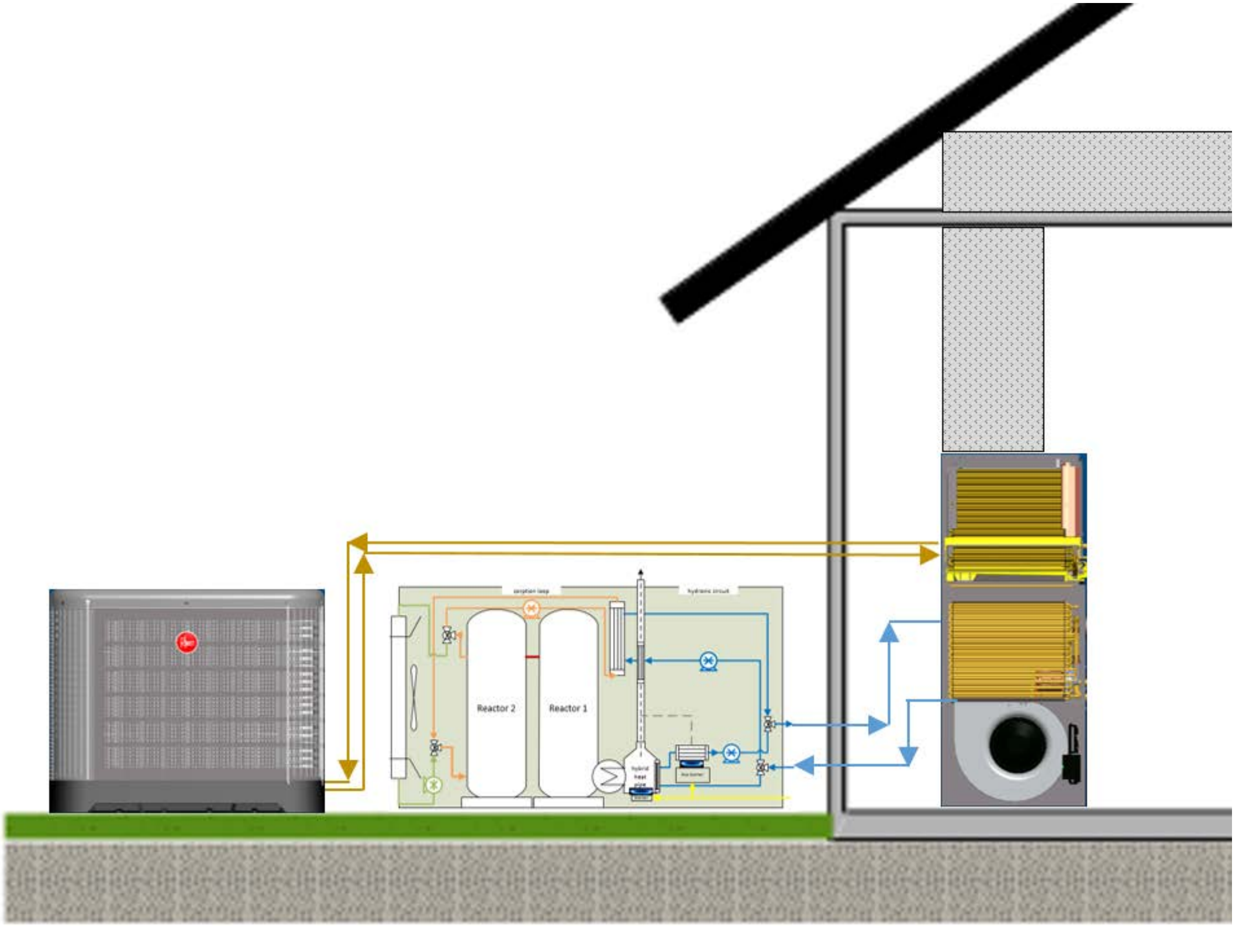
SaltX Residential Heat Pump

2017 Building Technologies Office Peer Review



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Project Summary

Timeline:

Start date: Oct 1, 2016

Planned end date: Sept 30, 2019

Key Milestones

1. Market assessment; Dec 2016
2. Product requirements spec sheet; March 2017

Key Partners:

ClimateWell (SaltX Technology Holding, AB)
Rheem Manufacturing Company

Budget:

Total Project $ to Date:

- DOE: $2000k ORNL
- Cost Share: $10k

Total Project $:

- DOE: $2000k
- Cost Share: $234k

Project Outcome:

Demonstration of gas-fired sorption heat pump with 1.4 seasonal gas COP at acceptable price premium

Proposed Goals

Metric	State of the Art	Proposed
Primary SCOP	*0.87 (furnace)* *0.83 (elec. HP)*	*1.4*
GCOP @ 0°F	*0.87 (furnace)* *0.30 (elec. HP)*	*1.20*

Purpose and Objectives

Problem Statement: Develop and demonstrate, through laboratory and field testing, a gas-driven residential space-heating device with 140% energy efficiency.

