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Driving the Future: Intersection of Emerging Transportation Technologies and Energy Consumption

Tanmoy Bhowmik
Portland State University

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Intersection of Emerging Transportation Technologies and Energy Consumption

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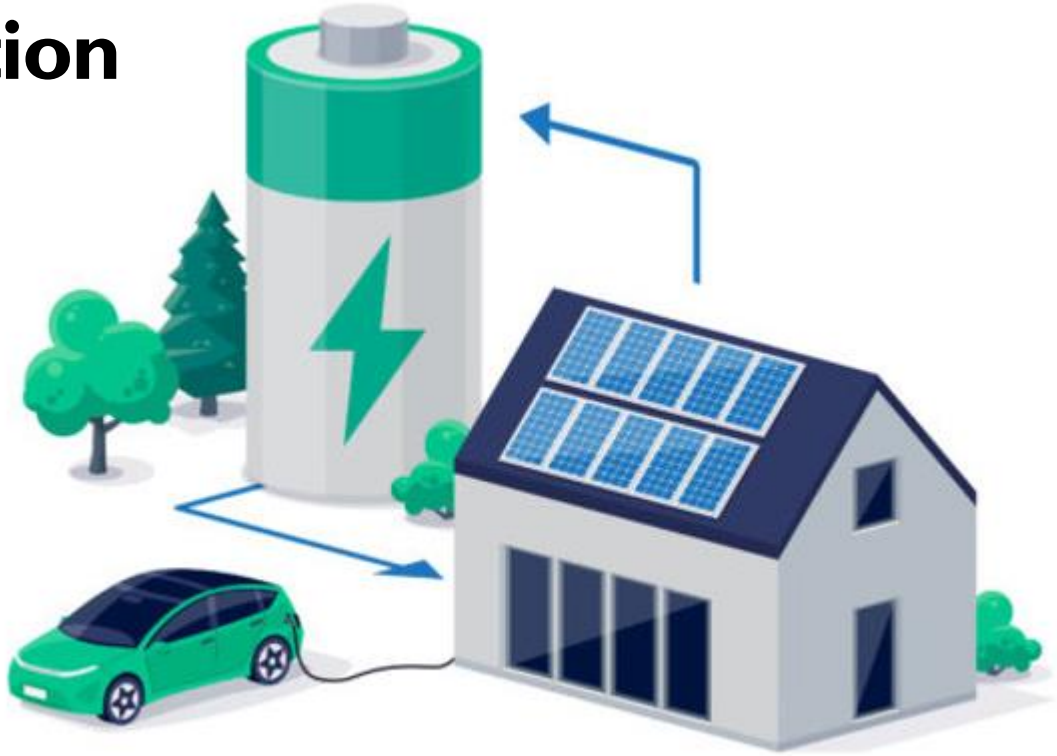
December 1st, 2023



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UNIVERSITY

Motivation

Influx of EVs and CAVs

- US market share of EVs projection: 2.7% to 28% from 2020 to 2030.
- EVs on the road projection (2021-2030): 2.13M to 48M

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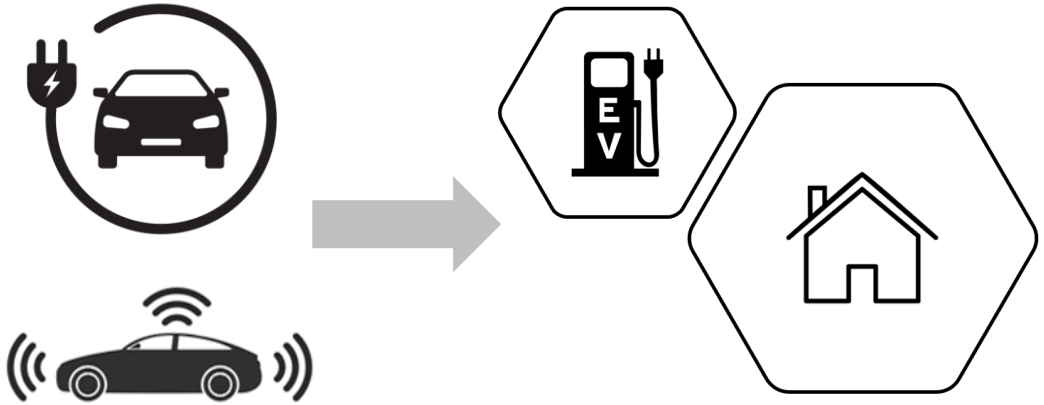

