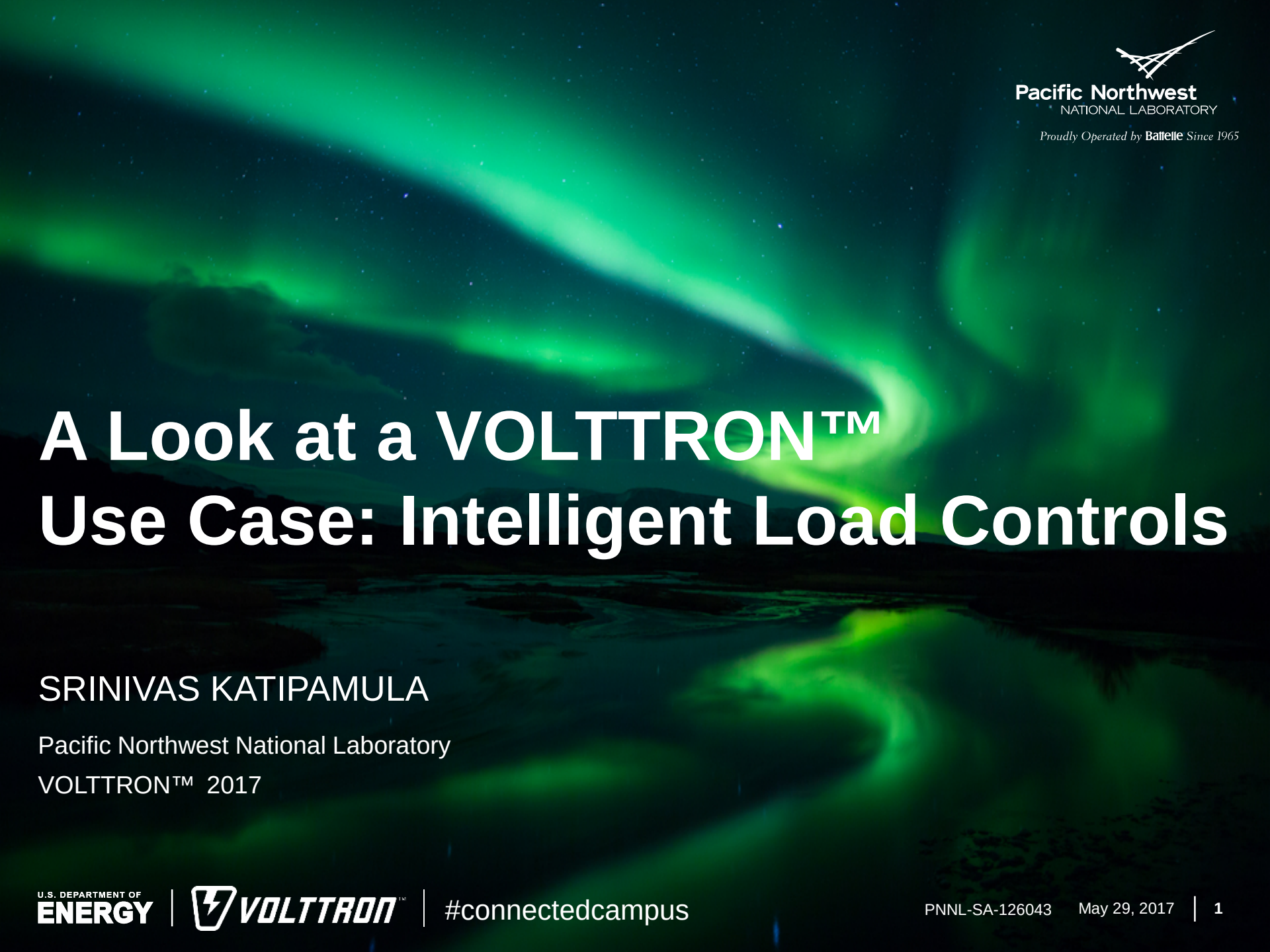

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A Look at a VOLTTRON™ Use Case: Intelligent Load Controls

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Pacific Northwest National Laboratory

VOLTTRON™ 2017

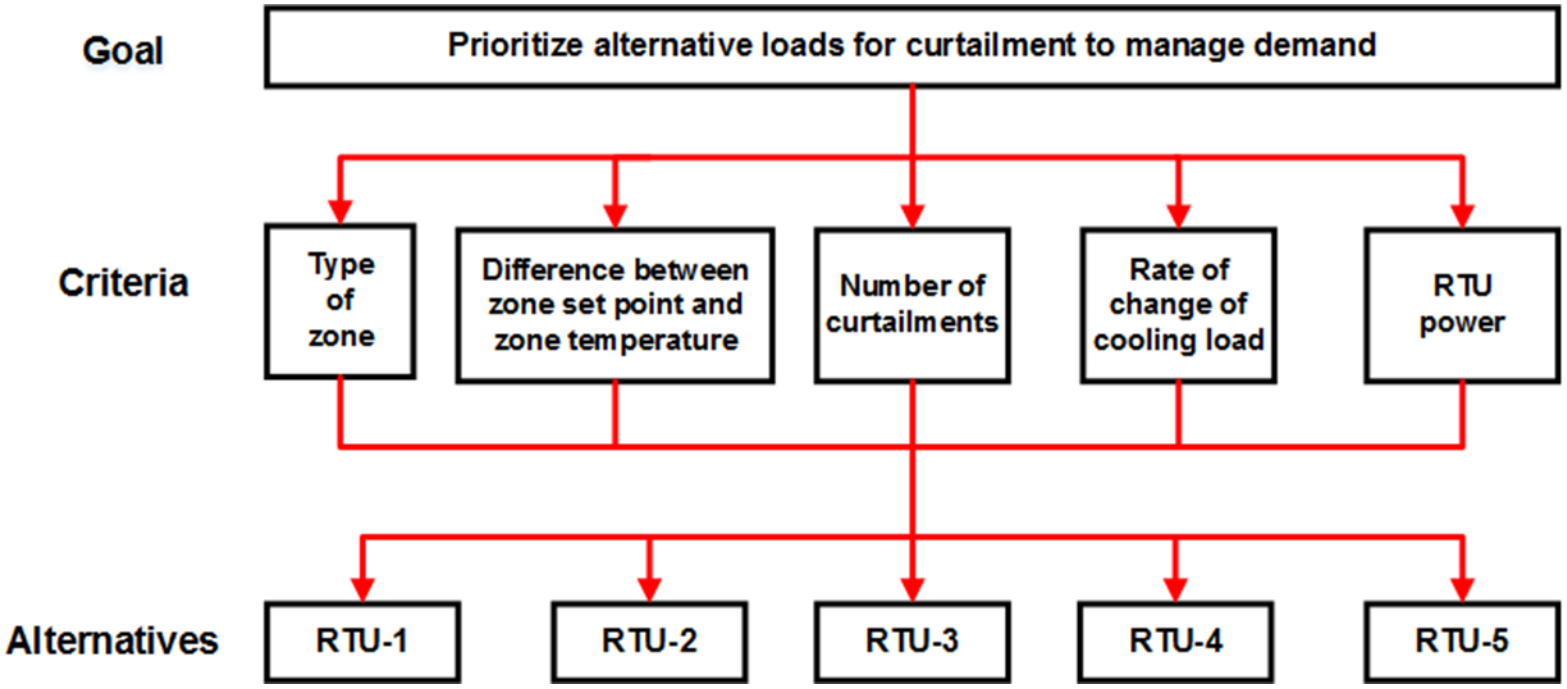
Automated Dynamic Load Shaping

- Automated dynamic load shaping (ADLS) has a number of use cases in commercial buildings
- Mitigating short- (<10 minutes) and long-term (>1 hour) variability from distributed renewable generation assets
- Supporting traditional utility rate structure
  - Demand charge (15 min or 30 min average or rolling-average)
  - Typically based on a 30-day billing cycle
  - Traditional demand response programs
  - Time-of-use and critical peak pricing
- Supporting capacity bidding programs or demand bidding programs
- Supporting Transactive Energy
  - Dynamic rates (15 min or 60 min), real-time pricing as well as day ahead

Intelligent Load Control v-Agent

- Intelligent load control is a highly automated VOLTTRON™ v-Agent that will prioritize controllable end use loads (rooftop units, lighting fixtures and panels, pumps, variable-frequency-drives, etc.) for dynamic load shaping
  - Uses Analytical Hierarchical Process (AHP - a business decision making process) to prioritize available loads
  - Uses rules/criteria chosen by building owners/operators
  - Decision criteria can be both qualitative (difference between current zone temperature and zone set point) and quantitative (type of zone: directors, kitchen, closet, etc.)
  - AHP is a popular and widely used method for multi-criteria decision making
  - Process is executed in two steps:
    - Determine the relative weights of the decision criteria
    - Determine the relative priorities of alternatives (end use loads to curtail)
  - Once the priority list is created, v-Agent sends control actions to manage the building load to the desired shape; the process is repeated every 5-minutes

A Look at Analytical Hierarchical Process



ILC: Deployment

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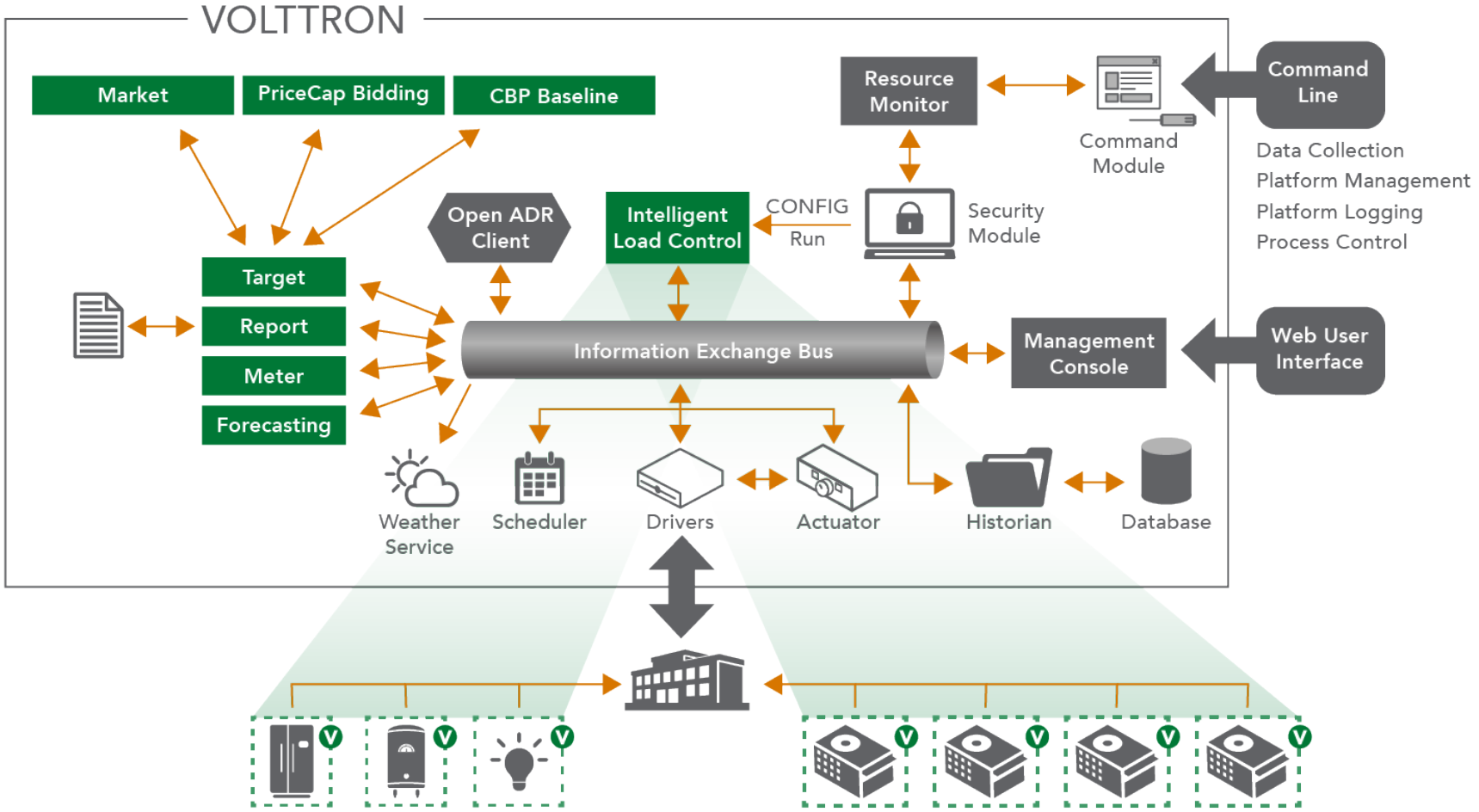
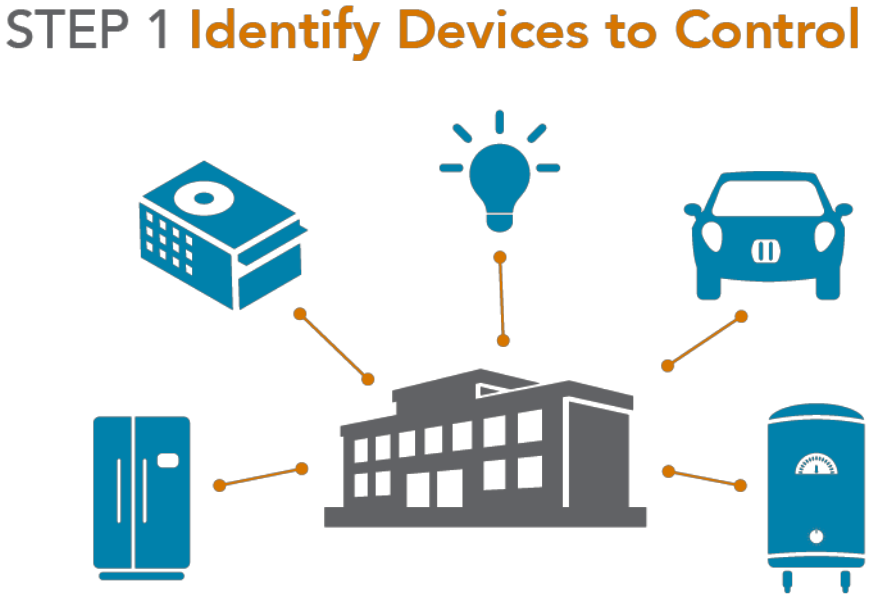
PNNL's VOLTTRON™ platform enables deployment of Intelligent Load Control in building devices



Preparing ILC for Deployment in a Building

- Step 1: Identify devices to control
- Step 2: Selection of criteria to “discriminate” between homogenous loads and non-homogenous loads
- Step 3: Create device and registry (points) configuration files to access data and to initiate controls
- Step 4: Create ILC agent configuration files
- Setup risk mitigation parameters
- Ready to launch ILC
- Ability to test ILC using EnergyPlus or Matlab model as a source of devices to control

