

# NEW PROJECT

## Hybrid HVAC with Thermal Energy

## Storage Research and Demonstration



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Dutton Co-PI Technical Lead

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# Project Summary

WBS # 2.2.2.42

## Timeline:

Start date: **New** October 2018

Planned end date: September 2021

## Key Milestones

1. Thermal energy storage model implemented in Modelica; 12/31/2018
2. Demonstration of system energy savings and load reductions 9/30/2019

## Budget:

### **Total Project \$ to Date:**

- **DOE:** \$900k
- Cost Share: \$0 (in Y1)

### **Total Project \$:**

- DOE: \$3504k
- Cost Share: anticipated late FY19, FY20 and FY21

## Key Partners:

UC Davis WCEC	UC Berkeley
Jonathan Woolley	

## Project Outcome:

**Help build electricity grids that are affordable reliable and cleaner.** Develop a grid integrative HVAC system that can help stabilize grids, electrify heating and facilitate broader utilization of renewable energy.

Packaged HVAC for commercial building retrofits, that combines Thermal Energy Storage, advanced heat pumps, low energy use cooling and model predictive control.

# Team



**Dr. Spencer Dutton**  
*Co-Principal Investigator, Technical Lead*



**Dr. Brett Singer**  
*Principal Investigator Group leader*



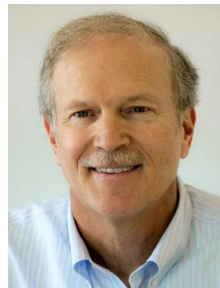
**Dr. Michael Wetter**  
*Simulation Lead*



**Prof. Vinod Narayanan**  
*Principal Investigator (HVAC integration)*



**Dr. David Vernon**  
*Co-Principal Investigator (HVAC integration)*



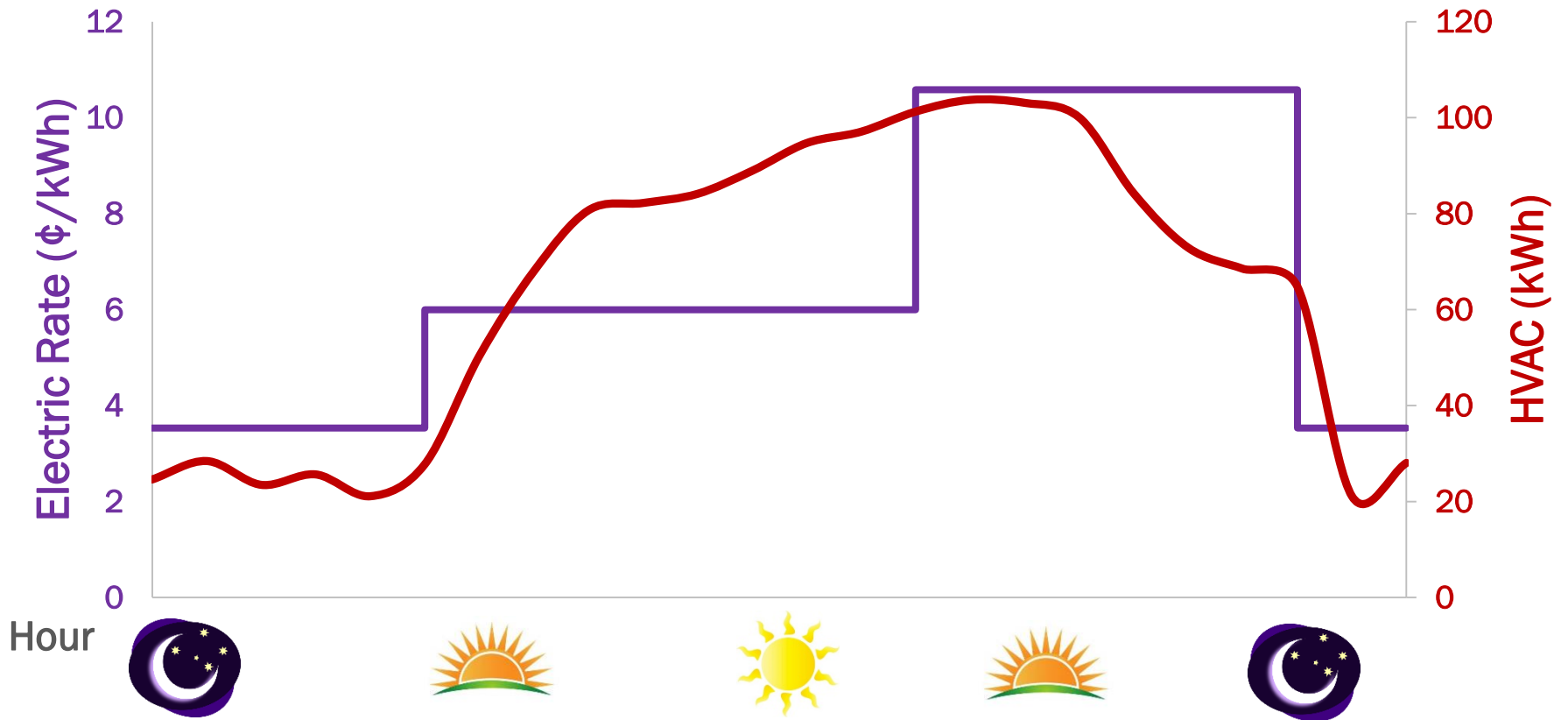
**Prof. Van Carey**  
*Principal Investigator (Thermal storage)*



