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# A Look at a VOLTRON™ Use Case: Transactive Control and Coordination

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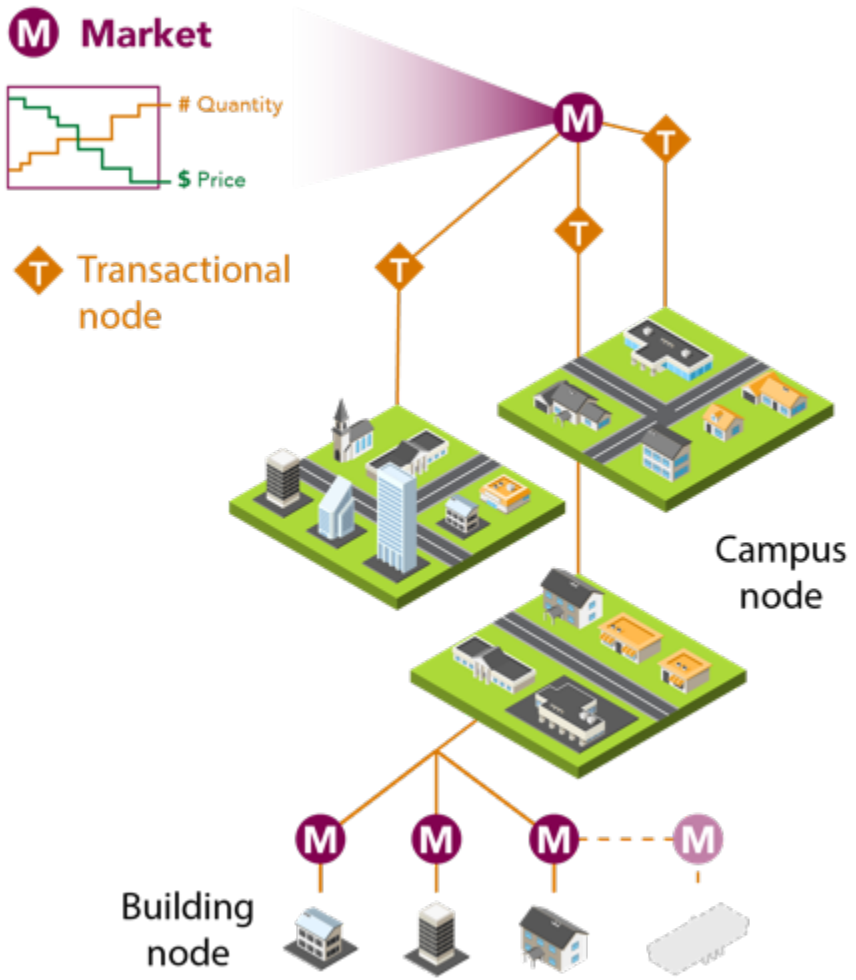
VOLTRON™ 2017

# Transactive Control and Coordination (TCC): Overview



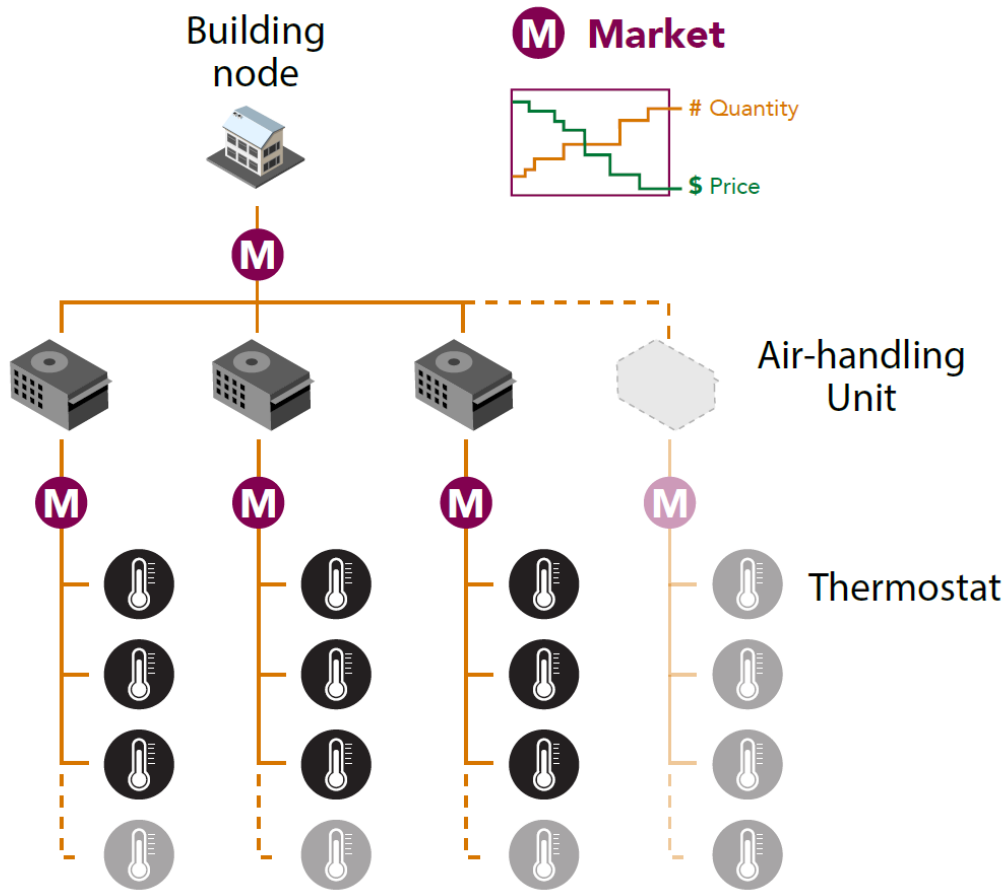
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Use of signals from external markets to create markets at campus and individual building levels, result in better management of energy consumption, lower energy cost, potentially improve comfort and result in a reliable electric grid