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- 80% of EV charging occurs at home,
- convenience and low cost of residential charging

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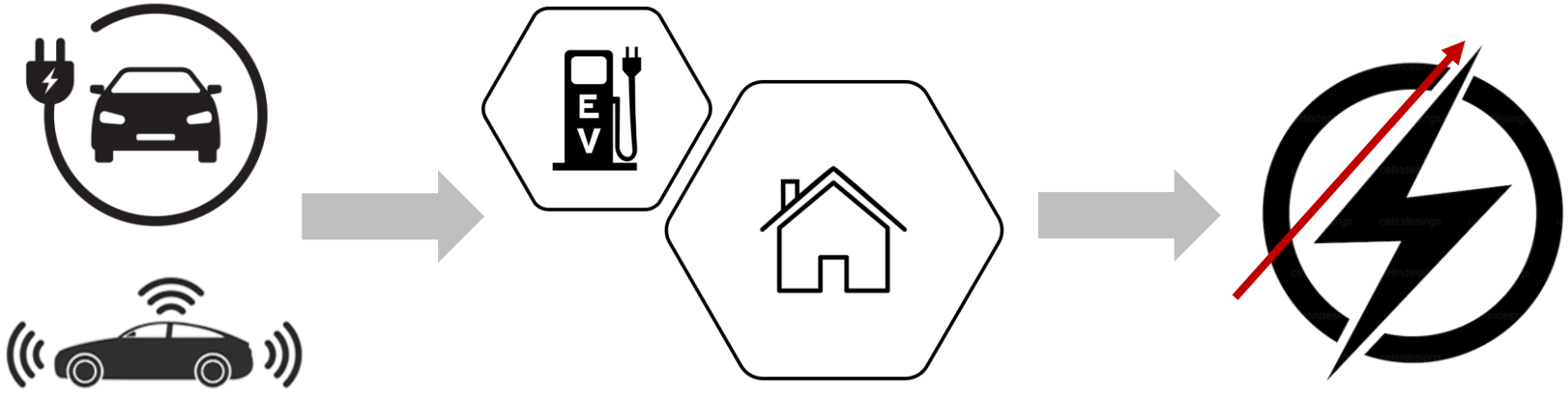

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- trend of residential EV charging is expected to cause a substantial increase in residential electricity demand

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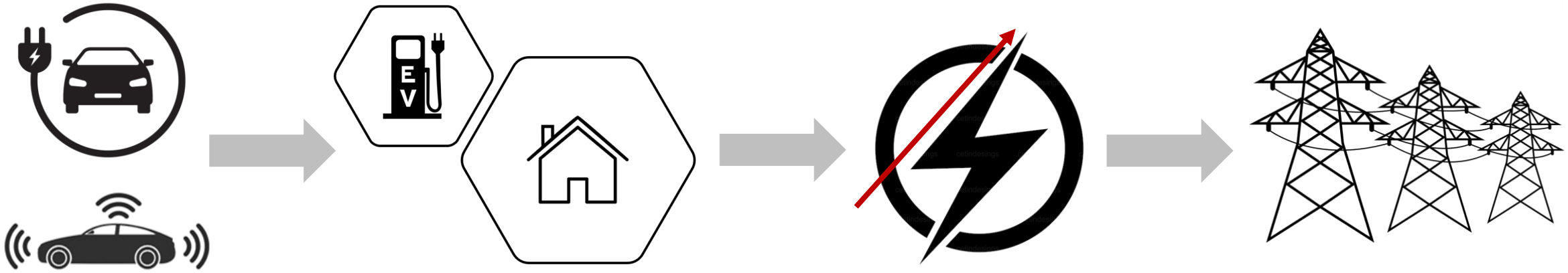

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Impact on Grid

- significant factor to consider in designing future electric grids

Motivation

Data Sources

Energy Consumption

Utility Companies

provides more specific information on actual energy consumption within their areas

represent a subset of households within a specific service area, not representative

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limited adoption of smart meters in residential buildings,

Motivation

Data Sources

Energy Consumption

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Surveys Questionnaires	gather detailed information directly from households, allowing for specific insights	represent a subset of households within a specific service area, not representative
Public Data sources, EIA	Readily available, provides information on national, regional and state level	