- Gas-fired, split residential space heating system
- Hydronic heat exchanger heats air in central duct
- Triple-state sorption is neither absorption nor adsorption cycle: intentionally crystallizes salt in reactor, for unprecedented high energy density
- Ammonia refrigerant, housed in outdoor unit with no moving seals (fully hermetic), enables high delivery temperature at low ambient

Target Market and Audience: Fuel-fired (gas, distillate, LPG, and kerosene) residential space heating is a **3,026 TBtu/yr market**. Fully deployed, by increasing seasonal efficiency from 92% to 140% the technology could **save 1,037 TBtu/yr** in primary energy, compared with 2030 typical condensing furnace technology.

Impact of Project: The project team will move the concept from its current pre-commercial state to a packaged prototype ready for scale-up. At the end of the project, Rheem Manufacturing will be able to make a determination regarding proceeding with commercialization of the technology.

Unprecedented Space Heating Efficiency with Gas

Natural gas heating:

- Typically US consumers are paying ~$9,000 for gas over furnace lifetime.

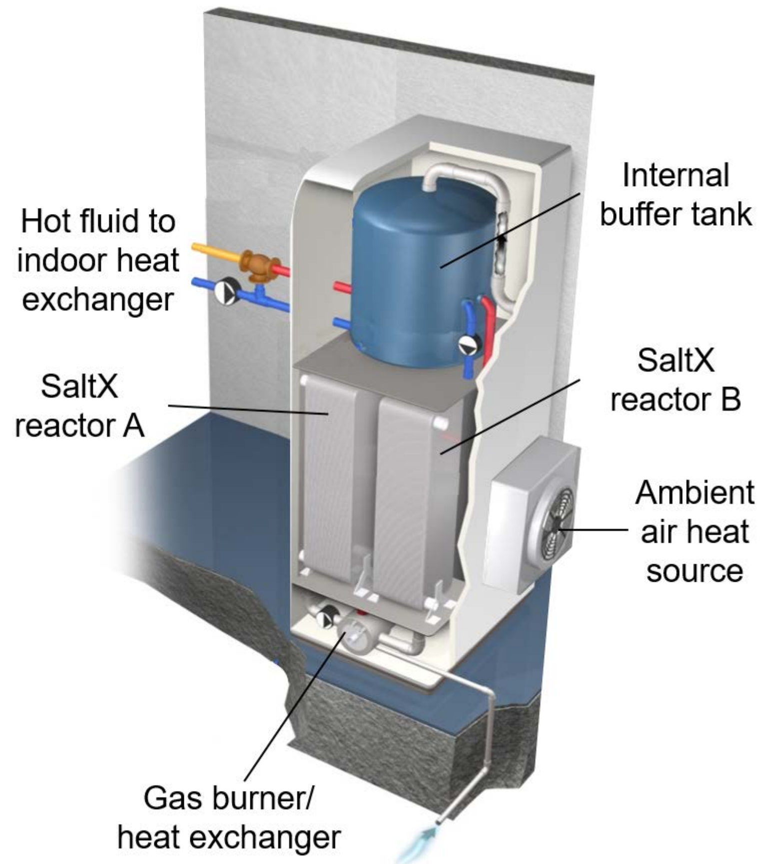
Maximum thermodynamically feasible furnace efficiency: 98%

- Current fleet average: approaching thermodynamic maximum!
- What's next?
- What if gas heating efficiency could exceed 100%?
- Existing gas heat pump technologies: too expensive for mass market
  - Absorption
  - Adsorption
  - Engine-driven heat pump
- Novel SaltX sorption heat pump technology addresses the challenges

High Efficiency, High Capacity Gas Heat Pump

Solution: SaltX Heat Pump Technology

- Retrofit-ready (boiler or furnace replacement)
- Low operating cost
  - 140% seasonal gas efficiency
- Excellent cold weather performance
  - Achieve 100% rated capacity to -4°F
  - Achieve 80% rated efficiency to 0°F
- Excellent comfort
  - Provide high delivery temperature under all conditions
- High reliability
  - No moving seals



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Approach

- MYPP: compared with 2010 TNT (0.78 AFUE), **44% energy savings**
- Compared with 2030 TNT (0.92 AFUE condensing furnace), **34% energy savings**
- 3-4 year simple payback for climate zones 1-2
- 1,037 TBtu/yr technical potential
- Straightforward installation for existing HVAC contractor base, with outdoor combustion and hydronic coupling between indoor/outdoor units

Key Issues: Complexity and cost of sorption heating technology

Distinctive Characteristics: Utilize innovative SaltX matrix technology to overcome the traditional product complexity of gas heat pumps

