Baseline Estimation to Understand the Responsiveness of Demand Side

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Background

- Lecturer in Control and Power at Imperial
- Team: 4 PhD students and 1 PDRA
- Research interests
  - Forecasting: data-driven approaches, spatiotemporal forecasting of demand and RES, inertia forecasting, …
  - Control: stochastic controller, MPC, …
  - Cyber security: FDI attack against state estimation and data set
  - Social perspective of energy system: social acceptance of DR, privacy..
- Funded by EPSRC, ESRC, Innovative UK and National Grid

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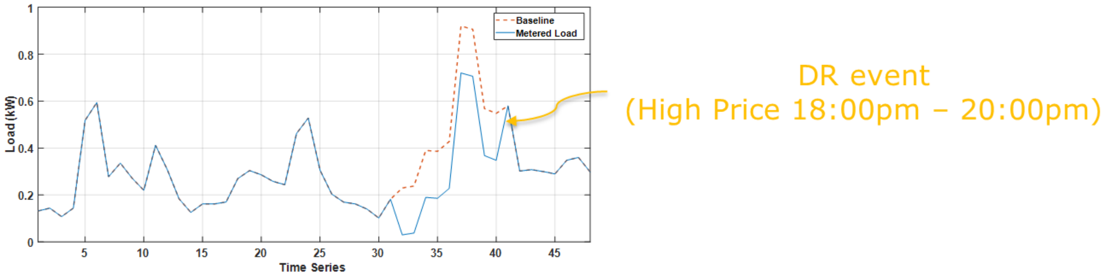
Introduction

- Demand response (DR) is one of the most flexible and cost-effective solutions for **reducing system operation costs** and can **displace or defer network reinforcement costs** by reducing the peak demand and peak-valley difference.

- DR is defined as **change in demand** as a result of a **price signal**, relative to the demand that would have been had the price signal not been sent.

$$DR = D^{actual} - D^{baseline}$$

- **Baseline estimation** is the fundamental but challenging component of DR. It is performed to estimate the electricity consumption under normal conditions during the DR events.



Challenges

Main Challenges

1) **Time-varying events:** different event durations (e.g., 3-hour, 6-hour, 12-hour) and various event time (e.g., start from 7:00am, 18:00pm);
2) **High Variability and Uncertainty** at household level;

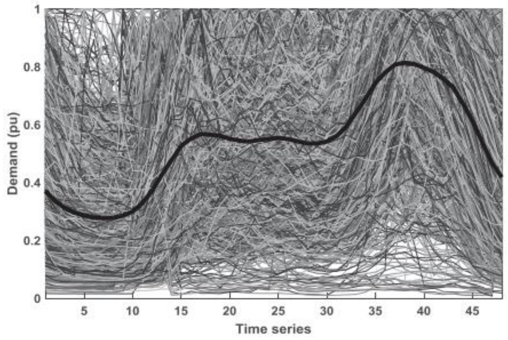


Fig. 3. RLPs for all 2,613 customers of the LCL smart meter trials. Thick black line shows the mean RLP.

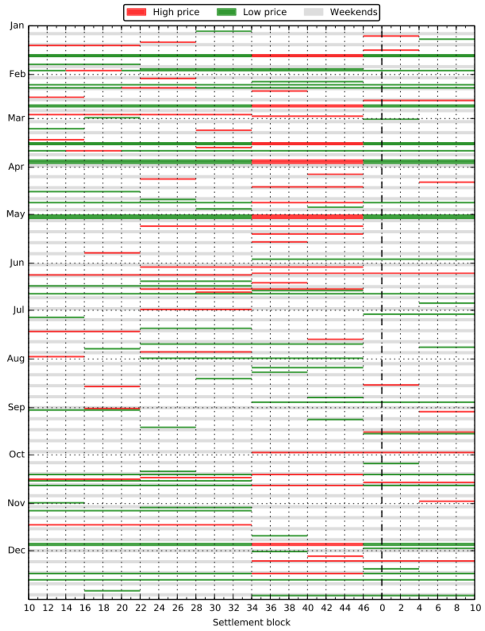


Figure 3.10: Event schedule in local time.

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Introduction and Challenges

Current Approaches:

- **Average Methods/Similar Day Methods**

Use the average load of X days in the past Y non-DR event days.

- **Regression Methods:**

Fit a linear/nonlinear model to describe the relationship between the load the explanatory variables including historical demand and weather data such as temperature, wind speed.