Data Description

RECS

- ***2015 RECS Data*, conducted by EIA**
- 5,686 households, representing 118.2 million US HH
- total energy use of each building is provided for
  - electricity, natural gas, fuel oil and propane (BTU)
- Provides information on other variables:
  - housing characteristics
  - appliances location related variables; and
  - climatic variables
    - **4,000 for estimation, 1,686 for validation**

Data Description

RECS

- ***Miss other important variables***
  - ***No. vehicles***
  - ***Employment information***
  - ***Vehicle types owned (EVs)***

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Data Description

- ***National Household Travel Survey (NHTS) 2017***

  Data

  - Consumer's information
  - 129,696 households, representing the properties of 118,208,251 households in the entire USA

NHTS

Information Present

- ***Miss other important variables***
  - ***No. vehicles***
  - ***Employment information***
  - ***Vehicle types owned (EVs)***

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NHTS

Information Present

❑ *Miss other important variables*

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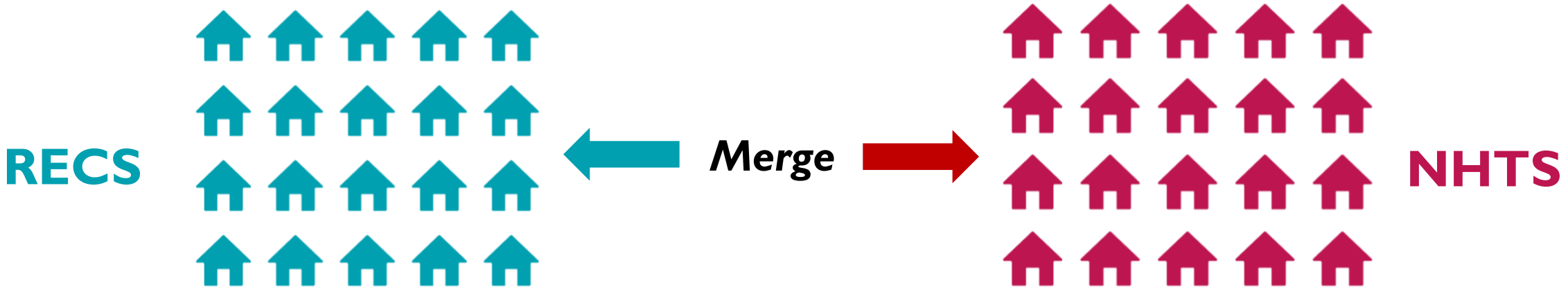
- ➢ *Vehicle types owned (EVs)*

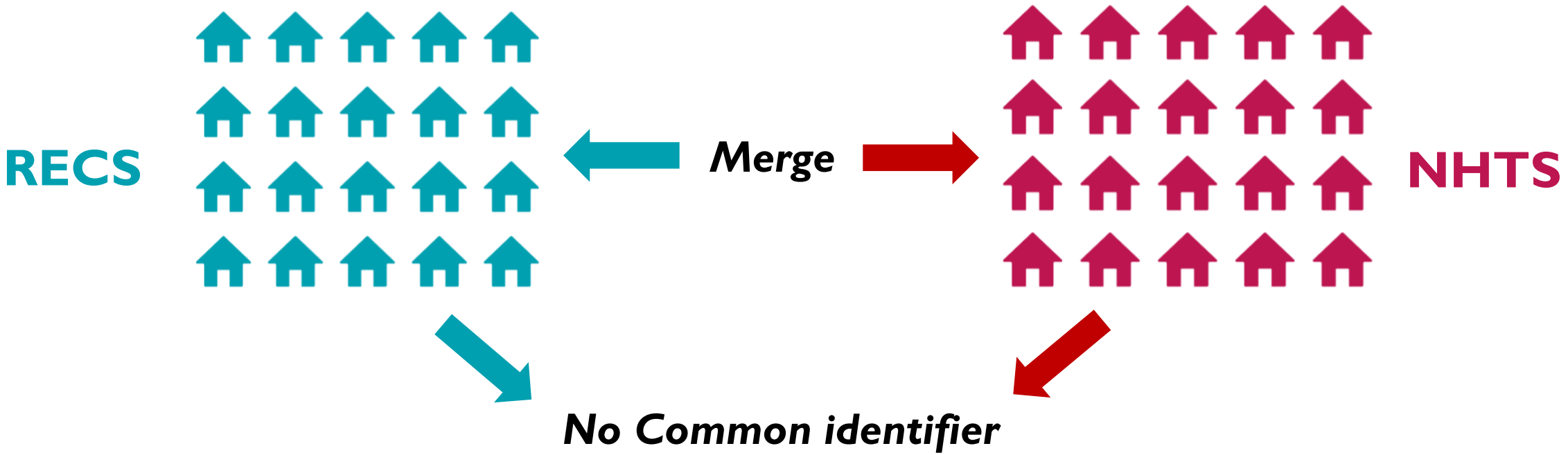
❑ ***Miss information on Energy consumption***