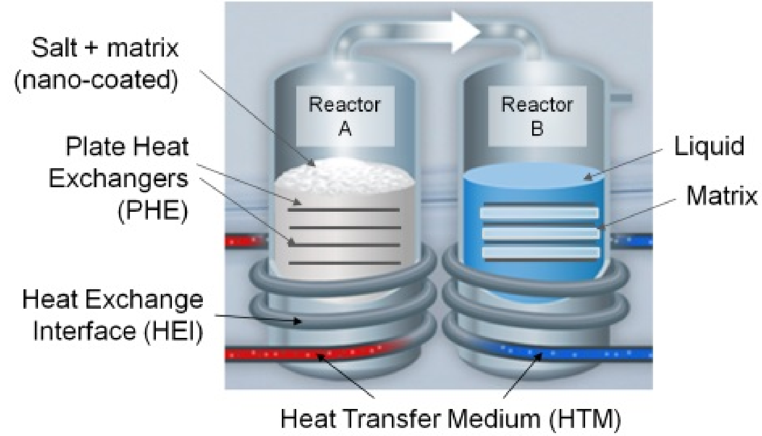
The “Triple-State Sorption” SaltX Technology

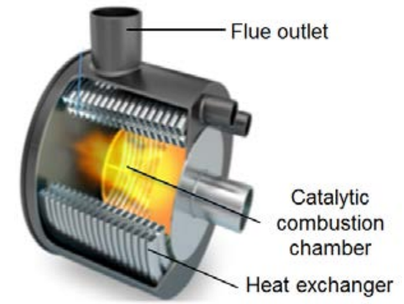
- Improved **cost effectiveness**: novel integration with plate heat exchangers leverages existing high volume manufacturing
- Improved **compactness**: higher energy density by crystallizing sorbent; using ammonia
- Improved **reliability** and **reduced complexity**: no moving seals, no ammonia pump, fully hermetic outdoor system, low vibration
- High **efficiency**: ammonia refrigerant well-suited to very cold ambient temperatures; good turndown performance aid part-load efficiency

Approach

Distinctive Characteristics

- Innovative SaltX matrix technology overcomes the traditional product complexity of gas heat pumps
  - Passive ammonia check valves; no ammonia pump
  - High power density reactors
- Innovative hybrid burner/heat exchanger

