Machine learning powered residential load profiles analysis and flexibility estimation

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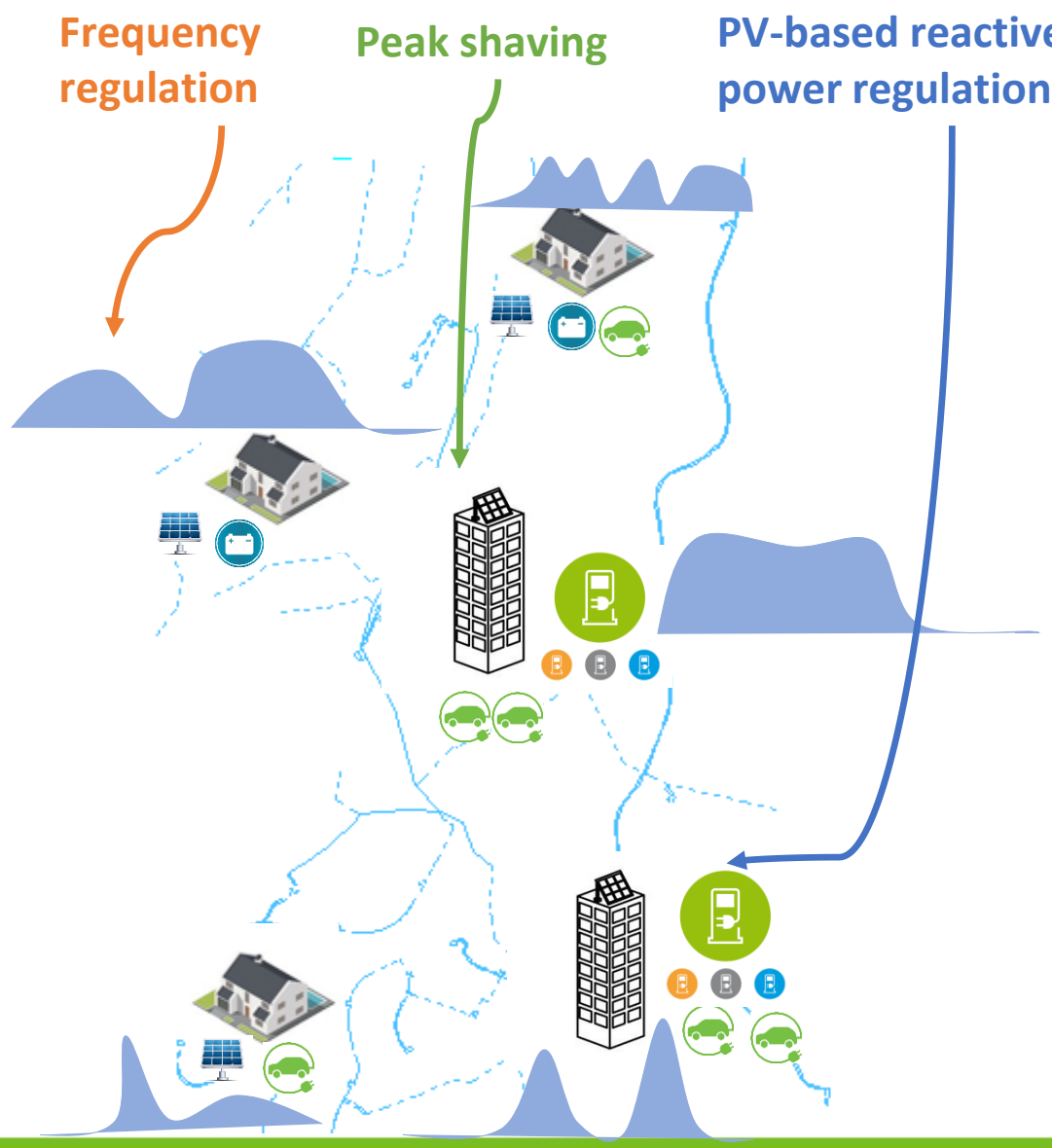
Grid Flexibility from Grid Edge