- **CONTROL Group Methods:**

Use the load data of non-DR customers who exhibit the most similar electricity consumption behaviours to the DR participants.

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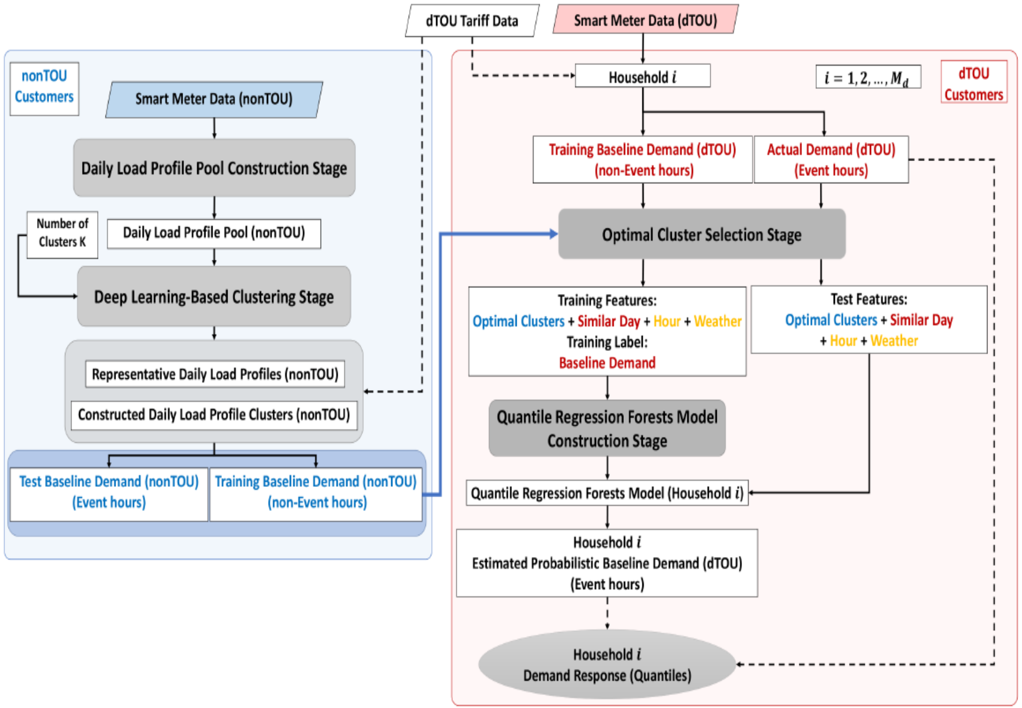
Proposed Framework



A Daily Load Profile Pool is proposed to significantly enrich the database of daily load patterns for clustering-based baseline estimation methods.

Deep Embedded Clustering: A deep learning-based clustering method, namely, deep embedded clustering (DEC), is employed for the first time to cluster this large number of daily load patterns, integrating dimensionality reduction and clustering into a single end-to-end learning framework. In particular, DEC can jointly extract informative features and construct separable clusters.

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Case Studies

- **Tested Methods**

  M1: Simple Average;

  M2: Average Daily Load Profile + k-Means Clustering +Quantile Regression Forests;

  M3: Average Daily Load Profile + k-Means Clustering+ Gaussian Process;

  M4: Proposed + k-Means Clustering + Quantile Regression Forests;

  M5: Proposed + DEC + Quantile Regression Forests;

DETERMINISTIC BASELINE ESTIMATION PERFORMANCE

	M1	M2	M3	M4	M5
MSE (kW^2)	0.0302	0.0297	0.2592	0.0278	**0.0260**
ARE (kW)	**0.0009**	0.0151	-0.0273	0.0051	0.0020

PROBABILISTIC BASELINE ESTIMATION PERFORMANCE

	M2	M3	M4	M5
PL(kW)	0.0351	0.1575	0.0330	**0.0315**
Winkler Score (kW)	8.2426	45.5724	8.0536	**7.8784**
PICP	0.8050	0.4626	0.9252	**0.9282**

