A Method to Disaggregate Structural and Behavioral Determinants of Residential Electricity Consumption

Stanford ARPA-E Buildings Research

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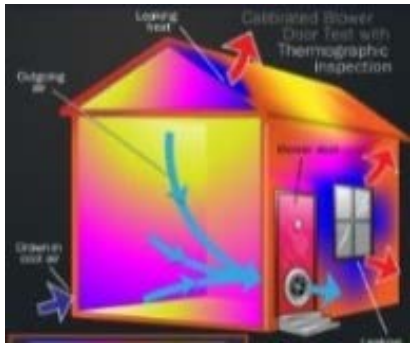
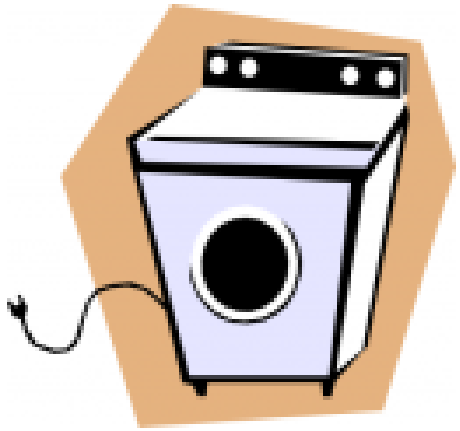
Outline

- **Background and motivation**
- Proposed model
- Summary of data and preprocessing efforts
- Results

Purpose: quantify the contribution of individual electricity consumption determinants.





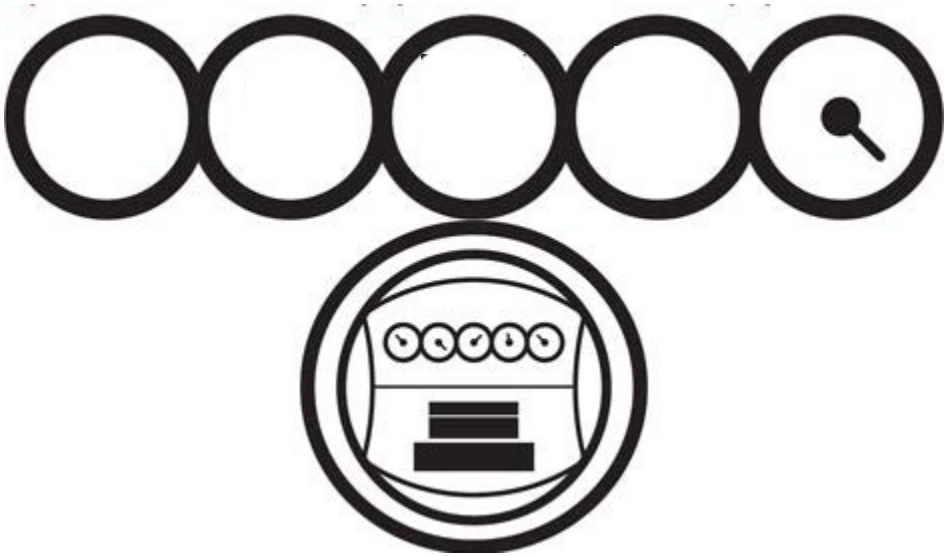
Purpose: inform short-, medium-, and long-term energy efficiency plans.

Short-term efforts

Medium-term efforts

Long-term efforts

"Always on (idle)"