- *Decision-making on system need: which DERs should provide how much services?*

Grid edge DERs provide flexibility to participate grid services

DER-Load interactions are very diversified

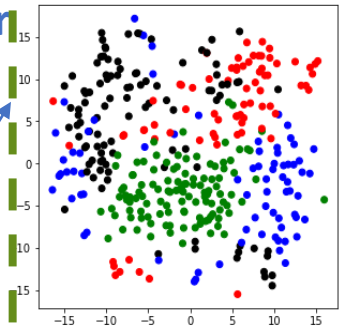
- *Decision-making on DER capability: which DERs can provide how much flexibility at what time duration?*

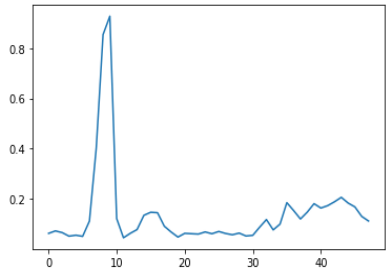
Solution ⟶ Load and DER flexibility estimation

DER-Load Flexibility Estimation

K-means and MLP to **cluster** the profiles

load pattern and characteristics

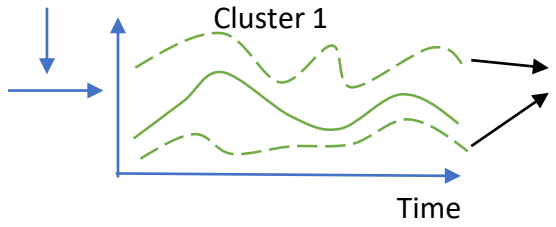




