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Remote Energy Auditing: Energy Efficiency through Smart Thermostat Data and Control

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National Research Council

- Canada's Research and Technology Organization (RTO)
- 3,550 employees, with $895M annual R&D investment
- Serve thousands of industrial and government clients annually

Motivation for Remote Energy Audit

- Evaluation of energy performance of a building

On-site audits	Remote energy audit
Requires on-site visit by a professional energy auditor	Conducted from a remote site by processing data through algorithms
On-site data collection	Uses data remotely from smart home devices, smart meters, and public datasets
Relatively accurate	Good enough to identify energy performance issues
Relatively expensive ($300 to $500) per home	Inexpensive when done on a large scale

The paper describes "remote energy audit" techniques that were applied to a pilot study of 500 dwellings in Ontario, Canada to derive insights into energy performance

Data Sources

2 light control

2 door switches

Environment Canada weather data

Plug Loads

- Lighting
- Appliances
- Refrigeration

HVAC System

- Air Conditioner
- Natural Gas Furnace

2 motion sensors

Smart Meter
Data sampling rate: 60 min

smart thermostat

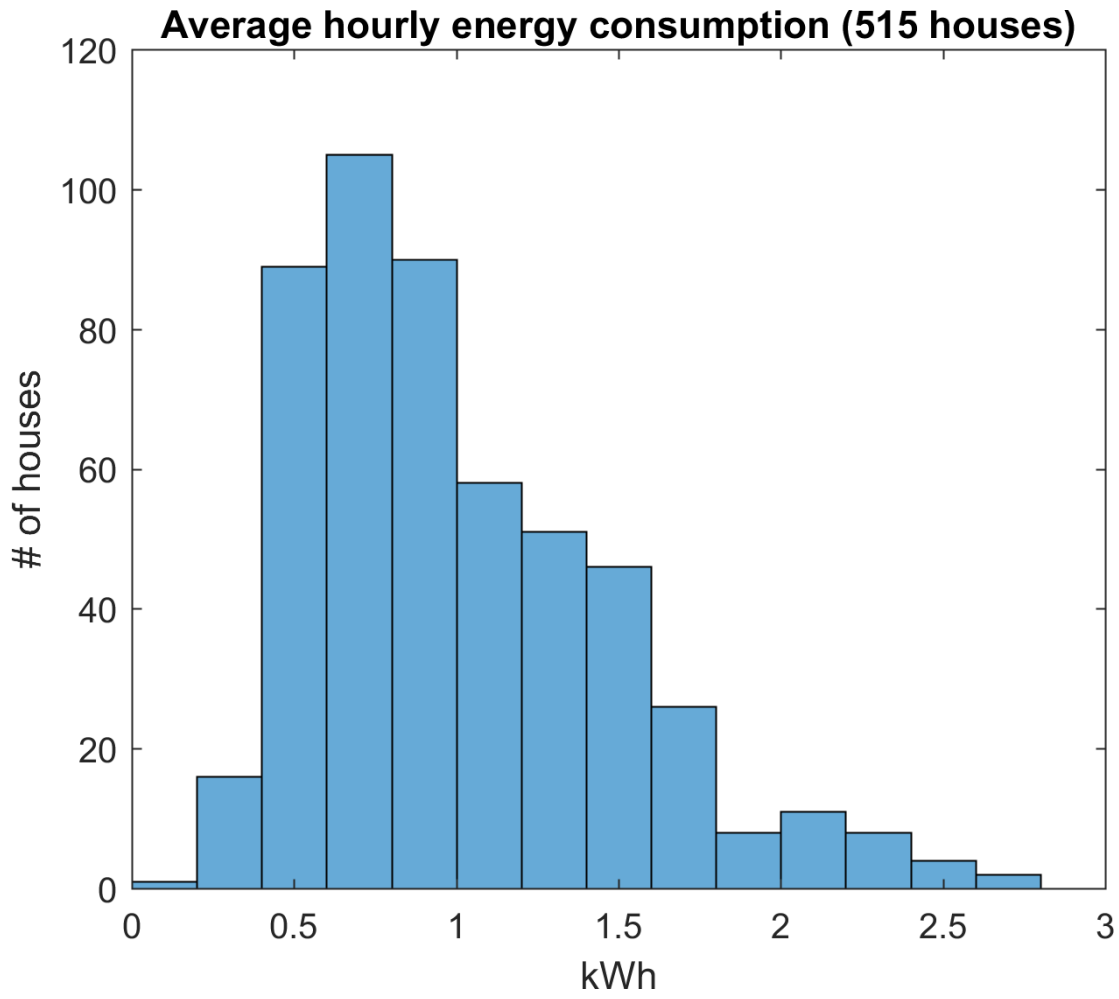
Customer on-boarding data about the type of house, number of occupants and bedrooms, and the type of heating system