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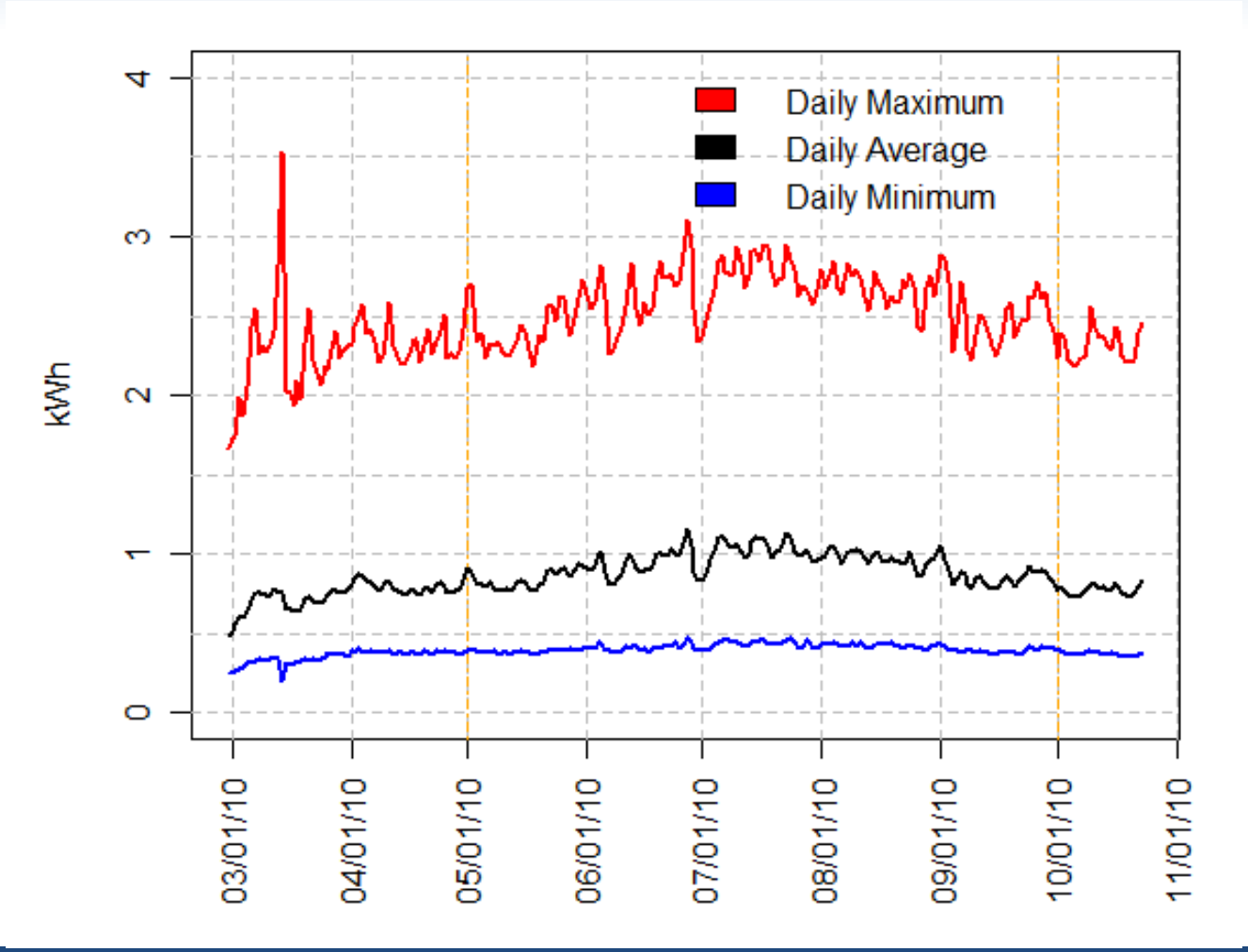
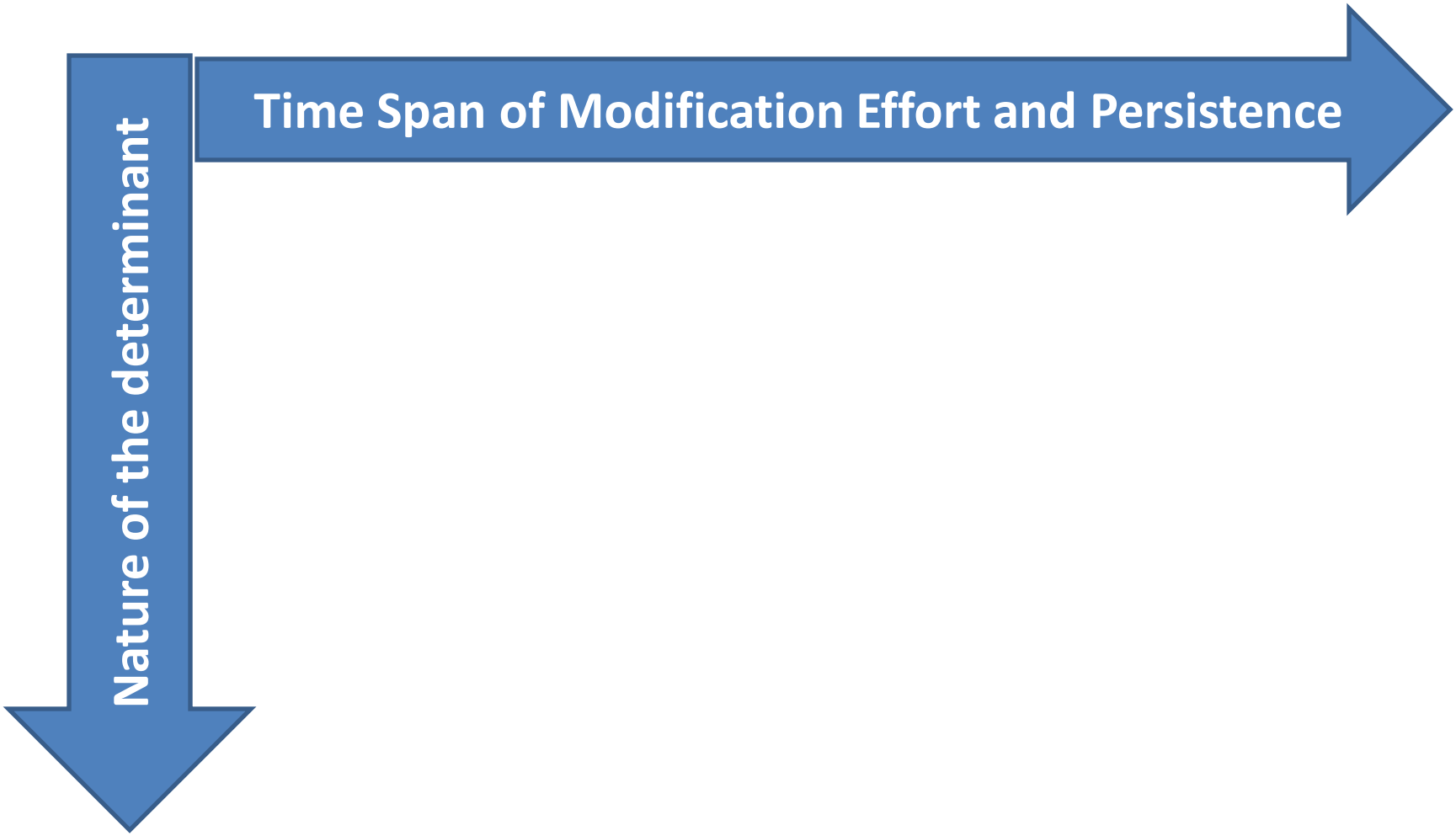
Distinguish between “idle” consumption of the house (“always on” loads) and peak consumption

