U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Fuel Cell Cooling, Heating, and Power (CHP)

Be Power Technology, Inc./Blue Frontier, LLC; ORNL

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Project Summary

Timeline:

Start date: 10/01/2017

Planned end date: 9/30/2020

Key Milestones

Milestone 1: Dehumidification with alternate liquid desiccants; June 30, 2018

Milestone 2: EP-HVAC Simulated results; September, 30, 2018

Budget:

Total Project $ to Date:

- DOE: $300K (FY2017)
- Cost Share :$1641K (Be Power Tech. Inc.)

Total Project $:

- DOE: $300K (Small Business Voucher CRADA Program, FY17)
- Cost Share: $100K in FY17
- $1641K (Be Power Tech.)
- $6M (Venture Capital)

Key Partners:

Blue Frontier, LLC	ORNL

Be Power Tech, Inc.

Blue Frontier, LLC

Project Outcome:

Natural gas –driven liquid desiccant air conditioning and onsite fuel cell for power generation.

(Natural gas driven heat pumps: Table 3. HVAC metrics, statuses, and 2020 targets, MYPP 2016-2020, pp.66).

Team

- **Blue Frontier, LLC** has a strong Intellectual Property (IP) portfolio:
  - Heat and mass exchangers (HMX).
  - Control algorithms and control schemes.
  - Marketing and customer data.
    - Track record of in-house R&D on membrane fabrication and collaborative R&D with NREL.
- **ORNL** to provide large scale simulations of building energy consumption across all building types, climate zones using supercomputers.
- **ORNL's** focus is on liquid desiccants (LD) for dehumidification.
  - Alternate LDs to meet performance and cost targets.
- **The Small Business Voucher CRADA project.**
  - Completed on time and within budget.
  - Proved the feasibility of using natural-gas for on-site electricity production and HVAC without using any commercial refrigerant or a compressor.

Challenge

Problem Definition:

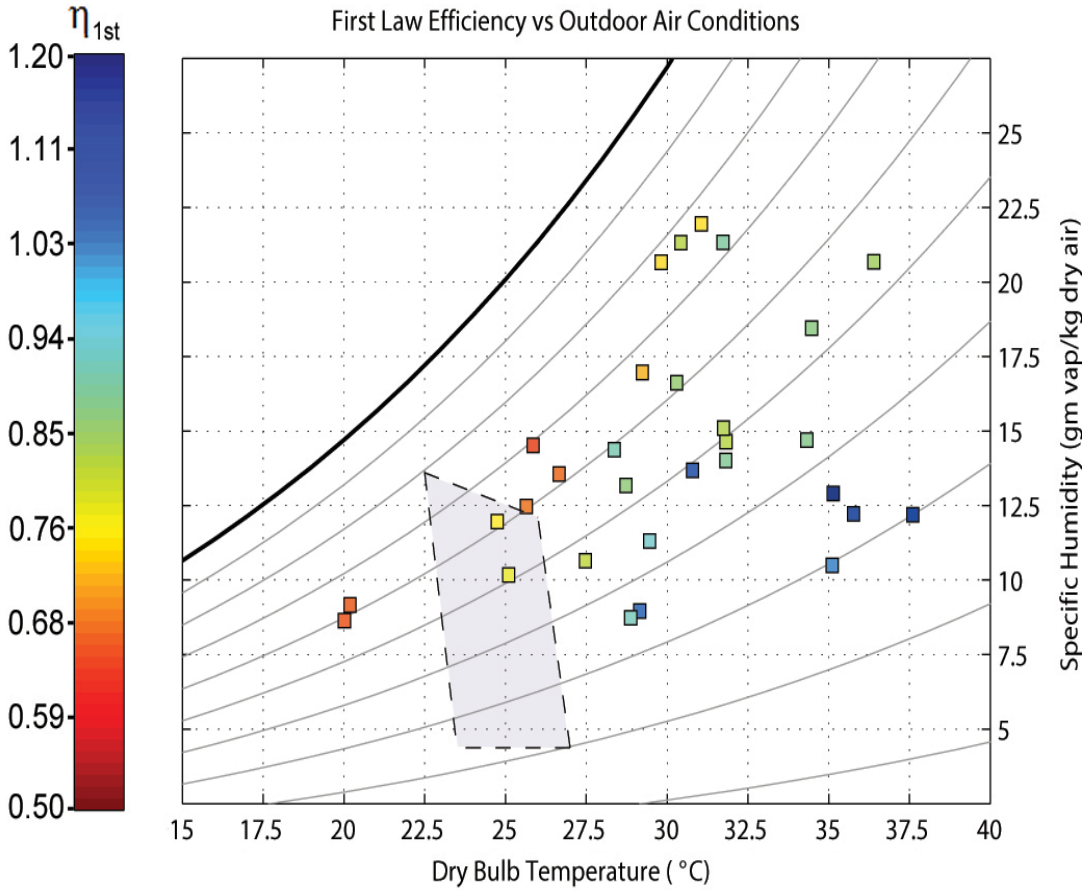
- Commercial buildings:
  - energy costs > $180B in 2014 (EIA data, BTO MYPP).
  - consume ~18 Quads of which HVAC is ~6 Quads (32%).
- Commercial customers want:
  - grid reliability
  - on-site electricity generation
  - higher primary energy to electricity conversion
  - energy savings
  - less expensive fuel
  - low GWP refrigerants
  - dehumidification
- Utilities want to serve their customers.
- Other stakeholders want:
  - a cleaner burning fuel
  - higher efficiency
  - less environmental impact