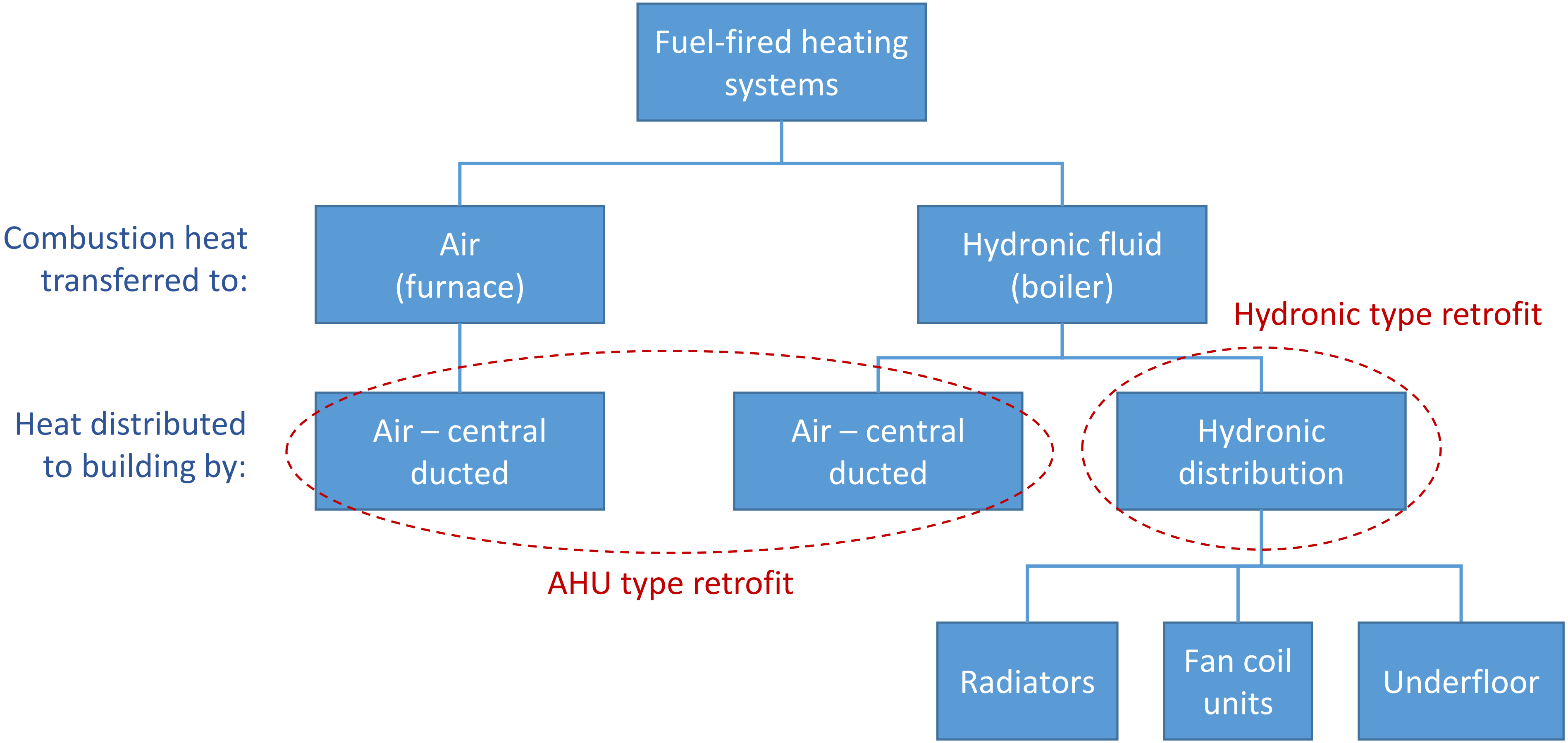




Feature:	Adsorption-like architecture	High energy density of triple state (fully crystallized) salt	Nanocoated SaltX matrix	Use of ammonia as refrigerant
Benefits:	- eliminates ammonia pump - long service life: completely hermetic ammonia-containing part of the system, zero moving seals	- allows compact and robust system - less complex controls - achieves high COP	enables low-cost plate heat exchanger technology	enables high performance at very low ambients

