Fluoroform) Health Hazard: Nervous system depression
- **ALL CURRENT ULT Systems: Very Poor Efficiency**
  - ULT Freezer 22 KwH/day Vs Refrigerator 1 KwH/day

Figure 3. Measured Coefficient of Performance



ECC+MHHX Heat Pumps are "Ideal" for ULTRA-LOW TEMPERATURE FREEZERS

T2M: Strategic Partnerships ULT Heat Pumps



- **ECC+MHHX: Most Efficient technology, No Moving Parts, Reliable, Scalable, Modular, noiseless, vibration free. Can cool down to -100C**
  - Bio-freezers for the preservation of viruses, bacteria, drugs, enzymes, chemicals, cell preparations and tissue samples among others. Temperature range of - 45C to - 86C.
  - $700 Mn Global market for Ultra-Low Temperature Freezer
    - Growing at a CAGR of 2.7%; Roughly 70,000 Units/year
    - **Approx. 560 GWH Energy USE - direct use**
      - Note, reject a lot of heat, so there is also massive loads on the HVAC systems in the facilities where these freezers operate
- **Partners**
  - Xergy is working Directly with Haier and So-Low (together have large Market Share); also working with others to launch commercial products within the timeframe of this program

Thank You

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