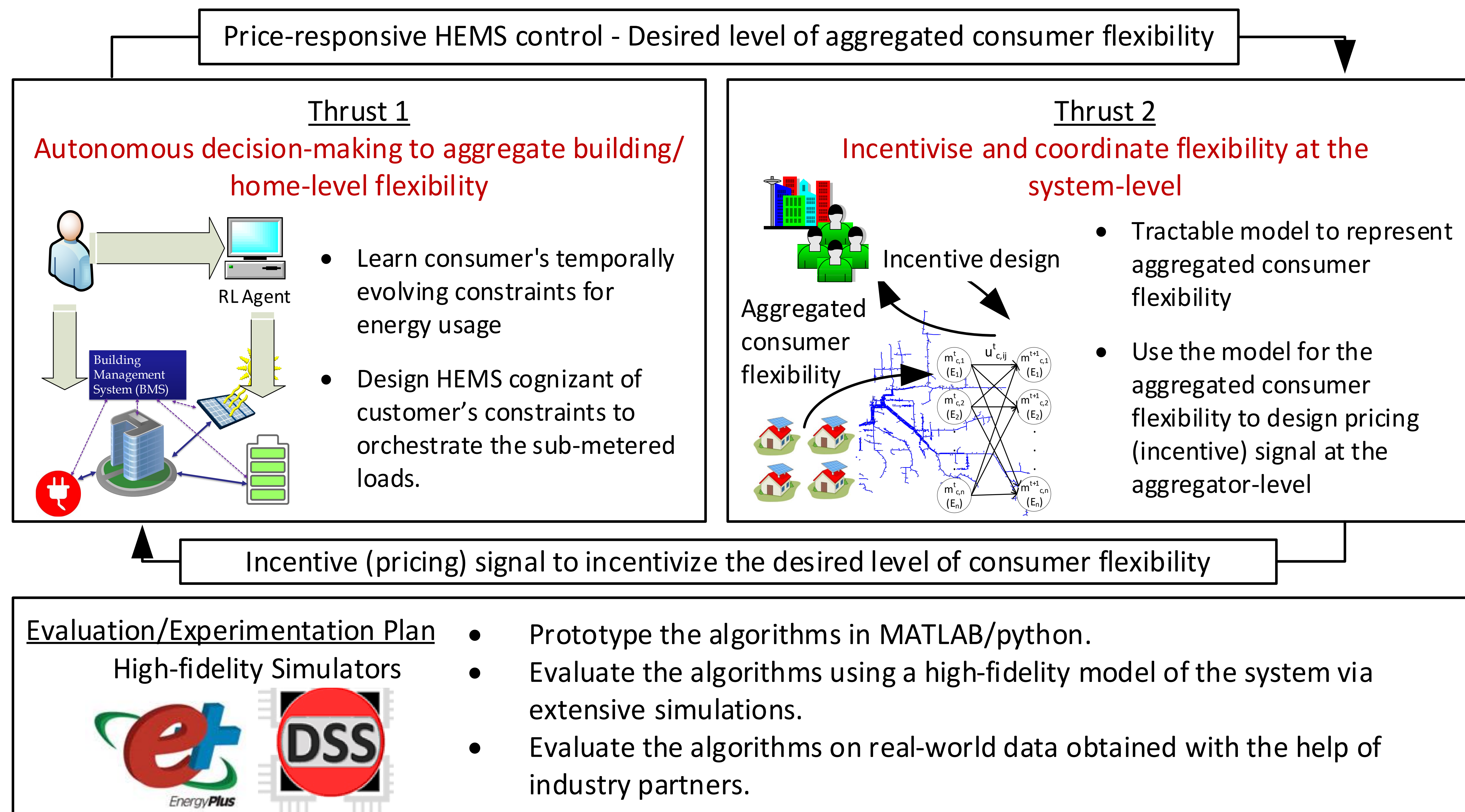# Collaborative Research: CPS: Medium: Adaptive, Human-centric Demand-side Flexibility Coordination At-scale in Electric Power Networks

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Project goal - Aggregation and coordination of demand-side flexibility at many small consumers in power grid by adequately representing the user constraints regarding electricity usage and their interactions with the system and the energy provider.

Price-responsive HEMS control - Desired level of aggregated consumer flexibility

Thrust 1
Autonomous decision-making to aggregate building/home-level flexibility

RL Agent

Building Management System (BMS)

- Learn consumer's temporally evolving constraints for energy usage
- Design HEMS cognizant of customer's constraints to orchestrate the sub-metered loads.

Thrust 2
Incentivise and coordinate flexibility at the system-level

Incentive design

Aggregated consumer flexibility

$m^t_{c,1}$ (E_1) $u^t_{c,ij}$ $m^{t+1}_{c,1}$ (E_1)

$m^t_{c,2}$ (E_2) $m^{t+1}_{c,2}$ (E_2)

$m^t_{c,n}$ (E_n) $m^{t+1}_{c,n}$ (E_n)

- Tractable model to represent aggregated consumer flexibility
- Use the model for the aggregated consumer flexibility to design pricing (incentive) signal at the aggregator-level

Incentive (pricing) signal to incentivize the desired level of consumer flexibility

Evaluation/Experimentation Plan
High-fidelity Simulators

EnergyPlus

DSS

- Prototype the algorithms in MATLAB/python.
- Evaluate the algorithms using a high-fidelity model of the system via extensive simulations.
- Evaluate the algorithms on real-world data obtained with the help of industry partners.

Technical Accomplishments:

- Model prosumers' demand flexibility: data-driven models to estimate and predict building-level thermal load demand for residential and commercial grid-interactive efficient buildings.

- Incentive design: adaptive incentive design algorithm and gradient-based optimization method to compute the optimal incentive strategy for the leader.

- Policy gradient-based learning algorithm for general sum stochastic Stackelberg games with theoretical guarantees for its convergence.

Broader Impacts:
- Provided solutions to adaptive and smart infrastructure systems with active participants, methods broadly applicable to other CPS
- Undergraduate research, recruit and train women students and other underrepresented minority students.