**Dre Helmns**  
*PhD Candidate UC Berkeley (Thermal storage)*

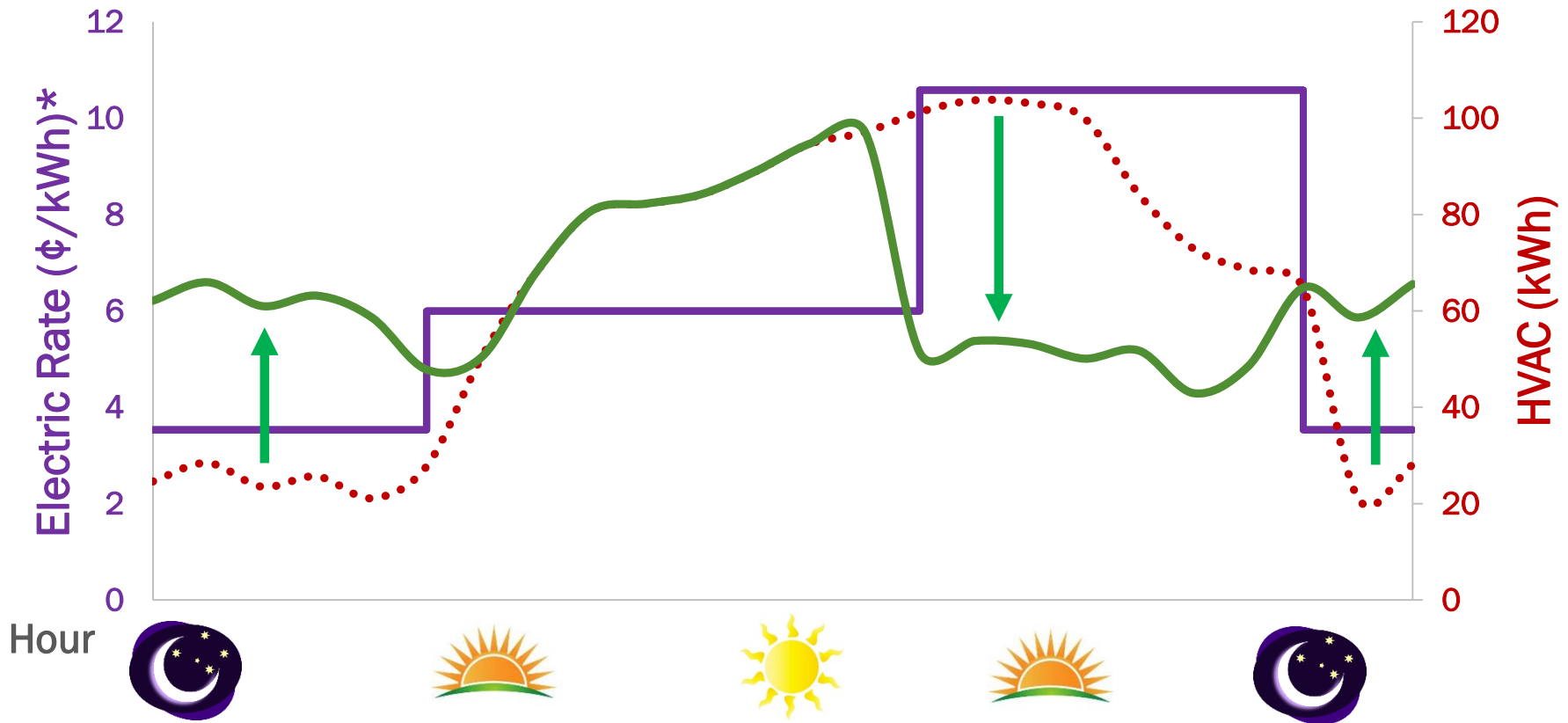
# Challenge: Variable rate energy costs

*Significant energy use at peak rates*



# Challenge: Variable rate energy costs

*Reduce peak HVAC electrical load by > 40%*  
*Reduce total energy costs (use + demand)*



# Challenge: Current state of the art

## Current

- Facility thermal storage (ice, cold/hot water)



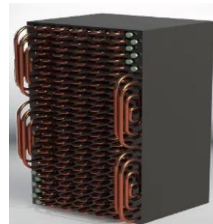
- Battery storage



- Ice Bear (packaged HVAC - Ice storage)