Approach

- Available markets

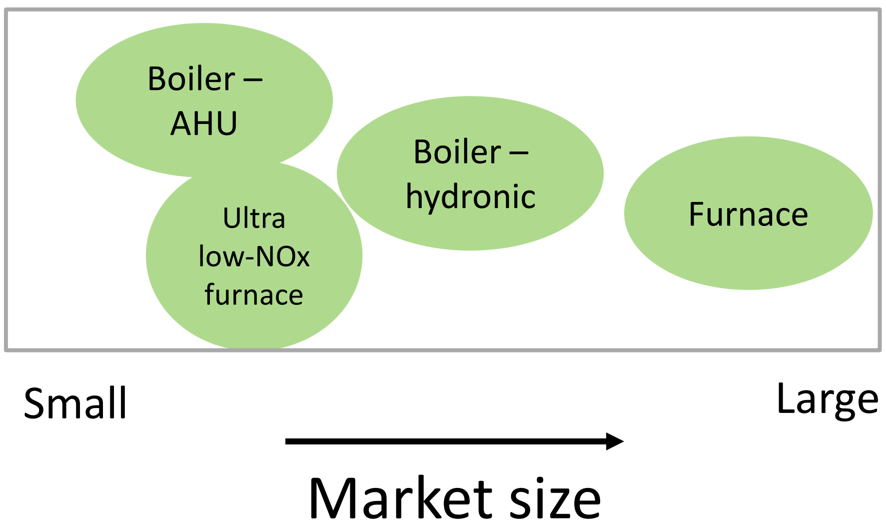


Approach

- Available markets: relative sizes

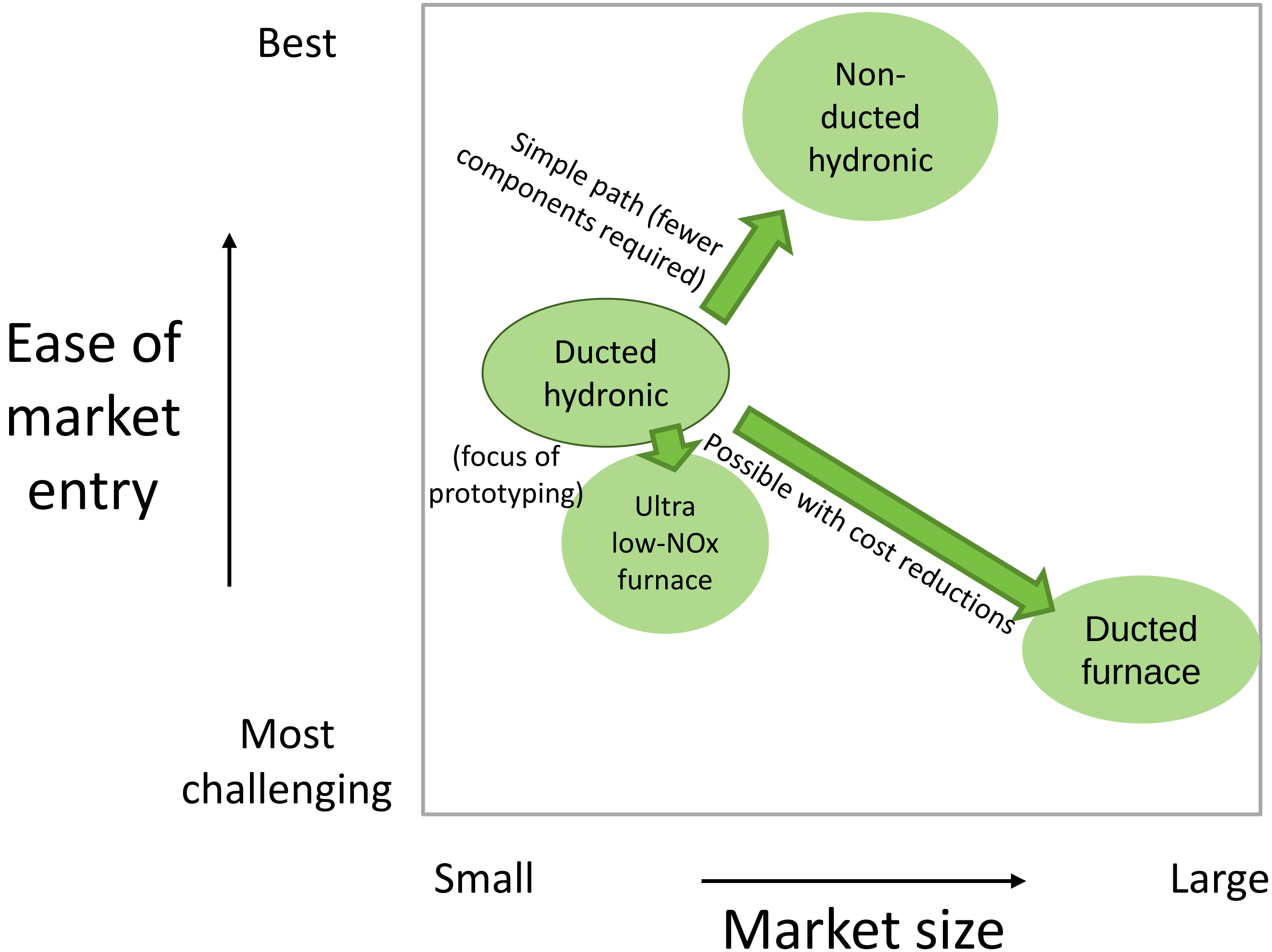
		AIA climate zones	*Equipment*	
			Central ducted furnace	*Boiler (air handler, radiator, and underfloor)*
Fuel source	Natural gas and LPG	1,2,3	1734.1	308.0
	Oil and Kerosene	1,2,3	90.4	161.9

Data source: DOE's Scout calculator: https://trynthink.github.io/scout/calculator.html



Approach

- Ease of market entry and project approach to the available markets



Progress and Accomplishments

Accomplishments: Subcontracting established. Milestones met: (1) market assessment authored with input from all three team organizations (2) IP Management Plan executed. Established most promising markets and configurations of unit.

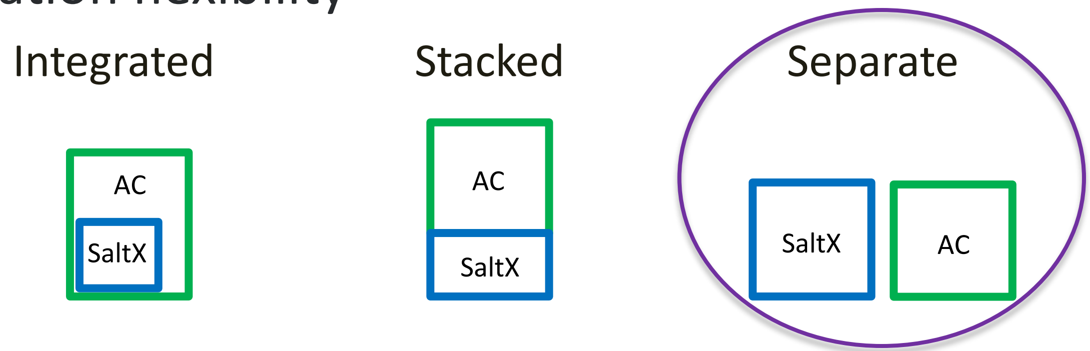
Market Impact: Discussion with Rheem installers. During project year 2, outreach to gas utilities