Step 1: Identify Devices to Control



Step 2: Selection of Criteria – RTUs

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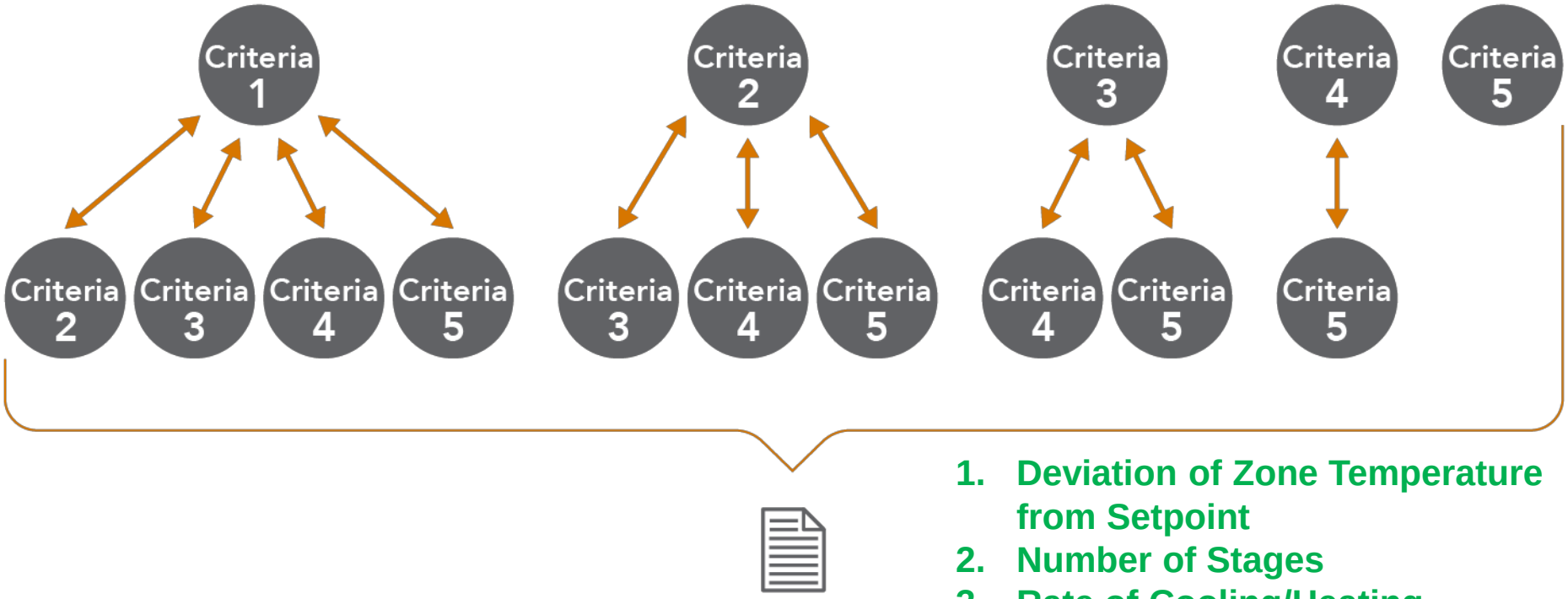
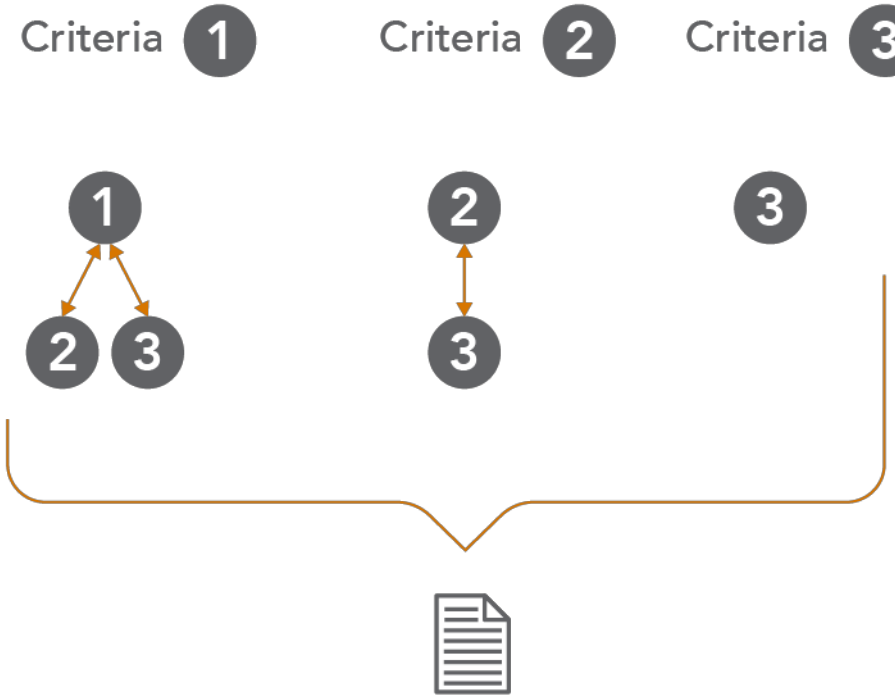
STEP 2 Prioritization Between Multiple RTUs



1. Deviation of Zone Temperature from Setpoint
2. Number of Stages
3. Rate of Cooling/Heating
4. Curtailment Count
5. Rated-Power
6. Room-type

Step 2: Selection of Criteria - Lights

STEP 2 Prioritization Between Multiple Lights



Lighting Dimming Level
Room-type
Curtailment Count

Merging Non-Homogenous Prioritization Lists

Clusters	Devices	Priority List	Cluster Weights	Weighted Combined Priority List	
RTU	RTU #1	0.65	0.8	0.52	1
	RTU #2	0.25		0.20	2
	RTU #3	0.1		0.08	4
Lighting	Zone #1	0.5	0.2	0.10	3
	Zone #2	0.25		0.05	5
	Zone #3	0.25		0.05	5
Sum		2	1	1	

Step 3: Device and Points Configuration

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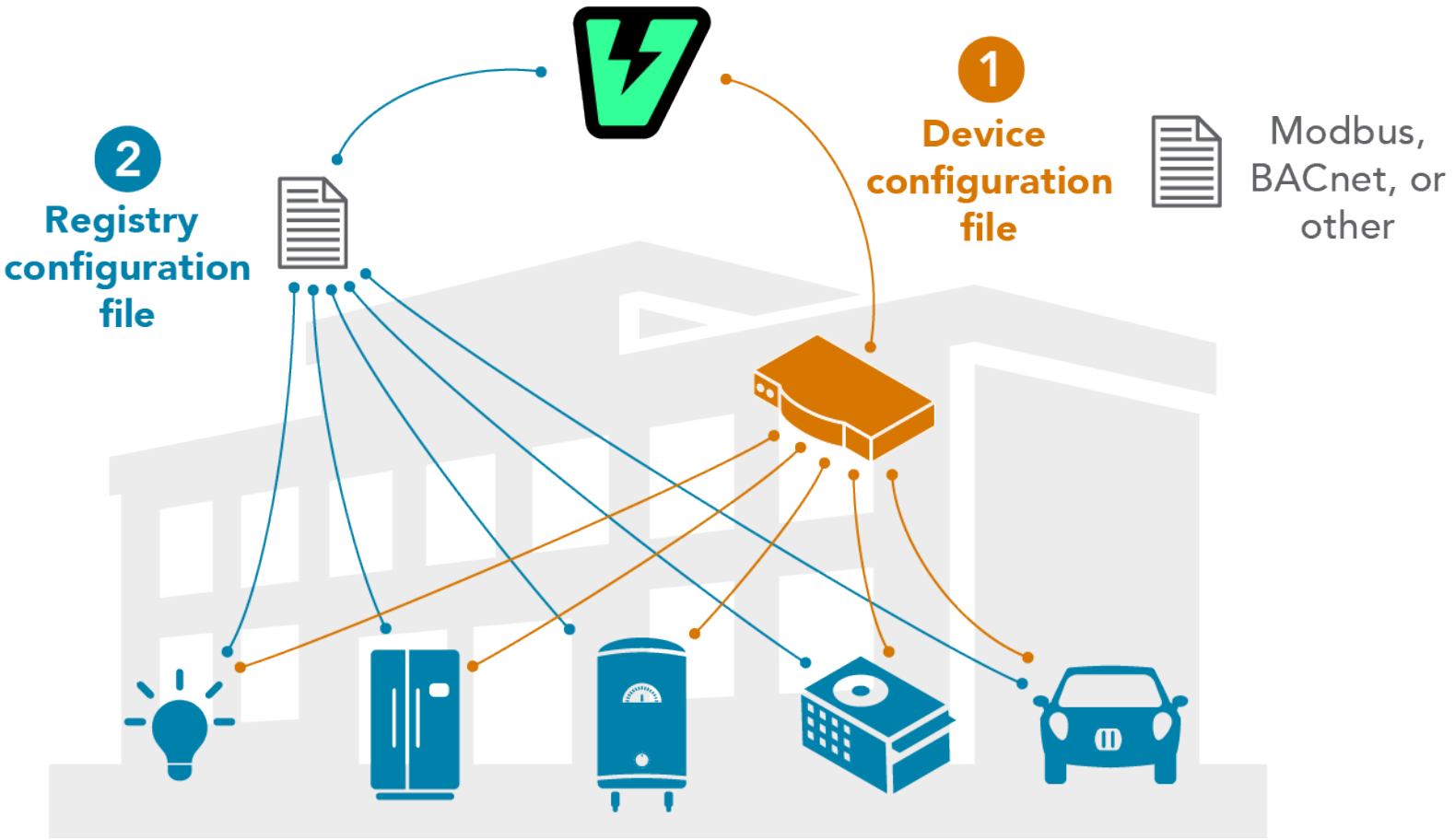
STEP 3 Create Configuration Files



Step 3: Device Configuration

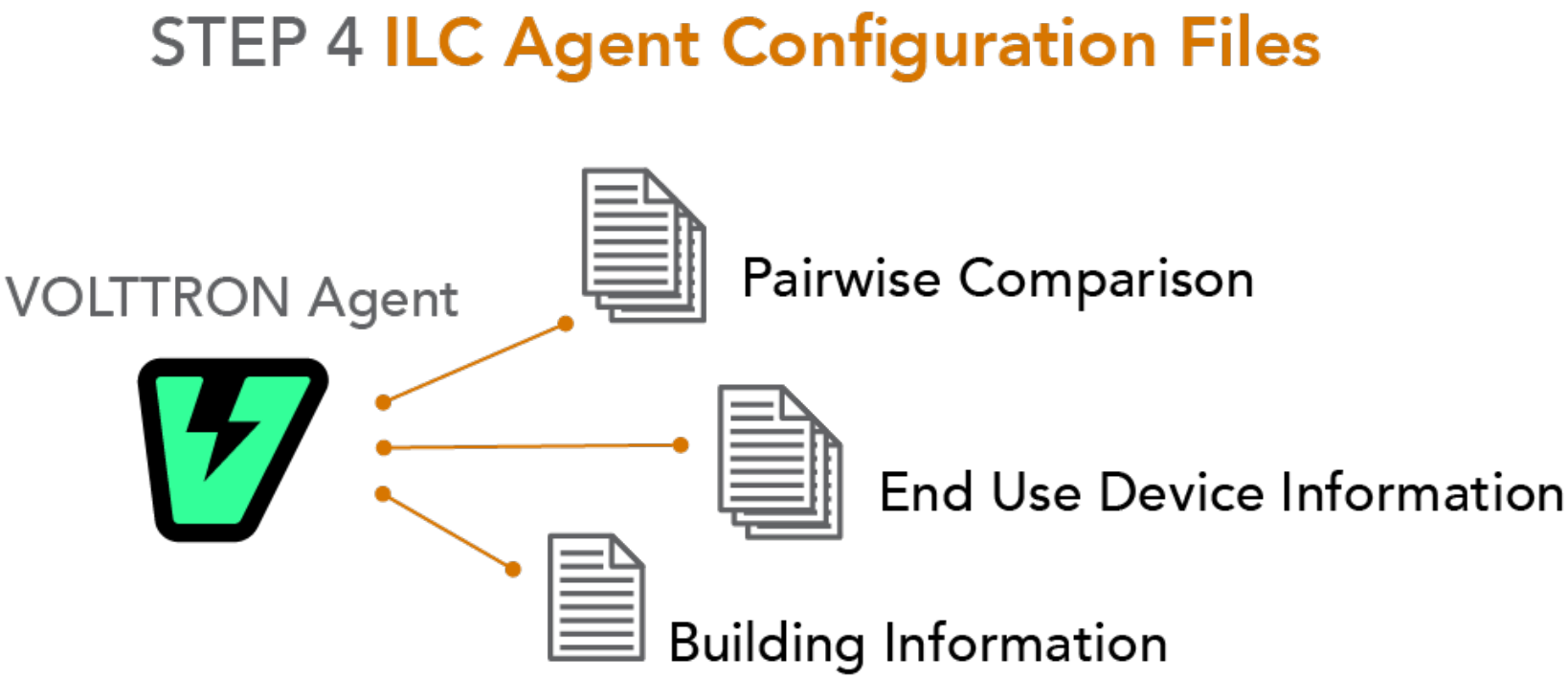

```
{
    "driver_type": "bacnet",
    "driver_config": {"device_address": "10.1.1.3",
                      "device_id": 500,
                      "min_priority": 10,
                      "max_per_request": 24
                     },

"registry_config":"config://registry_configs/BuildingRegistry.csv",
    "interval": 5,
    "timezone": "UTC",
    "heart_beat_point": "heartbeat"
}
```

Step 3: Registry/Points Configuration

Reference Point Name	Volttron Point Name	Units	Unit Details	BACnet Object Type	Property	Writable	Index	Write Priority
BLDG1STAT.HP1-RM-T	ZoneTemperature	dgr F	default 0.0	analogOutput	presentValue	FALSE	3000070	
BLDG1STAT.HP1-OAT	OutdoorAirTemperature	dgr F	default 0.0	analogOutput	presentValue	FALSE	3000071	
BLDG1STAT.HP1-OHTG-SP	OccupiedHeatingTemperatureSetPoint	dgr F	default 68.0	analogOutput	presentValue	TRUE	3000072	
BLDG1STAT.HP1-OCLG-SP	OccupiedCoolingTemperatureSetPoint	dgr F	default 74.0	analogOutput	presentValue	TRUE	3000073	
BLDG1STAT.HP1-UHTG-SP	UnoccupiedHeatingTemperatureSetPoint	dgr F	default 65.0	analogOutput	presentValue	TRUE	3000074	
BLDG1STAT.HP1-UCLG-SP	UnoccupiedCoolingTemperatureSetPoint	dgr F	default 81.0	analogOutput	presentValue	TRUE	3000075	