Load modeling

Solar/Wind Measurements
ES Model

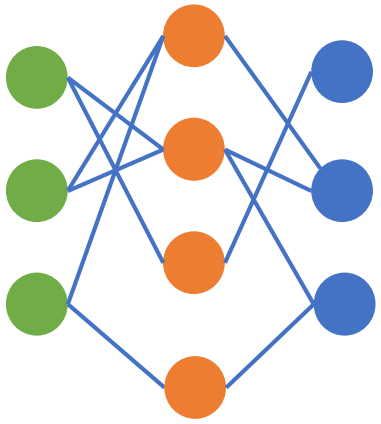
Human Input

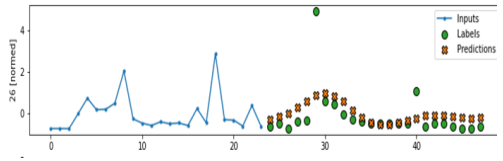


Flexibility Envelope

Consumption profiles

Transfer learning boosted LSTM to **forecast** the footprint

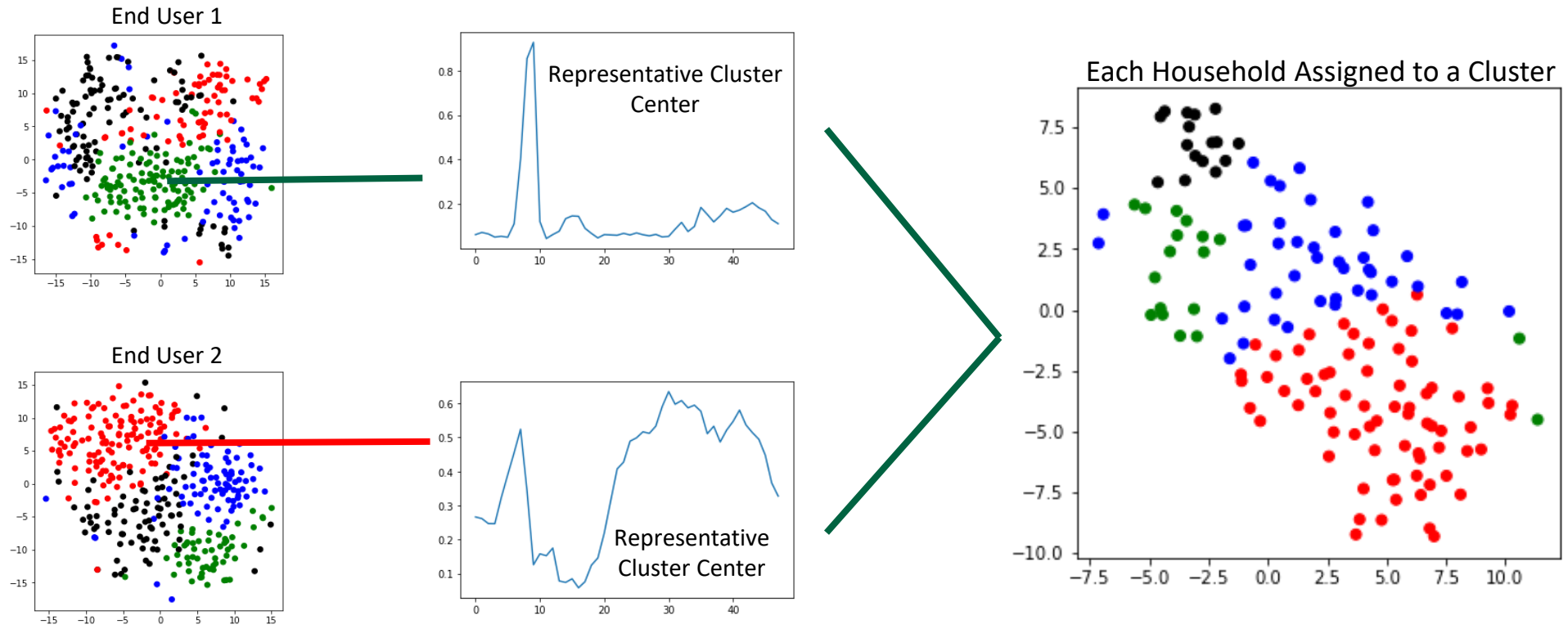




MLP: Multi-layer perceptron neural network

LSTM: long short term memory

Load Clustering



Clustering Methods

Hierarchical clustering:

- Agglomerative/Divisive algorithm

Partitioning clustering:

- K-means/K-Medoids/Fuzzy c-Means

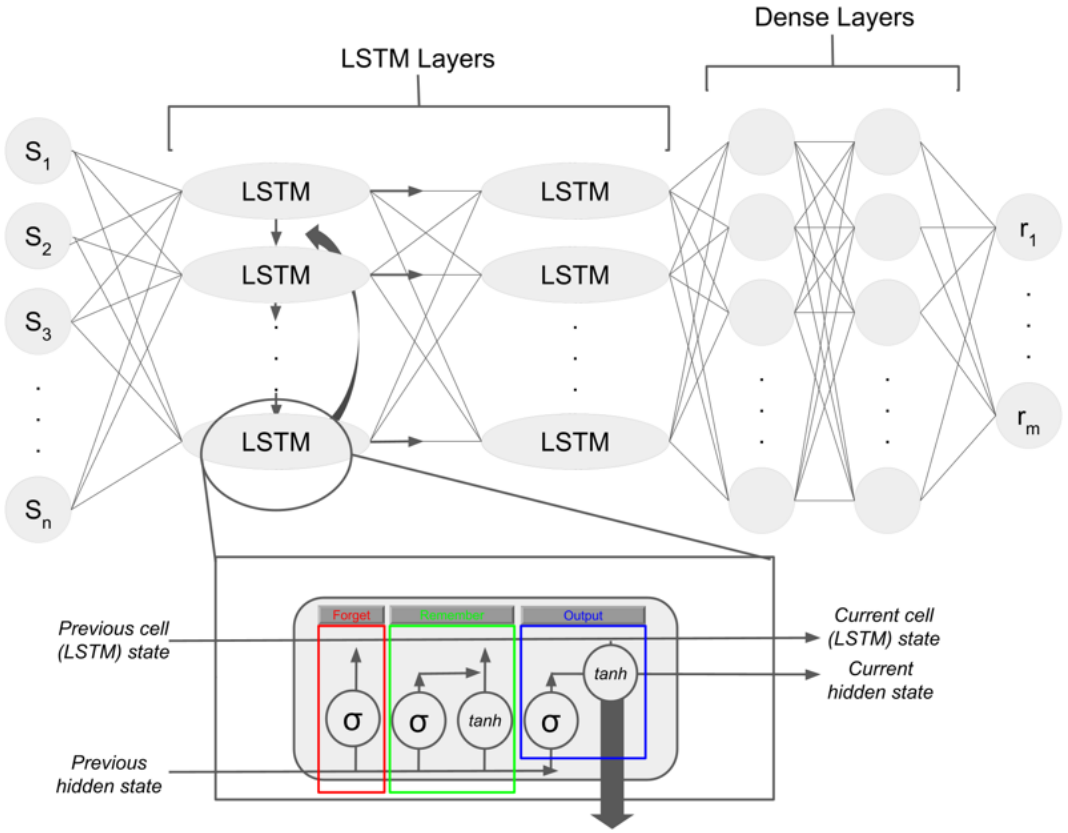
Model-based clustering:

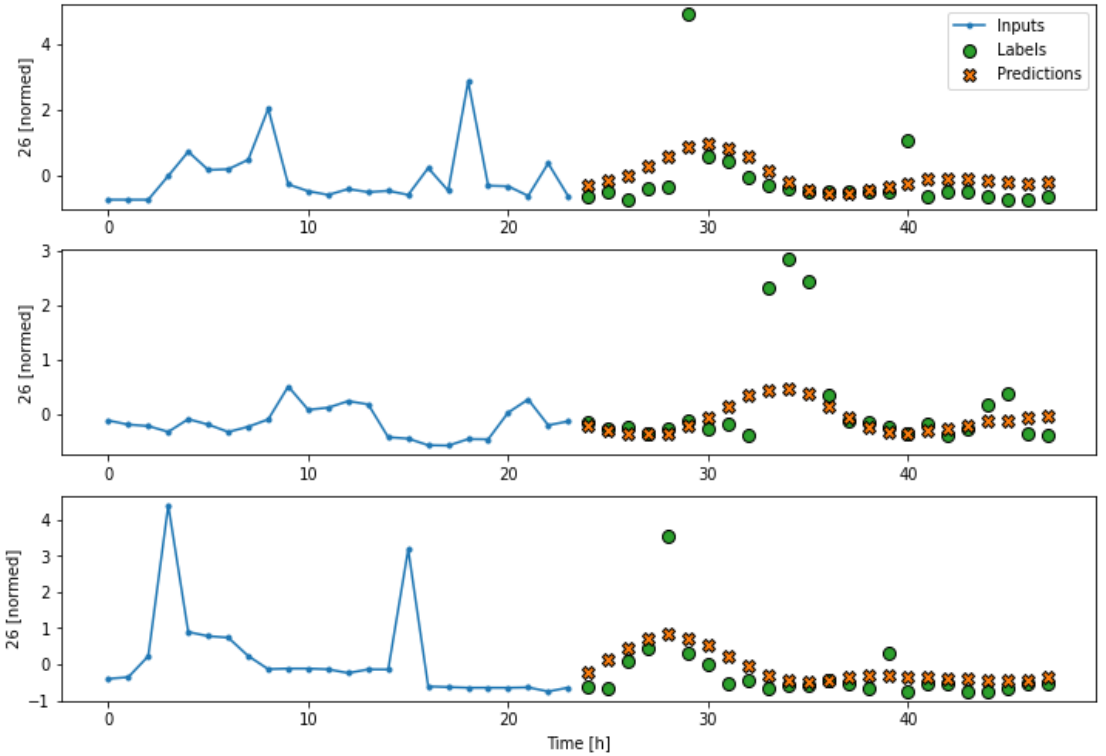
- Self-organizing maps

Method	Number of Clusters	Sihouette score
Kmeans	4	0.44
Agglomerative	4	0.34
Multi-layer perceptron	4	0.59

[1] Aghabozorgi, Saeed, Ali Seyed Shirkhorshidi, and Teh Ying Wah. "Time-series clustering–a decade review." *Information Systems* 53 (2015): 16-38.
[2] Javed, Ali, Byung Suk Lee, and Donna M. Rizzo. "A benchmark study on time series clustering." Machine Learning with Applications 1 (2020): 100001.
[3] Cherif, Aymen, Hubert Cardot, and Romuald Boné. "SOM time series clustering and prediction with recurrent neural networks." Neurocomputing 74.11 (2011): 1936-1944.