Research Method (Fusion)



- *Have information on Energy consumption*
- *Have information on vehicle and employment status*

Research Method (Fusion)



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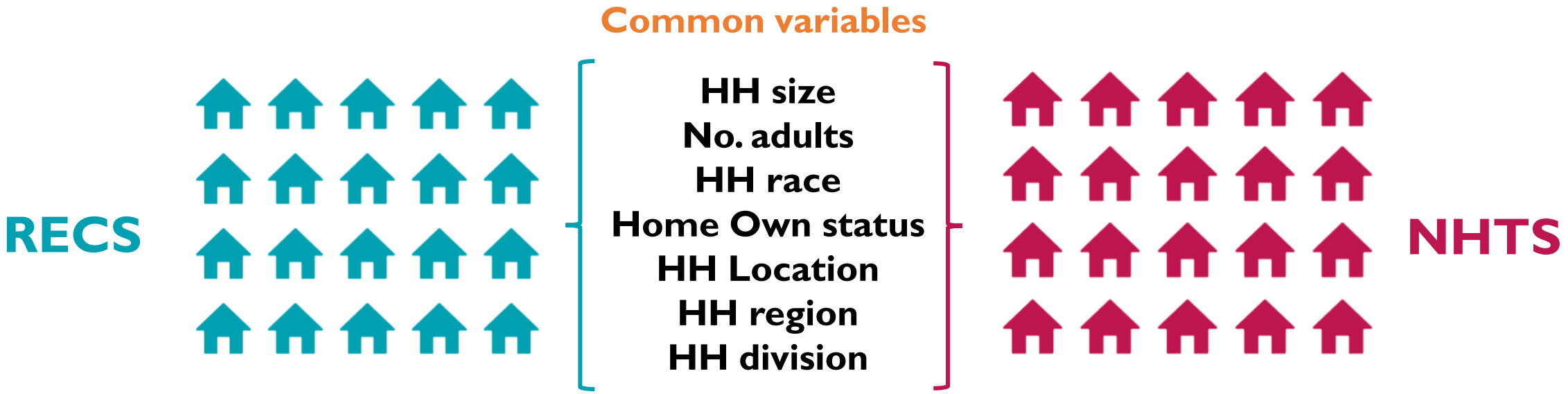

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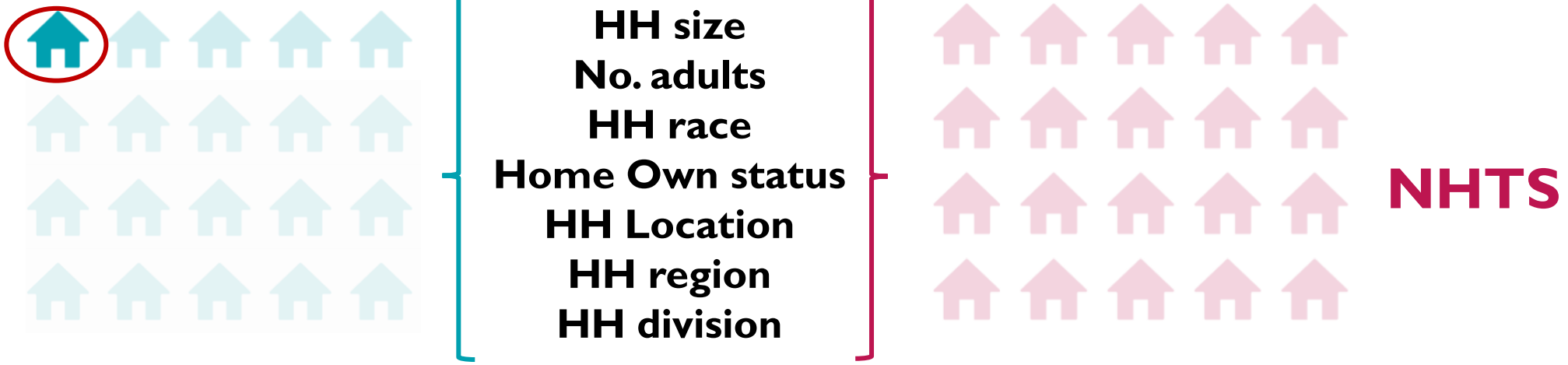