Step 4: ILC Agent Configuration Files



ILC: Example Building Configuration File


```
{
   "campus": "my_campus",
   "building": "my_building",
   "power_meter": {
      "device": "PowerMeter",
        "point": "power"
   },
   "agent_id": "ilc",
   "curtailment_time": 15.0,
   "curtailment_confirm": 5.0,
   "curtailment_stagger_time": 15.0,
   "average_building_power_window": 30.0,
```

```
"clusters": [
      {
         "device_file_path": "<directory
path>/ilc_cluster_config",
               "critieria_file_path": "<directory
path>/pairwise_criteria_RTU.json",
               "cluster_priority": 1.0
      }
   "mappers": {
      "zone_type": {
            "Directors office": 1,
             "Office": 3,
             "Empty Office": 7,
             "Conference Room": 1,
             "Mechanical Room": 9,
             "Computer Lab": 2,
             "Kitchen": 6
         }
       }
}
```

ILC: Example End Use Device Configuration File

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```
"HP1": {
   "FirstStageCooling": {
       "zonetemperature-setpoint-deviation":{
         "operation": "1/(ZoneTemperature -
CoolingTemperatureSetPoint)",
         "operation_type": "formula",
         "operation_args":
["CoolingTemperatureSetPoint","ZoneTempera
ture"]
        },
       "rated-power": {
         "on_value": 2.2,
         "off_value": 0.0,
         "operation_type": "status",
         "point_name": "FirstStageCooling"
      },
      "room-type": {
         "map_key": "Directors office",
         "operation_type": "mapper",
         "dict_name": "zone_type"
      },
```

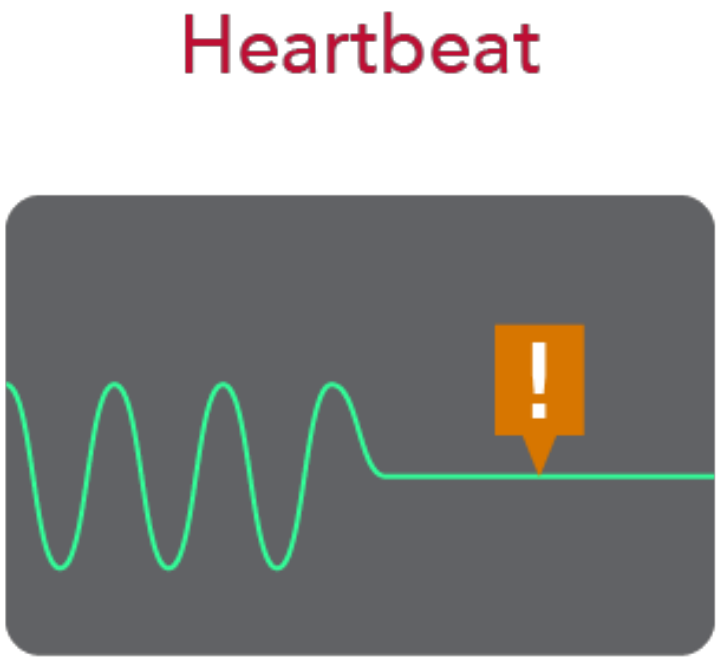
```
"stage": {
         "value": 1.0,
         "operation_type": "constant"
      },
      "historical-comparison": {
         "comparison_type": "direct",
         "operation_type": "history",
         "point_name": "ZoneTemperature",
         "previous_time": 5
      },
"curtail": {
         "point":
”OccupiedCoolingTemperatureSetPoint",
         "offset": 1.0,
         "load": 2.2 # Rated capacity
      }
   }
},
```

ILC: Example Pairwise Comparison Configuration File