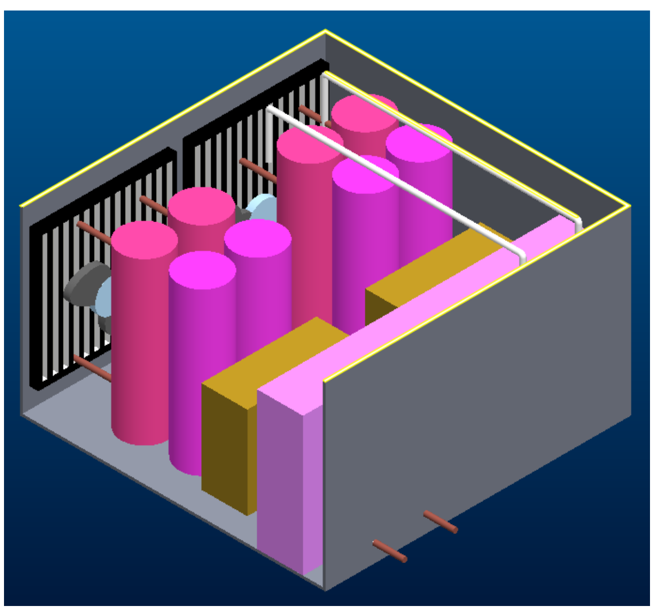
Awards/Recognition: None yet

Lessons Learned: The huge diversity of installation types demands a flexible platform to launch the product in a way that maximizes potential customer base.

Accomplishments: Choose Outdoor Unit Configuration

- Interaction with air conditioning must be considered: separate selected
  - Heating/cooling can be independently sized
  - Best installation flexibility





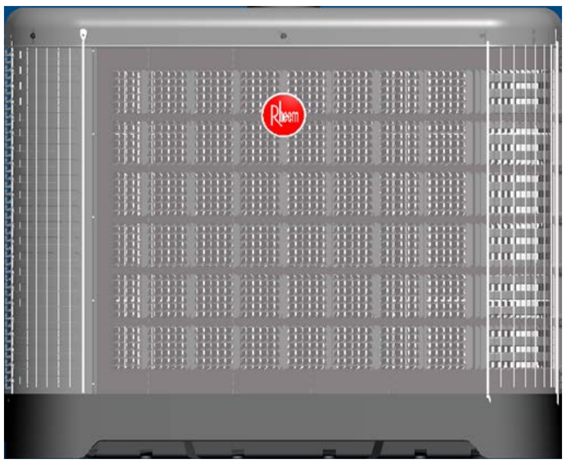
- Configuration of components within SaltX outdoor unit

Accomplishments: Product Sizing

Preliminary physical product sizing relative to existing outdoor units

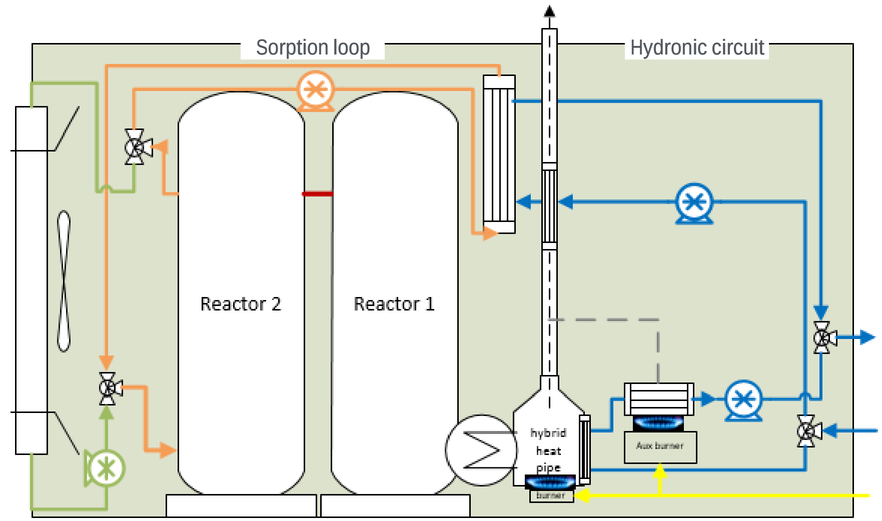
14 SEER 3 Ton Condenser

27”



33.75”

Sorption Heat Pump 83,000 Btu/h Hydronic Heater



~52”