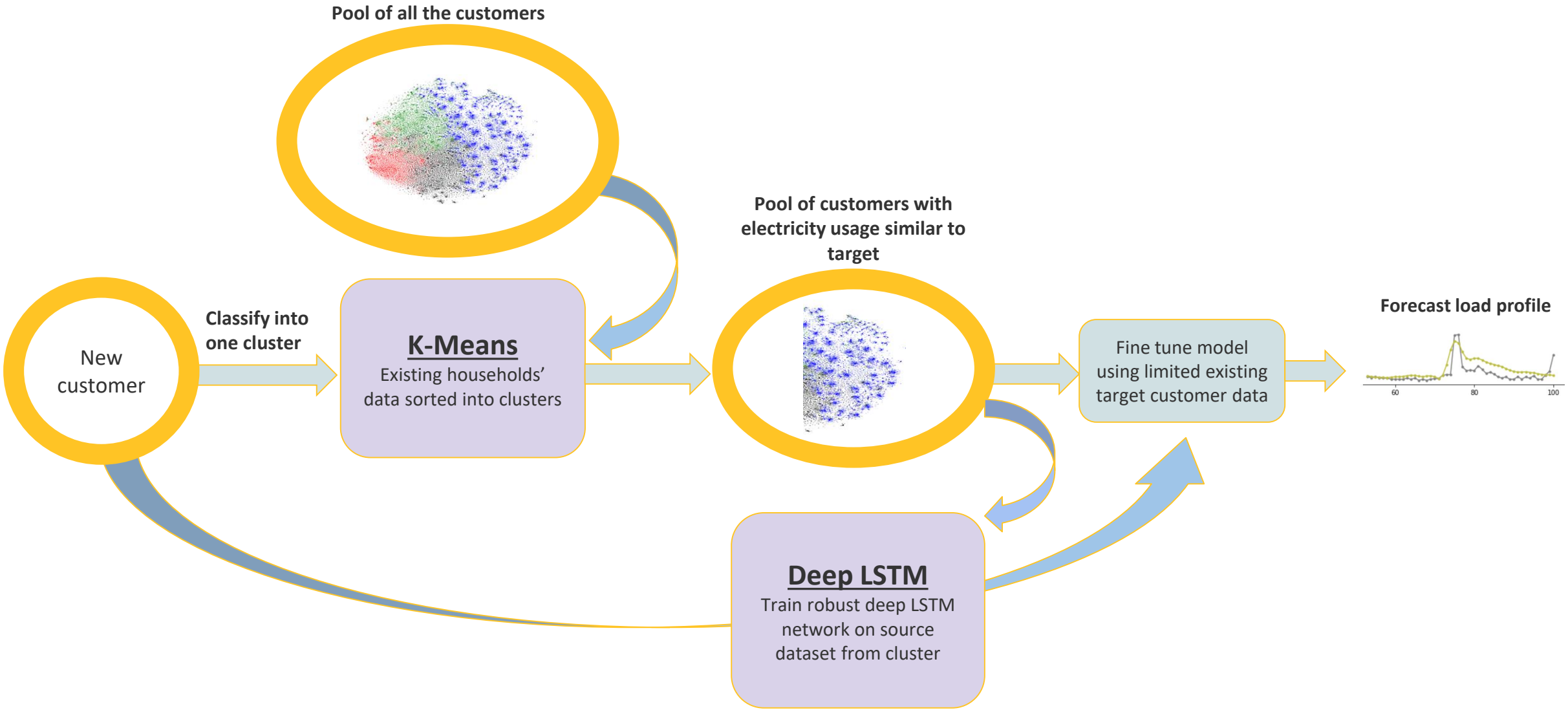
Load Forecasting
- Long Short Term Memory





