Creating a detailed energy breakdown from *just* the monthly electricity bill

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Monthly electricity bill

Ontario Residential Monthly Bill Statement

Account Number
123 456 789 101 2345 0

Meter Number
1234567

Your Electricity Charges

Electricity	$78.00
Delivery	$46.00
Regulatory Charge	$5.00
Debt Retirement Charge	$6.00
H.S.T.	$17.00
Ontario Clean Energy Benefit 10 per cent off applicable electricity charges and taxes	$(15.00)
Total	**$137**

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20 kWH

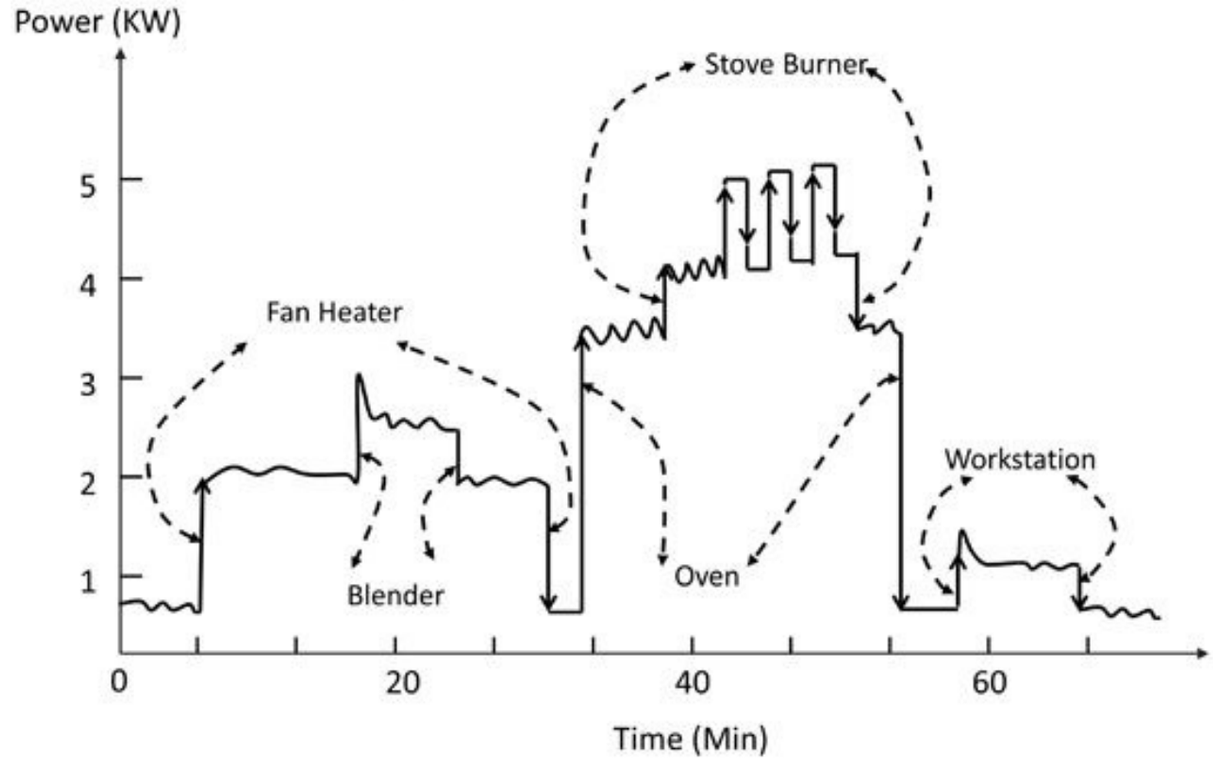
120 kWH

10 kWH

Obtaining energy breakdown

Sensor per appliance

Smart meter based energy disaggregation

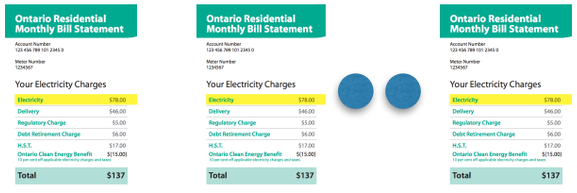


Intuition

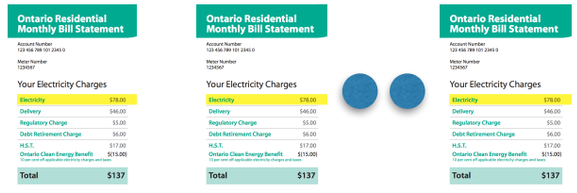
Home A

Home B

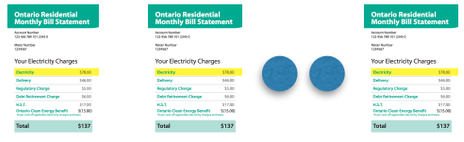
Home C



Jan Feb Dec

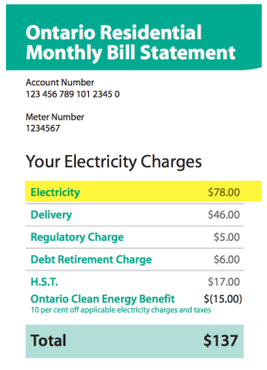


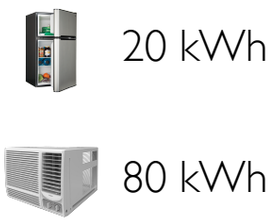
Jan Feb Dec

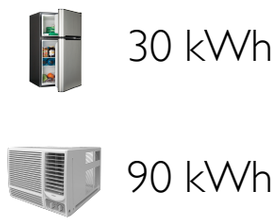


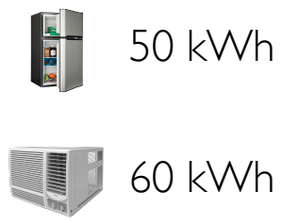