- NetEnergy+NREL packaged HVAC-PCM



- Custom PCM based HVAC



## Issue

- Practical only at scale

- Limited cycles

- Needs rebates
- Utility control
- No heat storage
- Second compressor

- Costs unknown
- No heat storage

- Project specific
- Not manufactured

## Metrics

(~\$60-600 \$/kWh) electric equivalent installed

(~1000\$/kWh) or (\$2600/kW) installed

(~600 \$/kWh or ~2400 \$/kW) installed  
6000lb vs 600lb

unknown

(~\$300 -1100) kWh thermal installed

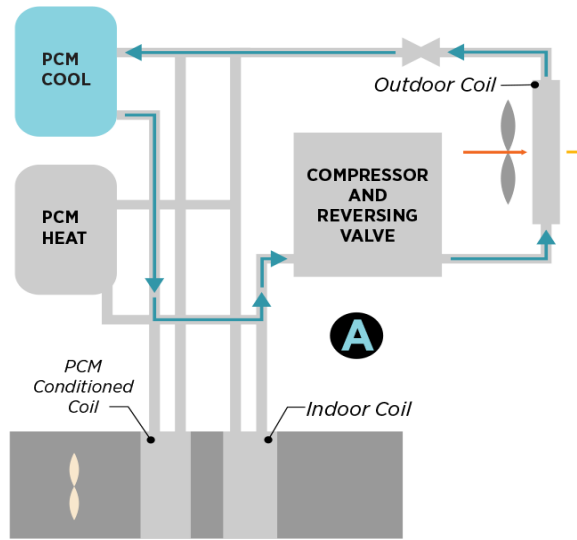
# Approach: FY19-21

- **FY19: Select prototype design using models**
  - Component models in Modelica, including new TES model, and **Model Predictive Controls**
  - Develop packaged system concepts using guidance from I-Corps, industry partners and TAC
  - Model three system concepts, three building types, minimum of >30% HVAC energy cost savings and >20% peak.
  - Select prototype configuration.
- **FY20: Build and test prototype**
  - Engineer, build + test UC Davis Western Cooling Efficiency Center.
  - Improve MPC algorithms
  - Calibrate models
- **FY21: Install and characterize**
  - Perform a side-by-side comparison with a code-compliant packaged unit, using LBNL's FLEXLAB® facility.
  - Develop data needed for compliance methods, improve MPC

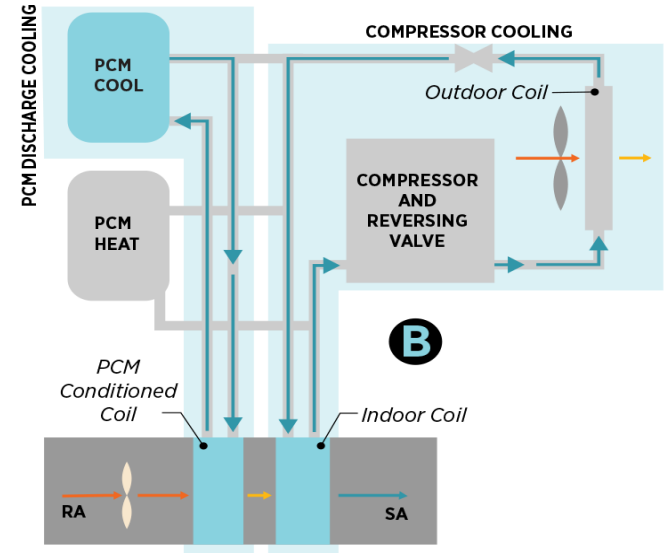
# Approach : Develop system concepts

- Cold TES charged off peak by heat pump (A)
- Use PCM and /or heat pump during peak (B)
- More efficient cooling available at night at lower cost