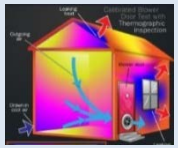


Factor categorization



Factor categorization

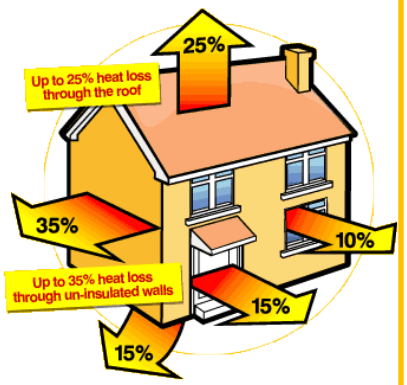
Daily maximum — Daily minimum

	Short-term	Medium-term	Long-term	Outside the scope of influence
 Weather and Location				
 Physical characteristics of the building				
 Appliance and electronics stock				
 Occupancy and occupants behavior				

Distinguish between determinants affected by floor area and the rest

Assign different weights for variables affected by floor area;

$$y_j = \beta_{0j} + \sum_{i=1}^{m} \beta_{ij} X_{ij} + A_j \cdot \sum_{i=m}^{k} \beta_{ij} X_{ij} + \epsilon_j$$



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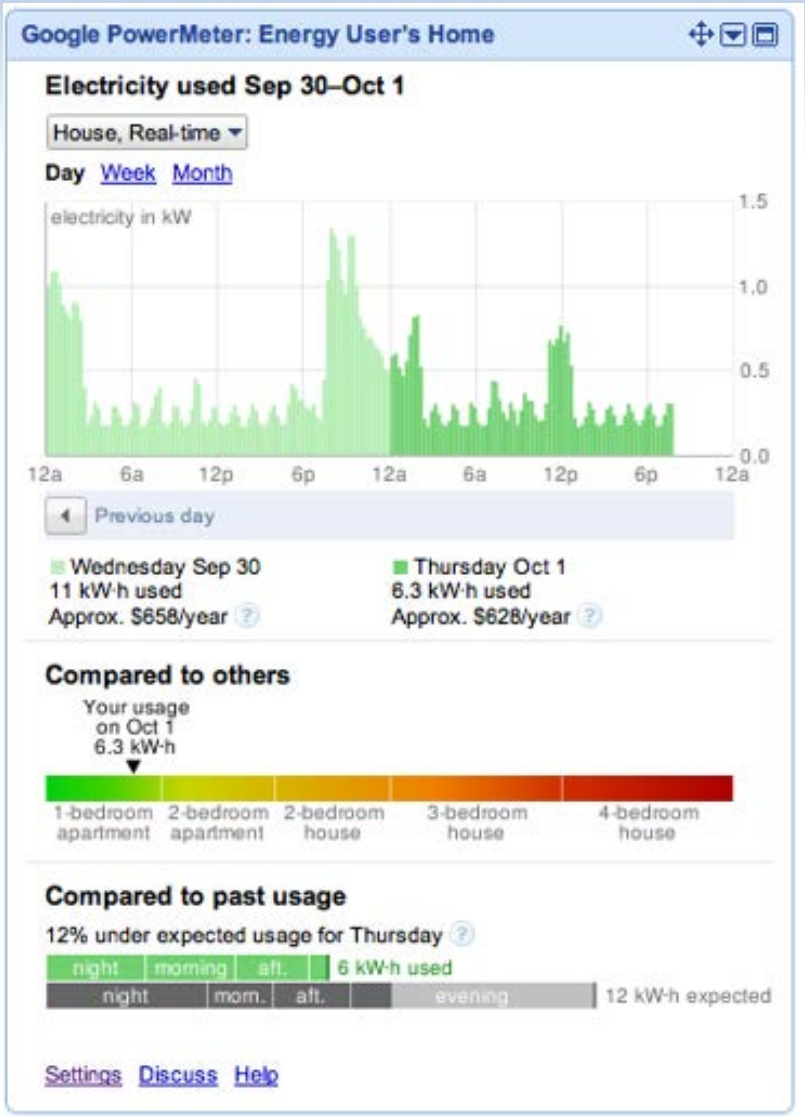
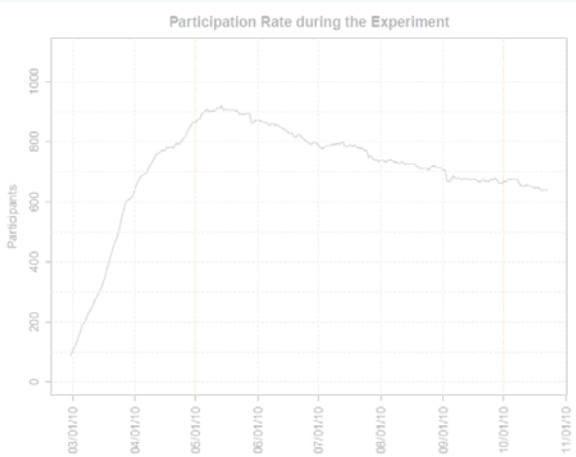
Google Powermeter