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Case Studies

M5: Different Number of Clusters

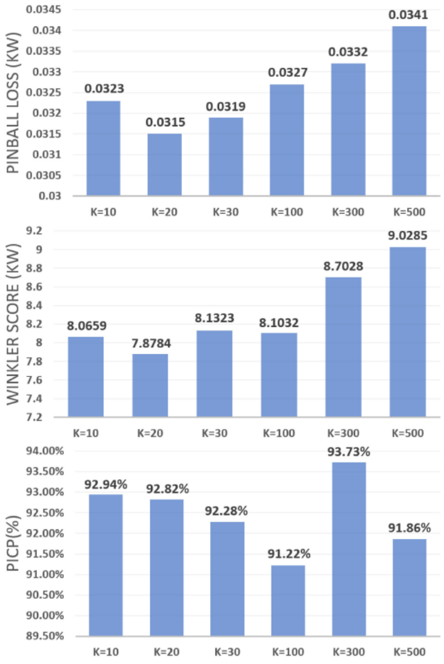

Fig. 5. Probabilistic estimation results for different numbers of clusters.

M5: Different Events

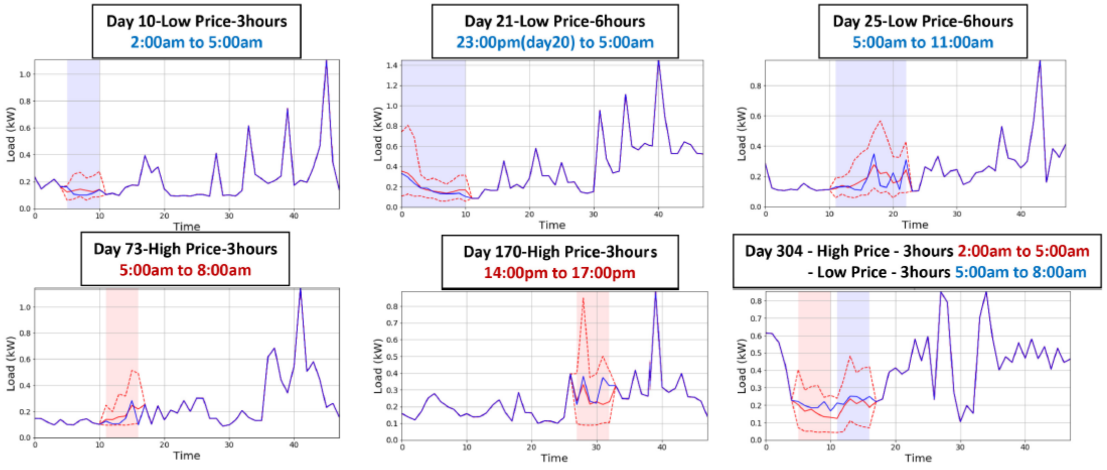

Fig. 6. Actual and estimated baseline demand obtained via the proposed method M5 based on a series of random days with different types and durations of events (blue area: low-price event; red area: high-price event). Note that the upper/lower bounds and the mean profile are indicated by two red dashed lines and one red solid line, respectively.

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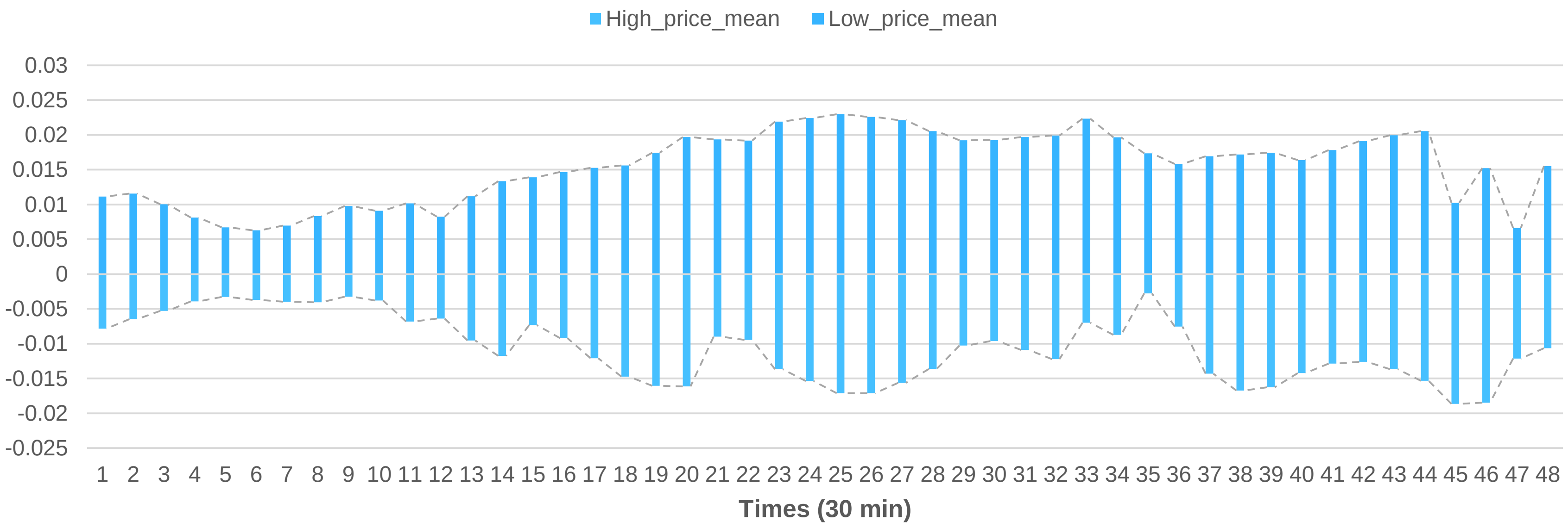
Responsiveness across the day