Household Sample

500+ residential units in Greater Toronto Area
254 participants responded to the on-boarding survey

Dwelling Type	Total	Number of Bedrooms				Number of Occupants				
		2	3	4	5	1	2	3	4	5
APARTMENT	2		1		1			1		1
ATTACHED	51	1	36	13	1	3	11	12	14	11
DETACHED	201	1	39	127	34	7	35	41	64	54
Grand Total	254	2	76	140	36	10	46	54	78	66

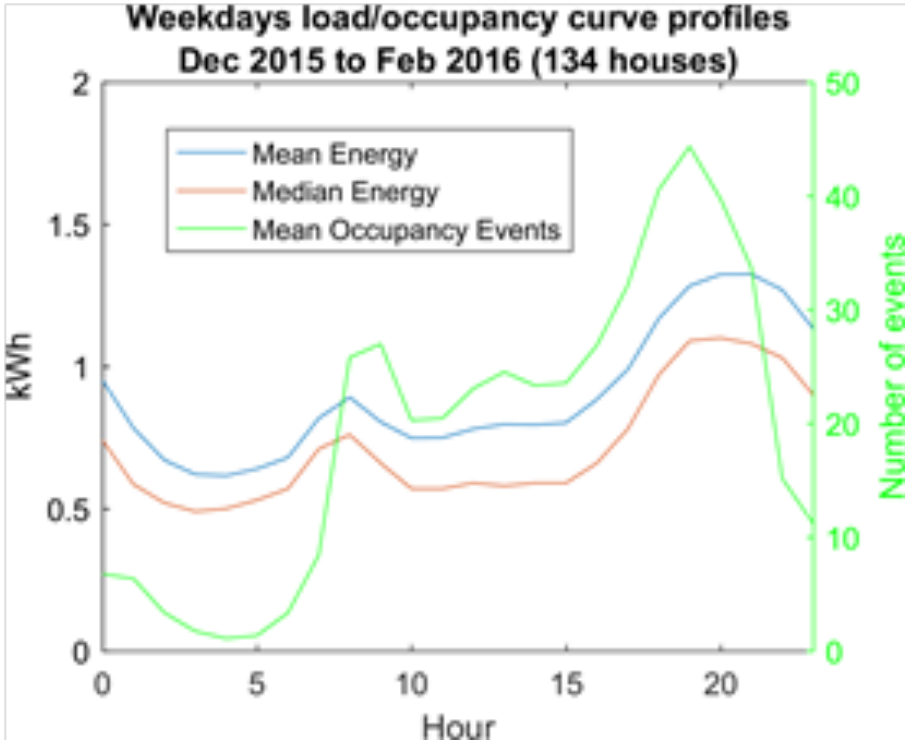
Household Electricity Use Characteristics