Jan Feb Dec

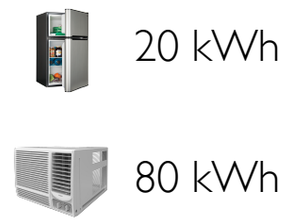
Approach overview











Approach overview

20 kWh

80 kWh

10 kWh

30 kWh

90 kWh

20 kWh

50 kWh

60 kWh

10 kWh

20 kWh

80 kWh

10 kWh

Approach overview


20 kWh


30 kWh


50 kWh


20 kWh


80 kWh


90 kWh


60 kWh


80 kWh


10 kWh


20 kWh


10 kWh


10 kWh

Approach overview

20 kWh

80 kWh

10 kWh

50 kWh

60 kWh

10 kWh

Approach overview

20 kWh

50 kWh

Approach overview

35 kWh

20 kWh

50 kWh

Approach overview

50 kWh

20 kWh

60 kWh

80 kWh

10 kWh

10 kWh

Approach overview

70 kWh

60 kWh

80 kWh

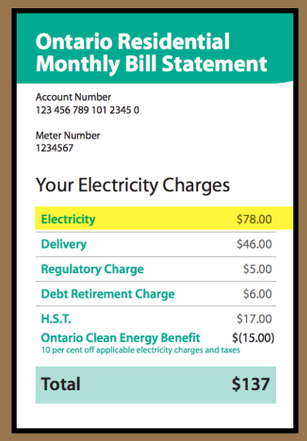
Approach overview

35 kWh

70 kWh

20 kWh

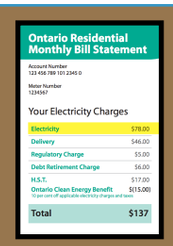
Features

		Derived
Area, #occupants, #rooms,	Aggregate home energy in Jan, Feb,..December	Variance, range, percentiles, ratio min to max., skew, kurtosis

Step 1: Feature selection

20 kWh 40 kWh 30 kWh



		Derived
Area, #occupants, #rooms,	Aggregate home energy in Jan, Feb,..December	Variance, range, percentiles, ratio min to max., skew..