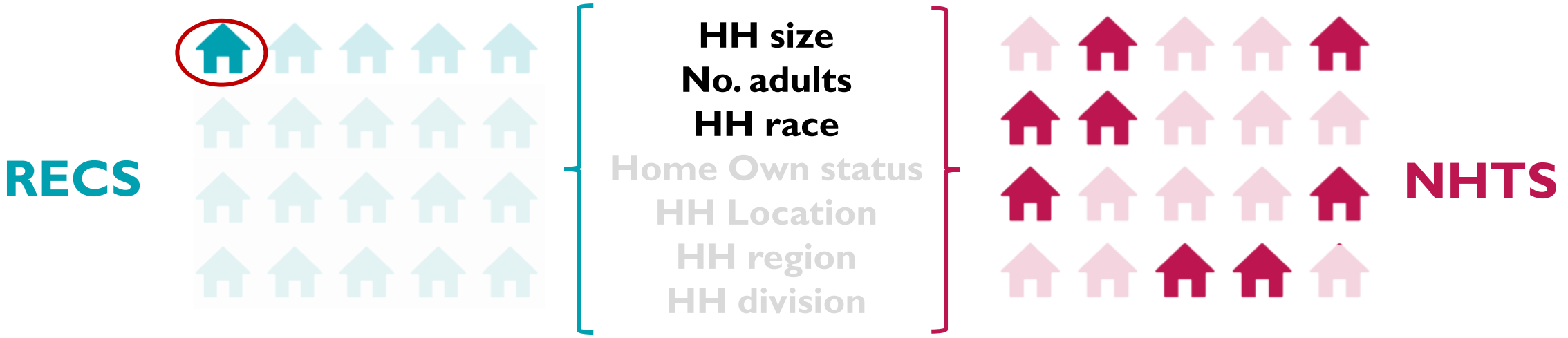
Research Method (Fusion)

RECS

HH size
No. adults
HH race
Home Own status
HH Location
HH region
HH division

NHTS

Research Method (Fusion)



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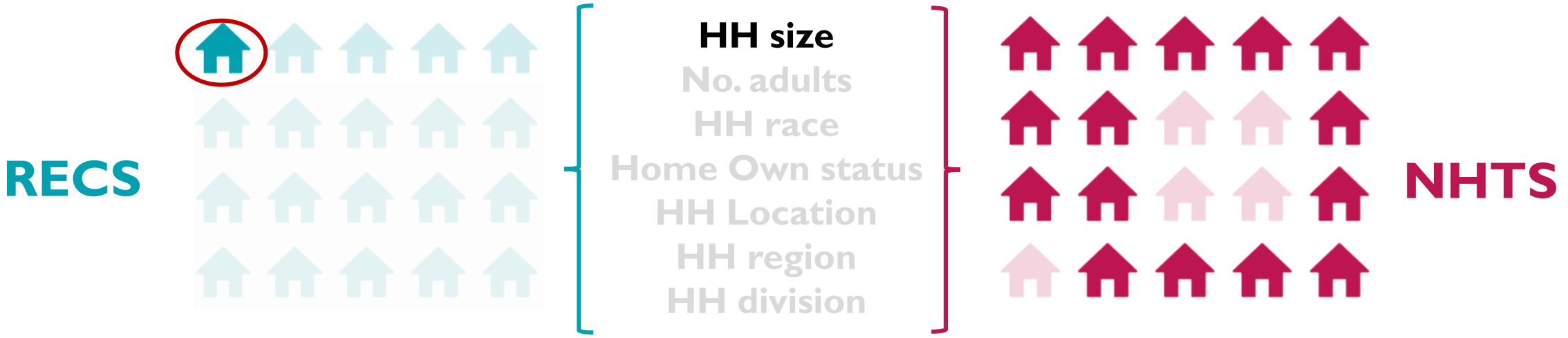