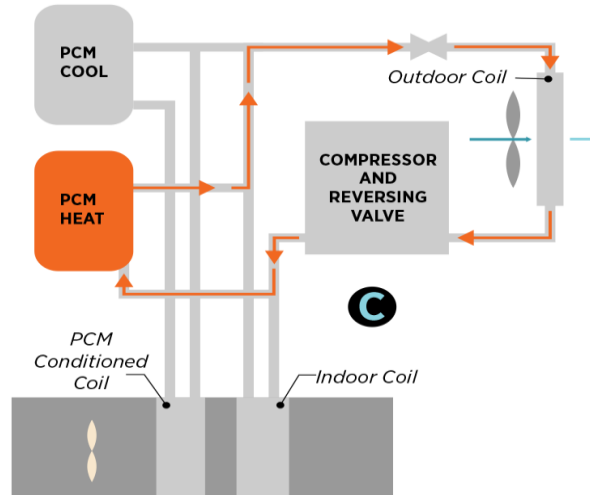
Charge PCM for Cooling



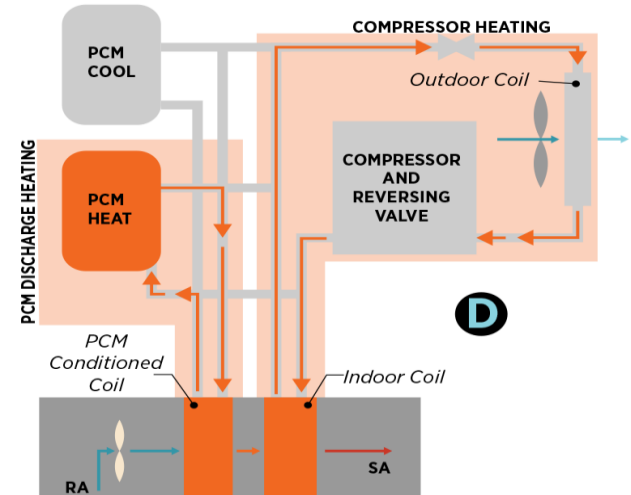
Cooling Operation



Charge PCM for Heating

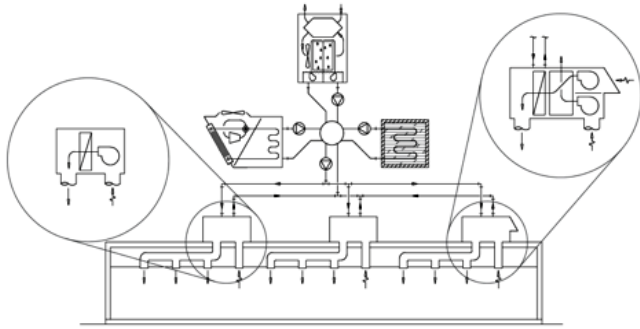


Heating Operation



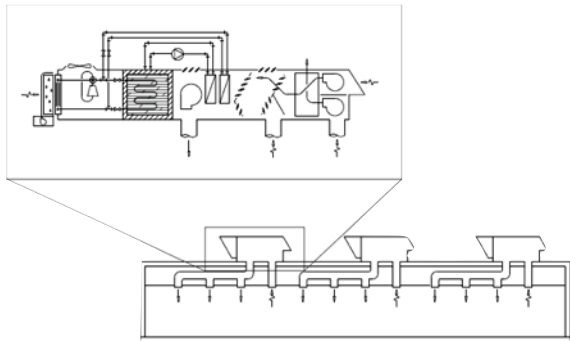
- Hot TES charged off peak by heat pump (C)
- Use PCM and / or heat pump during peak (D)
- Store heat off peak

# Approach: Develop high level system concepts

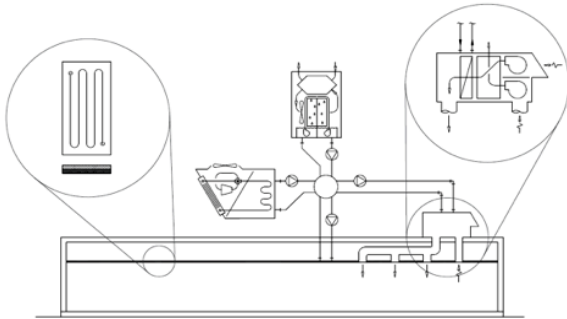


## Description

Centralized plant with evap. Chiller, multi. air handlers



Independent packaged hybrid, integr. PCM



Centralized plant with evap. Chiller, PCM in conditioned space

## Positives

High efficiency, energy savings, multi unit replacement.

Drop in single unit replacement, Night pre-cooling and economizing.

Efficiency gain from radiant conditioning, PCM in space (distributed)

## Challenges

Central plant location/weight

System complexity, size and weight

Not direct replacement, requires

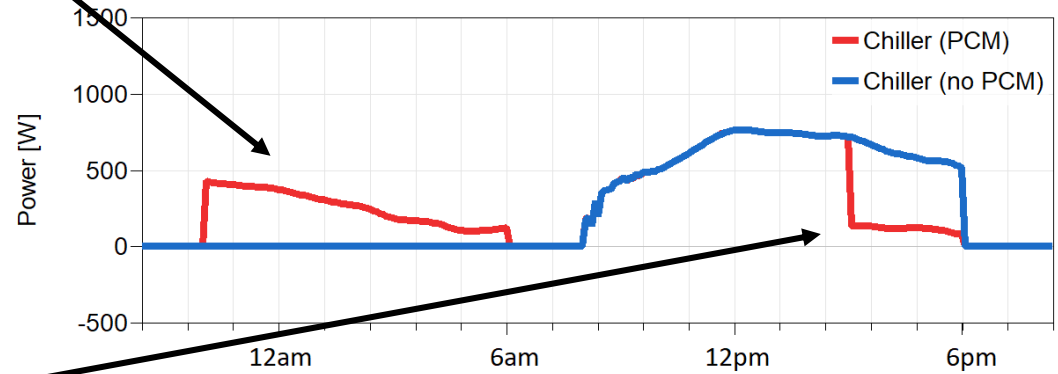
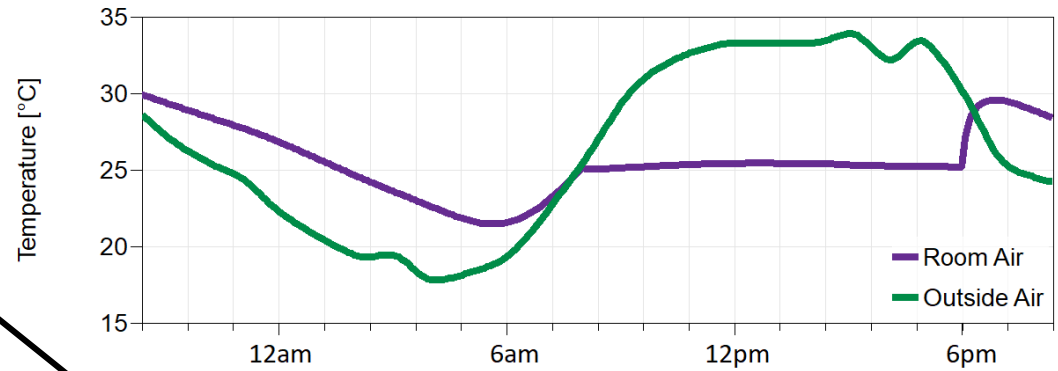
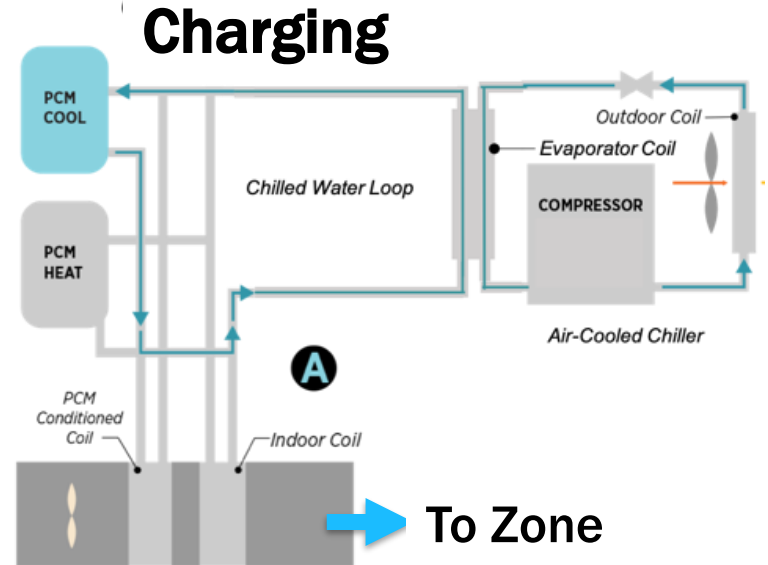
# Impact