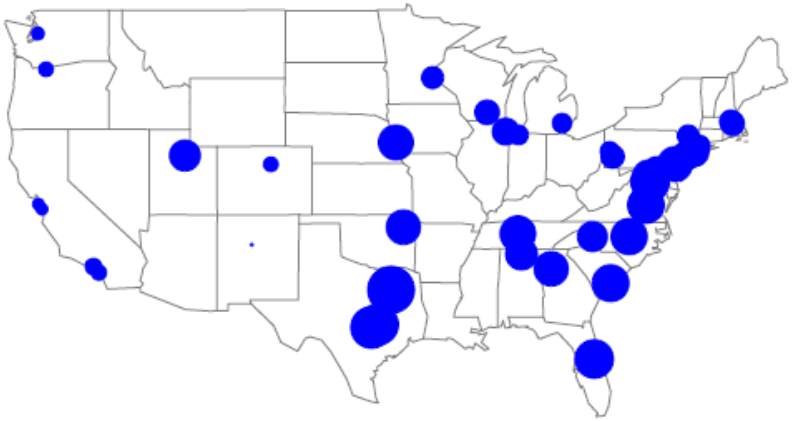
Home electricity
Consumption monitoring

Experiment design

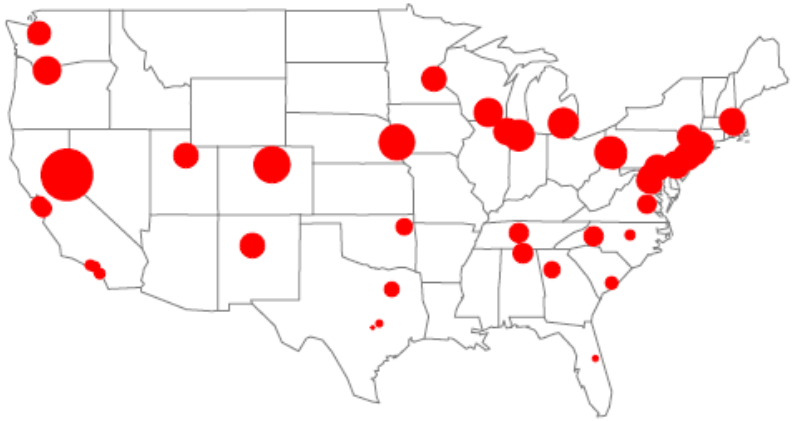
- Ten-minute interval smart meter data for 1628 households



- From February 28, 2010 through October 23, 2010 (238 days)



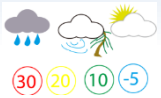
CDD

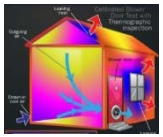


HDD

Parameters: 114 Survey Questions in Total, Broken Down into 5 Major and 12 Minor Categories

(I) External Factors	1- Climate and Geography (6)
(II) Building Design and Construction	2- Building (5)
	3- Home Improvements (12)
(III) Building Systems and Appliances	3- Fuel Use (6)
	4- Appliances (14)
(IV) Occupants	5- Occupants (12)
	6- Energy Efficiency Habits (14)
	7- Payment items, method, estimate, feedback (6)
	8- How informed about appliance usage (5)
	9- Motivation Level (17)
	10- Effort to learn EE measures (7)
	11- Personal Info of the Survey Respondent (6)
	12- Thermostat Setpoint (4)





Data analysis and modeling summary

- Factor analysis for behavioral factors

- Forward stepwise regression model on explanatory factors
  - Ranks variables based on their importance
  - Is easy to interpret: sequentially improving the model, one variable at a time.