Advice:

- The prototype tested at ORNL in FY2017 was the first-of-its-kind.
- It used natural gas (NG) to power a fuel cell to generate electricity at 48% efficiency.
- It used a LD system to dehumidify outside air using membrane HMXs.
- The dehumidified air was further conditioned with direct and indirect evaporative cooling to produce supply air.

Challenge (cont'd)

- Prototype achieved high First Law efficiency for a range of RH and OA temperatures.



$$\eta_{1st\ Law} = \frac{C+E}{F}$$

C= Cooling, kW
E= Electricity, kW
F= Fuel input, kW

Test points and $\eta_{1st\ Law}$ achieved. Comfort zone region is shown in dashed line polygon.

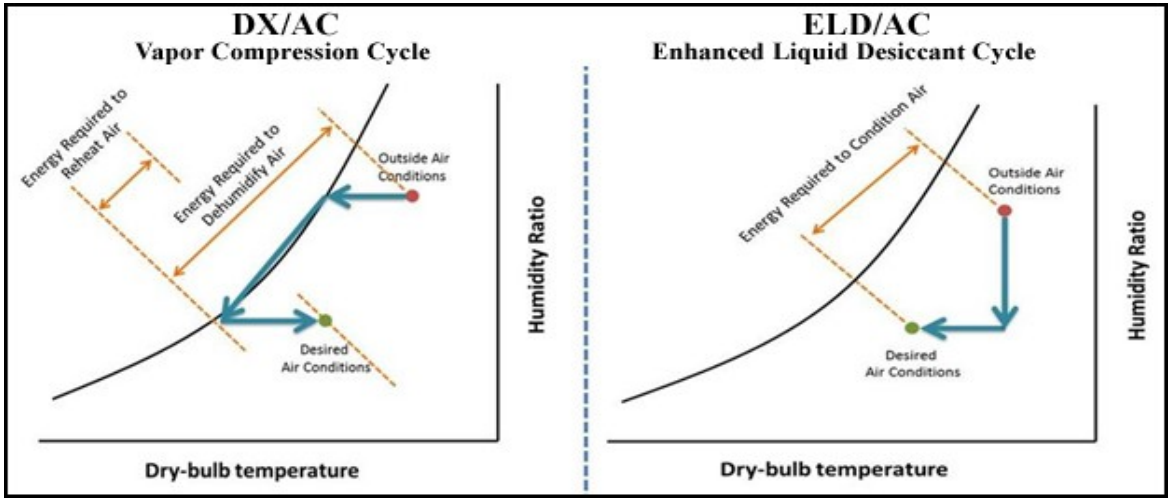
Approach

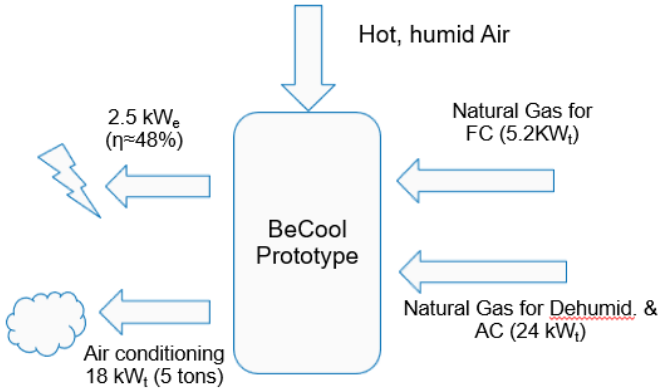
- NG-driven Fuel Cells pros and cons:
  - SOFCs efficiency ~45-75% but better FCs also cost more.
  - FC stack life is 2-3 years.
  - FCs must have a base electrical load.
  - They cannot be powered on and off frequently without damage to the stack.

- An alternate to FCs is to use a microturbine (MT) at the expense of sacrificing some efficiency.
  - MTs can be powered down easily and are durable.
  - MT cost is about 15% that of FCs.

Approach (cont'd)

- Dehumidifying OA first can remove up to 70% of the latent leads in hot–humid climates.