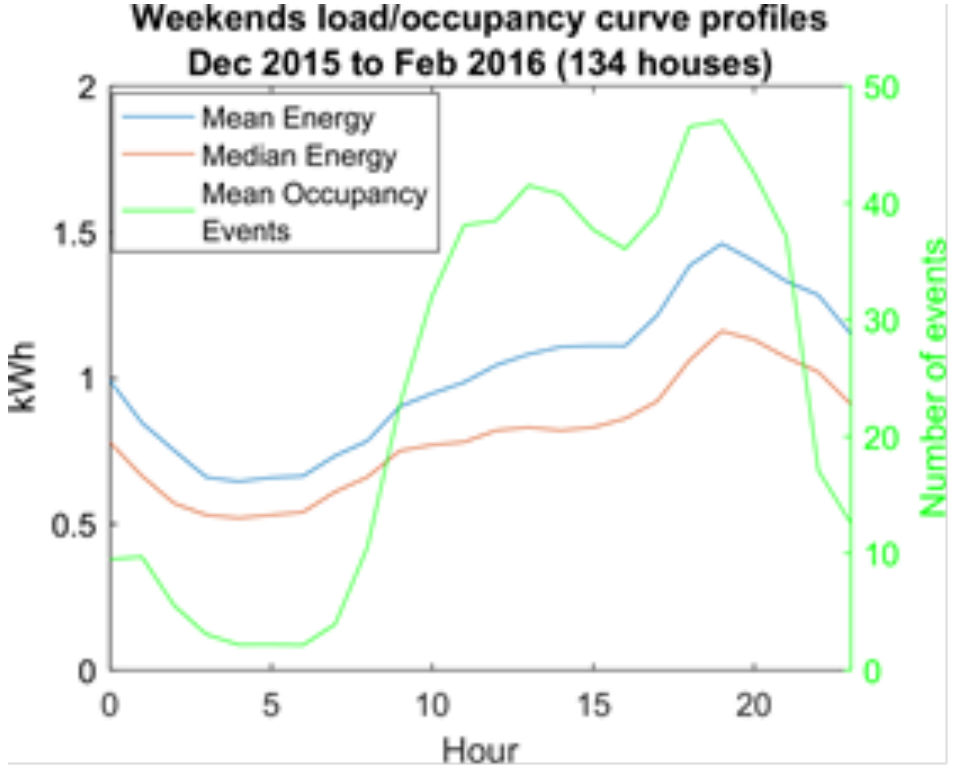


Mean = 1.05 kWh,
Median = 0.90 kWh,
SD = 0.56 kWh

# of occupants	Mean (kWh)
1	0.52
2	0.94
3	0.98
4	1.16
5	1.38

Average load and occupancy event profiles for the winter season (December 2015 – February 2016)