Research Method (Fusion)

Which variable/variable group we select to match the two datasets

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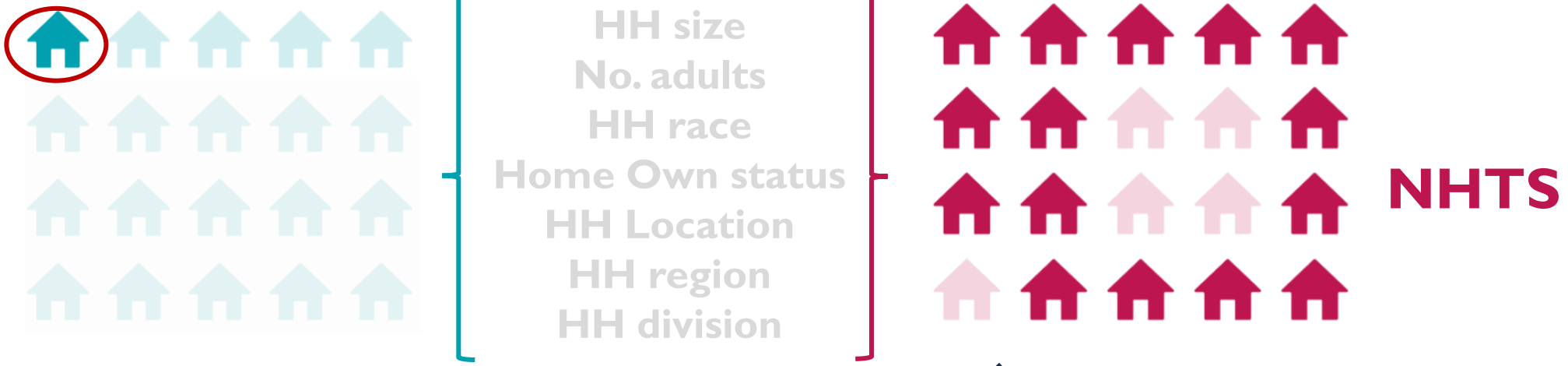

Which variable/variable group we select to match the two datasets

How many records do we match

Research Method (Fusion)

RECS

HH size
No. adults
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Home Own status
HH Location
HH region
HH division

NHTS

Which variable/variable group we select to match the two datasets

How many records do we match

- *Increased Complexity*
- *Biased result*
- ***Select an optimal solution***

Research Method (Fusion)

RECS

HH size
No. adults
HH race
Home Own status
HH Location
HH region
HH division

NHTS

Which variable/variable group we select to match the two datasets

optimal solution : 5 here (assume)

- *We can select any 5 out of 15*
- *Different selection might produce different results*

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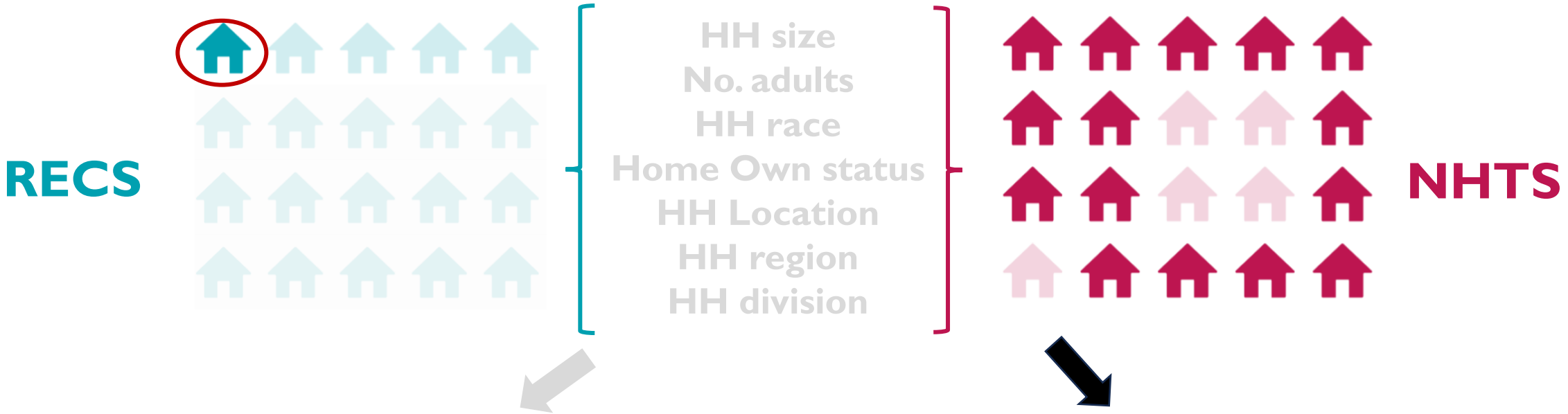

