# Co-simulation of Electric Power Distribution and Buildings with EnergyPlus and OpenDSS

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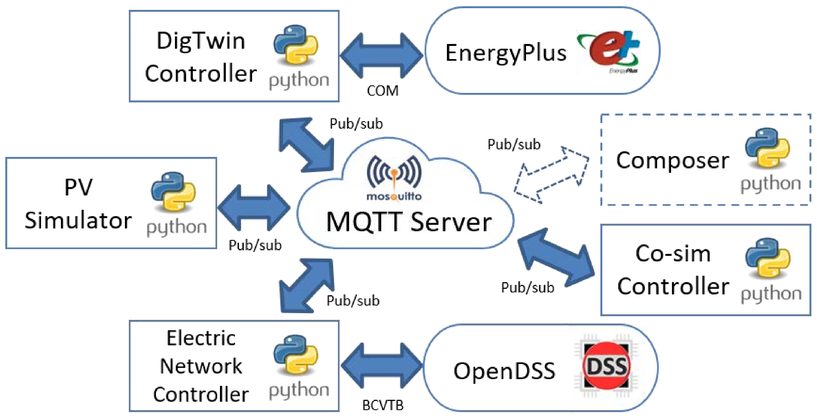
## Problem Formulation

- Need for accurate load modeling that incorporates human comfort into community-level demand response (DR) studies
- Achievable through co-simulation of advanced digital twins for buildings with EnergyPlus and distribution systems with OpenDSS.

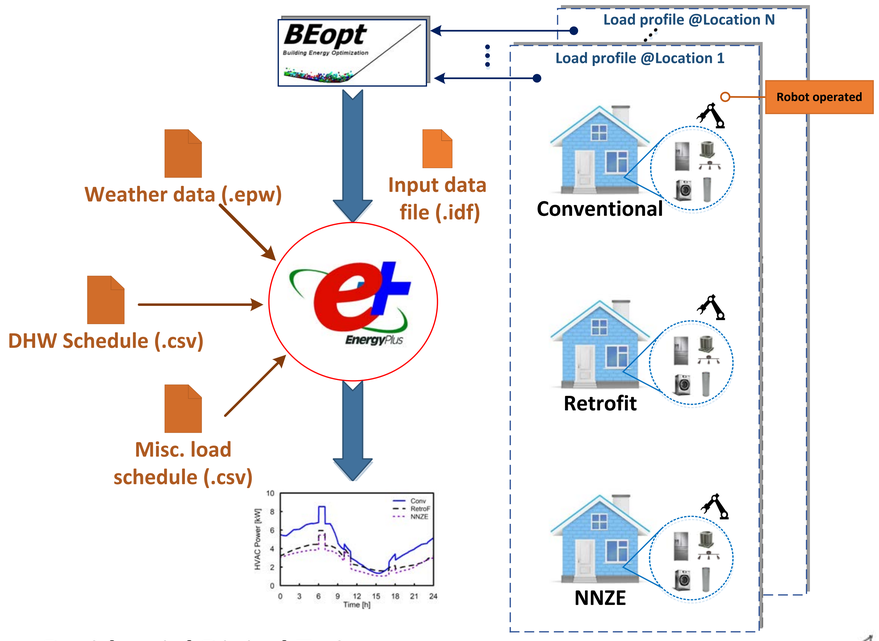
## Co-simulation Framework

- Major software components include EnergyPlus, OpenDSS, and Message Queuing Telemetry Transport (MQTT) server
- **EnergyPlus** is the DOE's flagship whole building energy simulation engine, and it includes distributed energy resources (DERs) such as HVAC and water heater appliance systems
- **OpenDSS** is an electric power distribution system simulator designed by EPRI to support DER grid integration
- **MQTT** enables data exchange and asynchronous simulation in a publish/subscribe manner
- Other stand-alone DER simulators may also be incorporated, such as the solar photovoltaic (PV) simulator utilized in the case studies
- EnergyPlus and OpenDSS communicate with Python via Building Controls Virtual Test Bed (BCVTB) and Component Object Model (COM), respectively.