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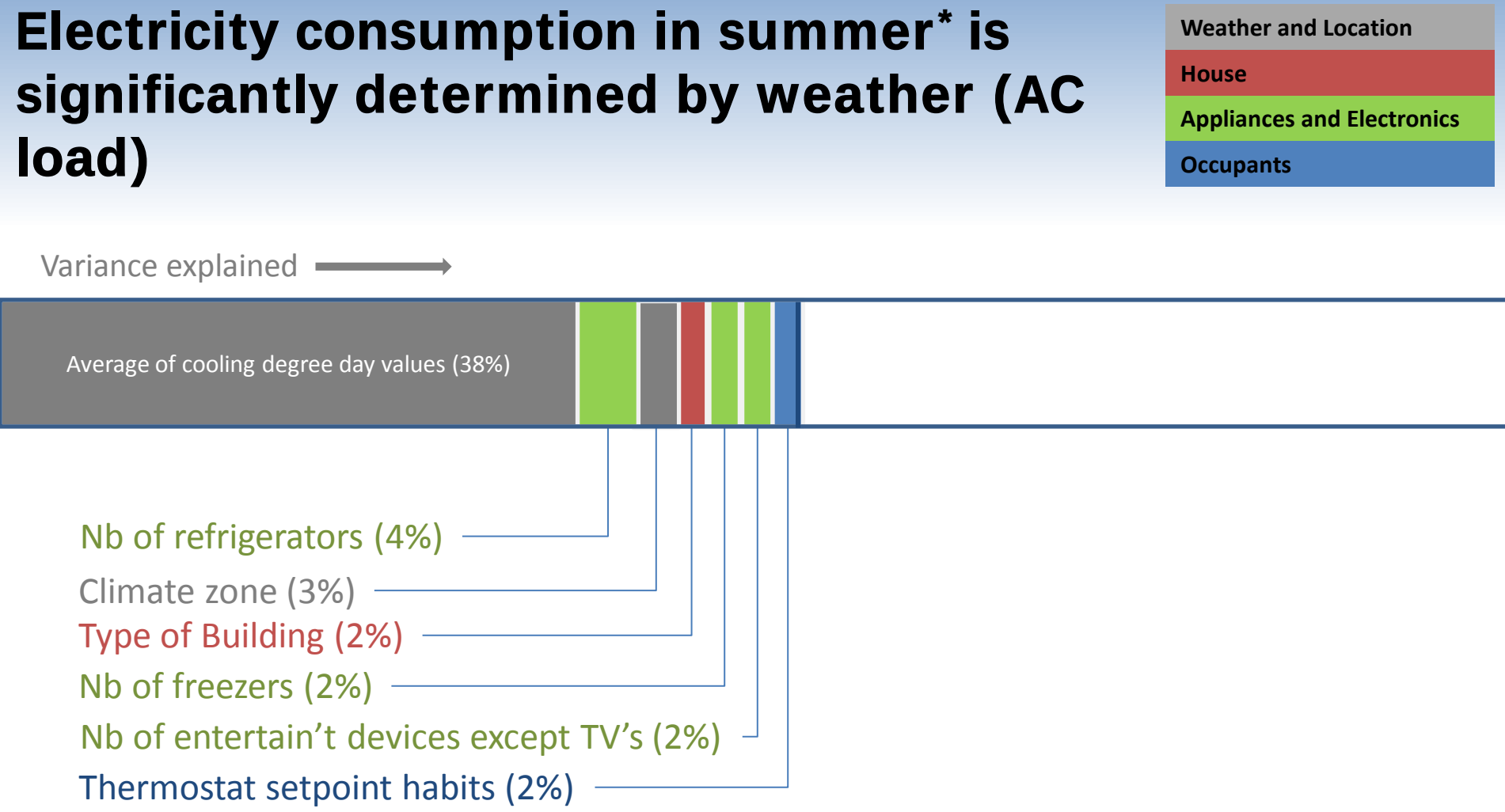
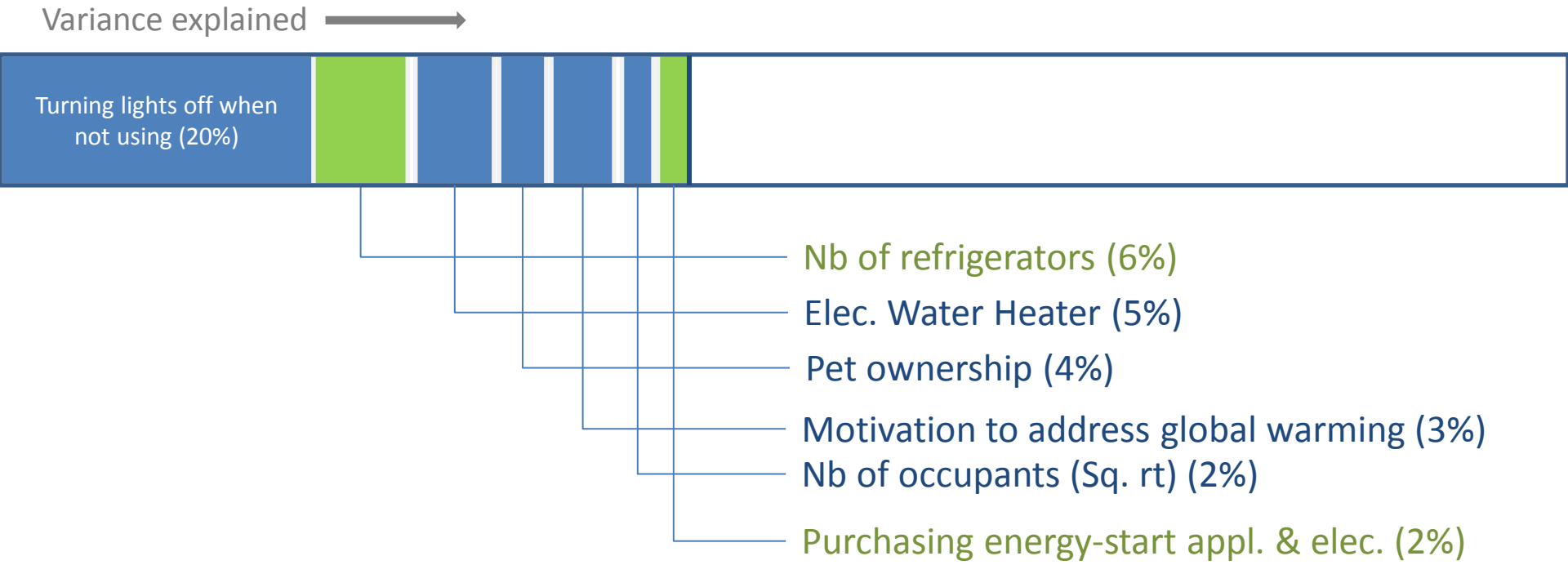
Electricity consumption in summer* is significantly determined by weather (AC load)



Model excludes Zip Code and Floor Area

Electricity consumption in winter* is mostly affected by occupant behavior and energy-intensive appliances