Feature selection algorithm

#rooms, aggregate energy trend, range

Step 11: Matching

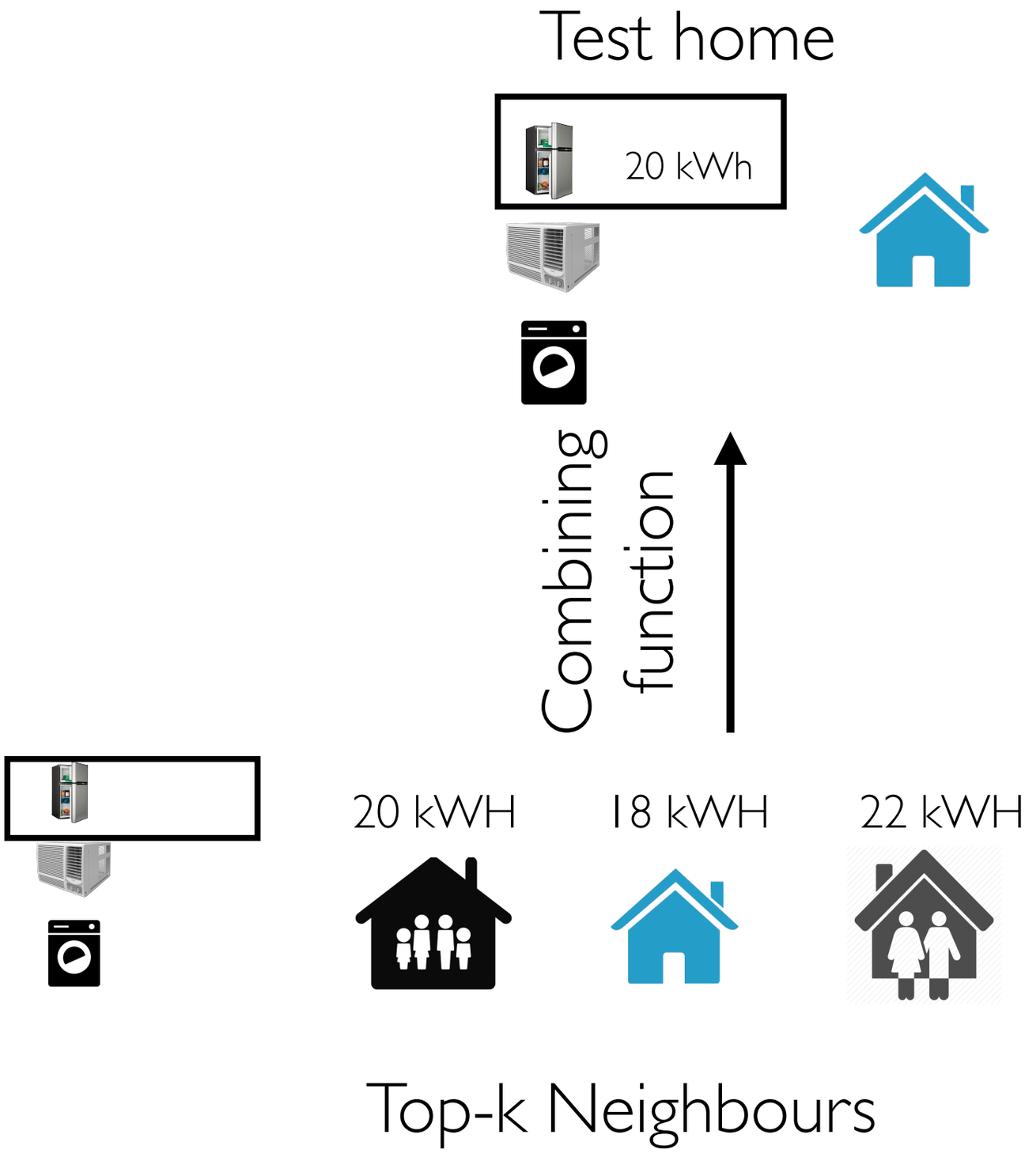
Test home

Train homes

	Feature 1	Feature 2	Overall	Rank
	..	..	0.3	3
	..	0.2	0.4	4
	..	0.05	0.1	1
	0.1	0.1	0.2	2