```
{
   "zonetemperature-setpoint-deviation": {
      "curtail_count": 7,
      "historical-comparison": 5,
      "room-type": 8,
      "rated-power": 6,
      "stage": 2
   },
   "stage": {
      "curtail_count": 5,
      "historical-comparison": 3,
      "room-type": 6,
      "rated-power": 4
   },
```

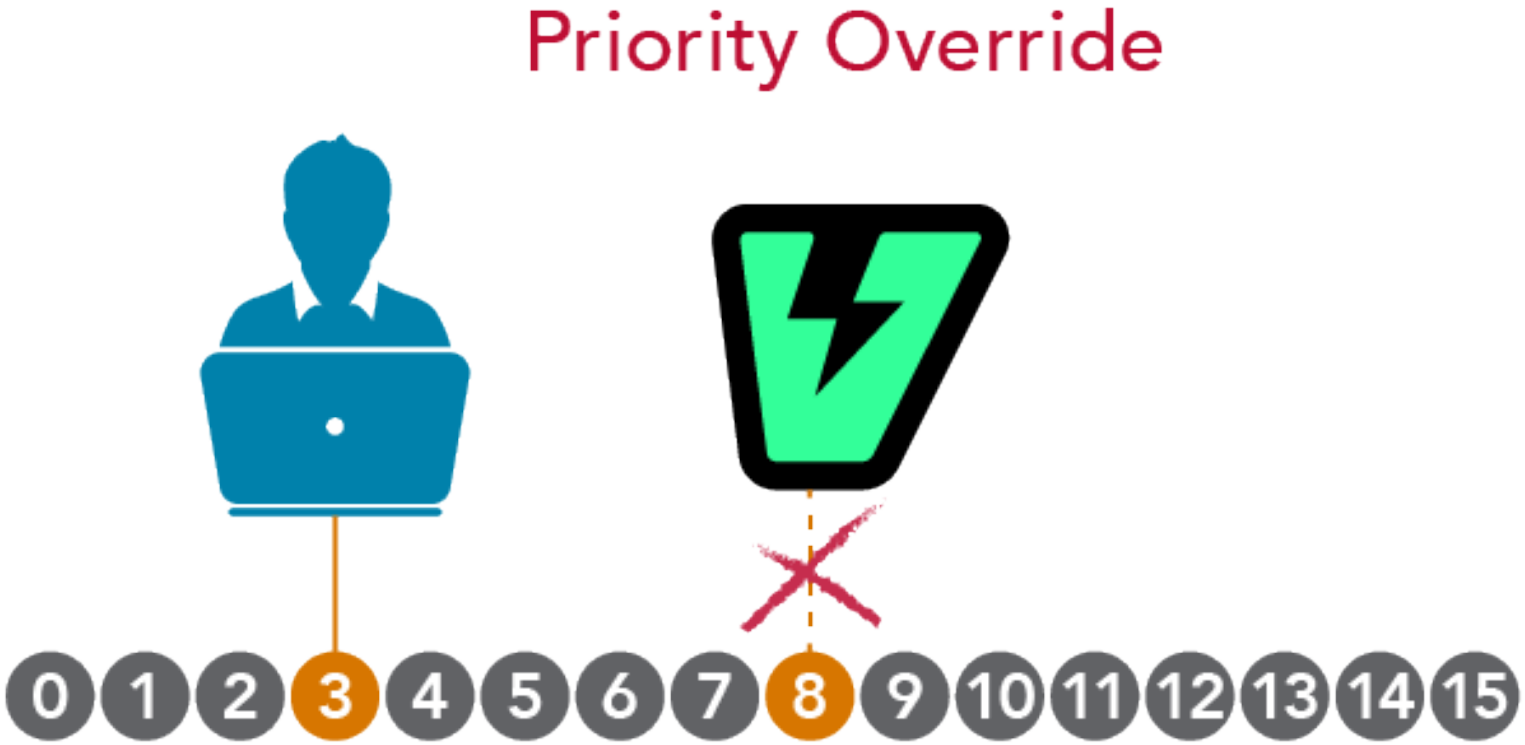
```
"historical-comparison": {
      "curtail_count": 3,
      "room-type": 5,
      "rated-power": 3
   },
   "curtail_count": {
      "room-type": 3,
      "rated-power": 5
   },
   "rated-power": {
      "room-type": 3
   },
   "room-type": {}
}
```

Risk Mitigation: Heartbeat …

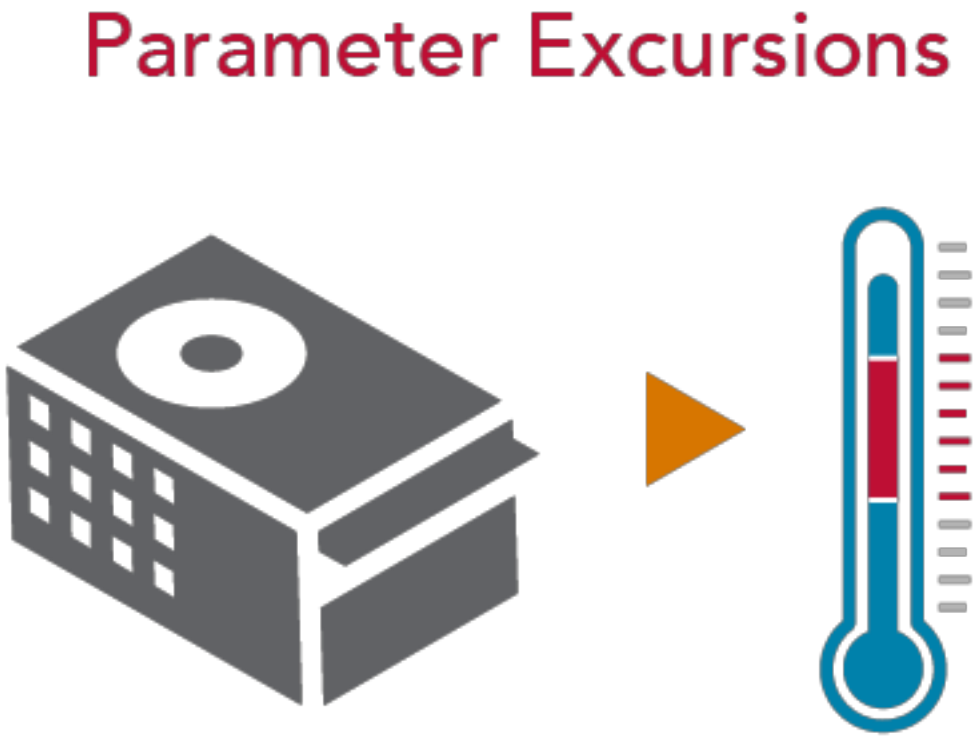


Risk Mitigation: Global Override

Risk Mitigation: Local Override



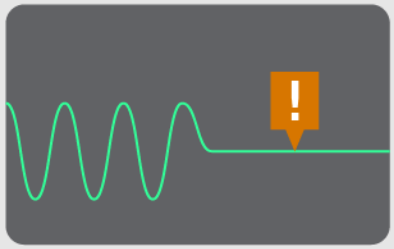
Risk Mitigation: Parameter Excursions



Risk Mitigation

Risk Mitigation

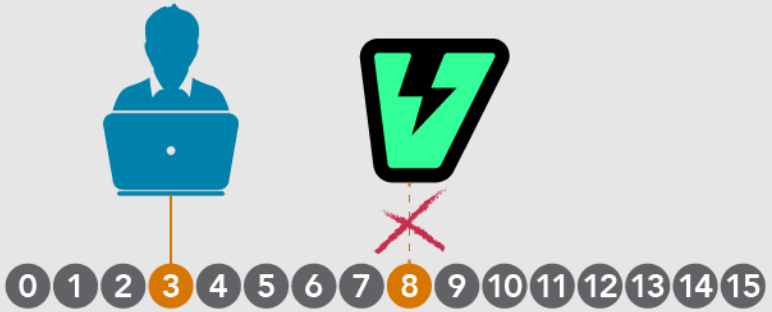
Heartbeat



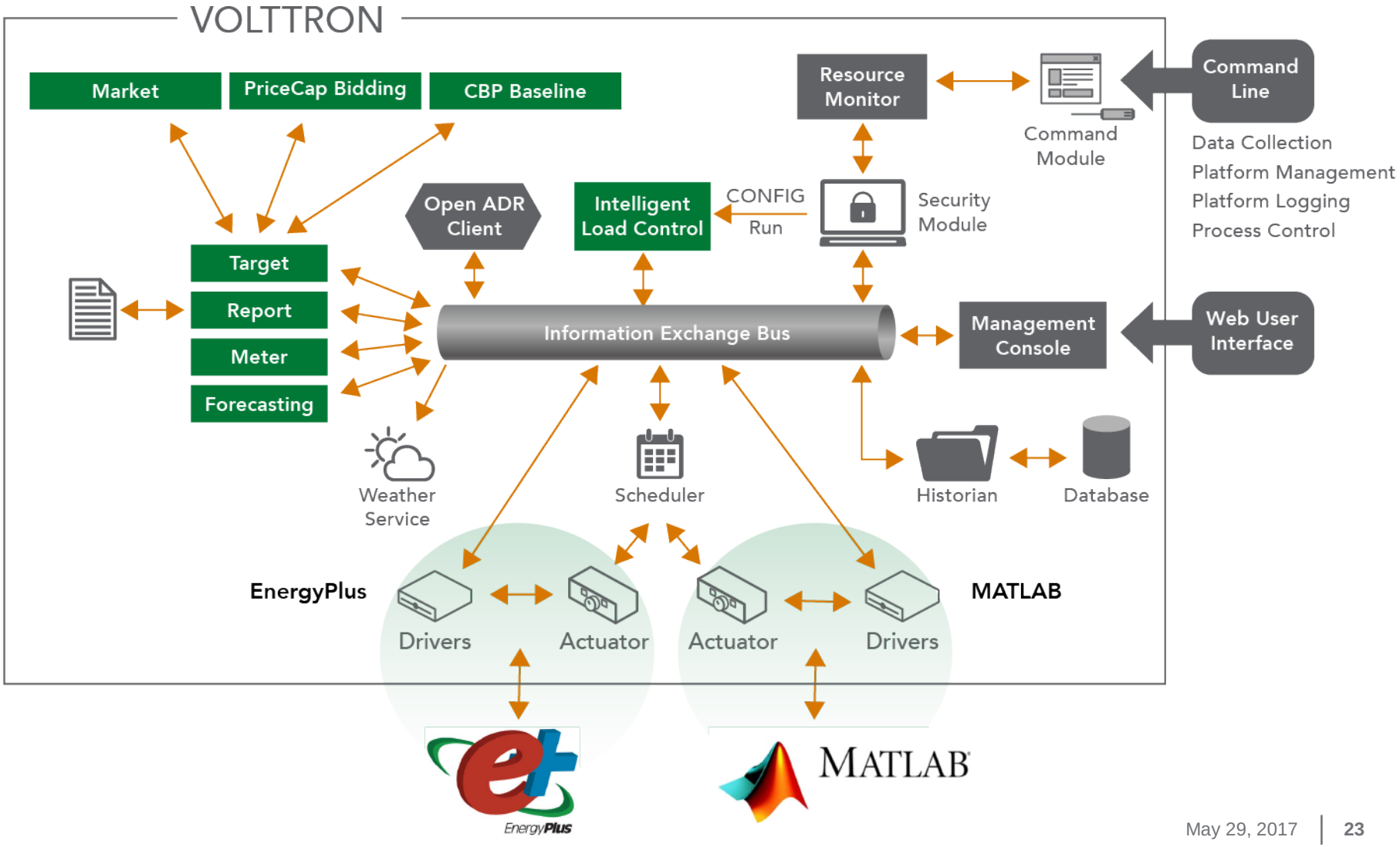
Parameter Excursions

Global Override

Priority Override



Validating Agents in Simulation Environment

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Backup Slides
U.S. DEPARTMENT OF
ENERGY
VOLTTRON™

ILC Load Shaping for Traditional Utility Rate Structure

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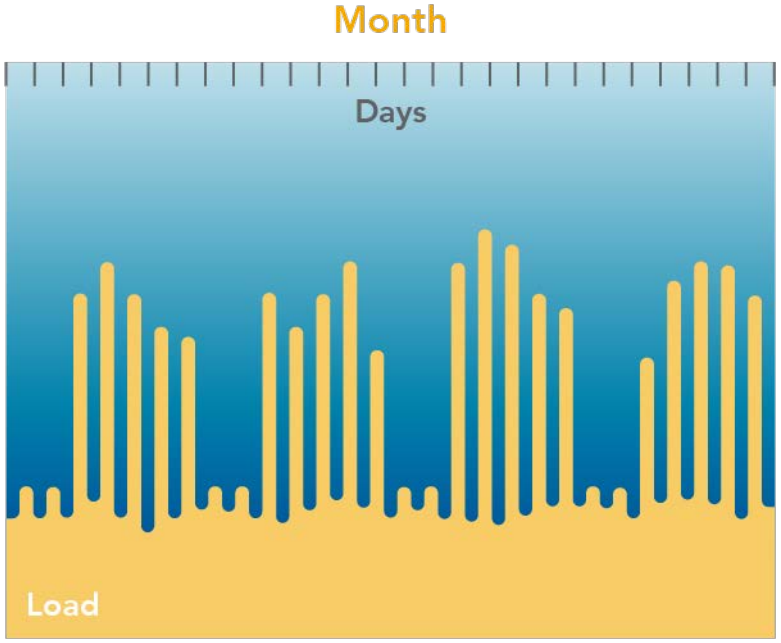
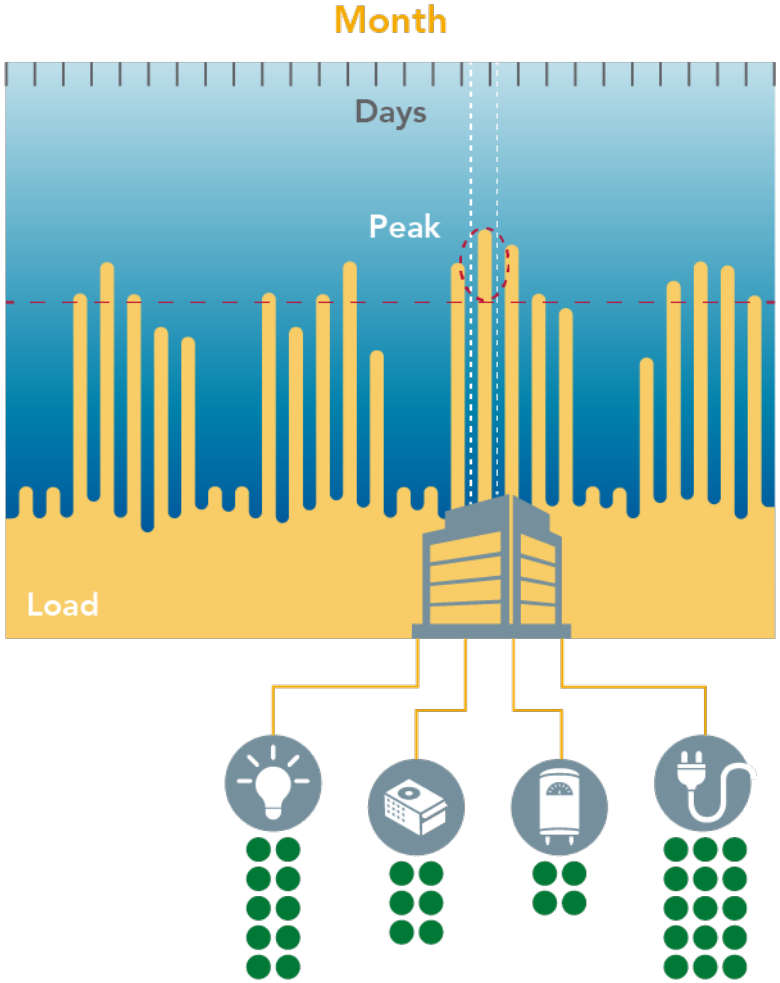
First Step, Forecast the Load for the Next Billing Cycle using VOLTTRON Forecasting v-Agent