# TCC: Use Case

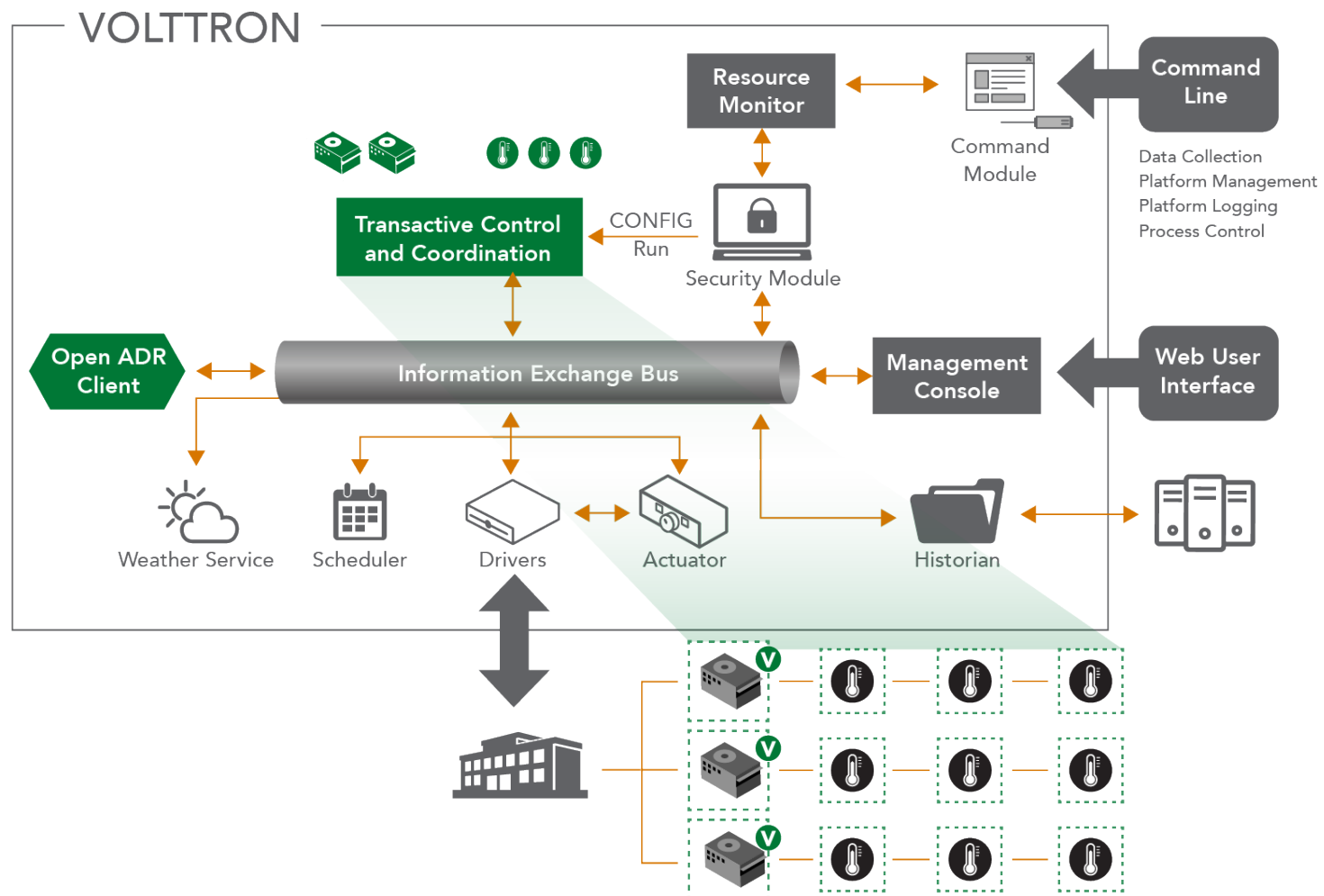


Under the TCC approach, controllable devices, such as, rooftop units, hot water heaters, variable-air-volume boxes serving building zones and devices become markets that “negotiate” prices and service levels



# TCC: Deployment

## PNNL's VOLTRON™ platform enables deployment of **Transactive Control and Coordination** in building devices





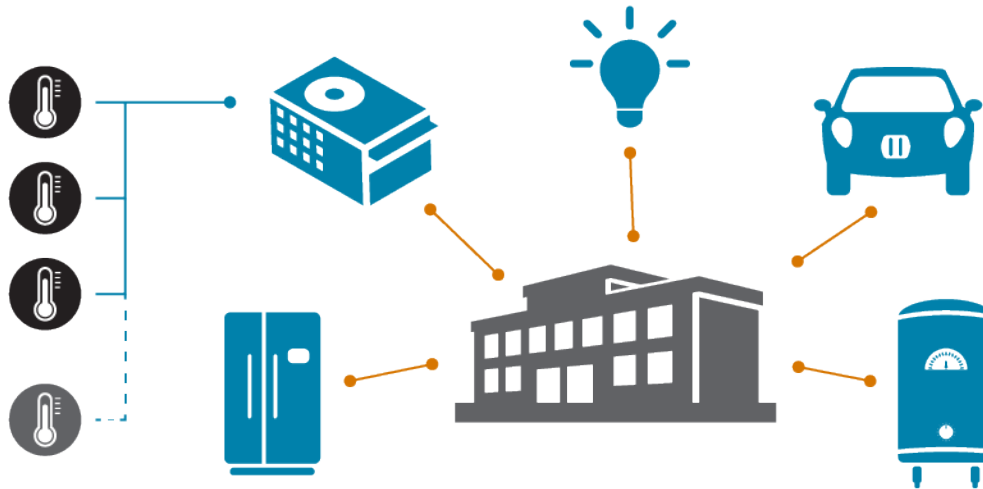
# Preparing TCC for Deployment in a Building

- ▶ Step 1: Identify devices to control
- ▶ Step 2: Develop price-capacity bidding approaches for each of the controllable devices
- ▶ Step 3: Create device and registry (points) configuration files to access data and to initiate controls
- ▶ Step 4A: Create VAV, AHU + Chiller, and Meter agents configuration files
- ▶ Step 4B: Market (air and electricity) agent configuration file
- ▶ Step 4C: Interface agent configuration file
- ▶ Step 4D: Director agent configuration file
- ▶ Setup risk mitigation parameters
- ▶ Ready to launch TCC
- ▶ Ability to test TCC using EnergyPlus or Matlab model as a source of devices to control



# Step 1: Identify Devices to Control

## STEP 1 Identify Devices to Control







# Step 2: Air-Market Price-Capacity Bidding

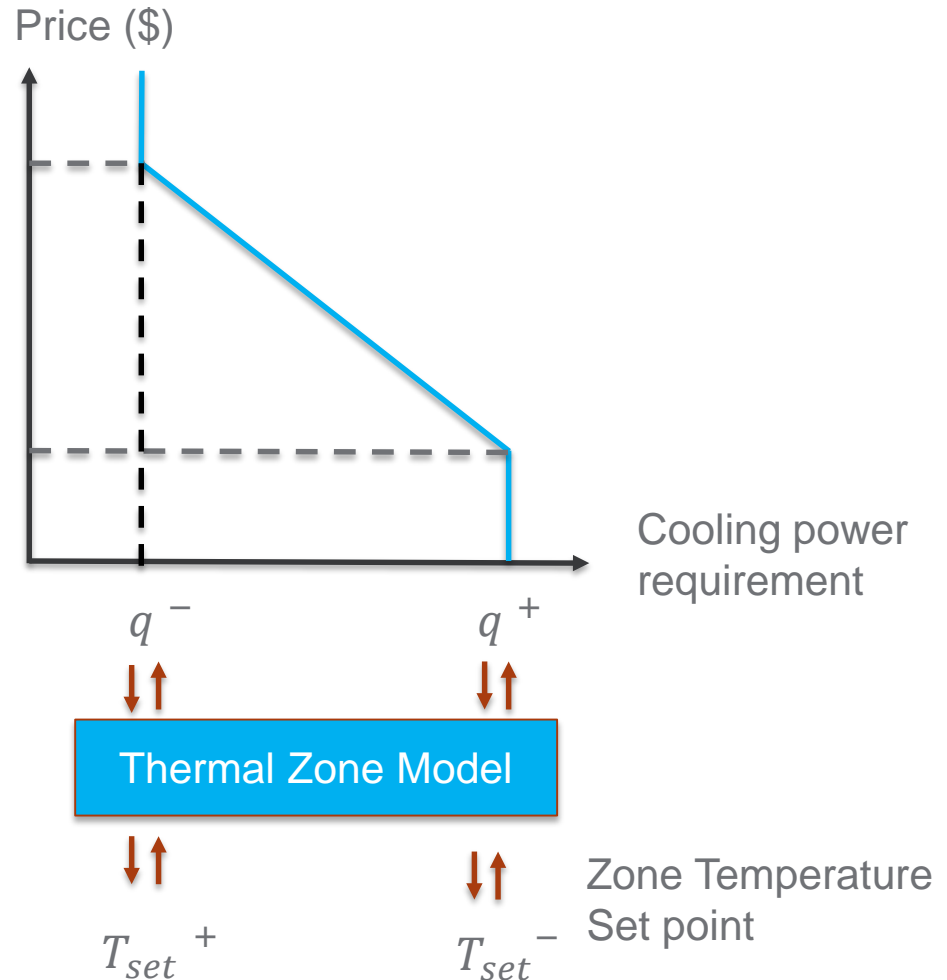
$$p^+ = \frac{\overline{p_{el}} + k^i \sigma}{\eta COP}$$

$$p^- = \frac{\overline{p_{el}} - k^i \sigma}{\eta COP}$$

$\overline{p_{el}}, \sigma$ : The average electricity price and the standard deviation over a certain period, respectively.