Top-K neighbours

Step III: Prediction



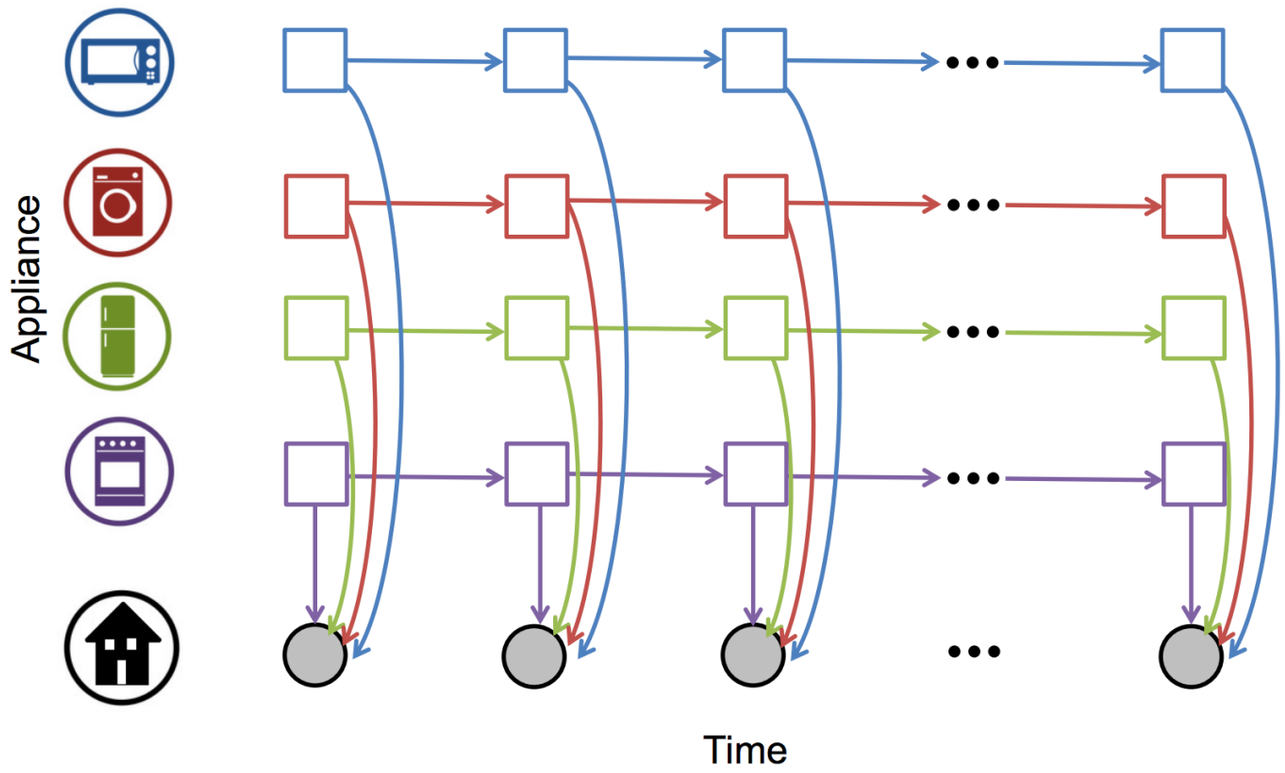
Evaluation- Dataset

Dataset	Region	#Homes	Dataset duration
Data port	Austin, TX	57	12 months

HVAC	Fridge	Lighting	Dryer	Dish washer	Washing machine
31	21	12	32	26	16

Evaluation- Baseline

Factorial Hidden Markov Model (FHMM) [AISTATS 2012]