  - Reduces energy load on the HVAC system.
  - The conventional method of cooling below the DP and then reheating to the thermostat set point is wasteful of energy.
  - Our technology offers a better pathway.



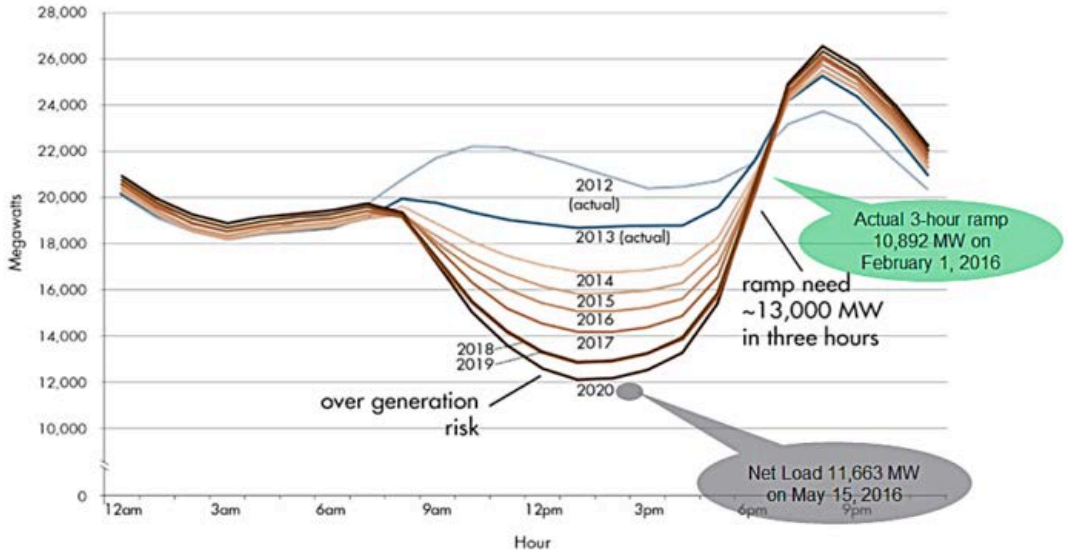


Approach (cont'd)

- The current plan:
  - simulations on using an alternate LD.
  - model the energy savings, by replacing the FC with a MT.
  - Balance cost versus performance.
- Critical path is whether the technology can meet or exceed BTO's stated objective of 44% primary energy savings at an installed cost premium of $1.1 sq. ft.
- Manufacturability of HMX on mass scale and cost reduction.
- Approach distributed generation differently.
  - Move primary focus from only producing electricity off the grid to a tie-in with HVAC and/or dehumidification.
  - Commercial buildings need more than electricity – they need cooling, heating, hot water and humidity control.
- Although the first prototype of its kind tested at ORNL under varying outdoor air conditions achieved high $\eta_{1sr\ Law}$ efficiency, further improvements are possible.
- Unique technology because dehumidification, cooling, electricity production, and heating are built into a single system, driven by natural gas, and does not require compressors or commercial refrigerants.