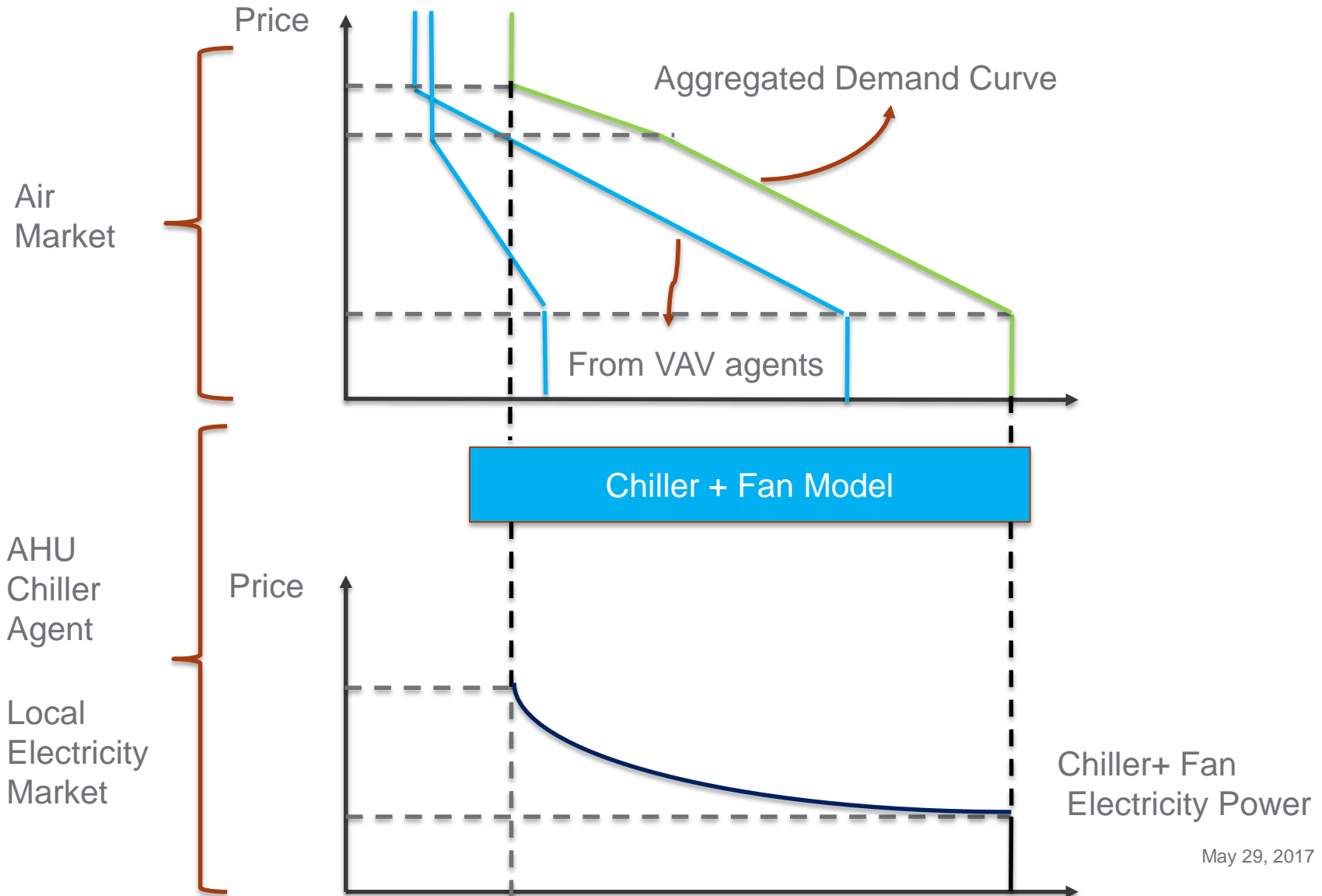
$k^i$ : The user-specified tradeoff parameter that balances energy efficiency and comfort

$\eta, COP$ : The heat exchange efficiency and the coefficient of performance for the chiller, respectively





# Step 2: Air/Local Electricity Market

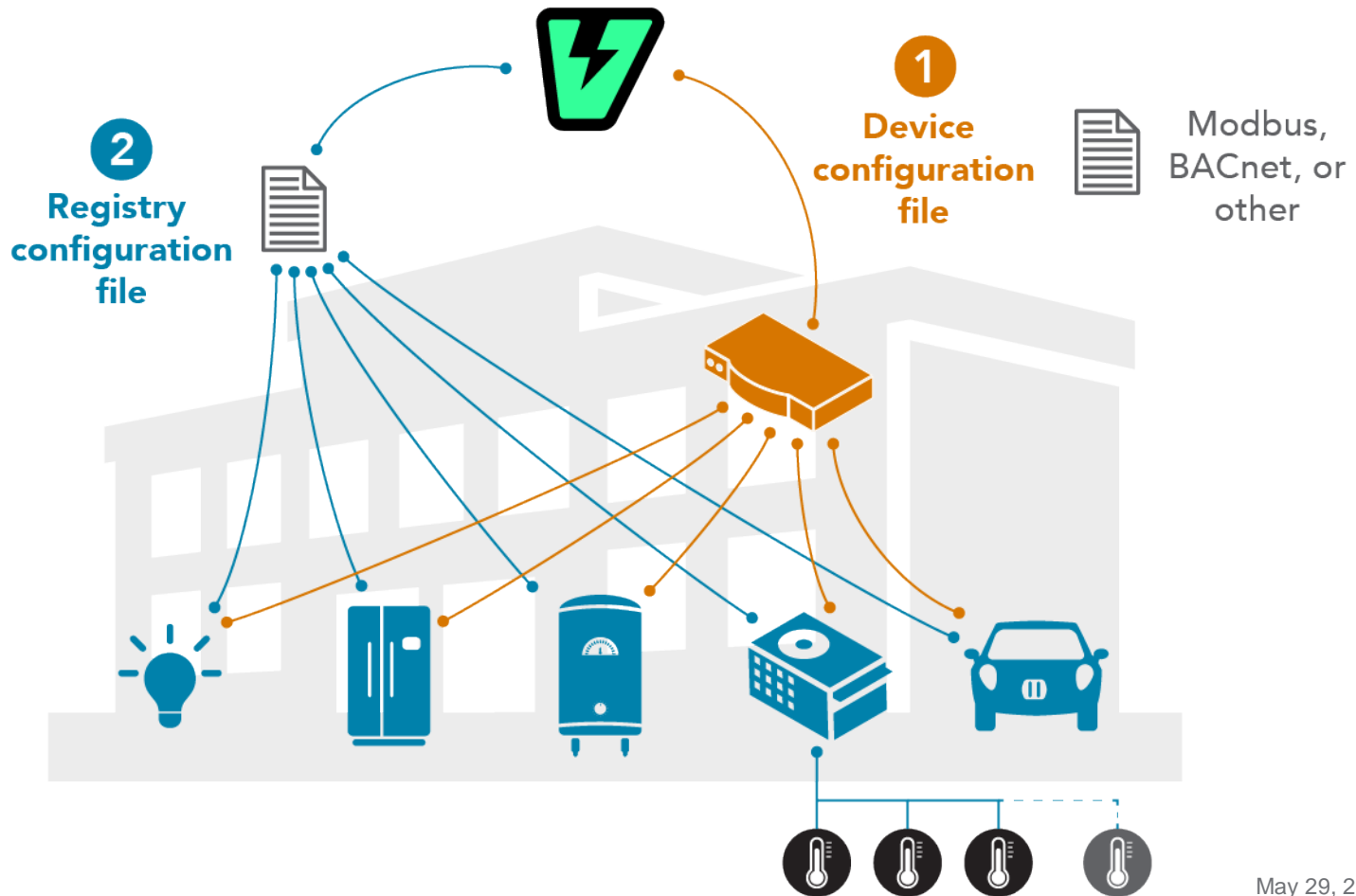






# Step 3: Device and Points Configuration

## 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"  
}
```



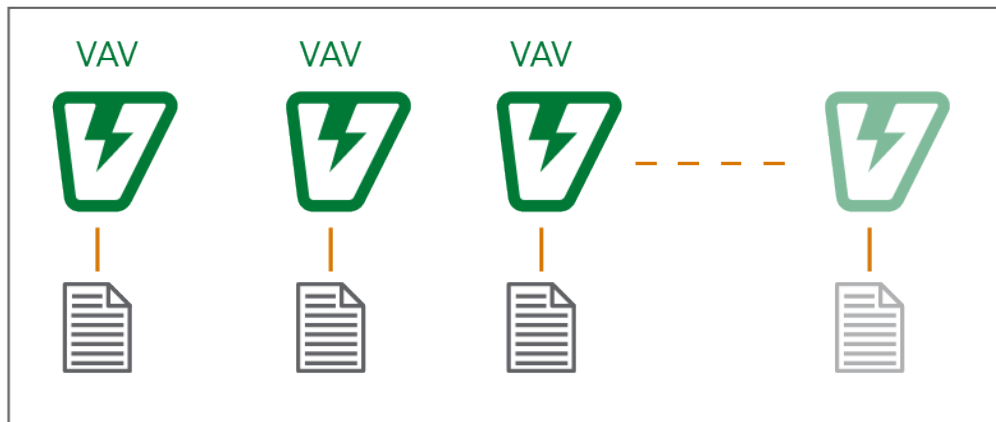
# Step 3: Registry/Points Configuration

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 4A: TCC Agents Configuration Files

## STEP 4A Device Agents Configuration Files



AHU+Chiller



Meter



# TCC: Example VAV Configuration File: Inputs



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```
"inputs": {
  "bidRequest": {
    "topic": "Building 1/air/offer/request",
    "commodity": "air"
  },
  "reservationRequest": {
    "topic": "Building 1/air/reservation/request",
    "commodity": "air"
  },
  "clearRequest": {
    "topic": "Building 1/air/clear/request",
    "commodity": "air"
  },
  "HVAC_ON": {
    "topic": "Building 1/AHU001-ONOFF"
  },
  "HVAC_T_sup": {
    "topic": "Building 1/AHU001-SUPPLY-TEMP"
  },
  "T_out": {
    "topic": "Building 1/OUTDOOR-TEMP"
  },
  "M_dot": {
    "topic": "Building 1/VAV100-FLOW-RATE"
  },
  "T_sup": {
    "topic": "Building 1/VAV100-SUPPLY-TEMP"
  },
  "T_in": {
    "topic": "Building 1/VAV100-ZONE-TEMP"
  },
  "OCCUPIED": {
    "topic": "Building 1/VAV100-OCCUPANCY"
  },
  "STANDBY": {
    "topic": "Building 1/VAV100-STANDBY"
  }
},
```