Latent bayesian melding (LBM) [NIPS 2015]

Evaluation- Metric

Absolute error = |Predicted energy - Actual Energy|

Normalised Absolute error = Absolute error/Actual Energy

Normalised percentage error = Normalised absolute error X 100

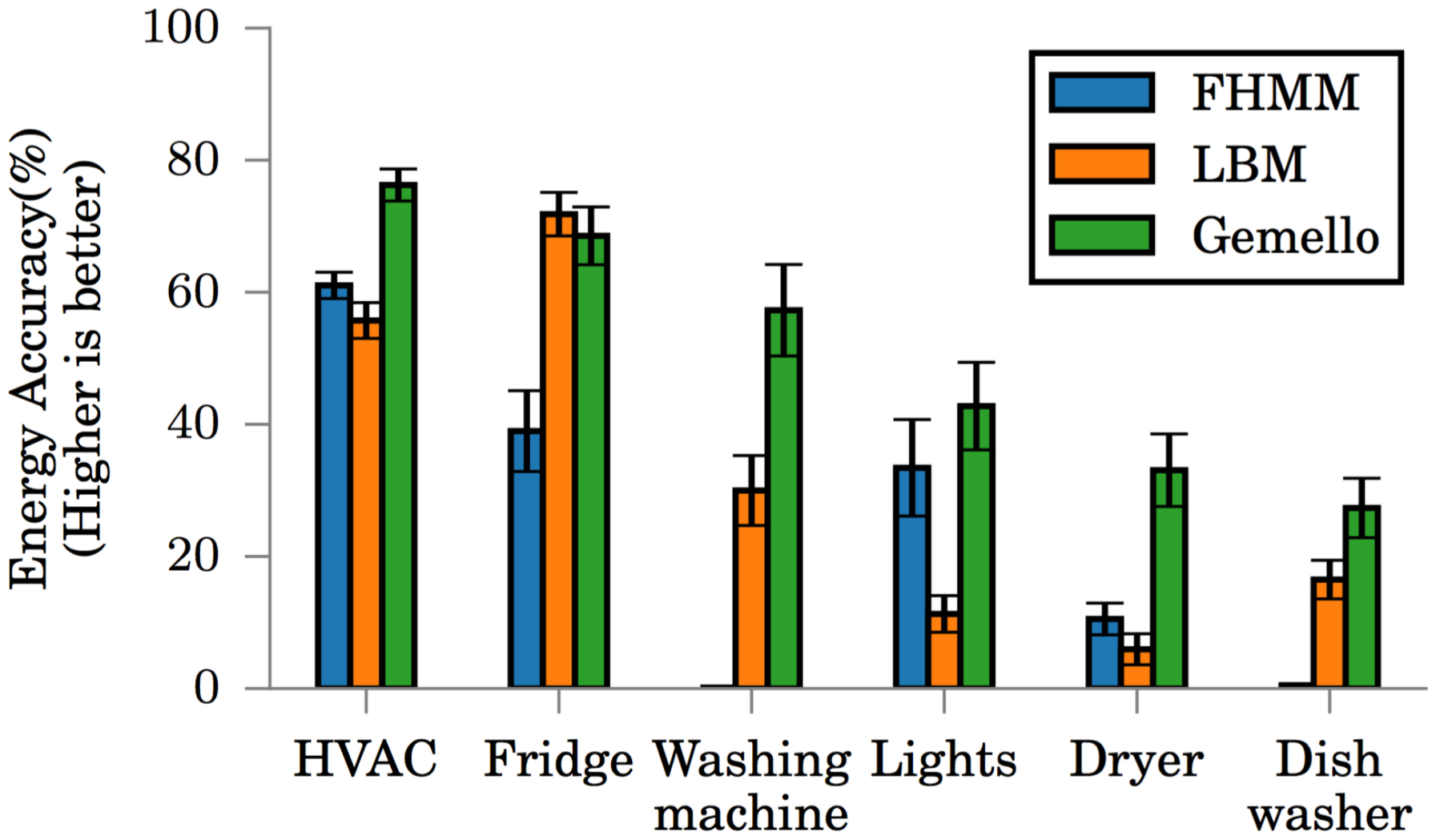
Percentage accuracy = 100 - Normalised percentage error