Weather and Location
House
Appliances and Electronics
Occupants



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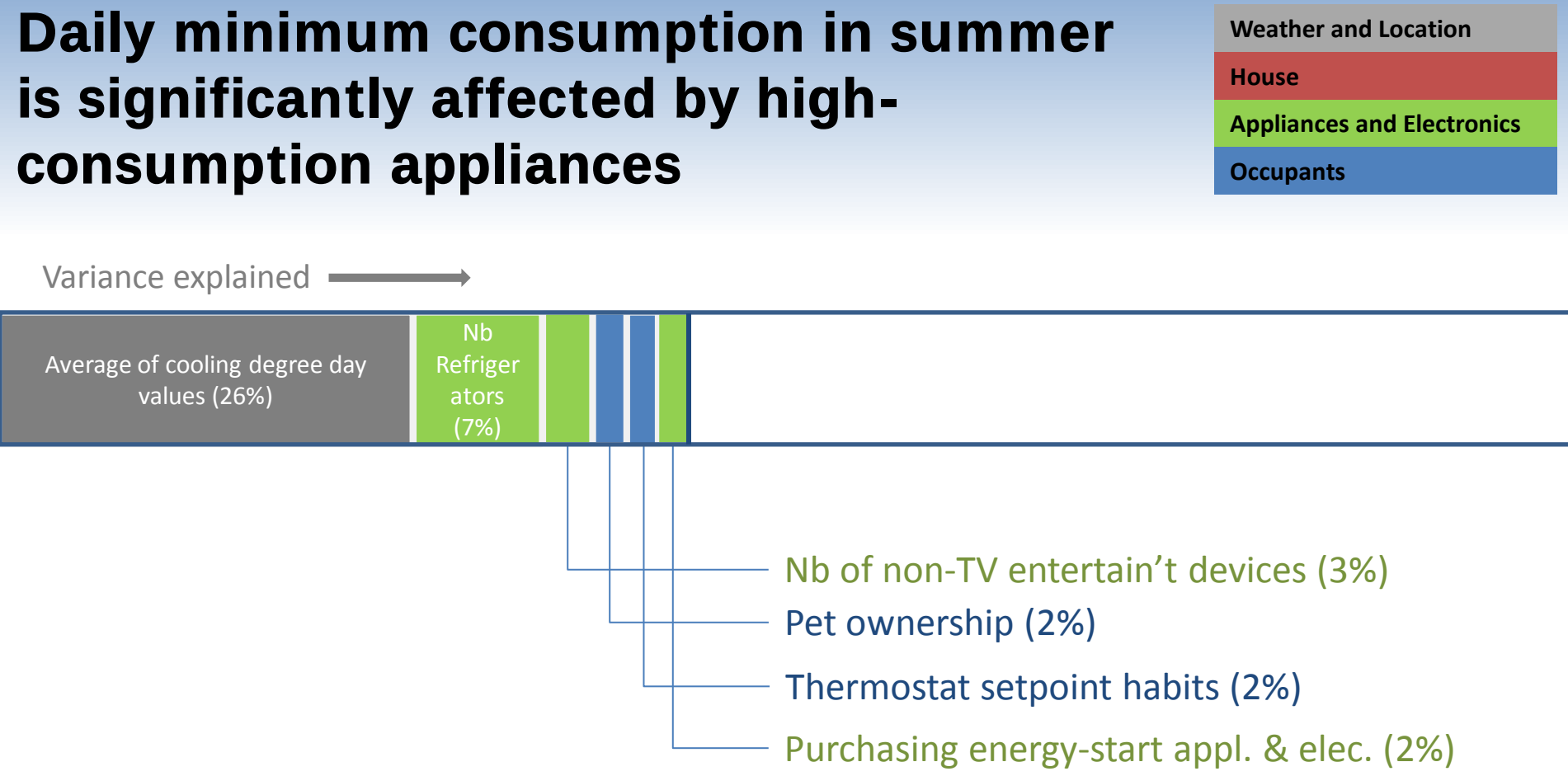
Daily minimum consumption in summer is significantly affected by high-consumption appliances