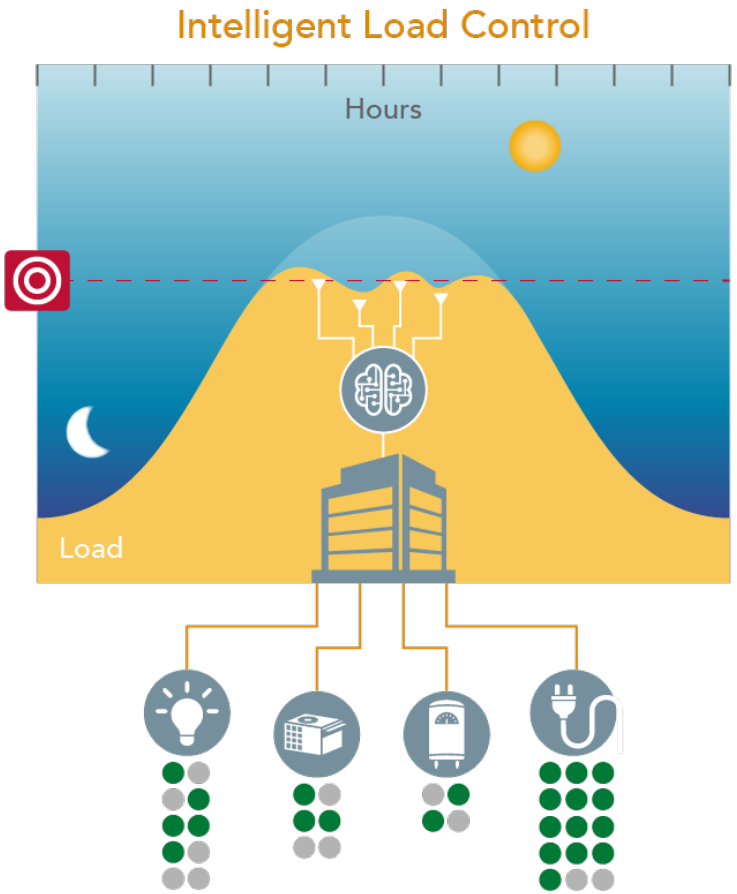


Next, Establish the Target Peak



ILC: Manage Power use to a Target

- Deployed for testing in real buildings on PNNL Campus
  - Showed ILC can manage or reduce peak electricity demand by controlling heat pumps
  - Without impacting occupant comfort



Kim W, and S Katipamula. 2017. "**Development and Validation of an Intelligent Load Control Algorithm**." Energy and Buildings, 135 (2016), pp 62-73. http://dx.doi.org/10.1016/j.enbuild.2016.11.040

ILC Deployment in a Building

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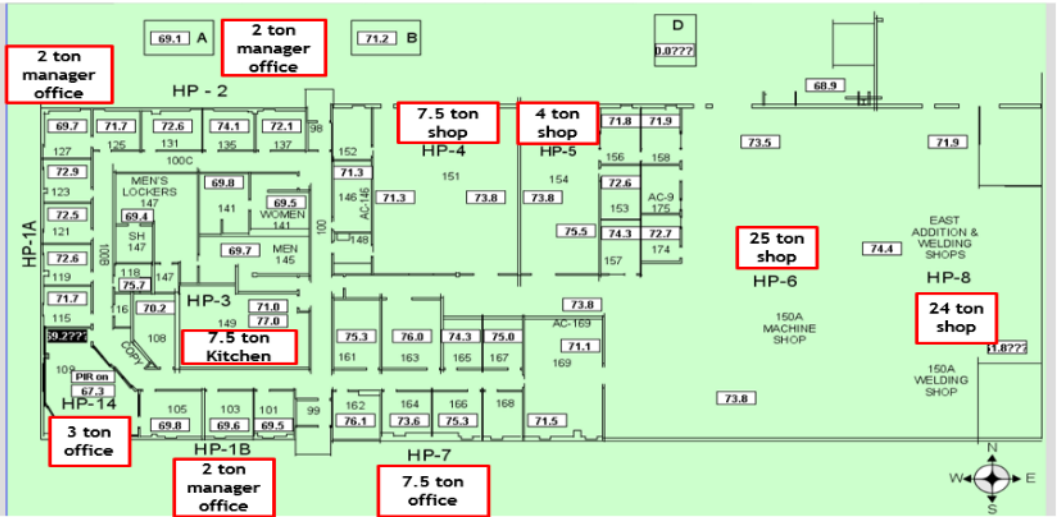
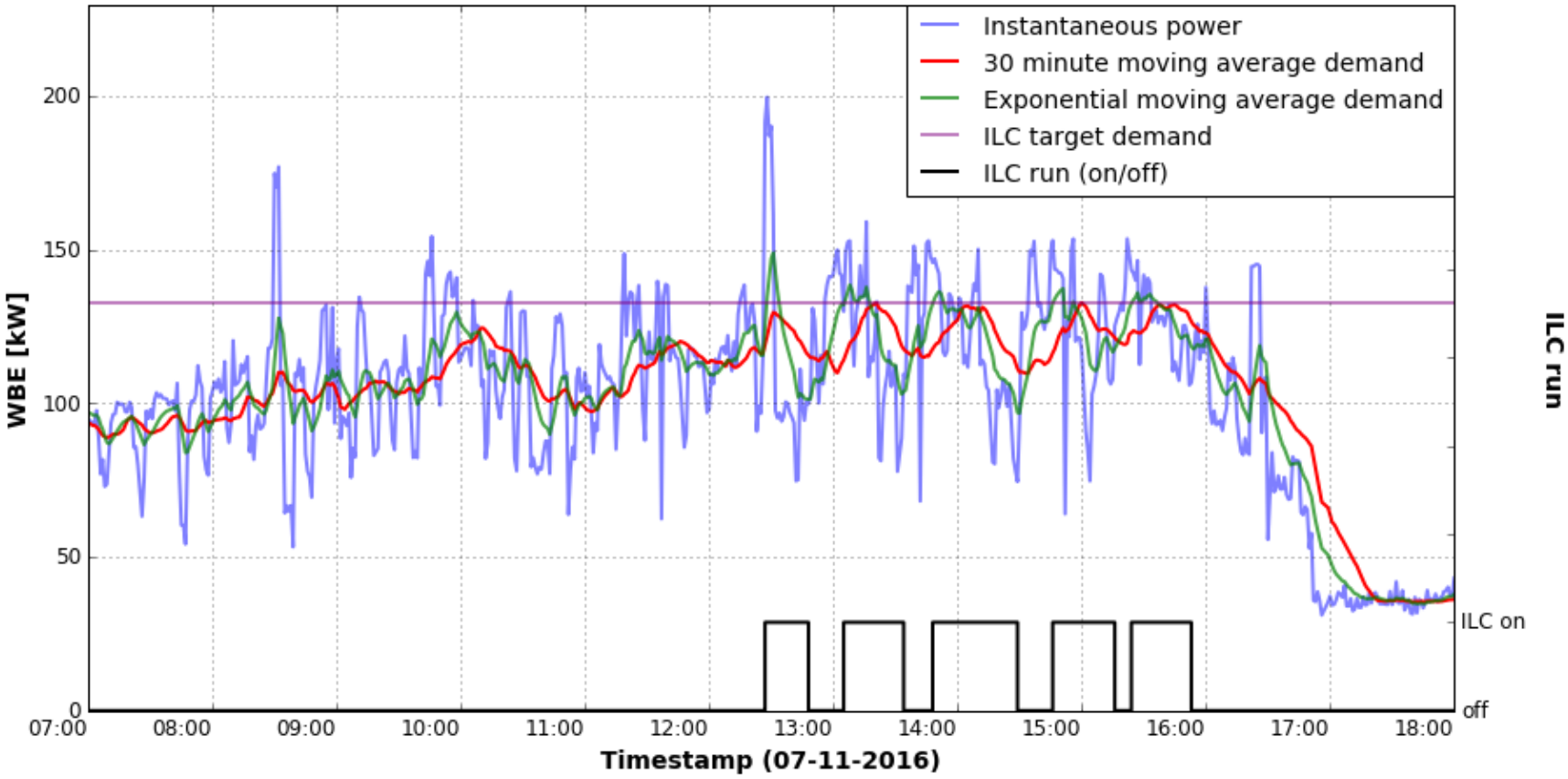


External view for the building	Location of heat pumps in the building

ILC Implementation Details



ILC Test During Heating Season

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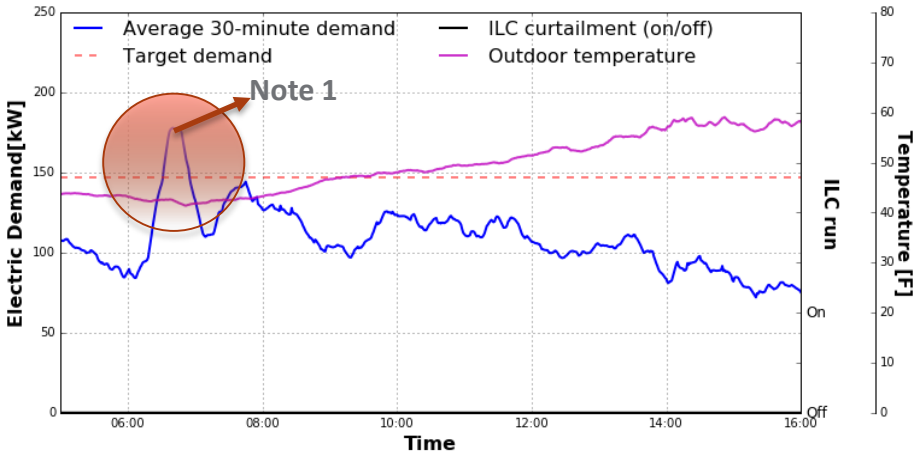
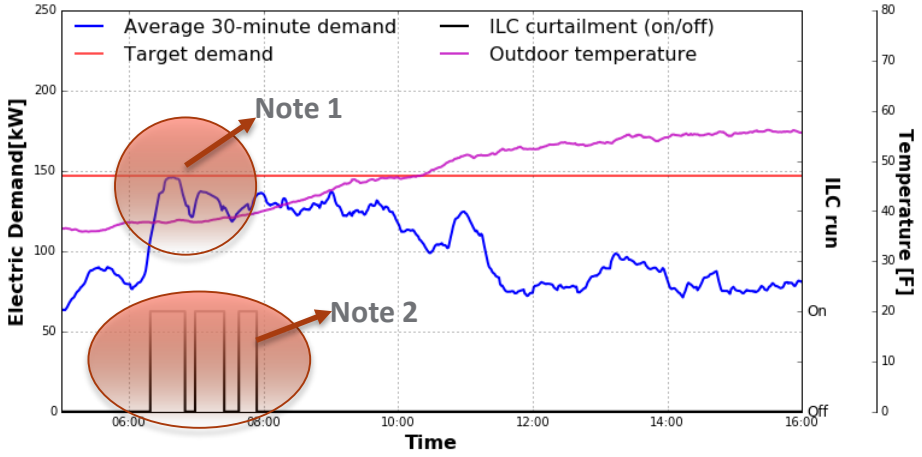
Business-As-Usual, No ILC: March 14



- **Note 1**: Peak demand for this day is 175 kW, which was set at around 7 a.m.
- Note that the rest of the day the demand never exceeded 145 kW
- Also, note that the duration of the peak demand was less than 15 minutes

Dynamic Load Shaping with ILC: March 15



- **Note 1:** Peak demand for this day **never exceeds** the target of 150 kW, which was set at around 7 a.m.
- **Note 2**: Some end use loads were turned off to manage the load shape