*PCM based TES costs < \$300 kWh, 50k cycles at <5% degradation*

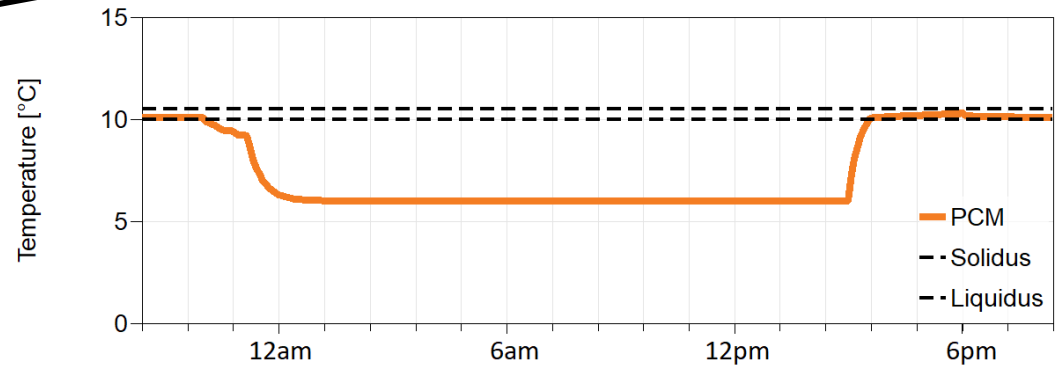
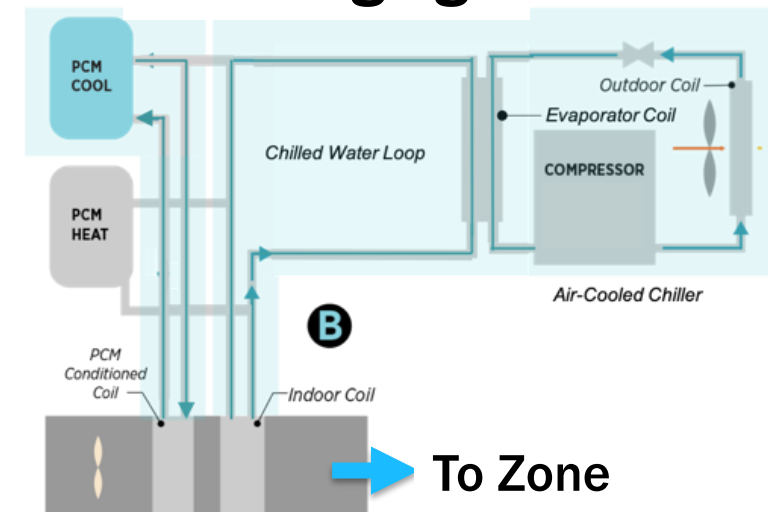
- BTO goals of reducing building EUI by 30% by 2030 + Emerging Technologies goal of reducing building energy use by 45%.
- BTO goal advancing grid interactive efficient buildings.
- Packaged system expands TES use to small and medium commercial.
- HVAC energy cost savings >30, peak power >20% lower, compared to conventional RTUs
- Maximize utilization of on-site and grid connected renewable
- Enable new business models based on demand response
- Support compliance pathways and rebate programs