# TCC: Example VAV Configuration File: Outputs



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```
"outputs": {  
  "bidResponse": {  
    "topic": "Building 1/air/offer/response",  
    "commodity": "air"  
  },  
  "reservationResponse": {  
    "topic": "Building 1/air/reservation/response",  
    "commodity": "air"  
  },  
  "T_set": {  
    "topic": "Building 1/VAV100-CLGSP"  
  }  
},
```



# TCC: Example VAV Configuration File: Model Parameters



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```
"properties": {  
  "name": "ZONE_VAV_100",  
  "c0": 0.304757407445036,  
  "c1": 0.984985717053459,  
  "c2": 0.00166363342545957,  
  "c3": -4.96578639930032e-06,  
  "c4": 8.8881510845309e-06,  
  "x0": -379.160405502245,  
  "x1": 1074.02243902789,  
  "x2": 2.0606140062771,  
  "x3": -1058.75585220333,  
  "x4": 0.991501190864198,  
  
  "mDotMin": 0.62509852,  
  "mDotMax": 1.36385132,  
  "tIn": 22.22,  
  "tNom": 22.22,  
  "tMin": 20.00,  
  "tMax": 23.89,  
  "tMinStandby": 20.00,  
  "tMaxStandby": 25.56,  
  "tMinUnocc": 19.44,  
  "tMaxUnocc": 26.67,  
  "pMin": 10,  
  "pMax": 100,  
  "pWin": 1E6,  
  
  "nonResponsive": false  
}
```

# TCC: Example AHU+Chiller Configuration

## File: Inputs



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```
"inputs": {
  "sellBidRequest": {
    "topic": "Building 1/air/offer/request",
    "commodity": "air"
  },
  "sellReservationRequest": {
    "topic": "Building 1/air/reservation/request",
    "commodity": "air"
  },
  "sellClearRequest": {
    "topic": "Building 1/air/clear/request",
    "commodity": "air"
  },
  "buyBidRequest": {
    "topic": "Building 1/electricity/offer/request",
    "commodity": "electricity"
  },
  "buyReservationRequest": {
    "topic": "Building 1/electricity/reservation/request",
    "commodity": "electricity"
  },
  "buyClearRequest": {
    "topic": "Building 1/electricity/clear/request",
    "commodity": "electricity"
  },
  "demandCurveResponse": {
    "topic": "Building 1/air/demandcurve/response",
    "commodity": "air"
  },
  "T_sup": {
    "topic": "Building 1/AHU001-SUPPLY-TEMP"
  },
  "T_ret": {
    "topic": "Building 1/AHU001-RETURN-TEMP"
  },
  "T_mix": {
    "topic": "Building 1/AHU001-MIXED-TEMP"
  },
  "M_dot_air": {
    "topic": "Building 1/AHU001-FLOW-RATE"
  },
  "P_static": {
    "topic": "Building 1/AHU001-STATIC-PRESSURE"
  }
}
```

# TCC: Example AHU+Chiller Configuration

## File: Outputs



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```
"outputs": {
  "sellBidResponse": {
    "topic": "Building 1/air/offer/response",
    "commodity": "air"
  },
  "sellReservationResponse": {
    "topic": "Building 1/air/reservation/response",
    "commodity": "air"
  },
  "demandCurveRequest": {
    "topic": "Building 1/air/demandcurve/request",
    "commodity": "air"
  },
  "buyBidResponse": {
    "topic": "Building 1/electricity/offer/response",
    "commodity": "electricity"
  },
  "buyReservationResponse": {
    "topic": "Building 1/electricity/reservation/response",
    "commodity": "electricity"
  }
},
```

# TCC: Example AHU+Chiller Configuration

## File: Model Parameters



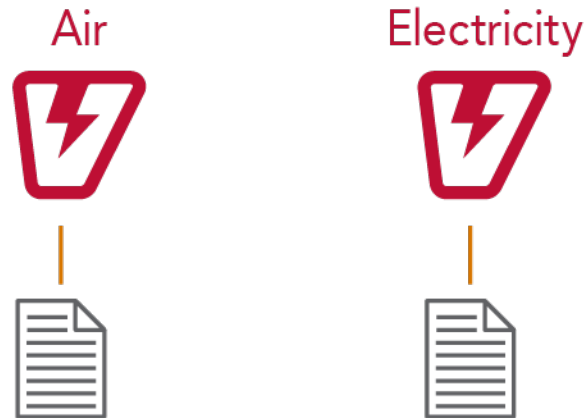
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```
"properties": {  
  "name": "AHUChillerAgent",  
  "c0": 0.0,  
  "c1": -5.105e-01,  
  "c2": 2.210e-01,  
  "c3": -8.793e-03,  
  "c4": 6.558e-03,  
  "c5": -7.414e-06,  
  "COP": 6.16  
}
```

# Step 4B: Air and Electricity Market Agents Configuration File

## STEP 3B Market Agent Configuration Files



# TCC: Example Air Market Configuration

## File: Inputs



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```
"inputs": {  
  "bidResponse": {  
    "topic": "Building 1/air/offer/response",  
    "commodity": "air"  
  },  
  "reservationResponse": {  
    "topic": "Building 1/air/reservation/response",  
    "commodity": "air"  
  },  
  "demandCurveRequest": {  
    "topic": "Building 1/air/demandcurve/request",  
    "commodity": "air"  
  },  
  "supplyCurveRequest": {  
    "topic": "Building 1/air/supplycurve/request",  
    "commodity": "air"  
  },  
  "collectOffersRequest": {  
    "topic": "Building 1/collectoffers/request"  
  },
```

```
    "collectOffersRequest": {  
      "topic": "Building  
1/collectoffers/request"  
    },  
    "collectReservationsRequest": {  
      "topic": "Building  
1/collectreservations/request"  
    },  
    "clearRequest": {  
      "topic": "Building 1/clear/request"  
    }  
  }  
}
```



# TCC: Example Air Market Configuration

## File: Outputs and Properties



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```
"outputs": {
  "bidRequest": {
    "topic": "Building 1/air/offer/request",
    "commodity": "air"
  },
  "reservationRequest": {
    "topic": "Building 1/air/reservation/request",
    "commodity": "air"
  },
  "clearRequest": {
    "topic": "Building 1/air/clear/request",
    "commodity": "air"
  },
  "demandCurveResponse": {
    "topic": "Building 1/air/demandcurve/response",
    "commodity": "air"
  },
  "supplyCurveResponse": {
    "topic": "Building 1/air/supplycurve/response",
    "commodity": "air"
  }
},
```

```
"properties": {
  "name": "AirMarket",
  "forceSettle": "DEMANDHIGH"
}
```

# TCC: Example Electricity Market Configuration File: Inputs



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```
"inputs": {
  "bidResponse": {
    "topic": "Building 1/electricity/offer/response",
    "commodity": "electricity"
  },
  "reservationResponse": {
    "topic": "Building 1/electricity/reservation/response",
    "commodity": "electricity"
  },
  "demandCurveRequest": {
    "topic": "Building 1/electricity/demandcurve/request",
    "commodity": "electricity"
  },
  "supplyCurveRequest": {
    "topic": "Building 1/electricity/supplycurve/request",
    "commodity": "electricity"
  },
  "collectOffersRequest": {"topic": "Building 1/collectoffers/request"},
  "collectReservationsRequest": {"topic": "Building 1/collectreservations/request"},
  "clearRequest": {"topic": "Building 1/clear/request"}
},
```