- If ILC were operational the previous day, the building could have avoided approximately $125 in Pacific Northwest or $500 in CA or NY

Zone Temperature Profile and Heat Pump Status: Heating Season

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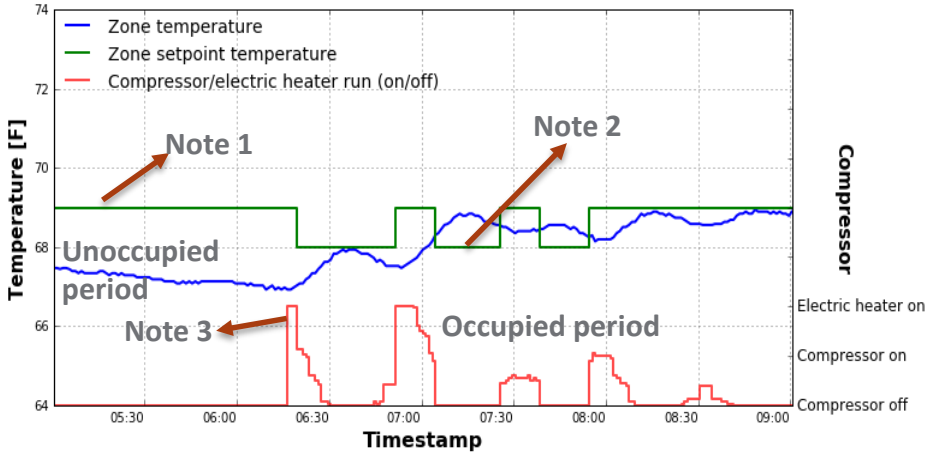
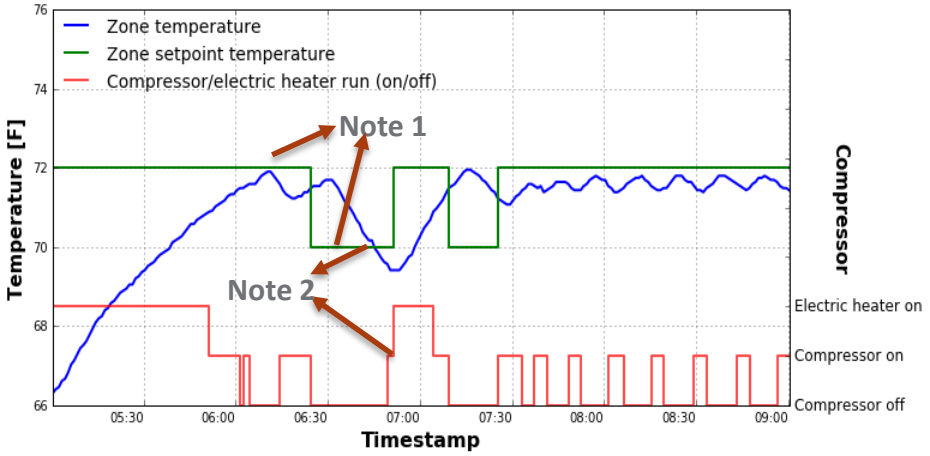
Heat Pump 4



- **Note 1**: Normal heating set point is 69°F for this heat pump
- **Note 2**: When ILC wants to control the unit, it lowers the set point to 68°F
- **Note 3**: Heat pump status
- Note the set point excursions are modest, to get the desired result; extending set point excursions to 2°F or 3°F will result in more deeper load management

Heat Pump 8



- **Note 1**: Normal heating set point 72°F and the set point was lowered to 70°F for load management
- **Note 2**: Although the unit was supposed to be OFF, it is released as soon the zone temperature falls below the set point

ILC Test During Cooling Season

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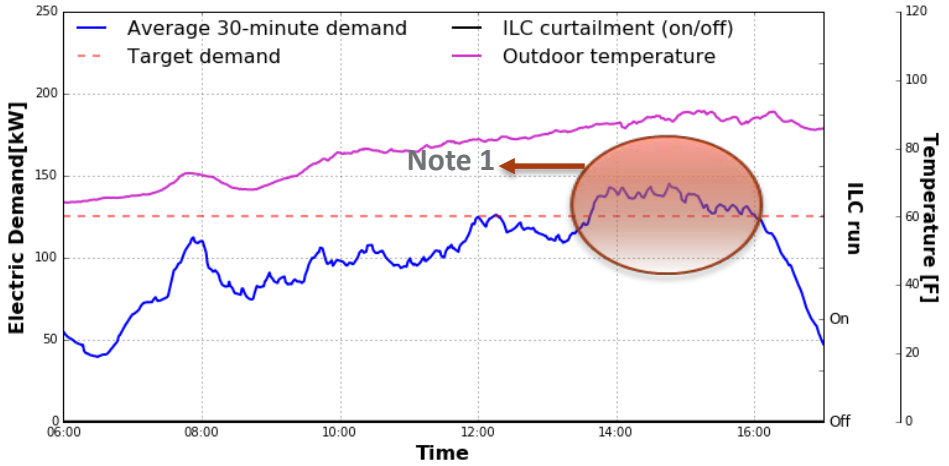
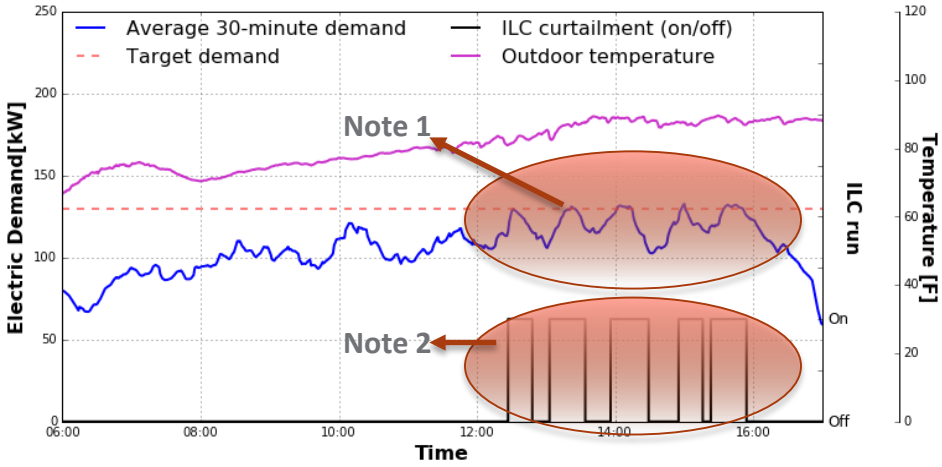
Business-As-Usual, No ILC: July 12



- **Note 1**: Peak demand for this day is 145 kW, which occurred between 2 p.m. and 4 p.m.
- Also, note that the duration of the peak demand was significant in this case

Dynamic Load Shaping with ILC: July 11



- **Note 1:** Peak demand for this day **never exceeds** the target of 135 kW, which was set several times between 12:30 p.m. and 4 p.m.