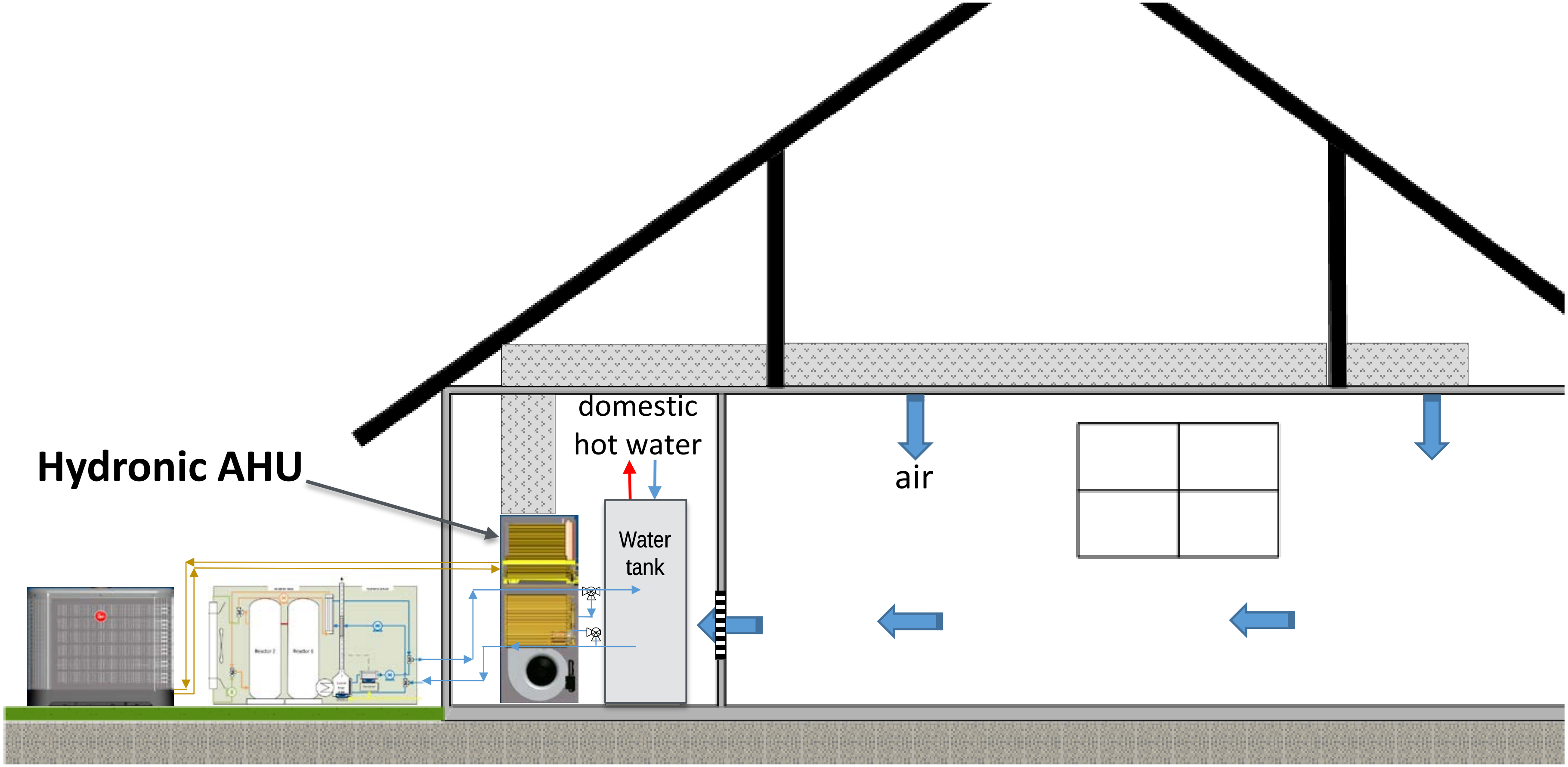
- ammonia
- domestic water
- water (desorption)
- water (resorption)
- natural gas
- flue gas

pump

3-way valve

Accomplishments: Building Integration

- Integration with the home: case of hydronic air handler unit (AHU)
- Optional water heater integration enhances energy savings



Project Integration and Collaboration

Project Integration: Key industry partner Rheem, a prominent manufacturer of furnaces in the US, is engaged in biweekly meetings and commercialization-related project deliverables to maximize market success. SaltX and suppliers are engaged with design and fabrication. Outreach to utilities is planned.

Partners, Subcontractors, and Collaborators:

- Rheem Manufacturing Company: ensure market relevance, provide prototype materials
- ClimateWell AB, wholly-owned subsidiary of SaltX Technology Holding AB: develop reactor cores, sealed system
- ORNL: System-level integration and evaluation
- Purdue University: establishing PhD student under GO! program

Communications:

- Updates provided at 7th Expert Meeting of IEA Annex 43 on Fuel-driven Sorption Heat Pumps for Heating Applications
- Abstract submitted to International Sorption Heat Pump Conference, August, 2017

Next Steps and Future Plans

Year 1:

- Reactor core modeling
- System modeling

Year 2:

- System fabrication and evaluation
- Breadboard system fabrication and evaluation
- Packaged system design

Year 3:

- Packaged system design
- Outreach and communication to utilities etc.