# Progress: Model development



## Charging



## Discharging



# Progress : Milestones FY19

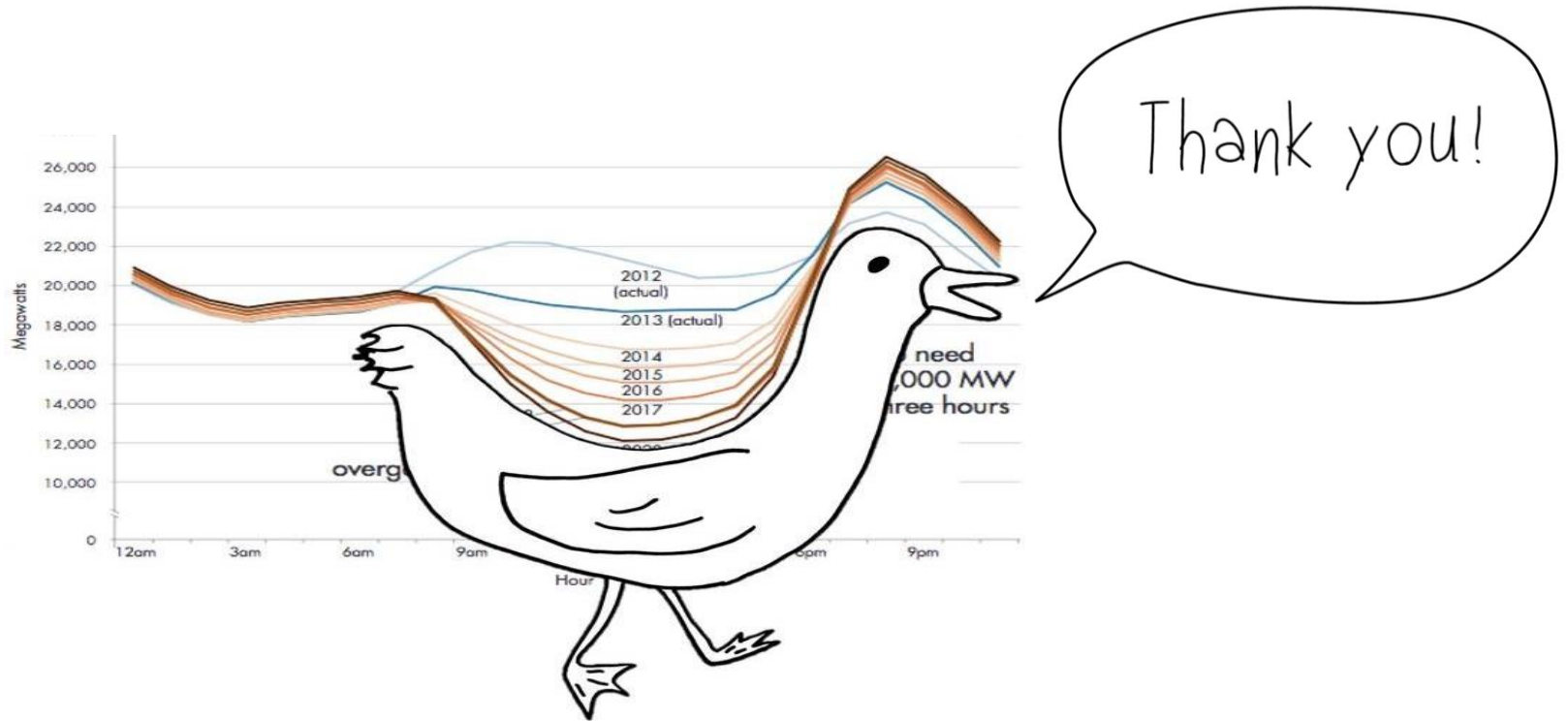
- M1.1. TES model implemented in Modelica. 
- M1.2. Demonstration of a coupled HVAC system model with integrated TES 
- M1.3. Specify candidate systems for analysis. 6/30/2019
- M1.4. Performance predictions for three candidate systems. 9/30/2019
- M1.5 Demonstration of system energy savings and load reductions. 9/30/2019

# Stakeholder Engagement

- Building technical advisory committee (**Dick Lord, Steven Slayzak, Tyler Bradshaw, Joe Huang, Gwelen Paliaga, Abhijeet Pande, Paulo Velasco.. Etc..**)
- Perform economic analysis and opportunity cost analysis throughout the project.
- Use I-Corps training and interviews to engage with stakeholders.
  - ESCOs
  - Utilities
  - Manufactures
  - Distributors
  - Facilities managers
  - Micro-grid developers

# Remaining Project Work

- **Short term FY19**
  - Develop detailed modeling plan
  - Develop system concepts in Modelica (3 or more)
  - Select prototype system (performance + market based)
- **Longer term FY20 – FY21**
  - Plan for FY20 development of prototype
  - Develop industrial partnerships commercialization
  - Identify system prototype build partner and contract
  - Plan and implement Flexlab installation
  - Characterize system performance and present findings



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# Project Budget

**Project Budget: \$900k FY19**

**Variances: No variances from original planned budget**

**Costs to Date: \$410k**

**Additional Funding: Non to date**

Budget History		
FY 2019 (current)	FY 2020 (planned)	FY2021 (planned)
\$900,000	\$1626,000	\$983,000