- **Note 2**: Some end use loads were turned off to manage the load shape
- If ILC were operational the previous day, the building could have avoided approximately $50 in Pacific Northwest or $200 in CA or NY

Temperature Profile and Heat Pump Status: Cooling Season

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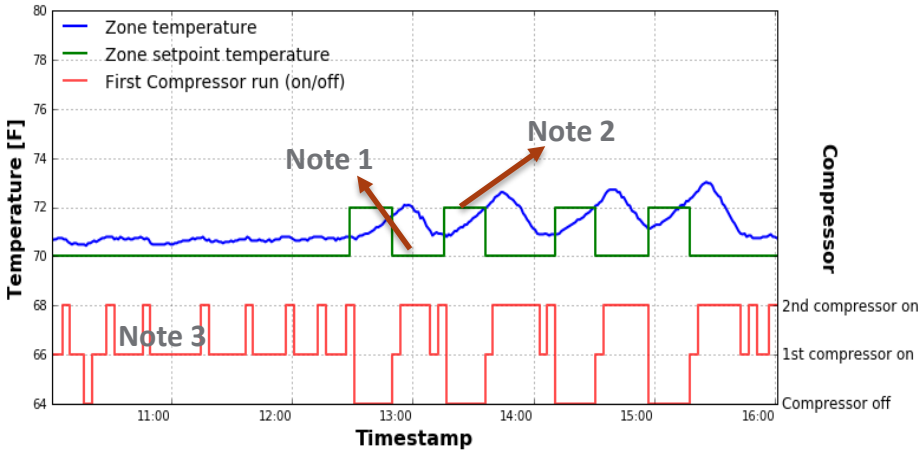
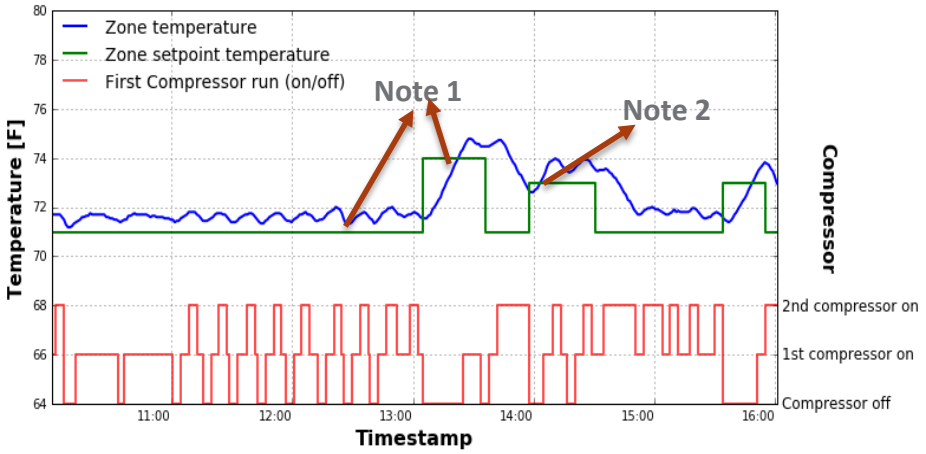
Heat Pump 4



- **Note 1**: Normal cooling set point is 70°F for this heat pump
- **Note 2**: When ILC wants to control the unit, it increases the set point to 72°F
- **Note 3**: Heat pump status
- Note the set point excursions are modest, to get the desired result; extending set point excursions to 2°F or 3°F will result in more deeper load management

Heat Pump 8

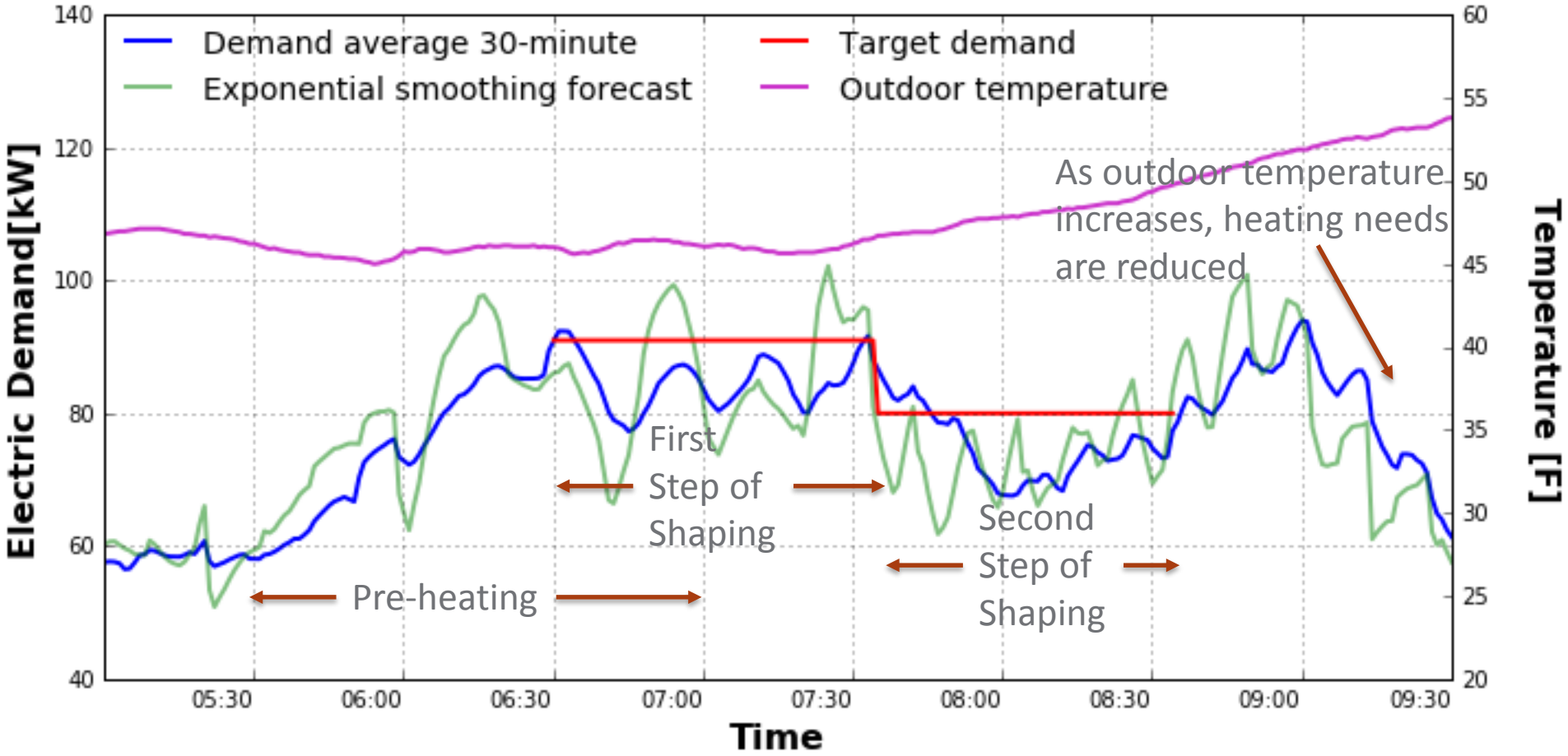


- **Note 1**: Normal cooling set point 71°F and the set point was increased to 73/74°F (stage 1/2) for load management
- **Note 2**: Although the unit was supposed to be OFF, it is released as soon the zone temperature exceeds the set point

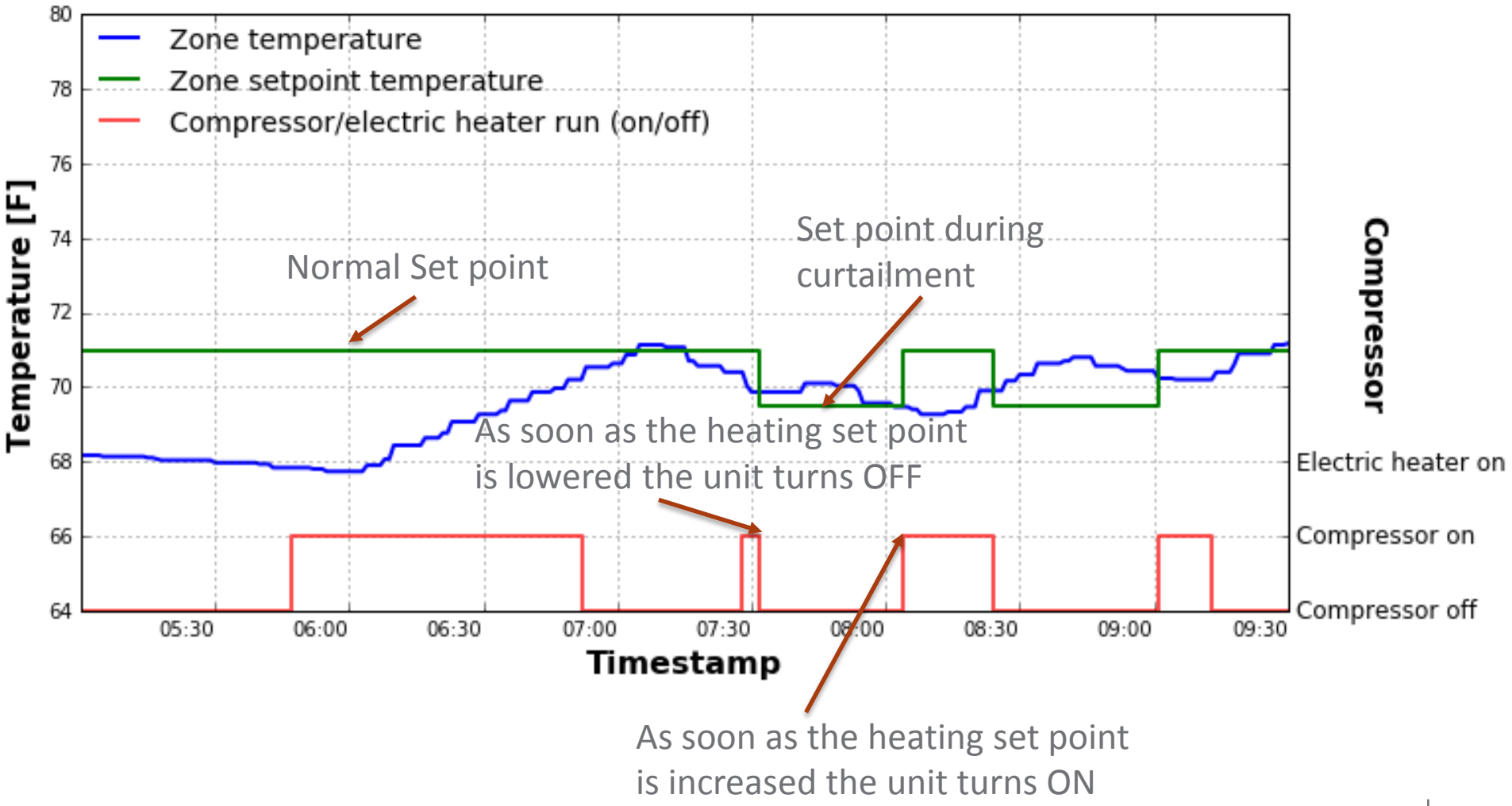
Dynamic Load Shaping Discussion

- Although in this deployment the target load was constant, ILC can handle continuously changing target (dynamic signals – price, emissions or renewable variability)
- Adding more end uses to control (lighting, pumps, fans, etc.) will allow for a more deeper and more precise load shaping