Evaluation- Experimental setup

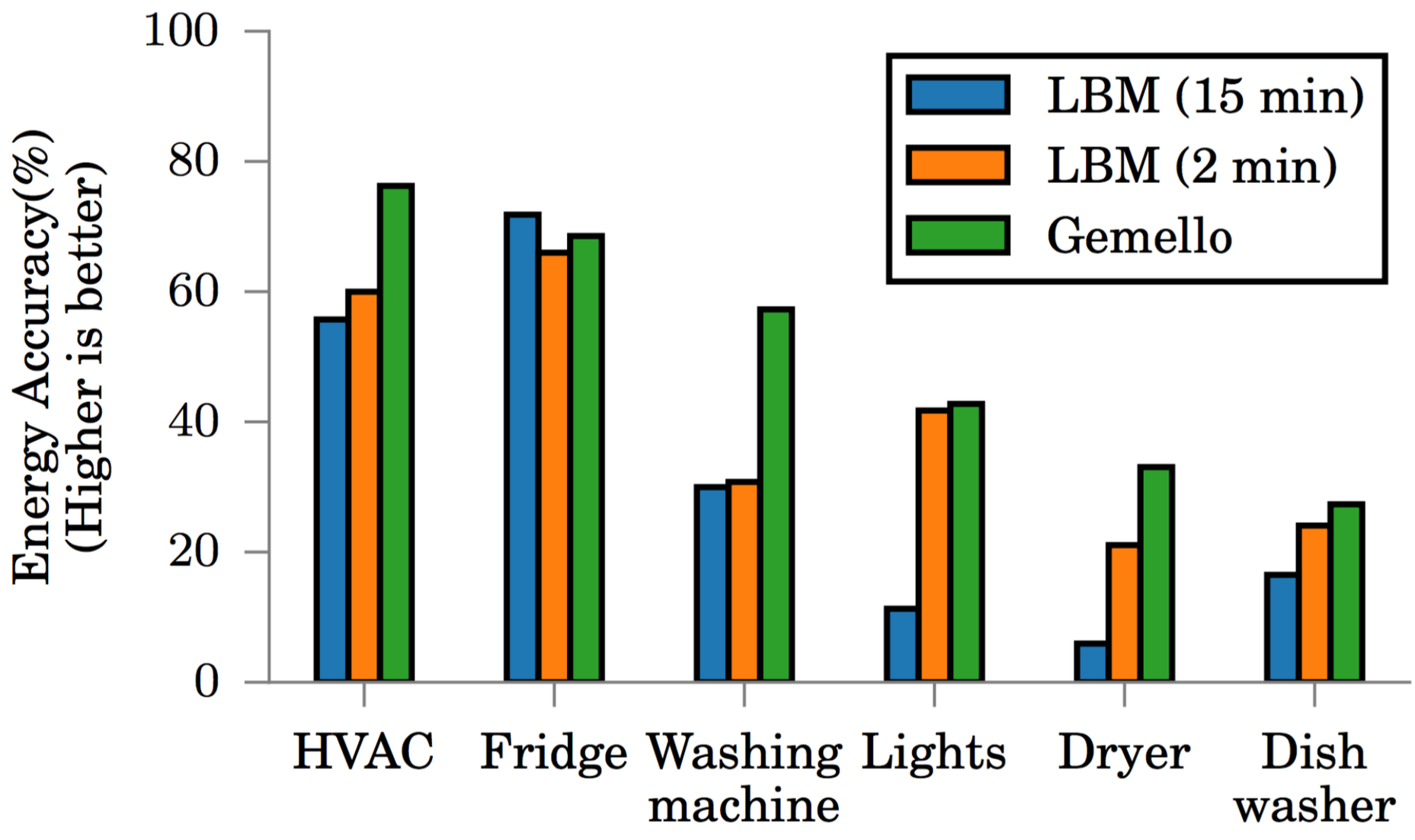
Cross-validation	Optimising #neighbours and feature selection	Feature ranking
Leave one out	Nested cross validation	Random Forest

