Incentivize Residential Demand-side Participation

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Motivation

Changing nature and requirements of the grid at the edge interfacing:

- Uncertain supply-demand unbalance imbalances resulting from misaligned infrastructure, integration of solar and wind generation technologies, and increasing frequency and intensity of extreme weather events
- Very-large penetration of distributed energy resources - 2.5 million solar PV installations (2020)
- Emergence of new load types: 1.6 million PHEVs/EVs sold (2020), in 5 years data centers to use 10% of the U.S. energy

Residential Demand-side Flexibility

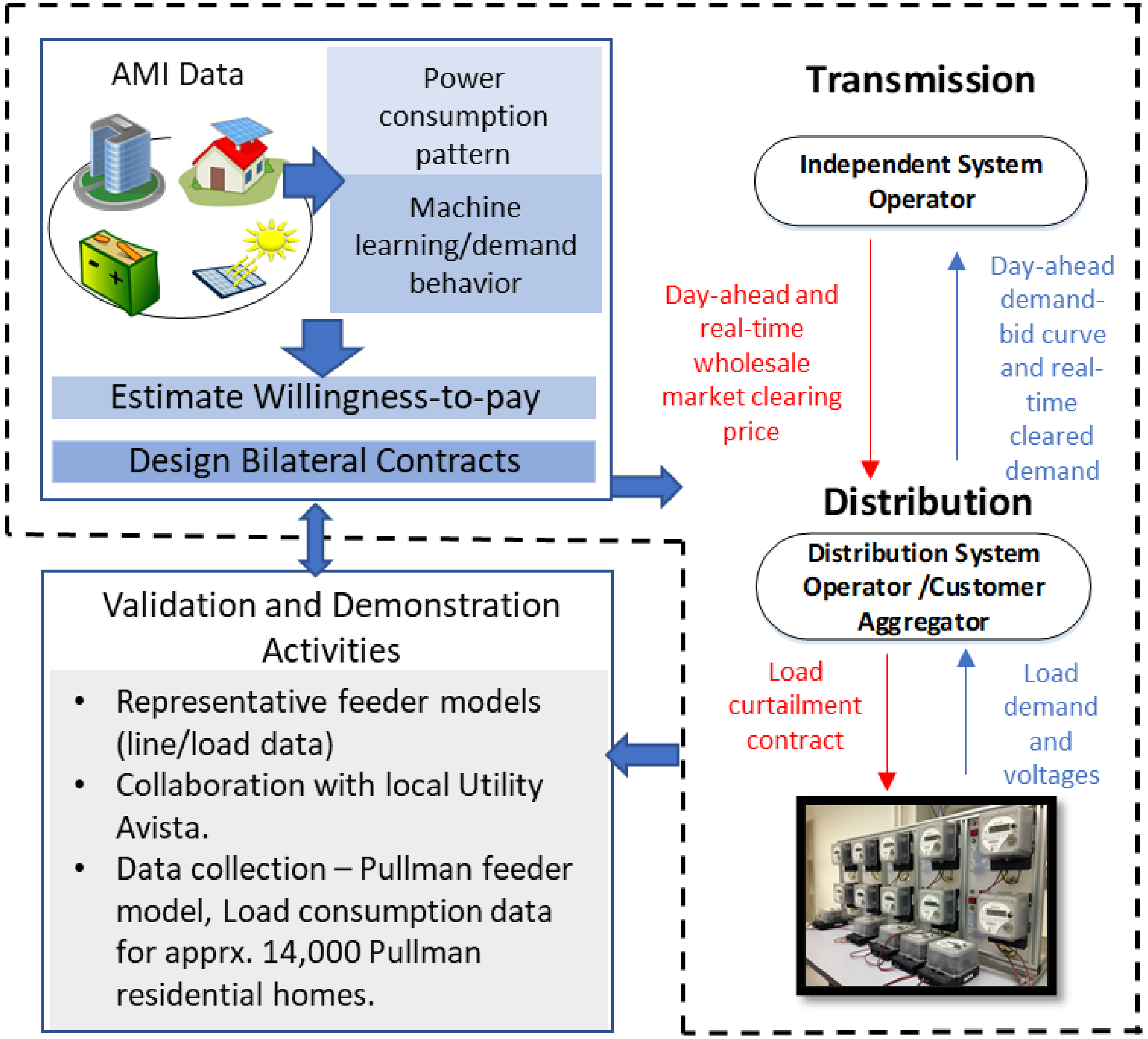
- Residential demand-side flexibility remain mostly untapped.
  - Although several efforts have been made, demand-side flexibility from small residential customers remain untapped even after massive penetration of edge-control devices and smart meters.
  - Moreover, customer drop-offs and no response prohibit realizing the existing demand-side potential.
- Our research funded by Alfred P. Sloan foundation grant brings together researchers from power systems engineering and economic sciences to design incentives to increase sustained demand-side participation to provide grid services specifically for peak reduction.
- Methods developed in our work can potentially be used in design and implementation of more resilient grids though enabling more localized grid balancing.