# TCC: Example Electricity Market Configuration File: Outputs and Properties



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```
"outputs": {  
  "bidRequest": {  
    "topic": "Building 1/electricity/offer/request",  
    "commodity": "electricity"  
  },  
  "reservationRequest": {  
    "topic": "Building 1/electricity/reservation/request",  
    "commodity": "electricity"  
  },  
  "clearRequest": {  
    "topic": "Building 1/electricity/clear/request",  
    "commodity": "electricity"  
  },  
  "demandCurveResponse": {  
    "topic": "Building 1/electricity/demandcurve/response",  
    "commodity": "electricity"  
  },  
  "supplyCurveResponse": {  
    "topic": "Building 1/electricity/supplycurve/response",  
    "commodity": "electricity"  
  }  
},
```

```
"properties": {  
  "name": "ElectricityMarket",  
  "forceSettle": "DEMANDHIGH"  
}
```

# Step 4C: Interface Agent Configuration File

## STEP 4C Interface Agent Configuration Files

Interface



# TCC: Example Interface Agent Configuration File: Inputs and Properties



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```
"inputs": {
  "isActuating": {
    "topic": "Building 1/ACTUATE"
  },
  "isConnected": {
    "topic": "Building 1/CONNECT"
  },
  "VAV102-CLGSP": {
    "topic": "Building 1/VAV102-CLGSP",
    "forward": [
      {"name": "VAV102-CLGSP", "transform": "C2F"}
    ]
  }
},
"outputs": {
  "VAV102-CLGSP": {
    "topic": "PNNL/Building 1/AHU1/VAV102",
    "handler": "handleCoolingSetPoint"
  }
},
```

```
"properties": {
  "isActuating": 0,
  "isConnected": 0,
  "actuator_vip":
    "tcp://x?serverkey=y&publickey=z"
  }
}
```