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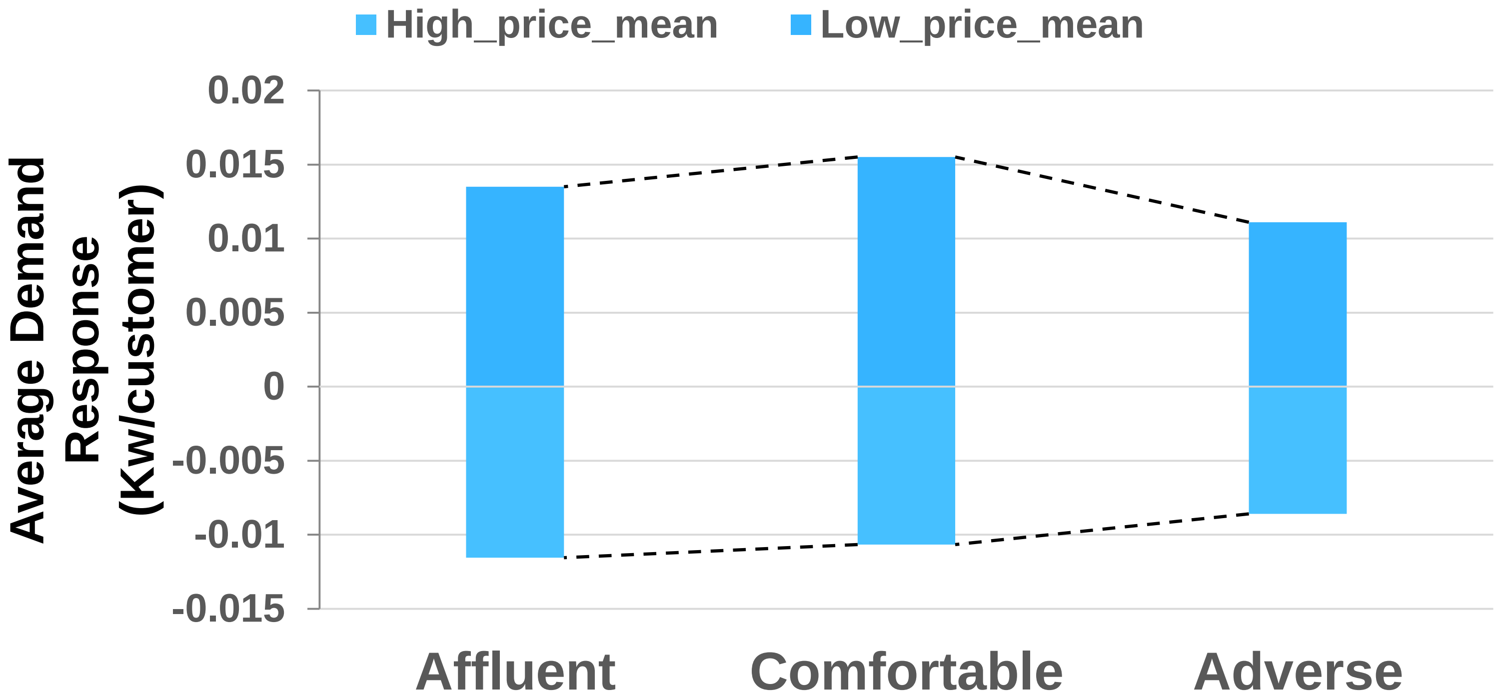
Responsiveness across income levels



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