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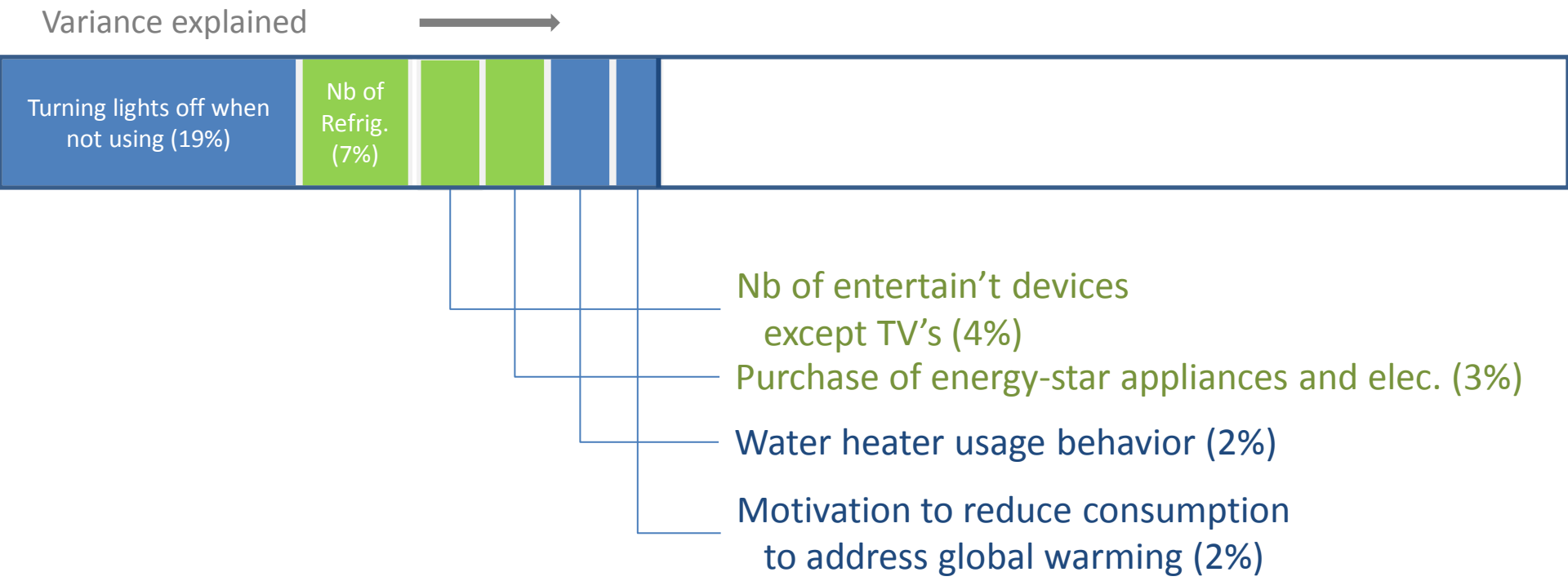
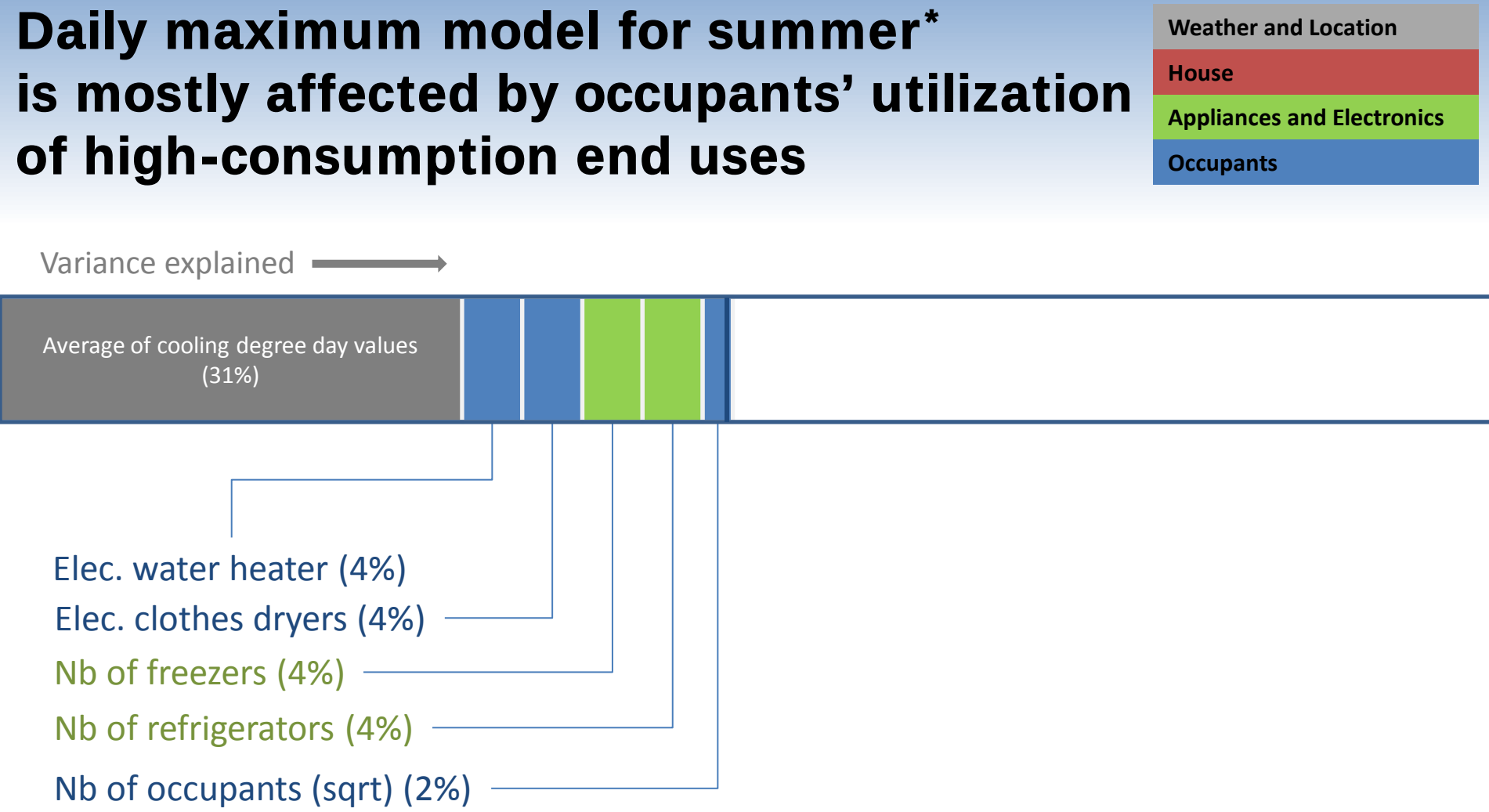