# Step 4D: Director Agent Configuration File

## STEP 4D Director Agent Configuration Files

Director





# TCC: Example Director Configuration File: Outputs and Properties



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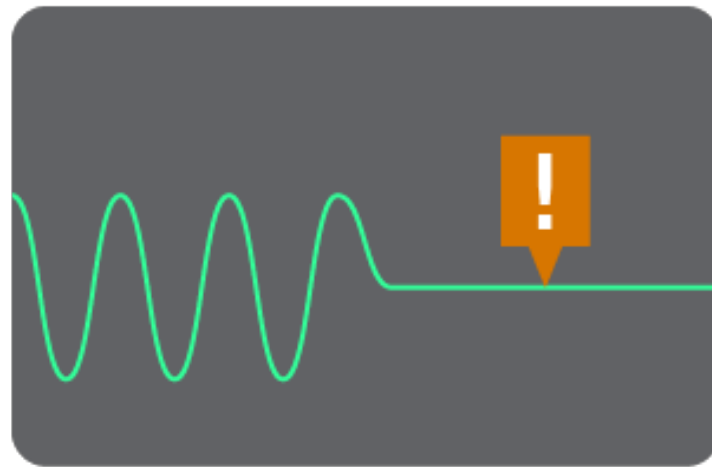
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```
"outputs": {
  "collectOfferRequest": {
    "topic": "Building 1/collectoffers/request"
  },
  "collectReservationsRequest": {
    "topic": "Building 1/collectreservations/request"
  },
  "clearRequest": {
    "topic": "Building 1/clear/request"
  }
},
"properties": {
  "marketPeriod": 300,
  "reservationDelay": 270,
  "offerDelay": 10,
  "clearDelay": 10
}
}
```



# Risk Mitigation: Heartbeat ...

## Heartbeat





# Risk Mitigation: Global Override

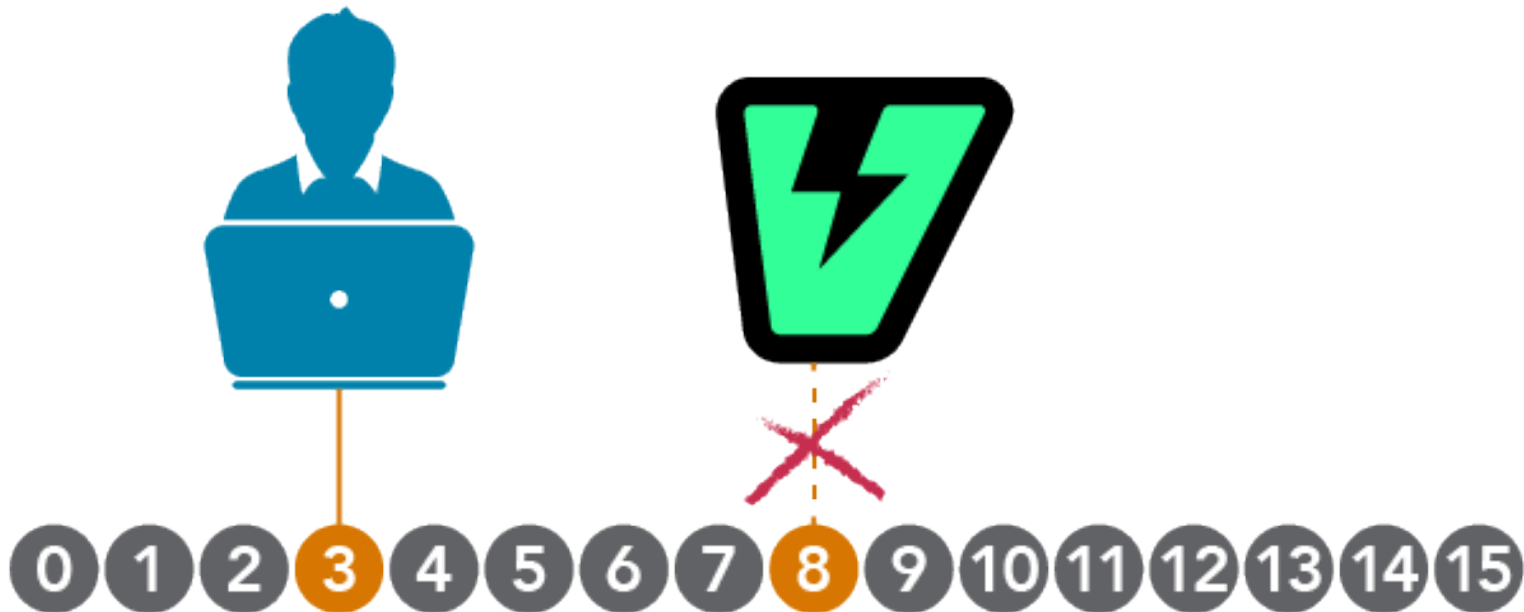
## Global Override





# Risk Mitigation: Local Override

## Priority Override





# Risk Mitigation: Parameter Excursions

## Parameter Excursions

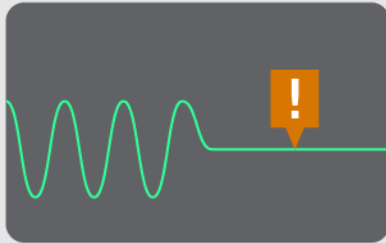