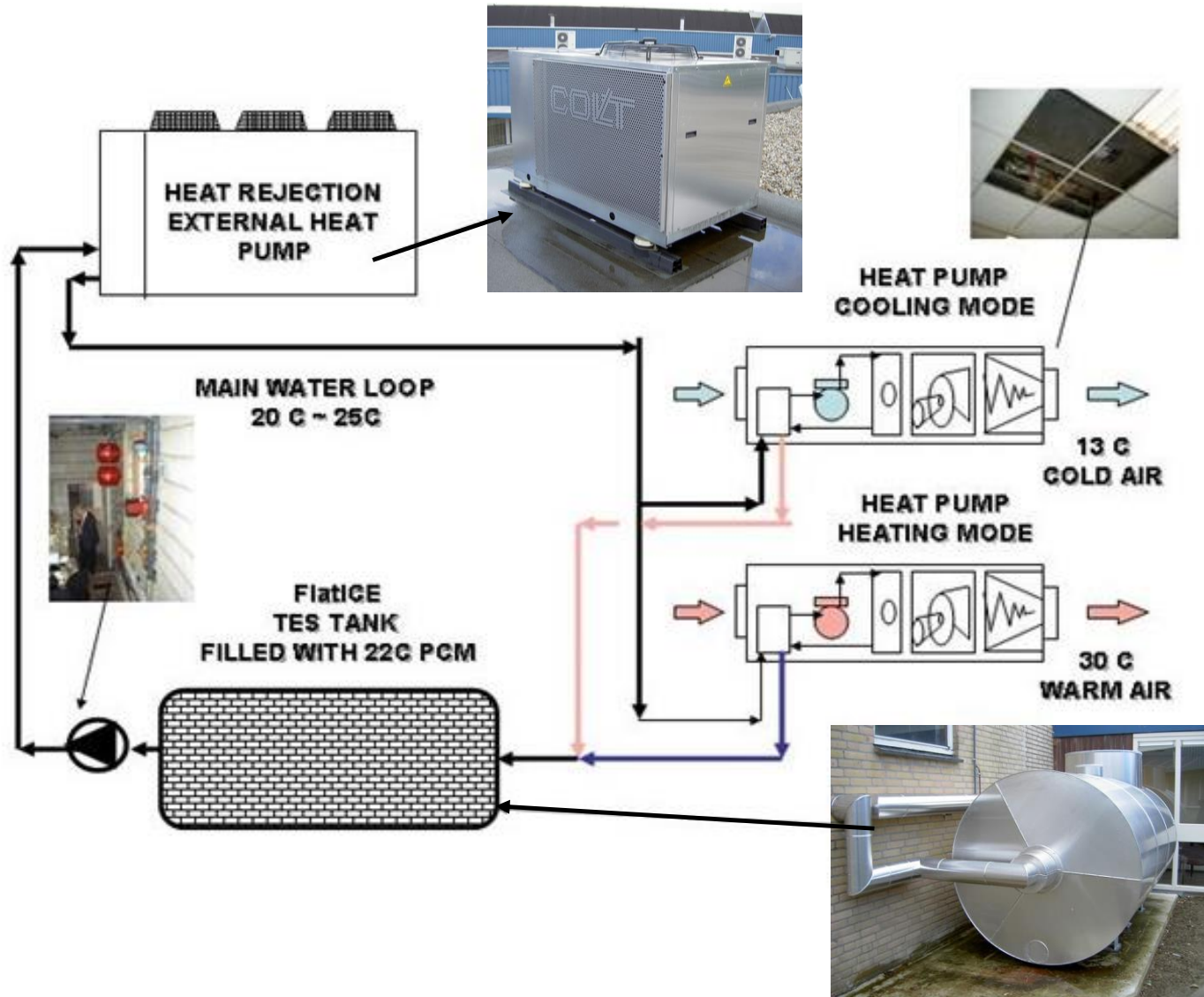
# Project Plan and Schedule

New Project Start: October 2018

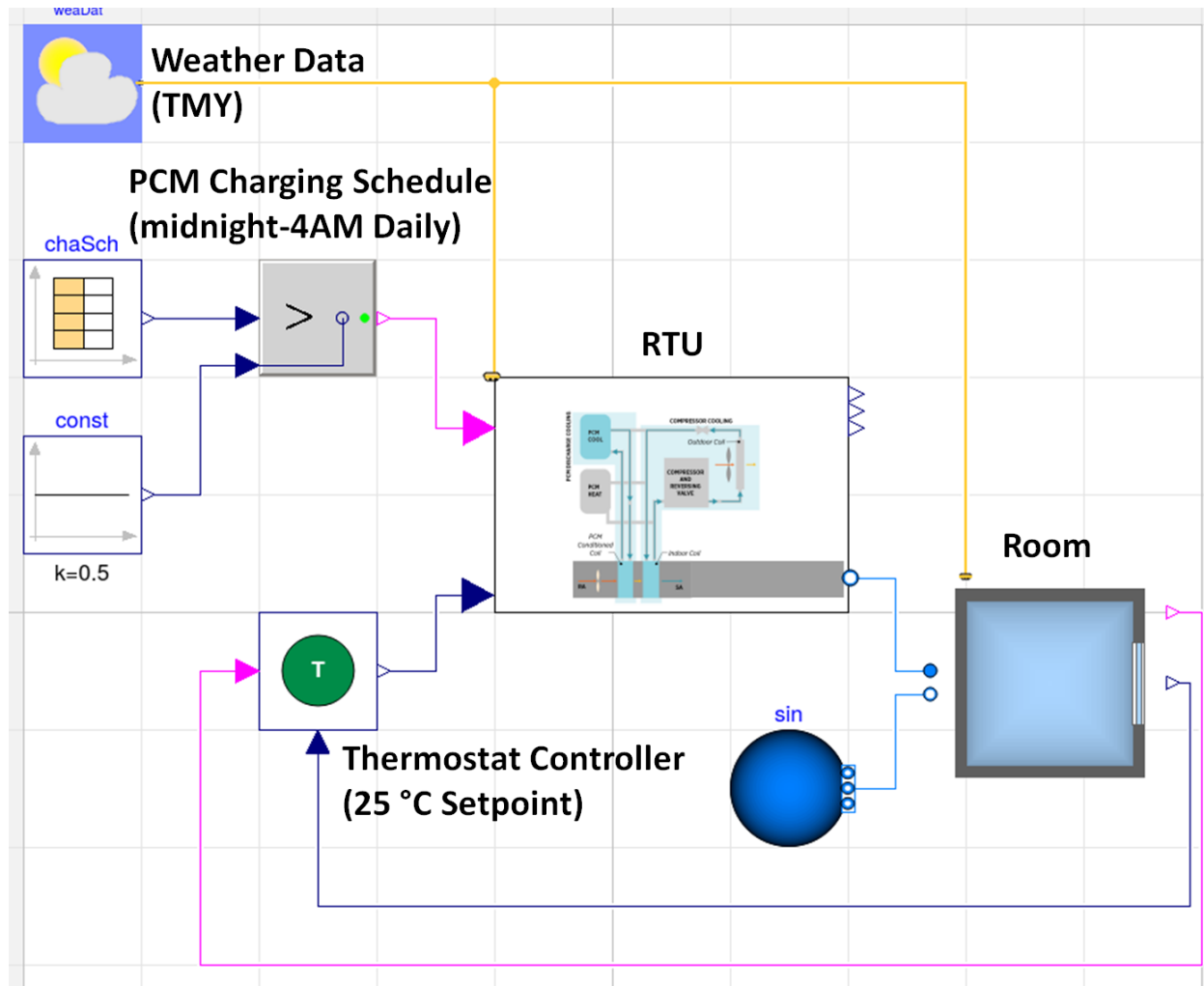
Projected End: September 2021

Milestone Name/Description	End Date	Type	Progress
M1.1. TES model implemented in Modelica.	12/31/2019	Quarterly Progress	Completed
M1.2. Demonstration of a coupled HVAC system model with integrated TES	3/29/2019	Quarterly Progress	Completed
M1.3. Specify candidate systems for analysis.	6/30/2019	Quarterly Progress	On schedule