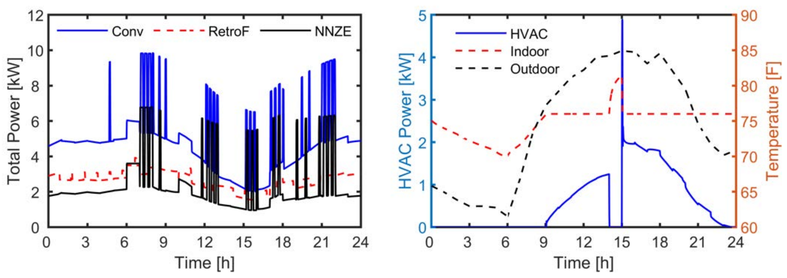

## Composer Module

- Being developed to create representative aggregated load profiles of communities by utilizing a distribution method and different residential load types, such as the simulated profiles from the three digital twins
- Minimizes required EnergyPlus simulations when adding groups of residential or community loads to a distribution system
- Since energy use for a total house load is dependent upon building materials and techniques as well as weather, the number of required EnergyPlus simulations is determined by the composer as the product of the number of house types and bus locations.




## Residential Digital Twins

- Three residential digital twins were developed to represent different building energy profiles: conventional, retrofit, and near net-zero-energy
- BEopt, an NREL-developed software, was utilized to create the base input data files (idf) for the EnergyPlus digital twins
- Based on three neighboring houses, in which human habitation was physically simulated by employing appliance scheduling resources from the DOE Building America Program
- Calibrated with experimentally-collected energy use and weather.



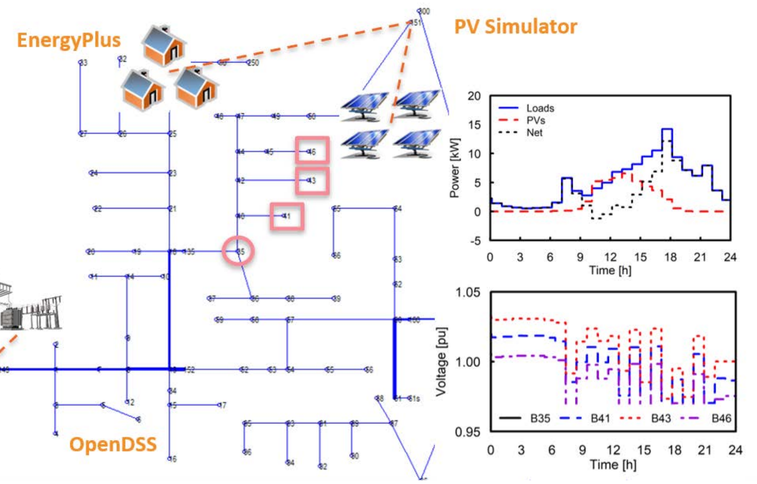

## Demand Response Considering Human Comfort

- EnergyPlus enables the consideration of human comfort when enacting DR schemes by providing indoor temperature, humidity, and other comfort metrics
- Example DR provide in which the HVAC is turned off at 2-3pm.

## Case Study - Multiple Buildings

- IEEE 123 bus distribution system with added building loads at 4 different buses
- Residential-level study with one of each house type and PV systems added to bus 151
- Early version of composer used to add around 120-140 houses to each of the other 3 buses with different house type combinations
- Although 383 buildings were added to the distribution system, only 12 EnergyPlus simulations were required.

| Bus | Conv | RetroF | NNZE |
|---|---|---|---|
| 151 | 1 | 1 | 1 |
| 46 | 60 | 40 | 20 |
| 43 | 20 | 40 | 60 |
| 41 | 60 | 20 | 60 |




## Conclusions

- Co-simulation of residential digital twins and electric power distribution systems is achieved through the proposed framework, which employs EnergyPlus and OpenDSS
- Simulates hundreds of buildings in a distribution system based on far fewer EnergyPlus simulations, which significantly reduces computation requirements
- Provides human comfort metrics considering weather effects.

## Future and Ongoing Work

- Further developments of the composer to enable the creation of representative aggregated load profiles with a distribution method and set of residential load types
- Additional electric vehicle (EV) and residential energy storage system (RESS) modules.

## Acknowledgement

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