# Risk Mitigation

## Risk Mitigation

Heartbeat



Parameter Excursions



Global Override



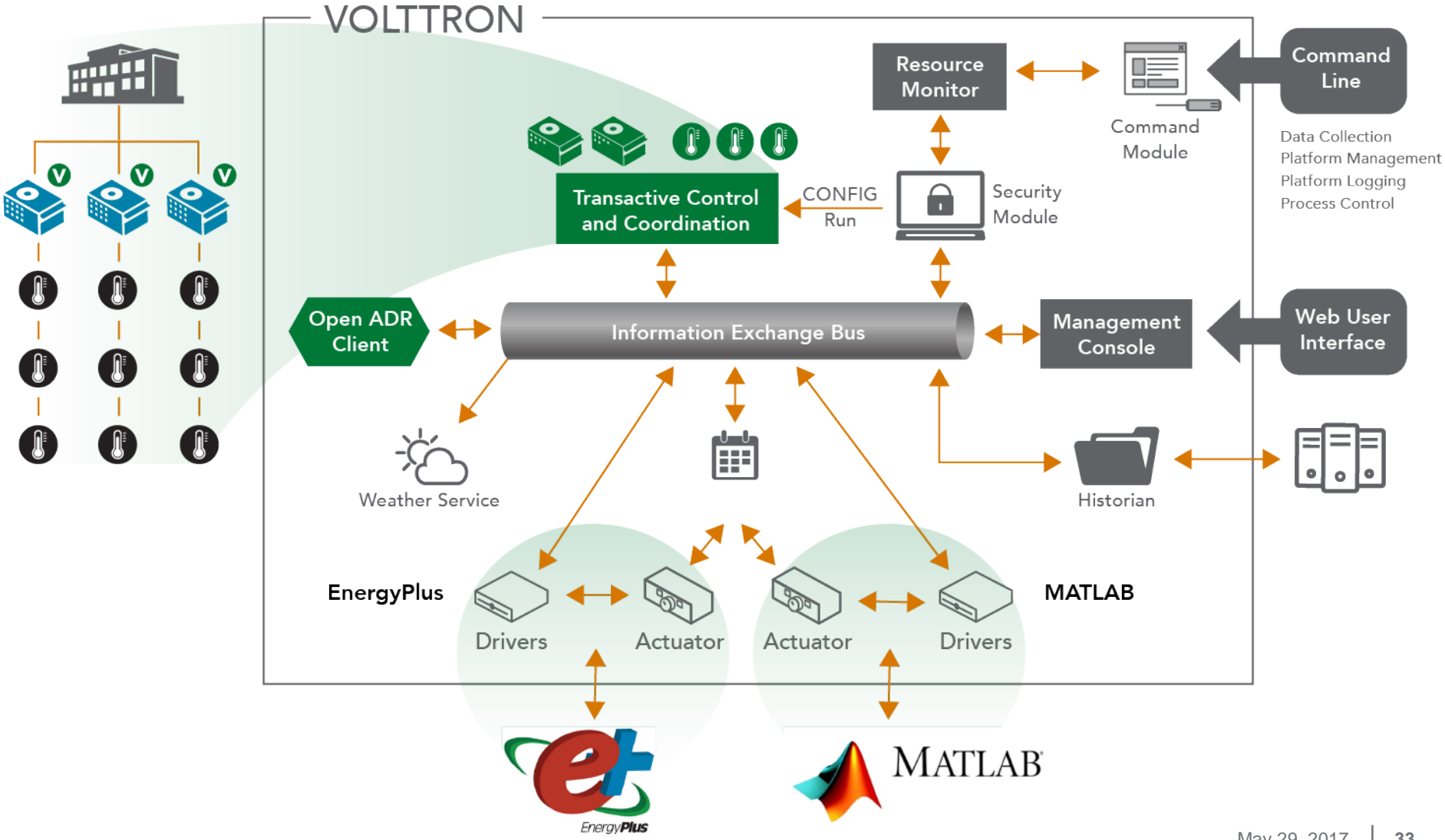
Priority Override

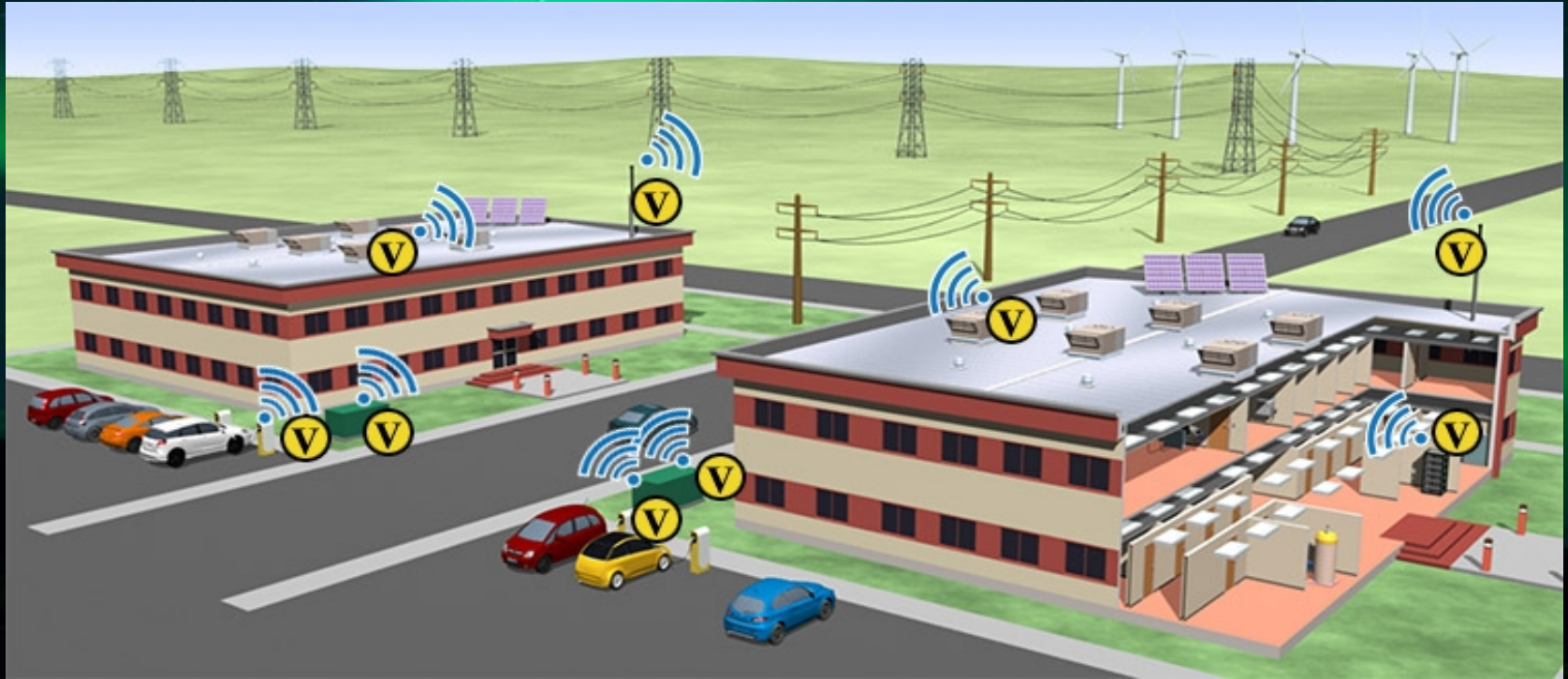






# Validating Agents in Simulation Environment





For More Information: <http://volttron.pnnl.gov>  
<http://bgintegration.pnnl.gov/volttron.asp> and [volttron@pnnl.gov](mailto:volttron@pnnl.gov)  
<https://github.com/VOLTTRON/volttron/wiki>

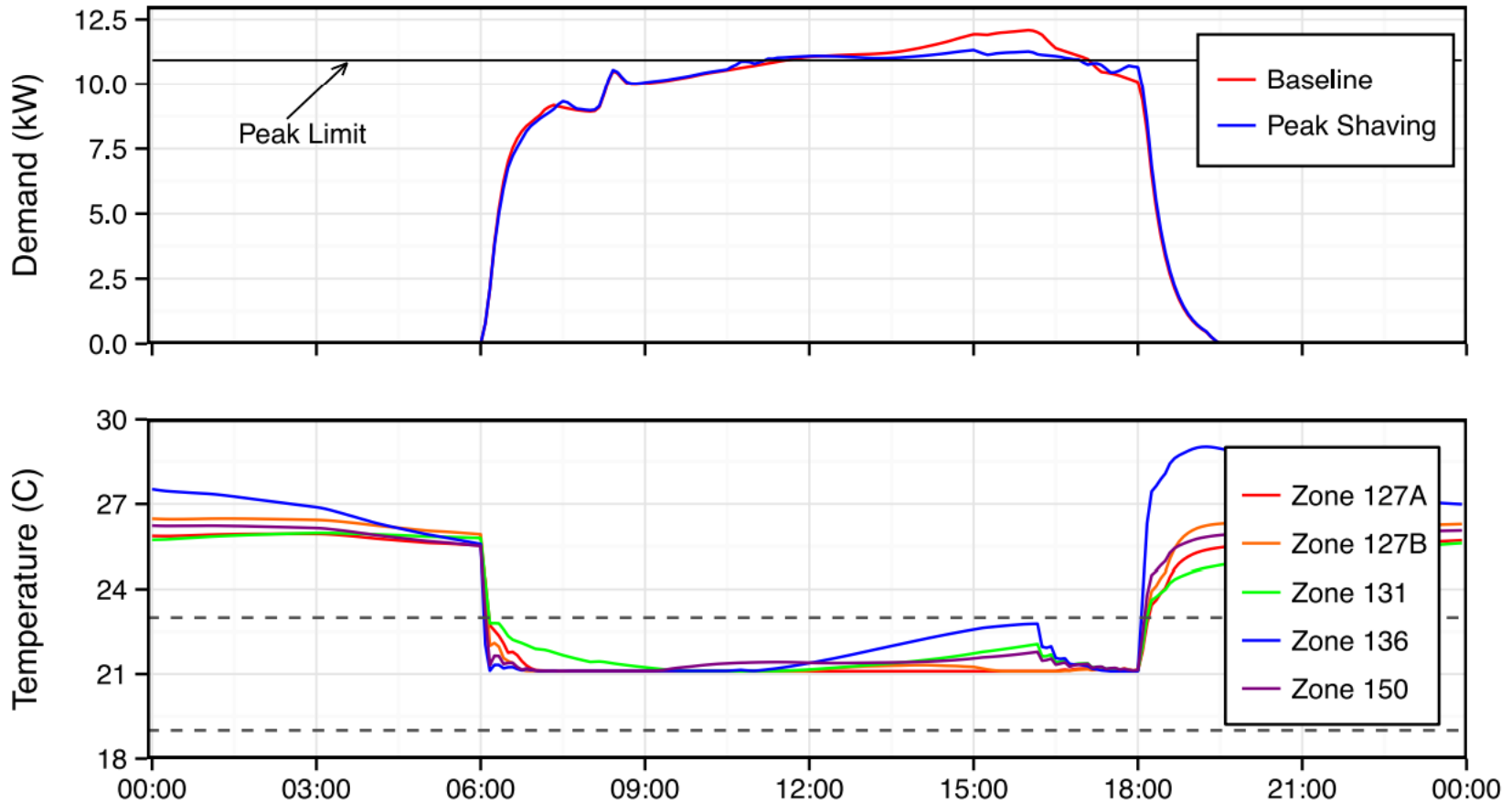


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# Backup Slides

# Transactive Control Test on Simulation Demand Limit



Note: 1. a constant 21°C temperature set point is used in the baseline case  
2. a hot summer week (8/20-25) from the Pasco, WA typical meteorological year (TMY3) weather file was used as inputs

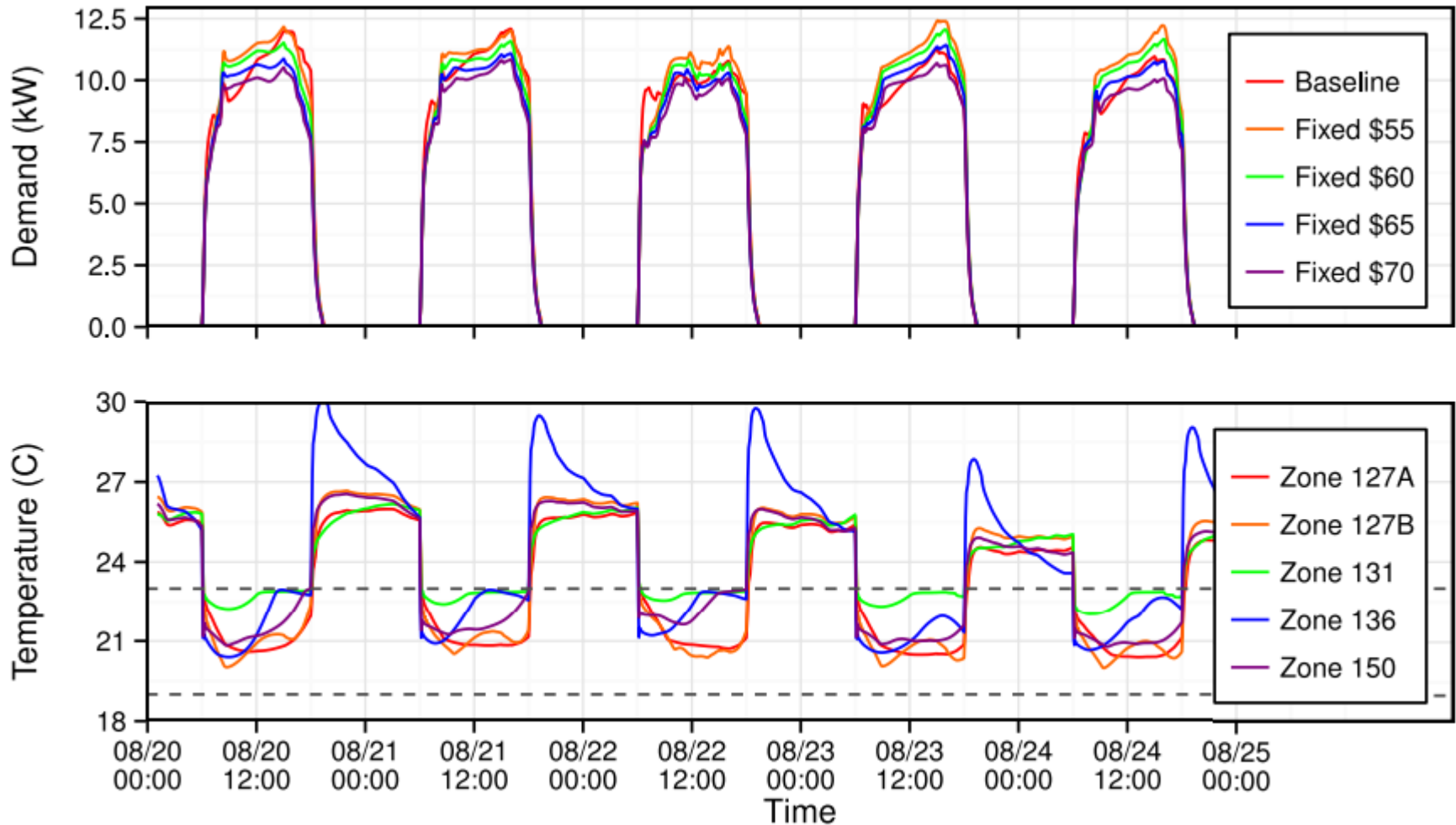