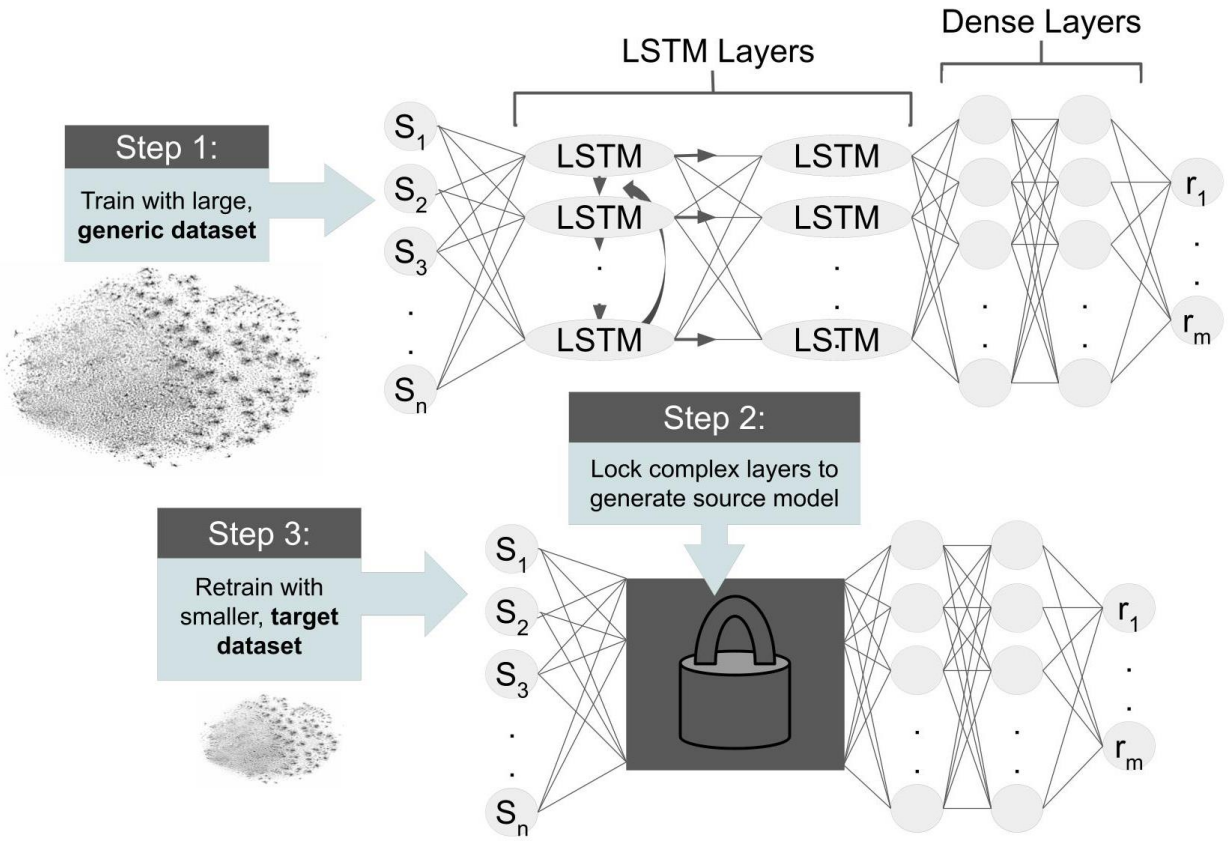
- Able to learn the daily trends of the electricity load profile
- Usually miss peaks

Transfer Learning Boosted LSTM

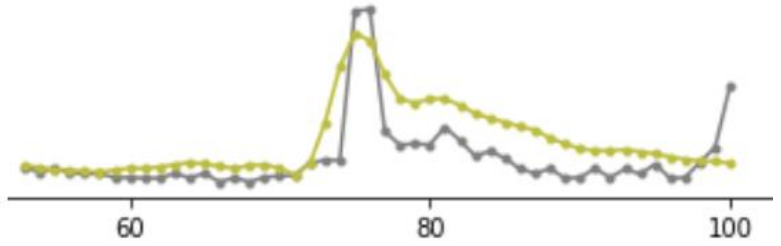


[9] Roshan Klein-Seetharaman, Xiangqi Zhu, and Barry Mather, "Transfer Learning Trained LSTM Models for Household Load Profile Forecasting"