REFERENCE SLIDES

Project Budget

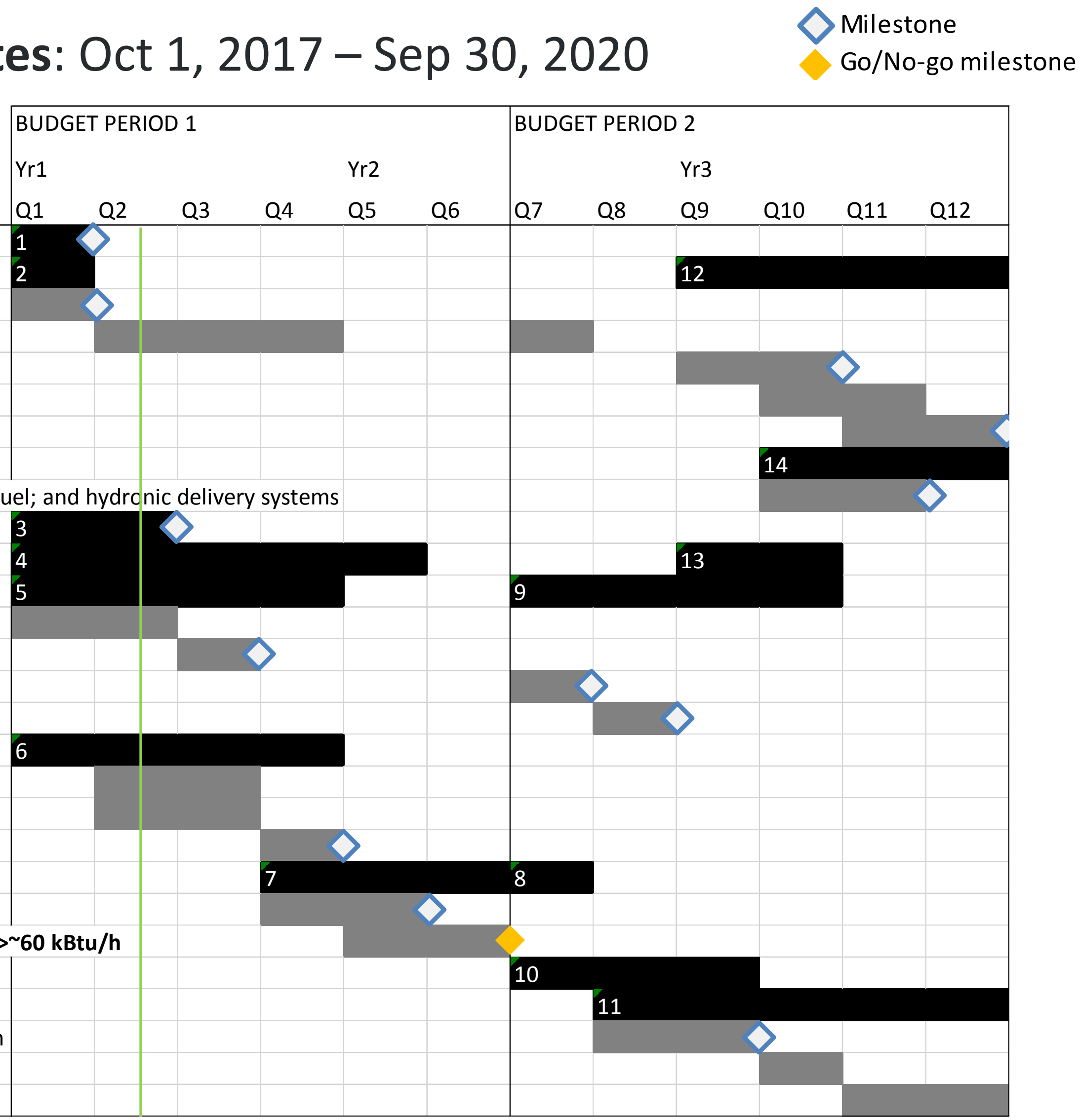
Project Budget: 2000k DOE plus 234k cost share, beginning in FY 2017
Variances: None
Cost to Date: 52k
Additional Funding: None

Budget History					
FY 2016 (past)		FY 2017 (current)		FY 2018 – FY 2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
0	0	571k	78k	1429k	156k

Project Plan and Schedule

Project Initiation and End Dates: Oct 1, 2017 – Sep 30, 2020

Slipped milestones: None



	Task
1	IP Management Plan
2/12	T2M activities
2.1	US market survey
	acquire feedback on market fit
12.1	commercialization determination
12.2	outreach to utilities
12.3	photorealistic CAD rendering for pamphlet
14	T2M: Expanded markets
14.1	product requirement definitions for oil and propane fuel; and hydronic delivery systems
3	product requirements: dimensions, capacity, interfaces
4/13	component design modeling
5/9	system design modeling
5.1	establish hardware-based cycle model
5.2	evaluate at design (47°F) and cold (-13°F, -4°F)
9.1	model validation - breadboard data
9.2	refine component sizes for packaged prototype
6	Breadboard prototype design and component development
6.3	build - reactor core
6.4	design - balance of system
6.5	reactor core component testing - CW
7/8	Breadboard prototype system assembly and evaluation
7.1	assembly - at ORNL
7.2	lab evaluation **Go/No-go: GCOP>120% and capacity >~60 kBtu/h**
10	Packaged prototype design and assembly
11	Packaged prototype evaluation
11.1	lab evaluation: AFUE>135% and capacity >~75 kBtu/h
11.2	installation - research home or FRP
11.3	evaluation - research home or FRP

Note: not all subtasks shown