# Transactive Control Test on Simulation Fixed Electricity Price

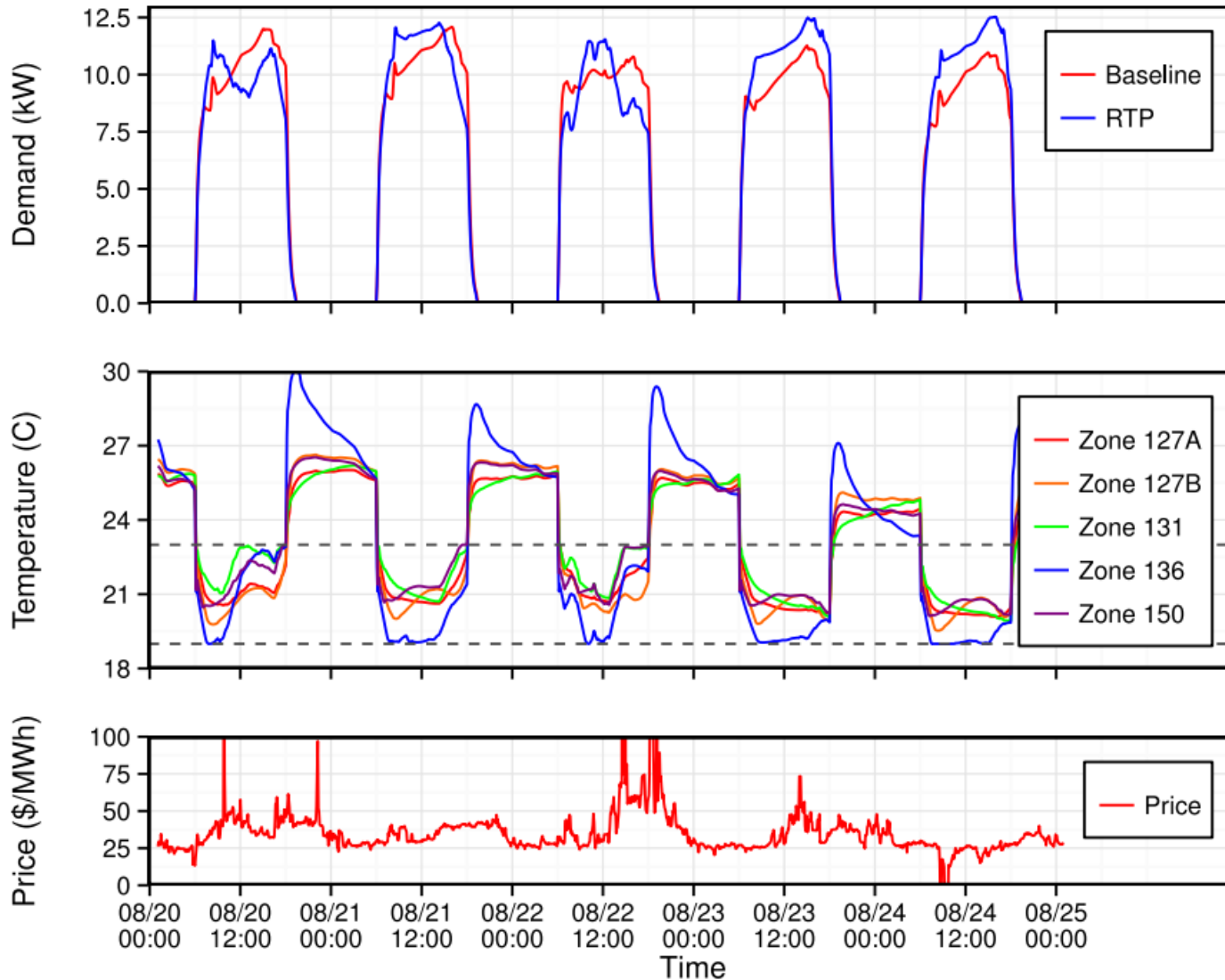


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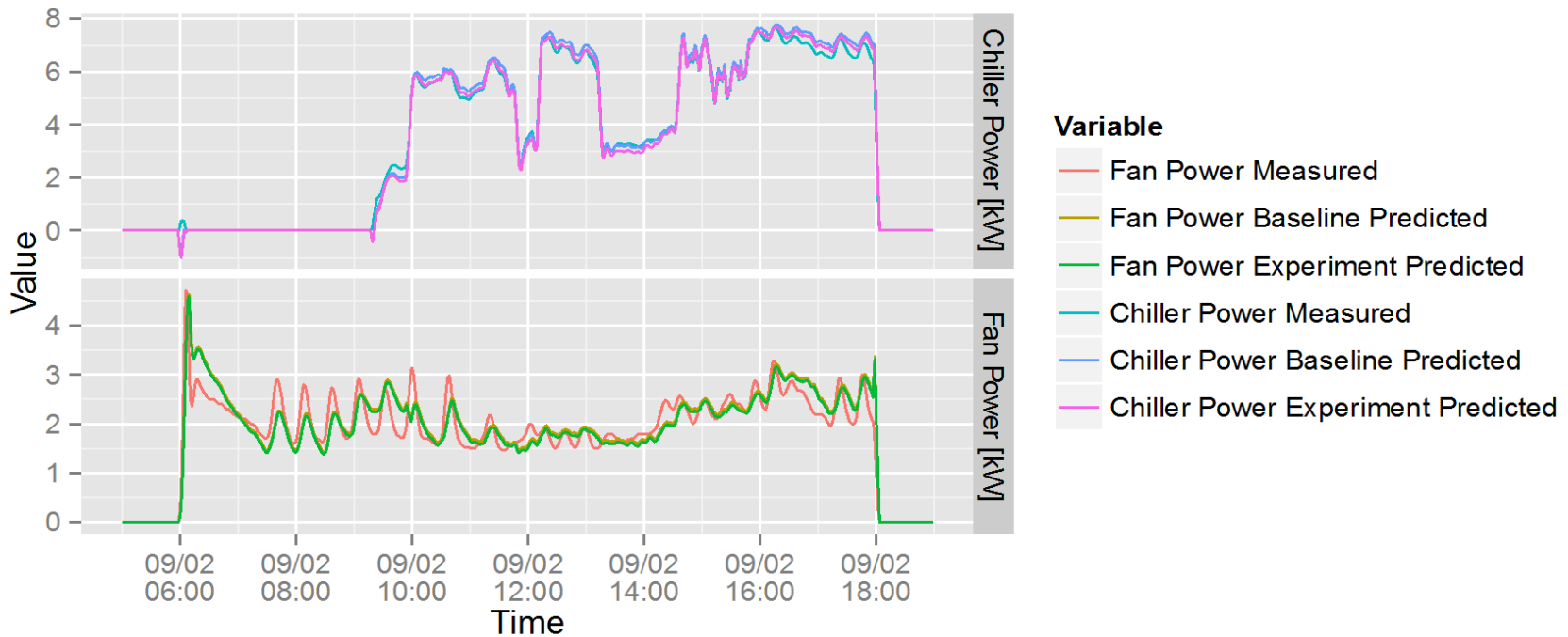
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# Transactive Control Test on Simulation Real Time Electricity Price



# Transactive Control Test on Real Building Demand Limit 6.5MW

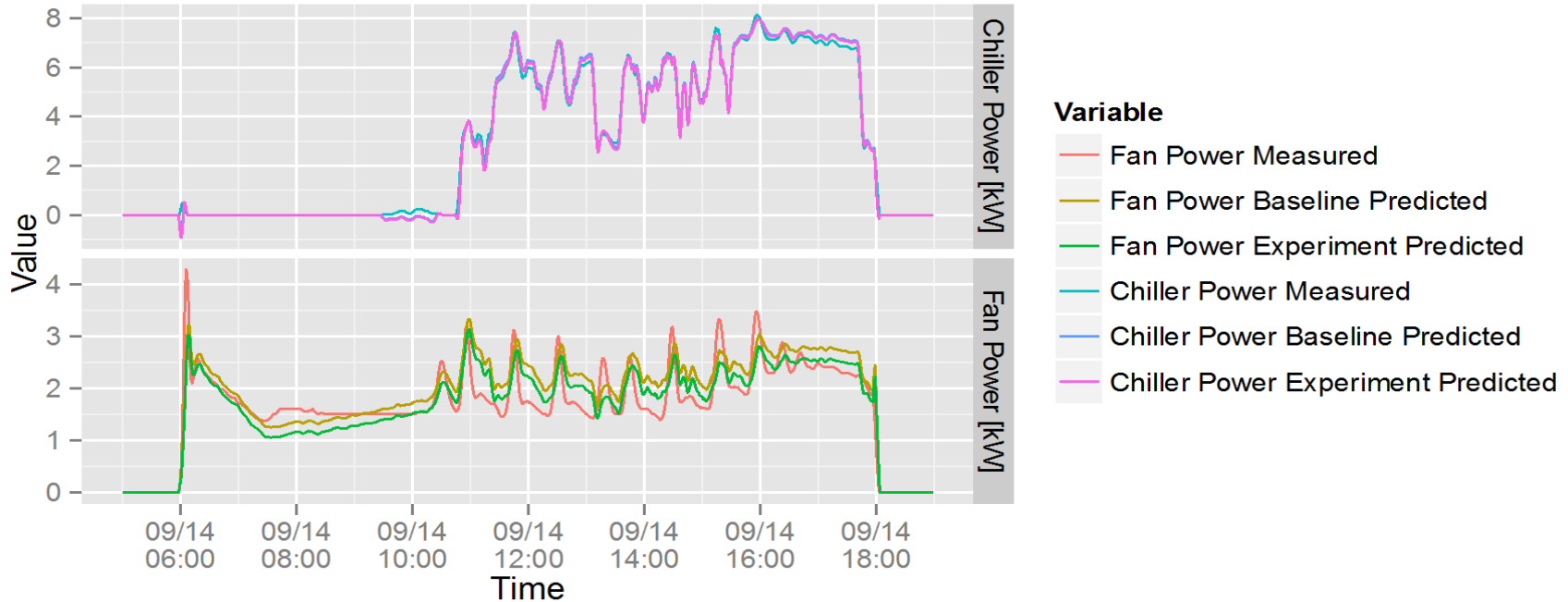


## Energy and power change compared to the baseline

Series	Energy [kWh]	Energy [%]	Demand [kW]	Demand [%]
Fan	-0.05	-0.04%	-0.05	-1.80%
Chiller	-0.12	-0.05%	-0.13	-1.66%
<b>Total</b>	<b>-0.17</b>	<b>-0.05%</b>	<b>-0.18</b>	<b>-1.71%</b>

# Transactive Control Test on Real Building

## Fixed Price \$65/MW



### Energy and power change compared to the baseline

Series	Energy [kWh]	Energy [%]	Demand [kW]	Demand [%]
Fan	-0.21	-0.17%	-0.21	-7.55%
Chiller	-0.04	-0.02%	-0.02	-0.26%
<b>Total</b>	<b>-0.25</b>	<b>-0.07%</b>	<b>-0.24</b>	<b>-2.35%</b>