Disaggregation of Household Electricity Consumption to End Uses

Whole House
Smart Meter

Disaggregation Analysis

Weather

Smart Devices

Refrigeration and Phantom Loads

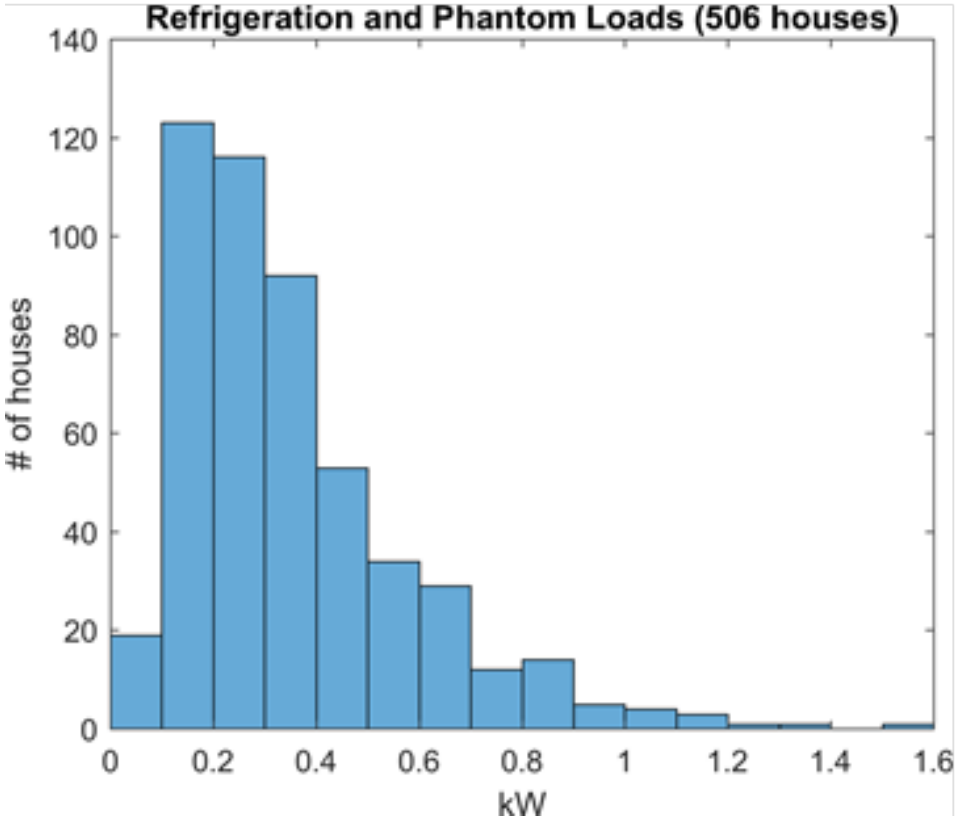
Air Conditioning Loads

Furnace Blower

Disaggregation of household loads that draw energy continuously

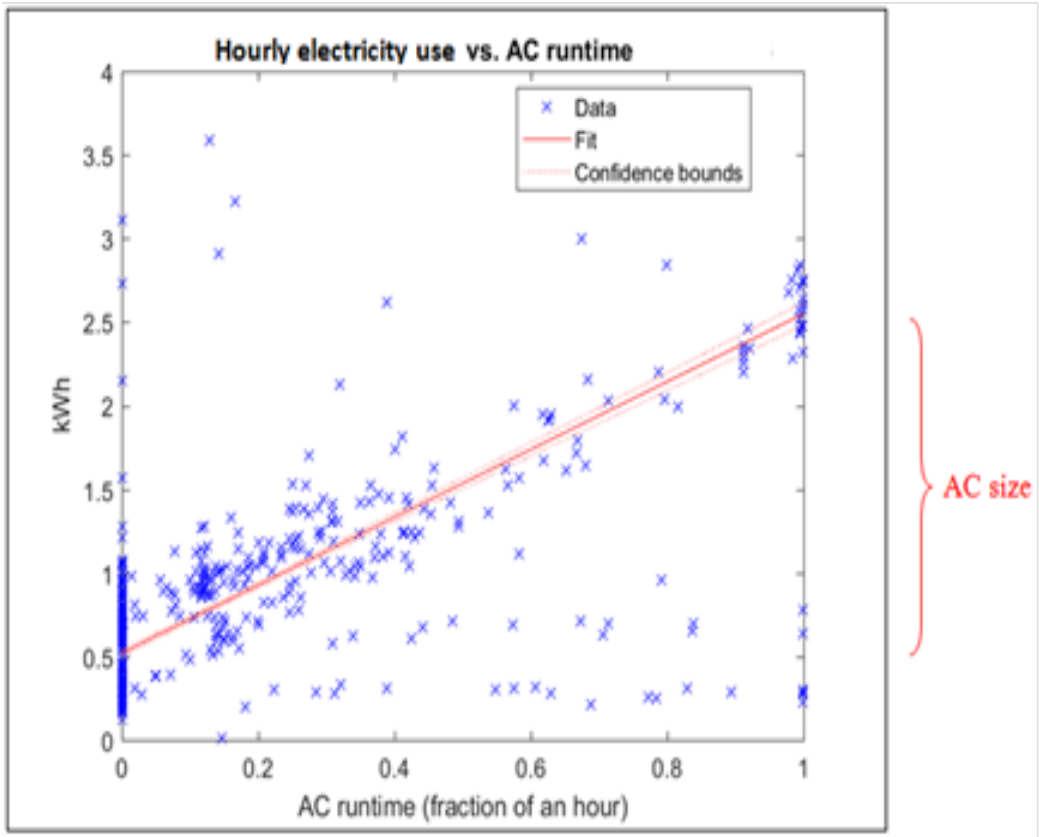
To estimate refrigerators and plugged in appliances:

- Examine electricity use for periods when HVAC not operating
- Rank order hourly loads
- 10th percentile value
- Other studies in Canada also report similar values
- Typical average values in Europe are half of Canada

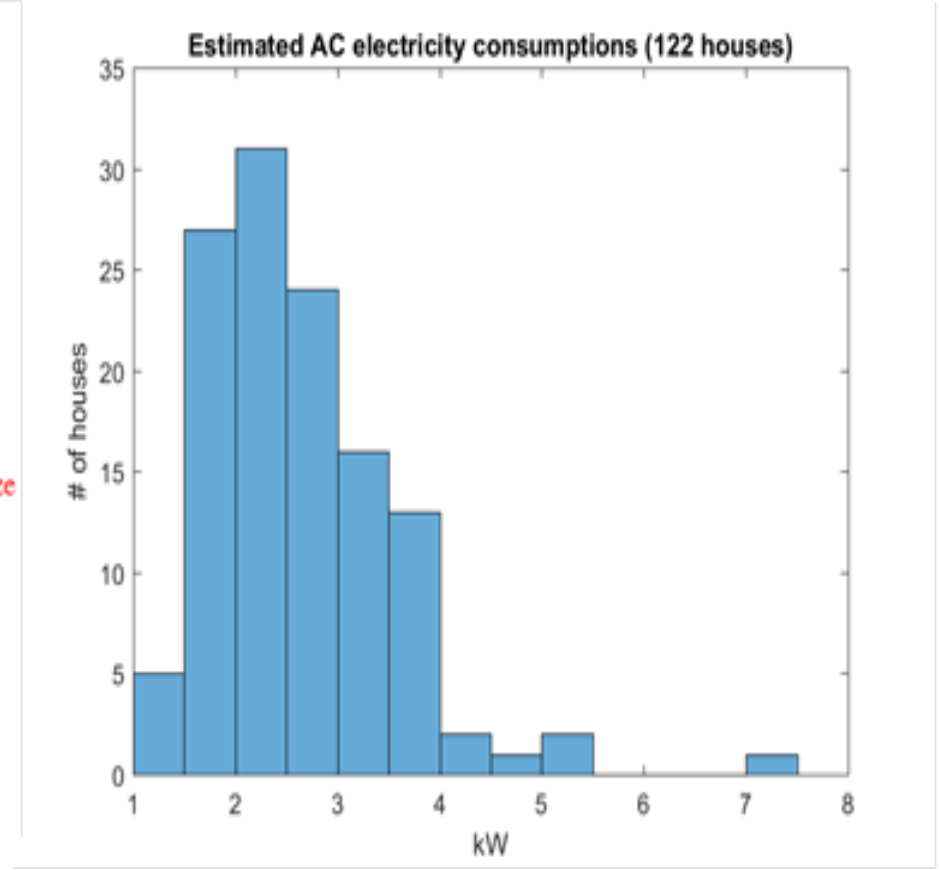


Mean = 0.35 kW,
Median = 0.30 kW,
SD = 0.23 kW

Disaggregation of Air Conditioning Use



An example house



122 houses with R^2 value >0.6

Mean = 2.63 kW, median = 2.45 kW, SD = 0.90 kW

Relative House Structure and Thermal Characteristics

Rate of cooling of house as an indicator of envelope performance

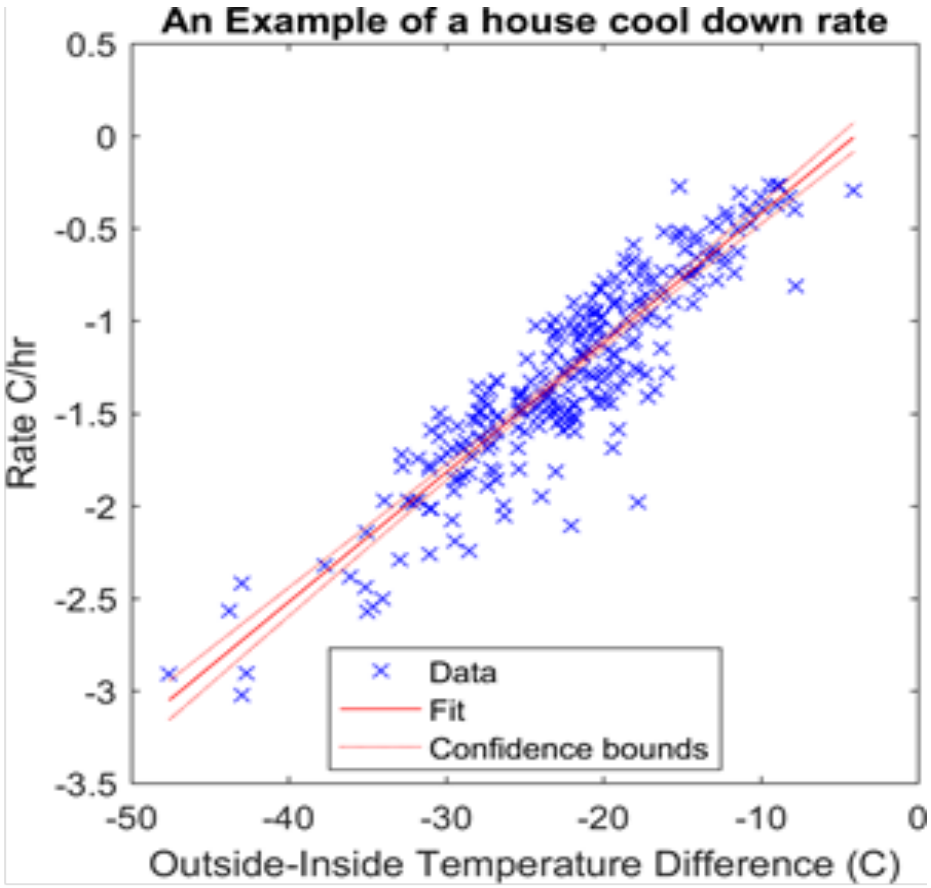
Change in indoor air temperature, $\Delta T = mx + c$

Where, ΔT is the rate of temperature drop in the cool down period

m depends on insulation and air tightness of the envelope

and, c represents the internals gains

Relative House Structure and Thermal Characteristics



An example house
Y = 0.07*X + 0.28

- A relatively high value of m, meaning relatively high heat loss:
  - a relatively poorly insulated envelope
  - an envelope with relatively high air leakage
  - a relatively large envelope area
  - or a combination of all above three.

Applications of Remote Energy Audit

- Benchmarking
- Energy usage habits
- Customized energy retrofit advise
- Alerting home owner to energy waste
- Equipment fault detection
- Energy use maps

Discussion

- How can we obtain building characteristics data (e.g. floor area, vintage, number of occupants, etc.)?
  - Municipal public data sets
  - Private data sets (e.g. MPAC in Ontario) for a nominal fee
- How can we overcome data privacy challenges to deliver meaningful results to owners?
  - High resolution meter and sensor data – privacy issues
- How can utility companies use remote energy audits for increasing the energy efficiency of their customers?
- How can we engage home owners?

Thank You!

Questions