Impact

- If the project specific goals are met, it should have a significant impact on BTO's target goal of achieving 44% reduction in primary energy savings at $1.1 installed cost premium.
- By removing humidity up front, this technology should reduce the energy consumption, especially in hot-humid climates.
- A change from current practice is needed.
- The technology helps the grid by flattening the "duck curve".



Impact (cont'd)

- With FCs, price points are hard to meet. Look at alternatives.
- Moving forward, looking at MT instead of FCs.
- Utilities and their customers have expressed interest because of its dual purpose of efficient electricity generation, and lowering the cost and energy consumption of conditioning air.
- The team is working on formal proposals at a funding level of $8M over 2 years for field tests.
- Dr. Daniel Beets and his team have established a track record of attracting capital from private investors.
- They have a history of successful partnership and licensing agreements with NREL.
- Their technical team interfaced seamlessly with ORNL engineers during testing of the prototype unit.

Progress

- Prototype developed and tested for proof-of-principle and high energy efficiency.
- Successful CRADA completed. Report may be accessed from https://resolution.ornl.gov/pub/preview/74419.
- Identified several areas of improvement/cost reduction/packaging.
- Moving forward with MTs to meet price points for market entry.
- Current focus is to sacrifice some efficiency to reduce costs, and increase operational flexibility.
- Alternate LDs to further reduce costs.
- Negotiate three field tests in hot-humid and hot-dry climates.
- Demonstrate that on-site electricity generation and grid independence is a value proposition.
- Demonstrate that utilities shall be enabled to cope better with steep changes in demand with distributed generation.
- Win-win situation for utilities, customers and grid operators.

Stakeholder Engagement

- This project is at mid-stage with a successful prototype demonstration.
- Electric and gas utilities are supportive of this technology.
- Provides customers with greater reliability and less grid dependency.
- It should improve grid stability and cause less pollution because of higher efficiency and less electrical losses.
- All parties actively engage in dissemination of technical information to various stakeholders.
- Representations to utility companies and commercial conglomerates are on-going with Blue Frontier, LLC.
- ORNL and Blue Frontier have a presentation at the International Building Physics Conference, (September 2018) endorsed by ASHRAE, REHVA and China committees of Building Physics.
- Three field demonstrations are in the planning stages involving ORNL, NREL, Blue Frontier, LLC , the California Energy Commission and an Illinois-based not-for-profit corporation.

Remaining Project Work

The prototype tests at ORNL provided valuable information on the viability of this technology and its potential in addressing the pressing issues (see, Challenge and Impact sections), as well as areas of improvement. To take the technology to the next level, the planned work must focus on the following:

- Assess the performance and price impact of substituting the FC with a MT.
- Investigate the use of an alternate low-cost LD and model its performance under various weather conditions for different building types.
- Include a dehumidifying air-handler that is simple in design and regenerate the LD using capacitive deionization. This will lower NG usage and lessen CO_2 emissions.
- Use advanced manufacturing techniques to improve the performance and quality of the membranes that comprise the HMX exchangers.
- Plan for field demonstrations in both hot-humid, and hot-dry climates.

The first three bullets are part of on-going work in FY18. The fourth bullet is an alternative plan in search of funding (potential sponsors, DOE Advanced Manufacturing Office). The fifth bullet is being pursued as discussed under Stakeholder Engagement.

Goal is to bring the technology to market through a utility, within 3 years.

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: $1641K (Be Power Tech.); $6M (private investment); $300K (DOE SBV); $100K ORNL.
Variances: Project accomplished with negative variance ($13K returned to DOE, SBV program)
Cost to Date: 38% of FY 18 money spent
Additional Funding: None

Budget History					
FY 2017 (past)		FY 2018 (current)		FY 2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$400K	$1641K	$300K	$0K	$150K	$0K

Project Plan and Schedule

Describe the project plan including:

- Project original initiation date:10/01/2017.
- Project planned completion 9/30/2020
- Schedule and Milestones
- Explanation for slipped milestones and slips in schedule
- Go/no-go decision points
- Current and future work