- Automated dynamic load shaping is possible while still maintaining the comfort in the desired range, this is unlike the old style demand limiting, duty-cycling, and direct load control

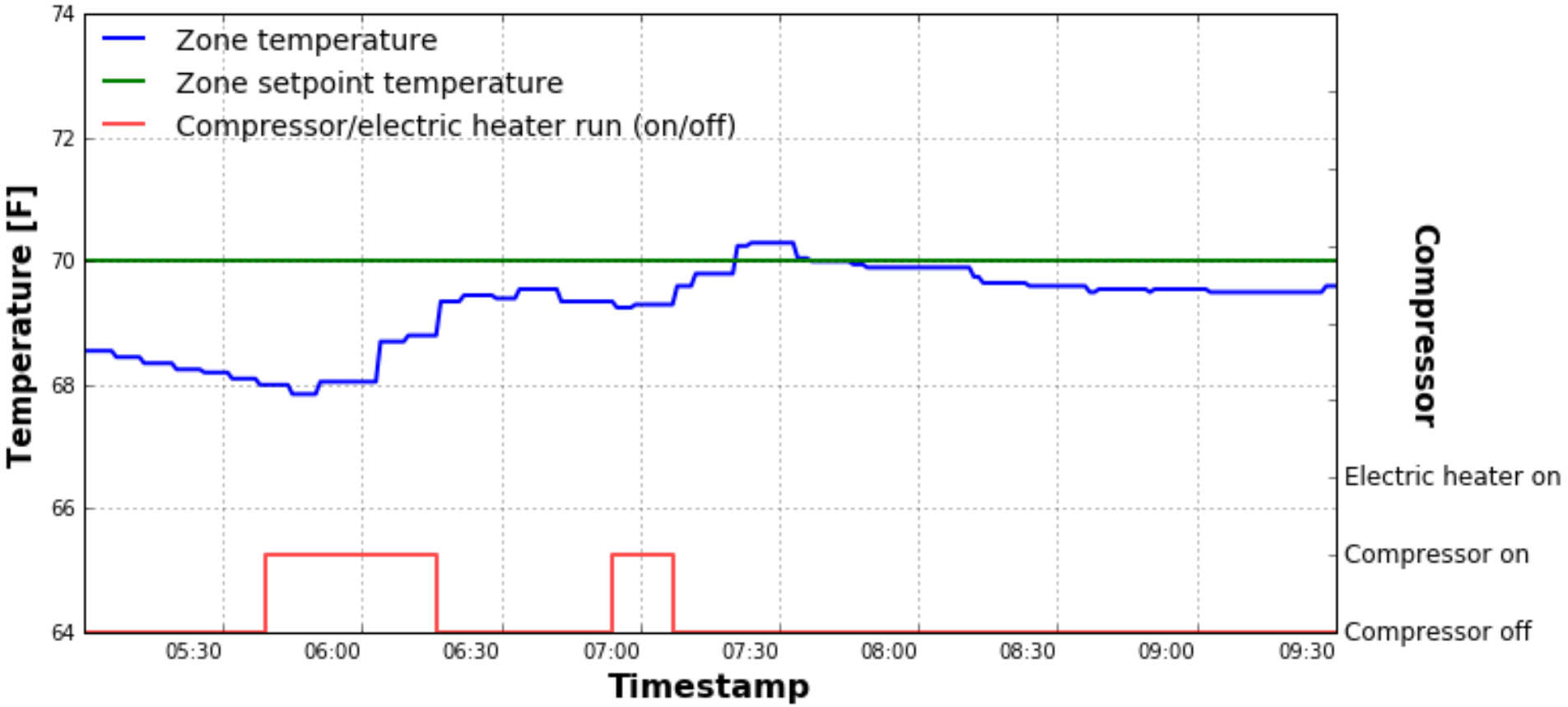
ILC: Stepwise Load Shaping (April 13)



ILC: Load Shaping HP1A (April 13)

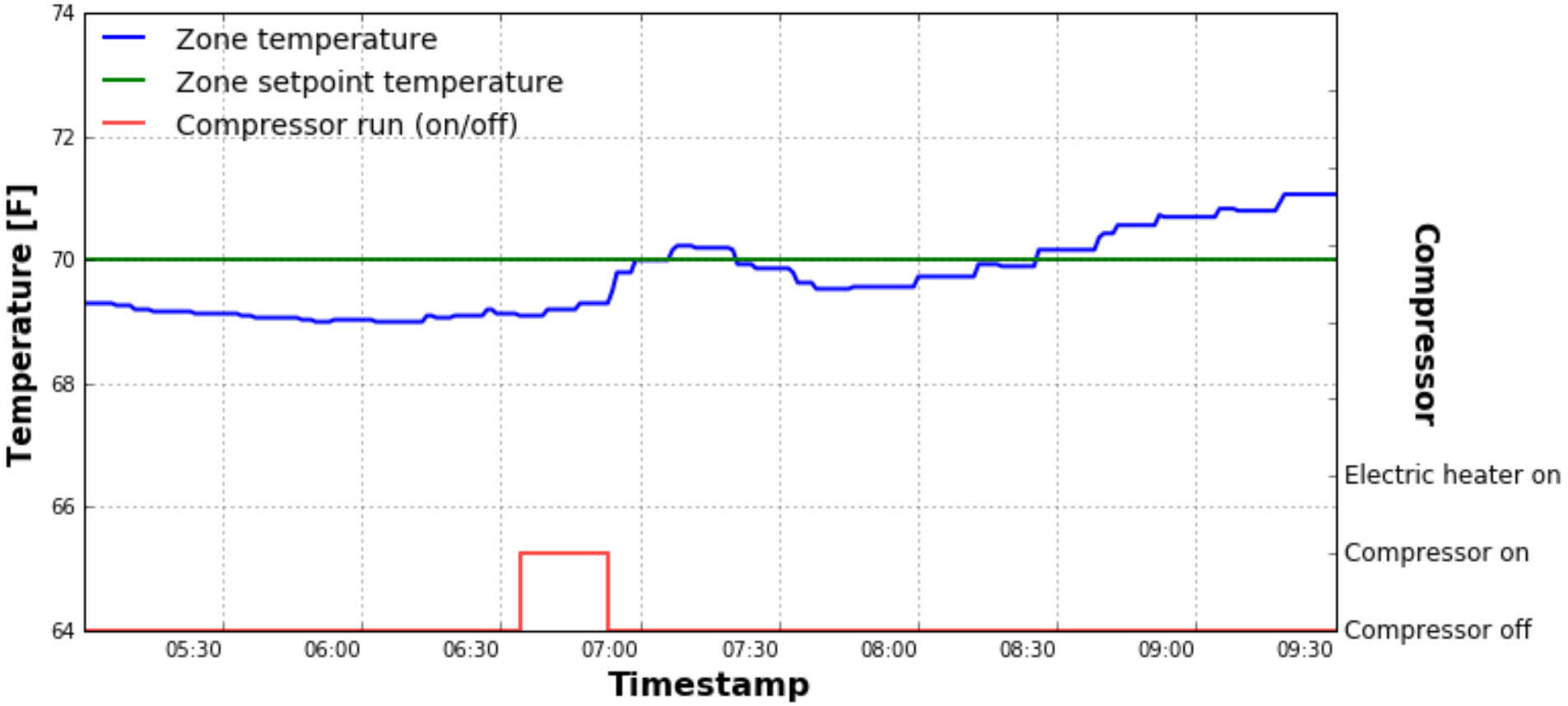


ILC: Load Shaping HP1B (April 13)



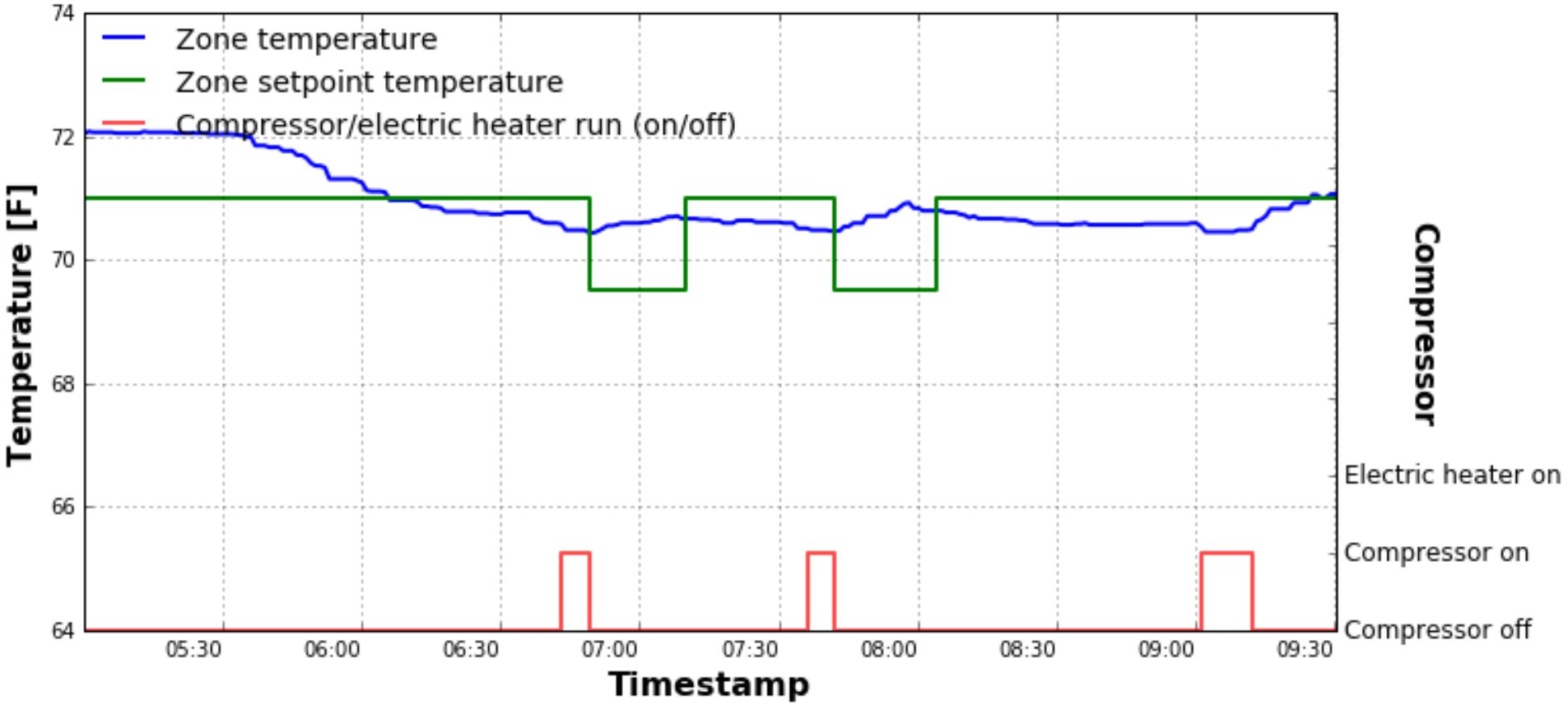
ILC did not curtail this device because it achieved its goal with its services

ILC: Load Shaping HP 2 (April 13)

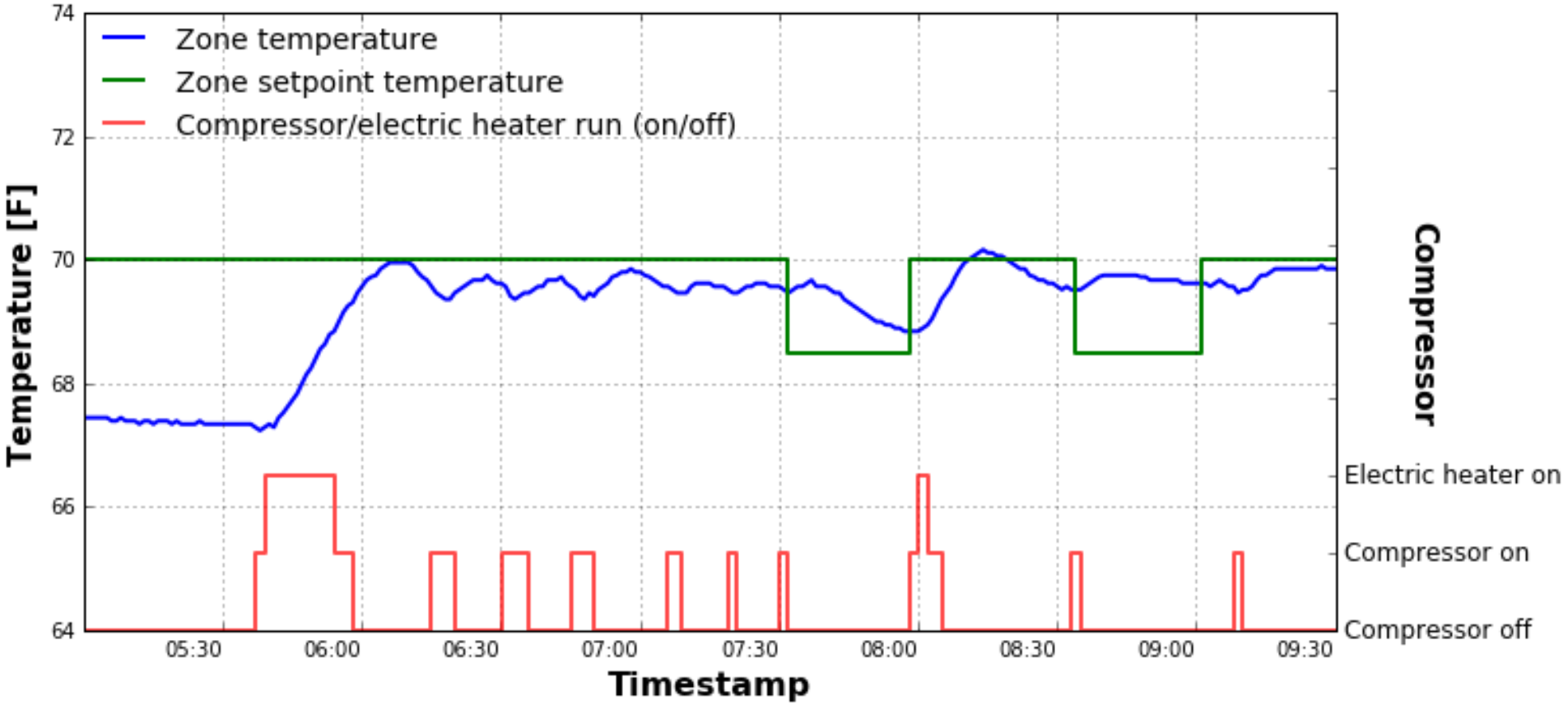


ILC did not curtail this device because it achieved its goal with its services

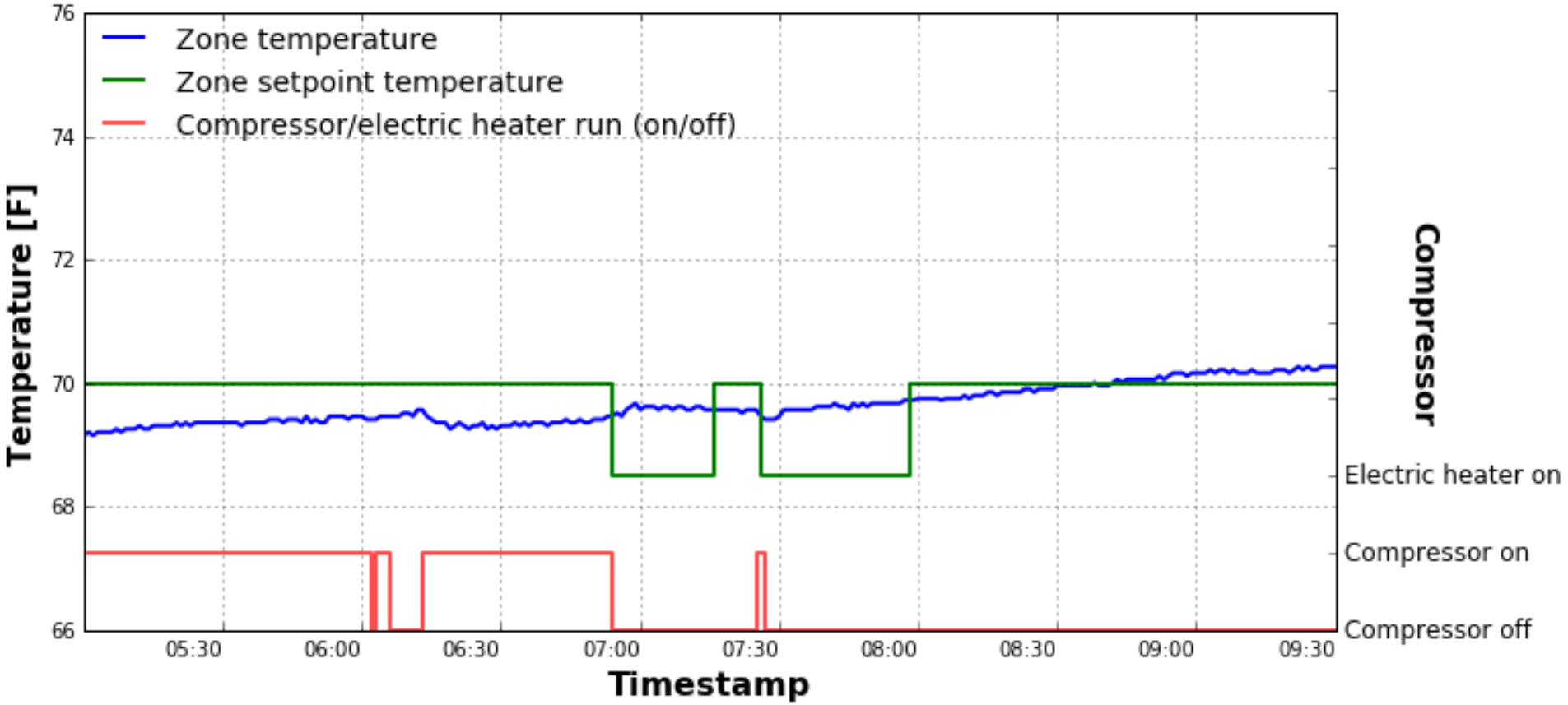
ILC: Load Shaping HP 3 (April 13)



ILC: Load Shaping HP4 (April 13)



ILC: Load Shaping HP 6 (April 13)



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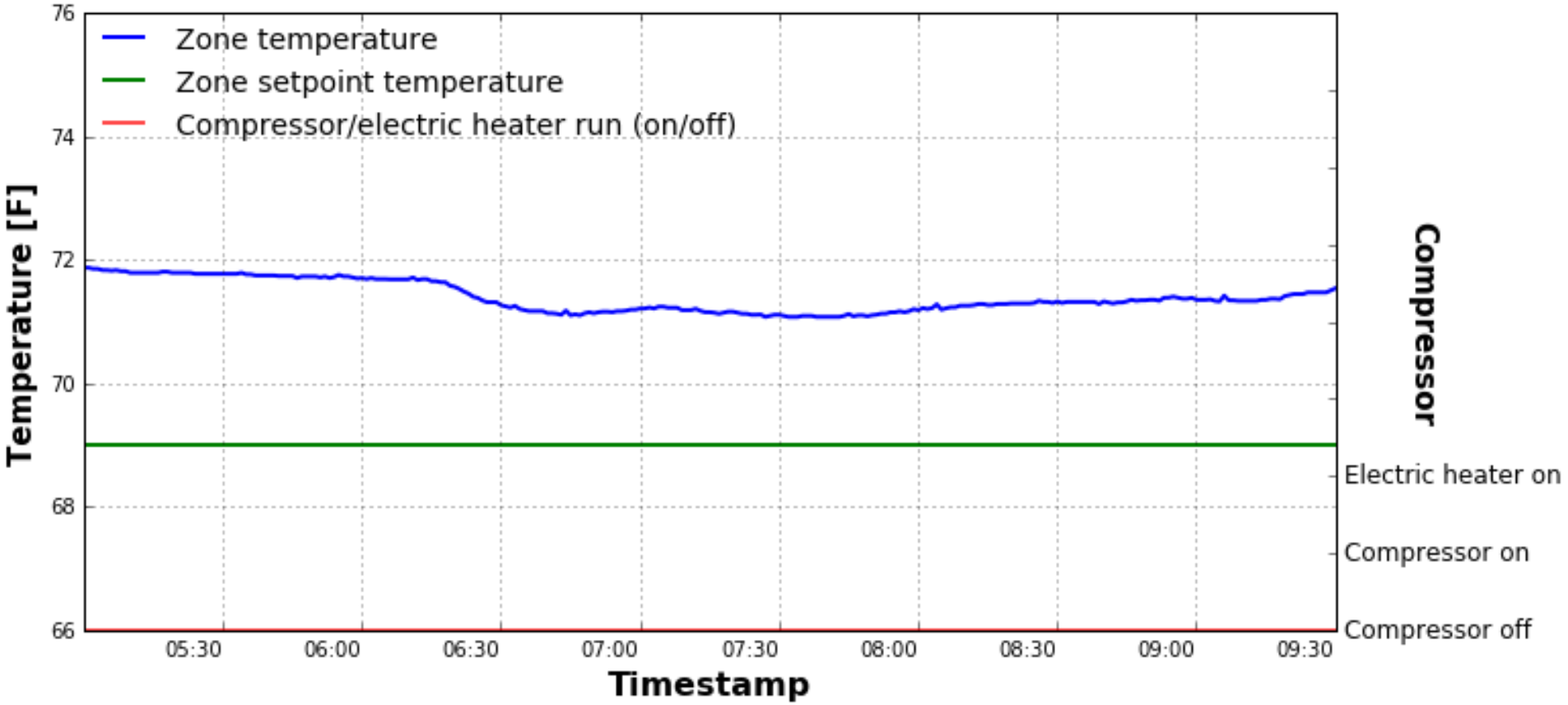

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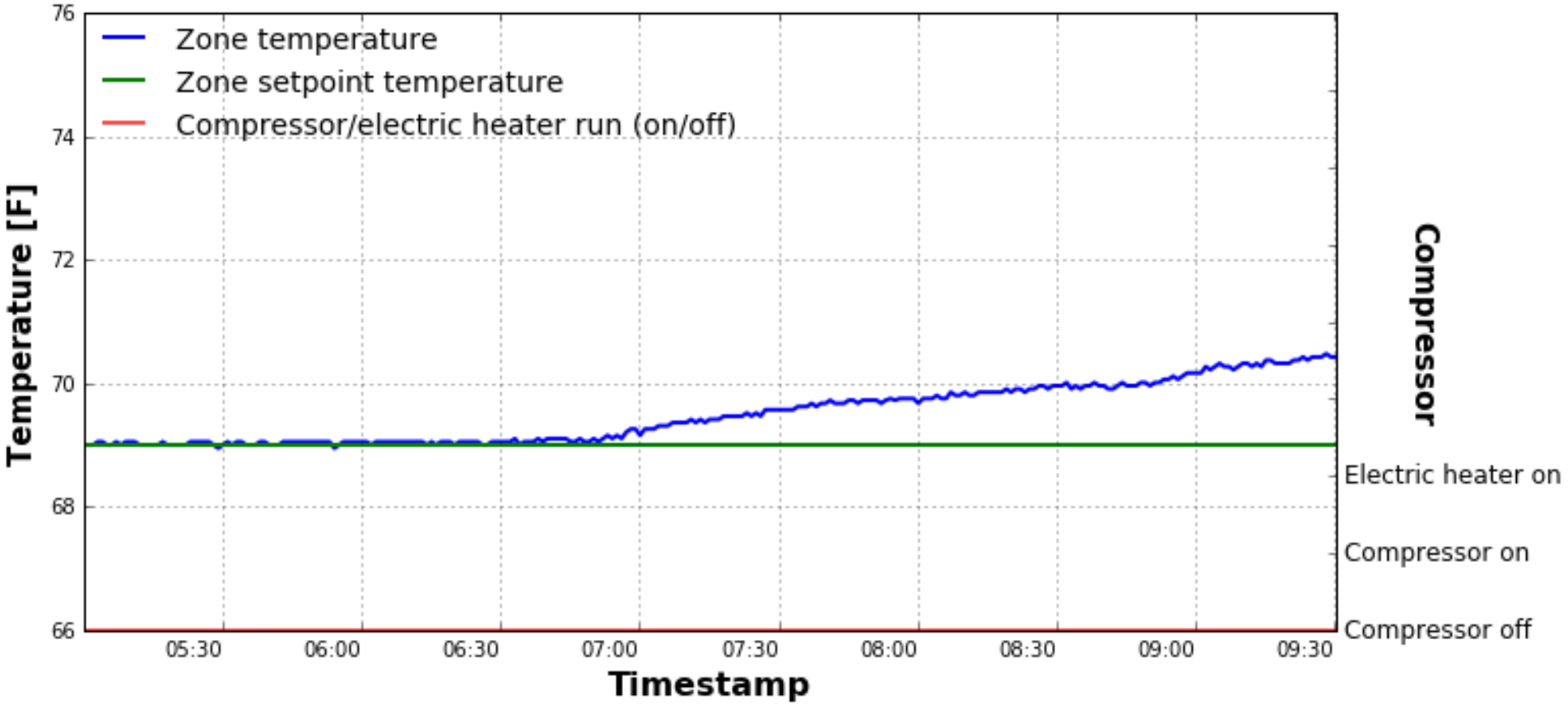

Capacity Bidding Program: Simulation Result

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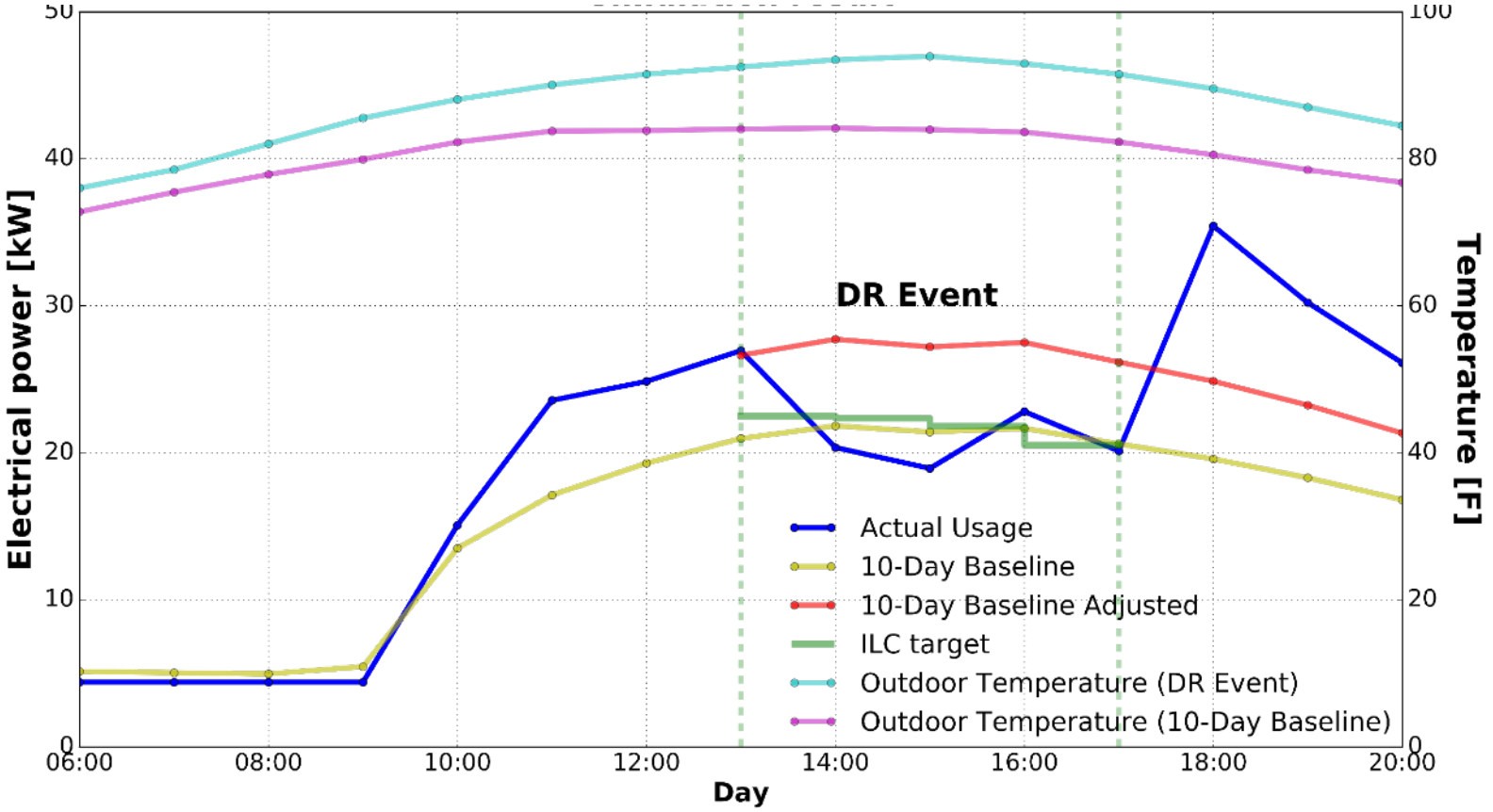
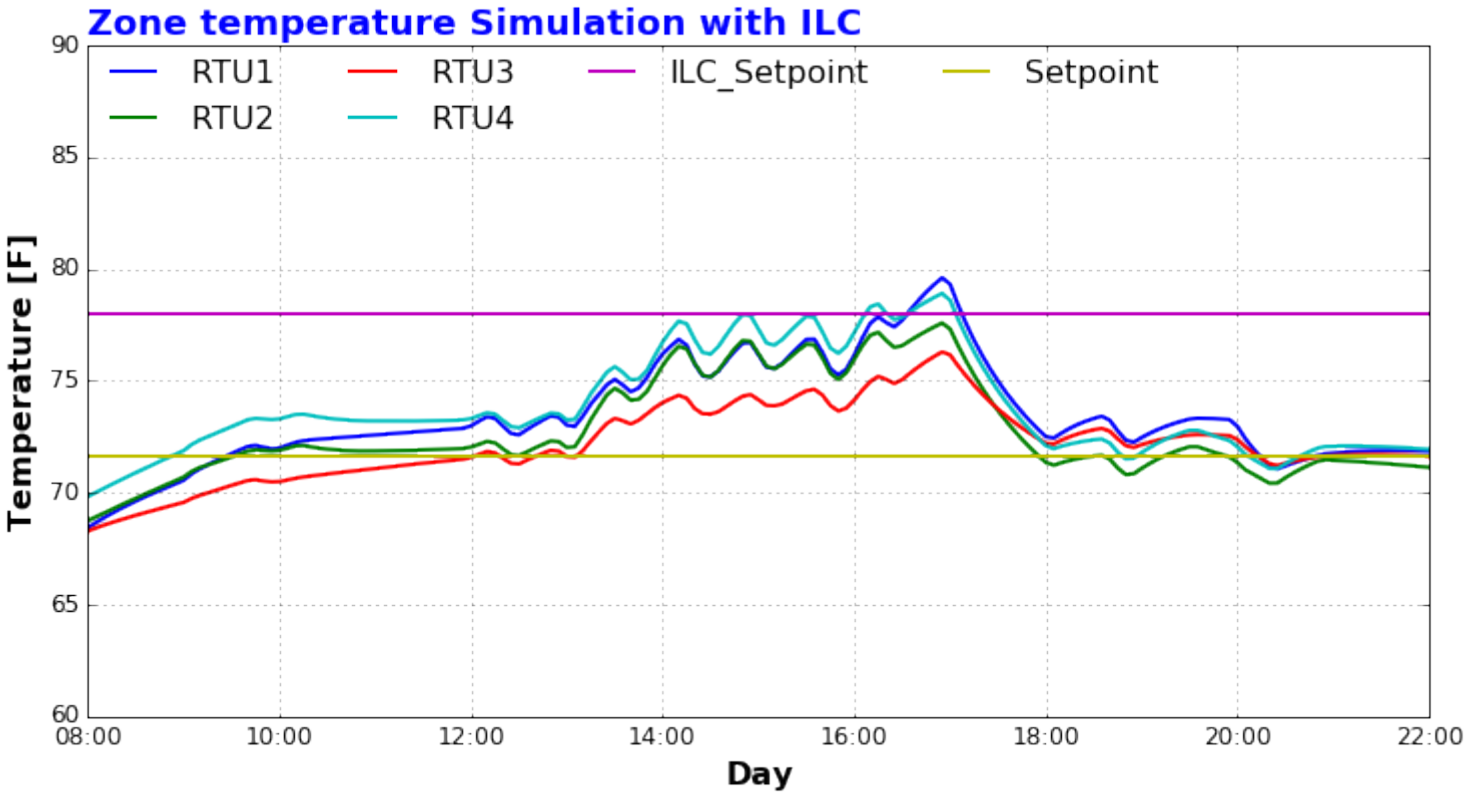


Capacity Bidding Program: Simulation Result



Capacity Bidding Program: Real Building Test

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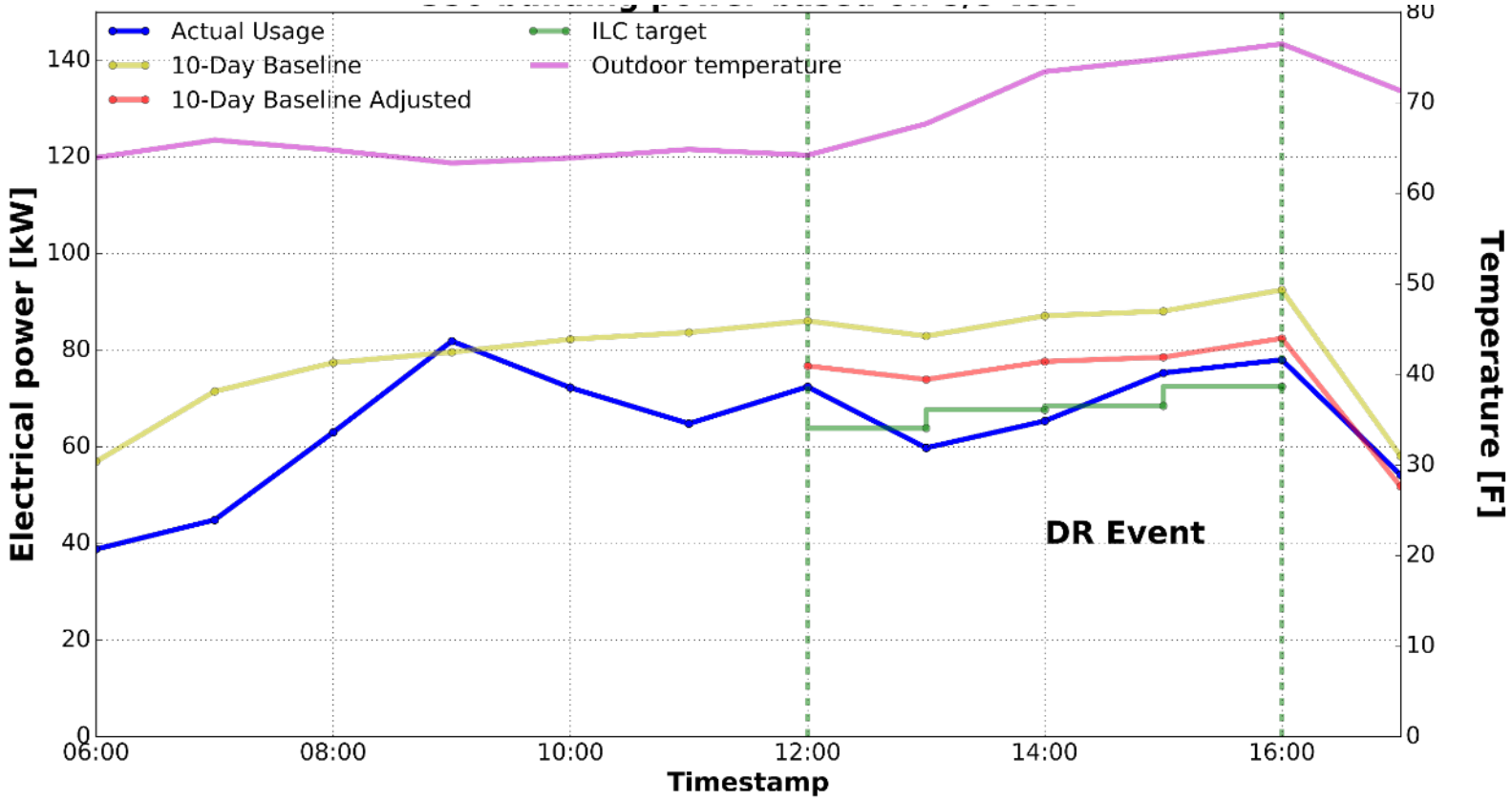

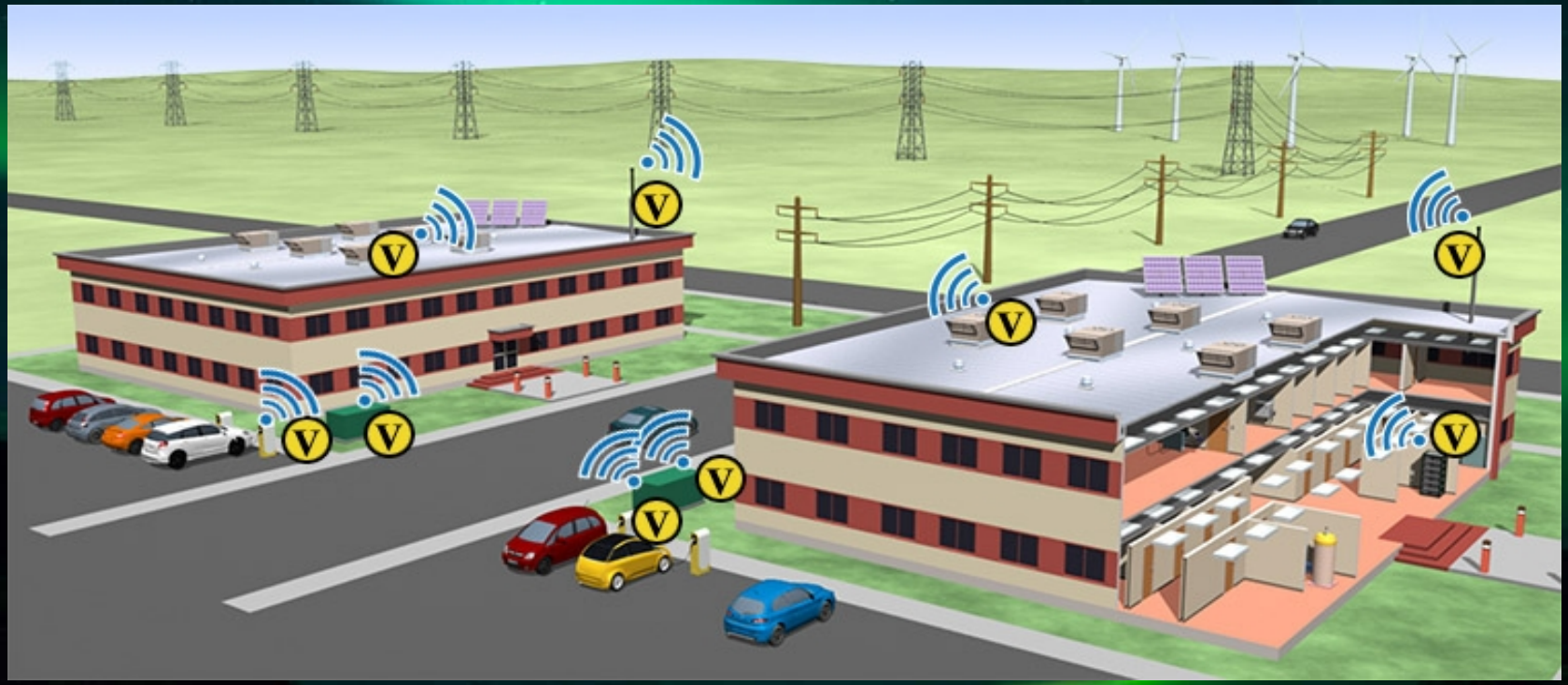

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