Proposed Approach

- Our research focuses on sustainable, effective household demand response.
- Household consumers make a financially risk-free decision to accept payment from the power authority in return for being subjected to the disutility associated with the discomfort of a warmer indoor temperatures than would otherwise be desired.
- To this end, in this project, we ask the following questions:

  (1) How likely it is that a specific consumer will change energy consumption in response to a change in electricity price?

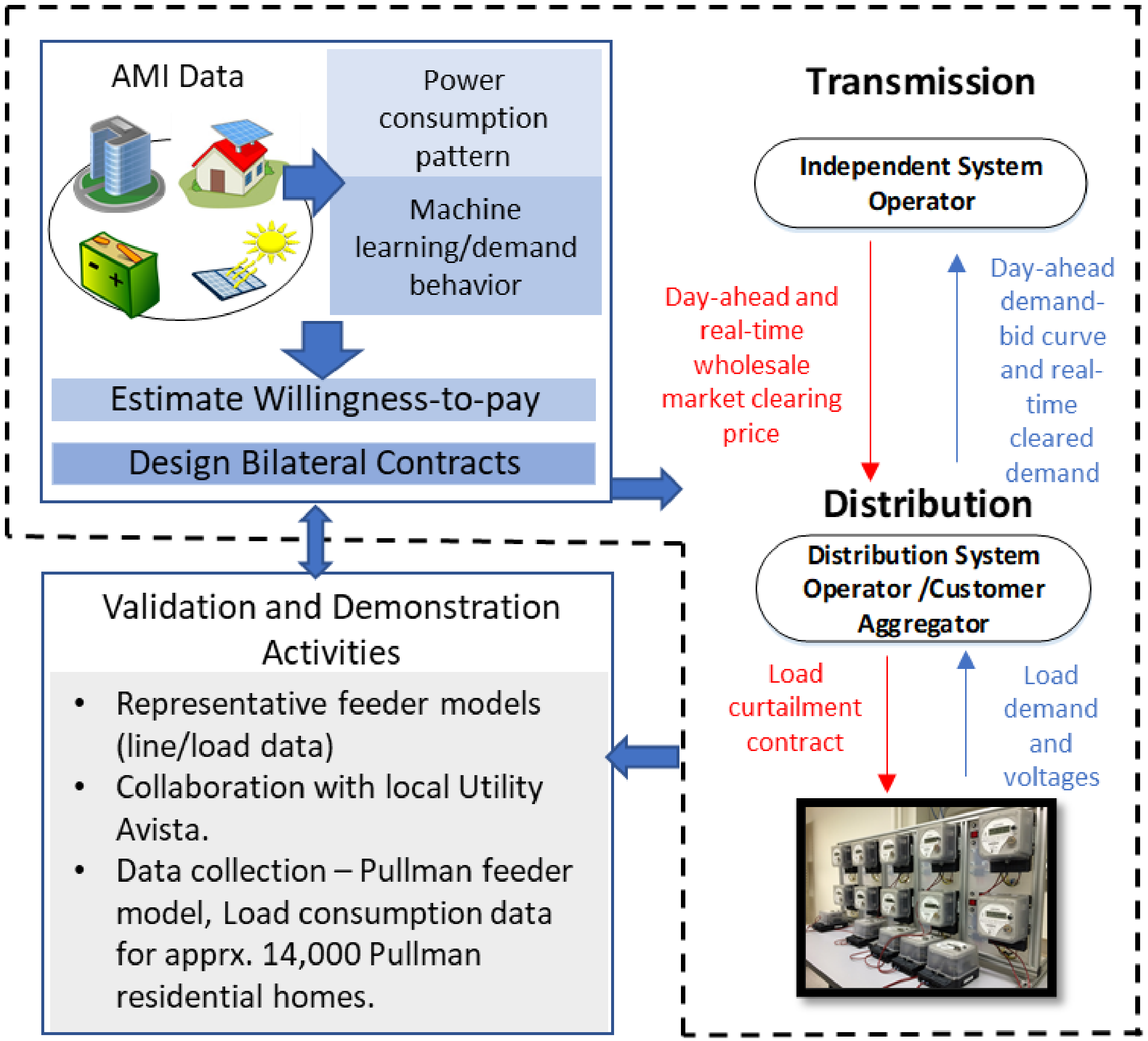
  (2) How to incorporate consumer preferences and behavior into DR programs to better influence their energy consumption behavior?



Proposed Approach

How likely it is that a specific consumer will change energy consumption in response to a change in electricity price?