M1.4. Performance predictions for three candidate systems.	9/30/2019	Annual Milestone	On schedule
M1.5. Demonstration of system energy savings and load reductions.	9/30/2019	Go/No-Go	On schedule

# Supplemental: Current state of the art example



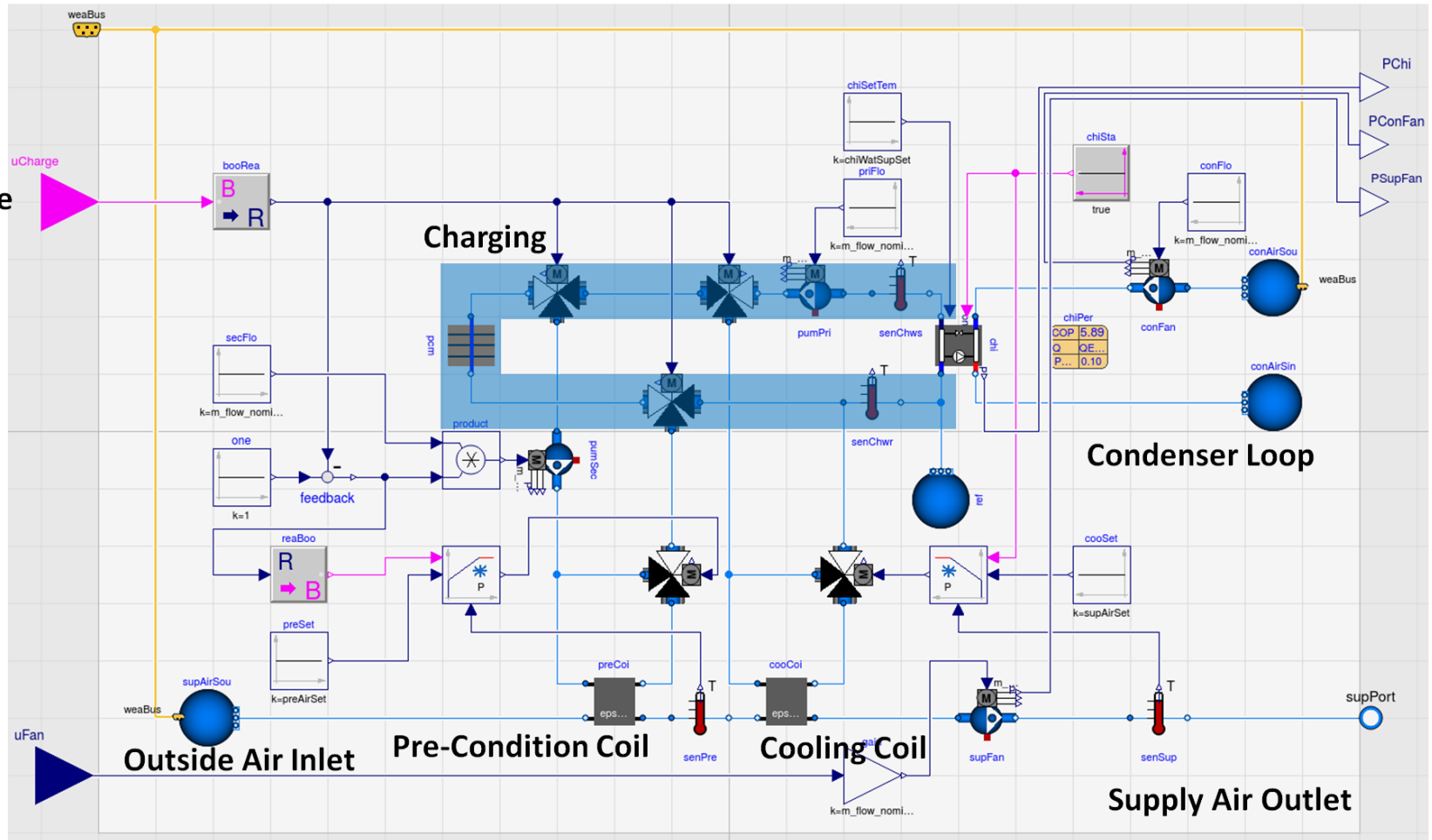
# Supplemental: Modelica Model High Level



# Supplemental: Model Charge Mode

Charge Mode

Fan Control



# Supplemental: Model Discharge Mode