Results Comparison



Forecasting result example



Results Comparison

Improvement

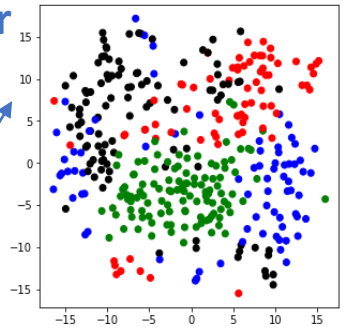
	Max	Mean
G+C	30.00%	16.40%

G+C: Generic model + clustered data retrain

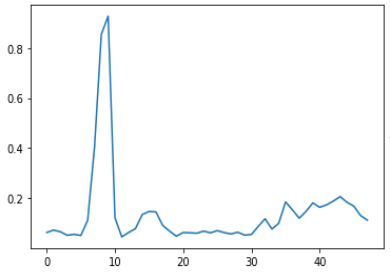
Baseline: LSTM only

K-means and MLP to **cluster** the profiles

load pattern and characteristics



Representative Cluster Center



Load modeling

Consumption profiles

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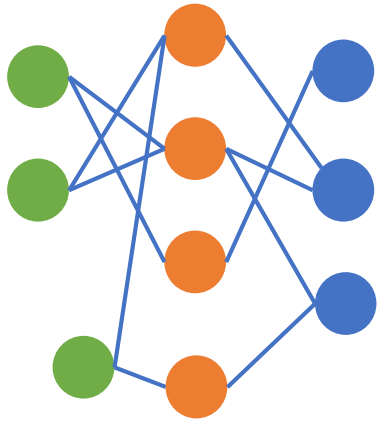
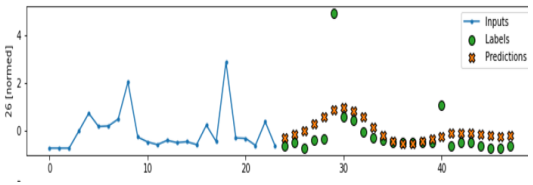
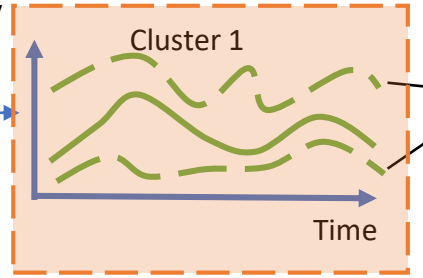