# HMM states	# appliances in model	Training on	Temporal resolution
3	6	Entire data	15 min

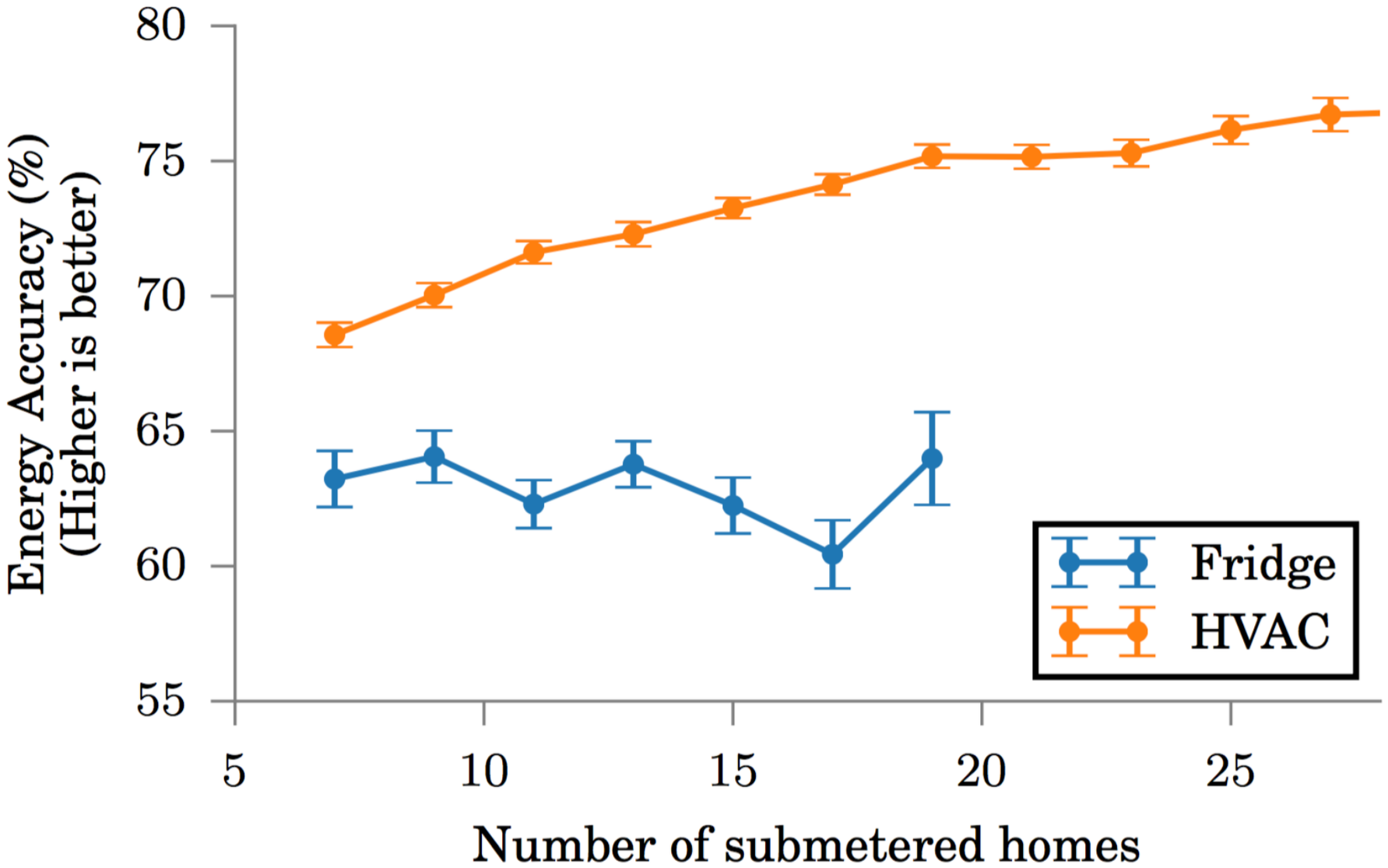
Result


Energy Accuracy(%)
(Higher is better)
100
80
60
40
20
0
FHMM
LBM
Gemello
HVAC
Fridge
Washing machine
Lights
Dryer
Dish washer

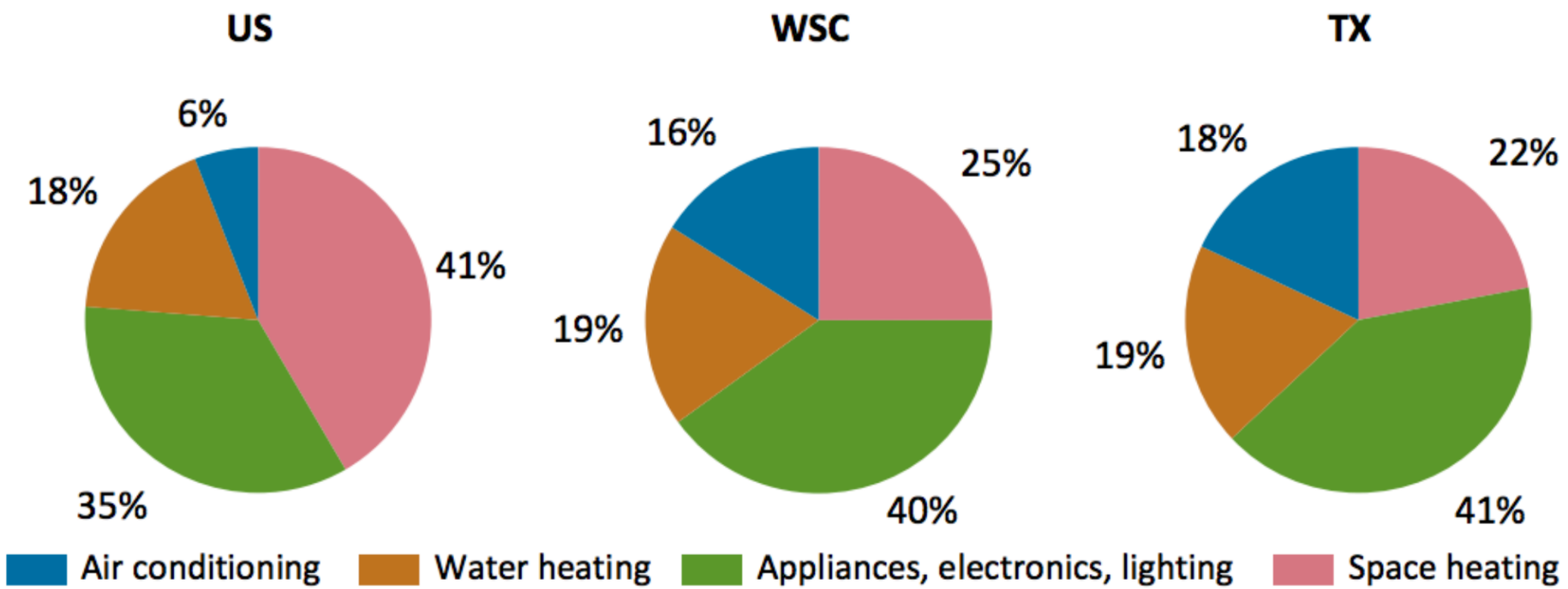
Result-II


Energy Accuracy(%)
(Higher is better)
100
80
60
40
20
0
LBM (15 min)
LBM (2 min)
Gemello
HVAC
Fridge
Washing machine
Lights
Dryer
Dish washer