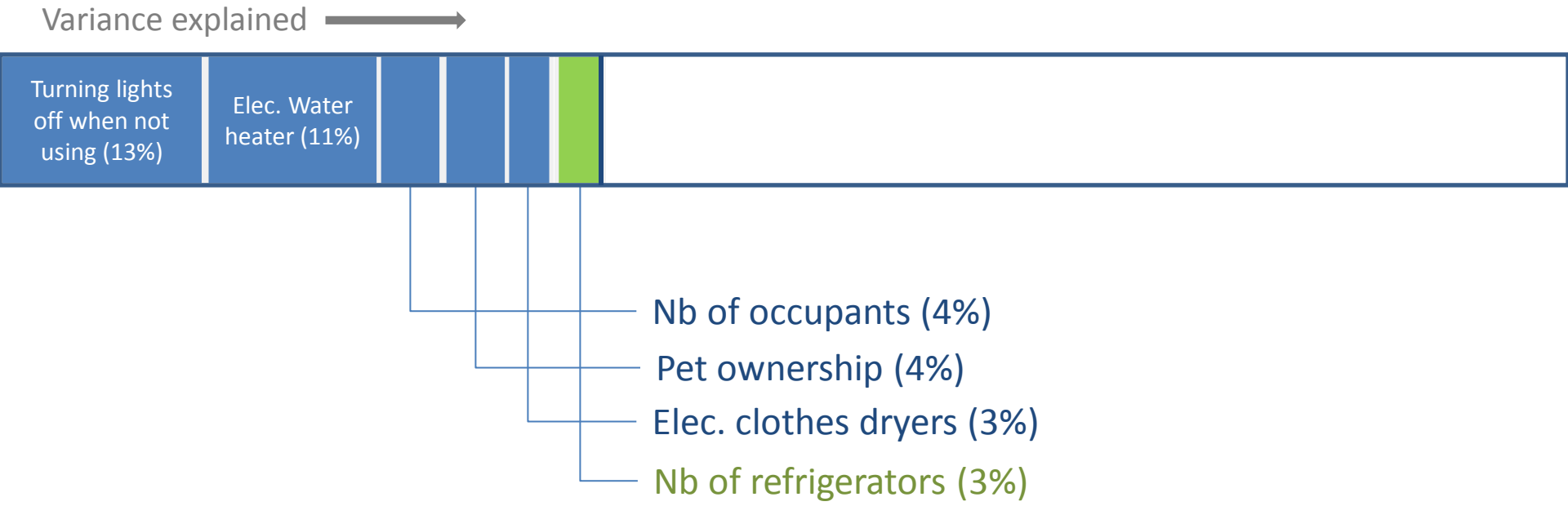
Daily maximum model for summer* is mostly affected by occupants' utilization of high-consumption end uses



* Model excludes Zip Code and Floor Area

Daily maximum consumption in winter* is mostly affected by occupant behavior and energy-intensive activities

Weather and Location
House
Appliances and Electronics
Occupants



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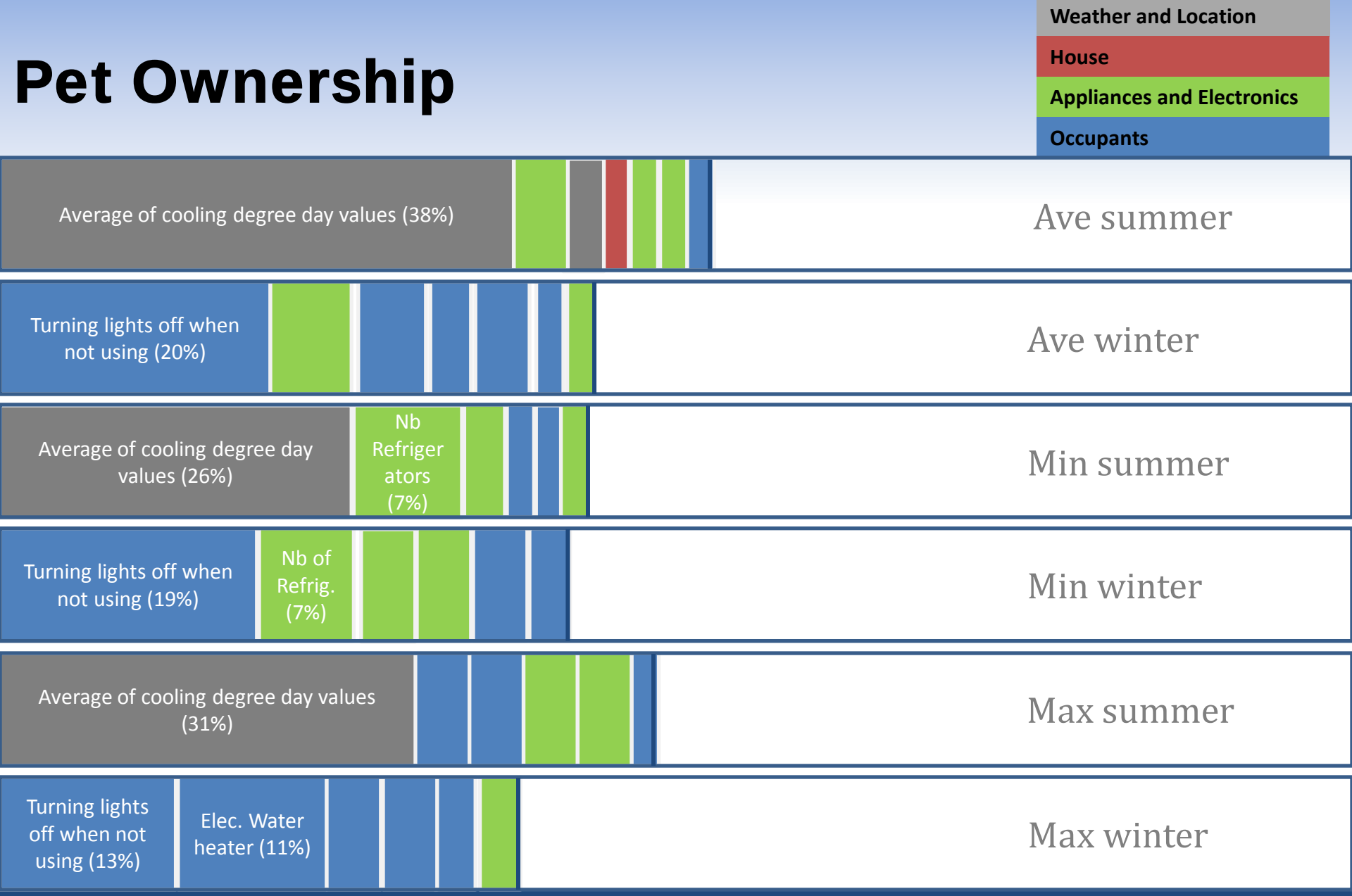
Pet Ownership



Thank you!