Solar/Wind Measurements

Community survey

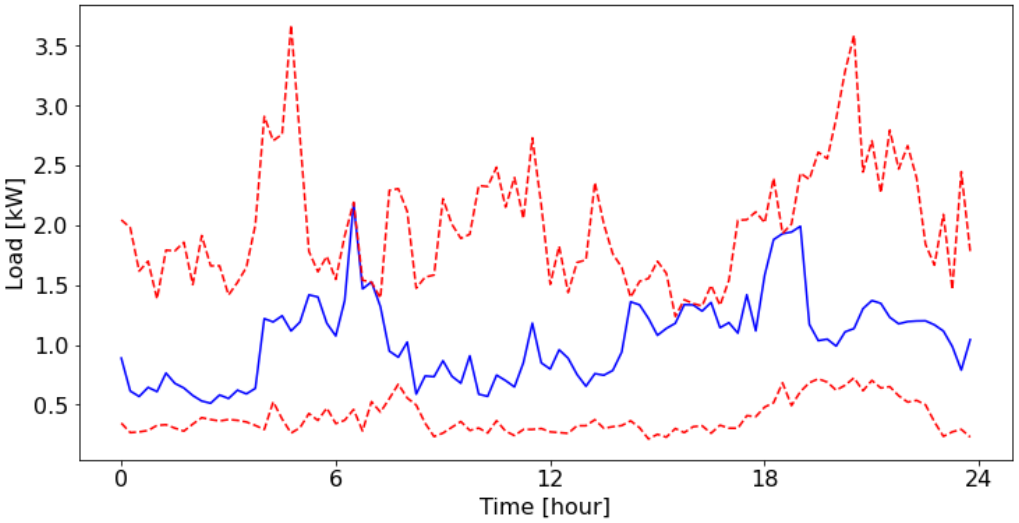


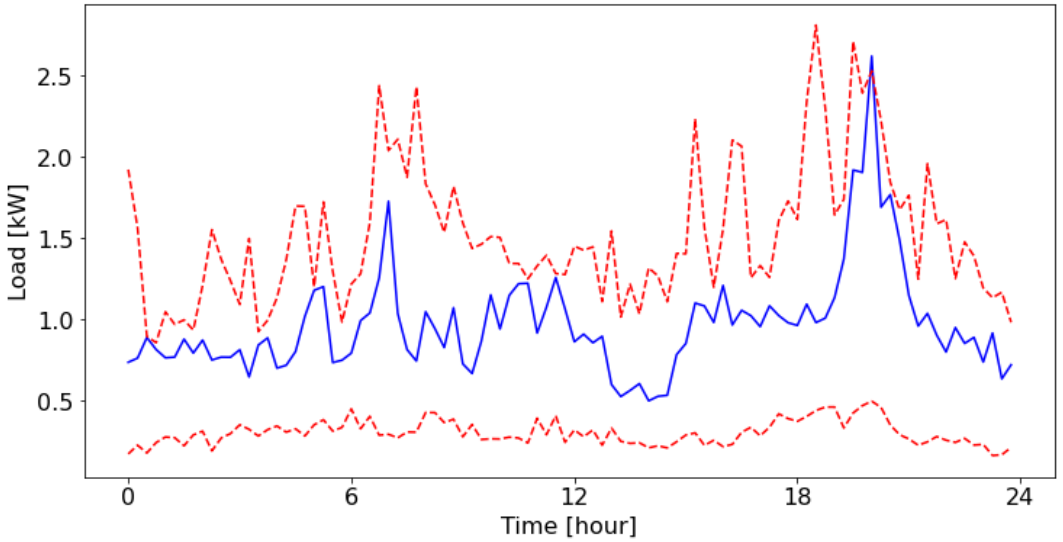
Flexibili Envelop

LSTM: long short term memory

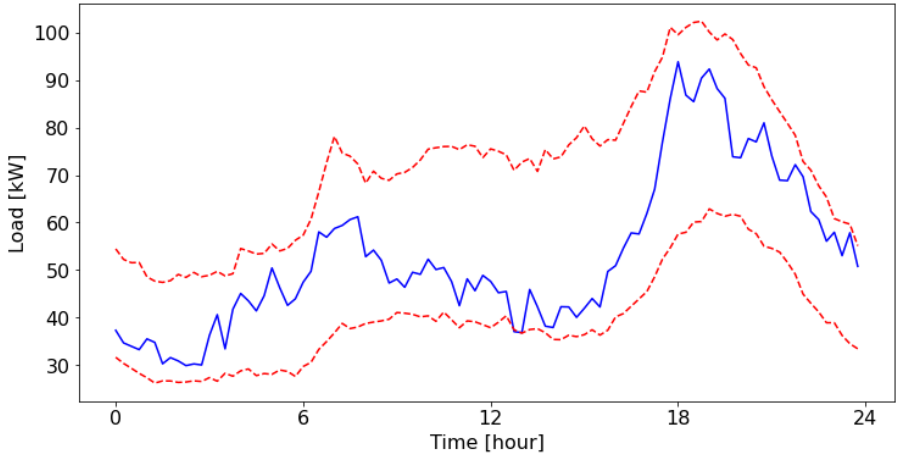
MLP: Multi-layer perceptron neural network

Demand Flexibility Estimation





- Different end users can provide different flexibility at different time of the day

- Need select appropriate end users to aggregate to obtain desired aggregated flexibility

Aggregated