Result-scalability



Predicting for different region

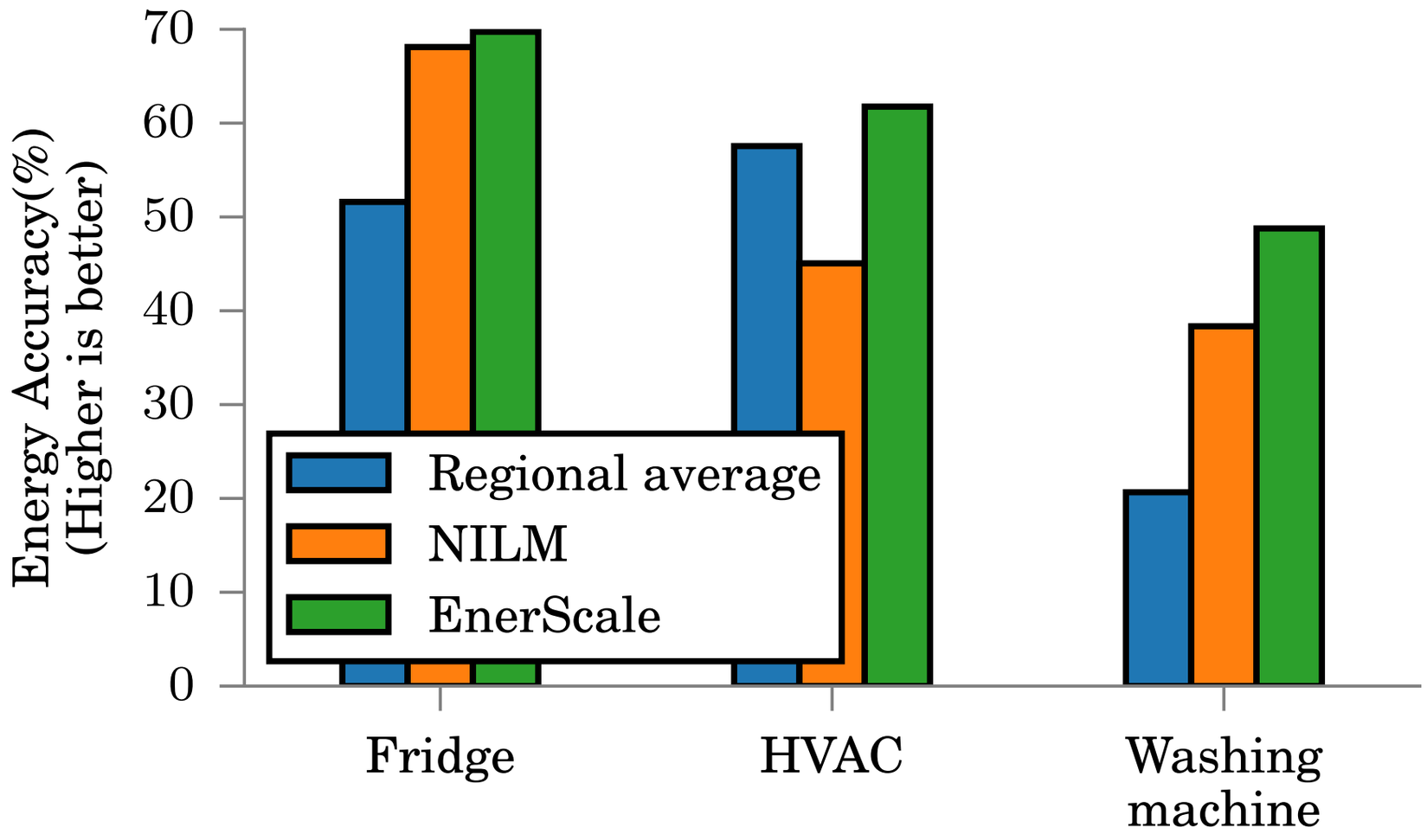


Transformation strategies

$$\underset{\text{HVAC energy in R1}}{\underset{200\ \text{kWh}}{\square}} \times \frac{\#\ \text{Degree days in R2}}{\#\ \text{Degree days in R1}} = \underset{\text{HVAC energy in R2}}{\underset{250\ \text{kWh}}{\square}}$$

$$\underset{\text{Appliance (A) energy in R1}}{\underset{10\ \text{kWh}}{\square}} \times \frac{\text{Mean proportion of A in R2}}{\text{Mean proportion of A in R1}} = \underset{\text{Appliance (A) energy in R2}}{\underset{15\ \text{kWh}}{\square}}$$

Result cross region training



Limitations & Ongoing work

1. Finding anomalous test homes
2. Adapting to people change behaviour

Conclusions

1. Gemello- scalable and accurate energy breakdown
2. Transformation- scale across regions
3. Potential to be rolled off as a service today