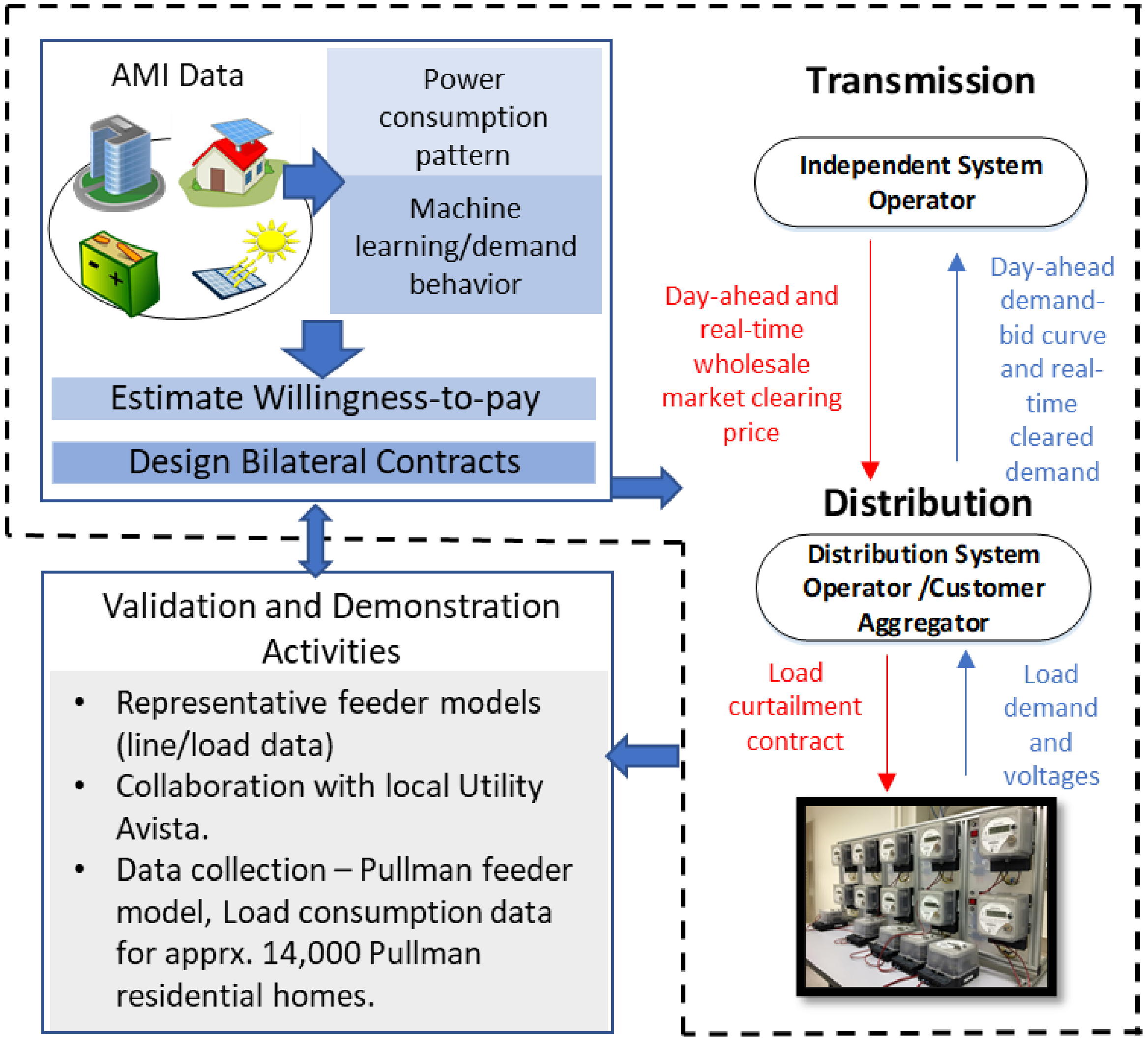
- We use of real-world data (Smart Meter Data, Time of Day, Meteorological Data) to understand consumer behavior and preferences for their electricity usage and estimate their willingness-to-pay for specific electricity uses.
- This research applies machine learning methods to smart meter data to detect and decode specific consumption patterns and estimate willingness-to-pay for specific electricity uses and ultimately for the design of bilateral critical peak rebate contracts between utility and customer.



Proposed Approach

How to incorporate consumer private information and behavior into DR programs to better influence their energy consumption behavior?

- We propose a critical peak rebate (CPR) contract to allow the utility operator to offer payments to households (based on their willingness-to-pay estimates) in order to alter thermostat settings at various times for various time intervals.
- The optimal contract is designed to optimize the Energy Authority's objective function while taking account of asymmetric information and potential household opportunistic behavior.
- Using economic constructs from principal-agent theory, the contract model ensures participation among households most aligned with the regulated utility's desire.



Discussions

- **Optimal contracts with financial risk reduction may lead to increased consumer retention in demand-response programs**
  - Errors in anticipated consumer response when designing contracts can lead to unanticipated results including customer discontent and profit losses.
  - Optimal contracts meet objectives of both utility company and residential consumers.
- **Generate new value streams for flexible loads at the residential-scale**
  - Peak management and defer utility investment via non-wires alternative;
  - More flexible power grid to better manage demand-supply imbalances
  - Leading to a more efficient and economical grid
- **Reduce price volatility and improve market efficiency using demand response;**
  - Reduce impacts of real-time wholesale market uncertainty (due to renewables or any other variables)
  - Encourage adoption of renewables such as solar and wind

Thank you

Questions?