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How to check the stability of the randomness

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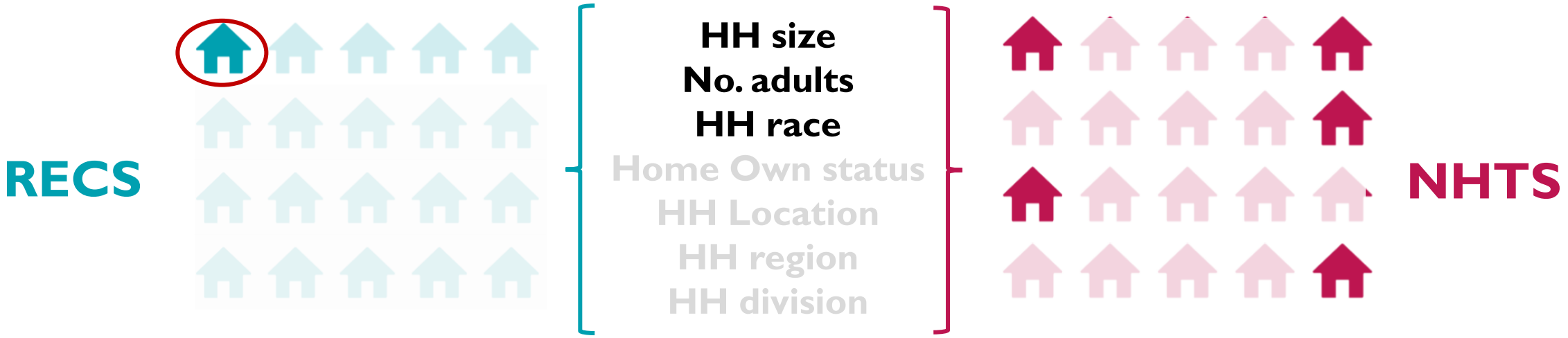

RECS HH: 1 ⟵ *5 records* ⟶ *optimal solution : 5 here*

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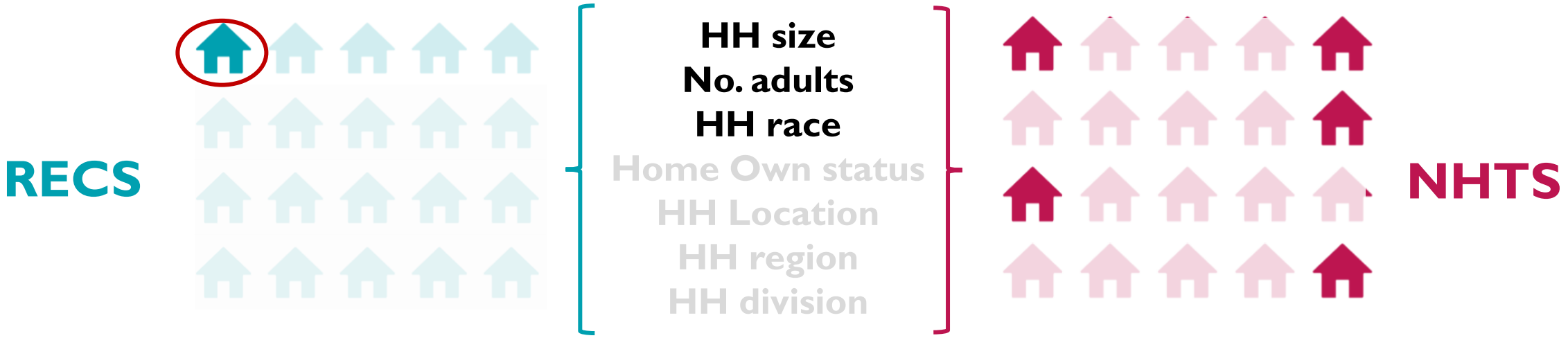

RECS HH: 1 ← *5 records* → *optimal solution : 5 here*

Deterministic weight: 1/5

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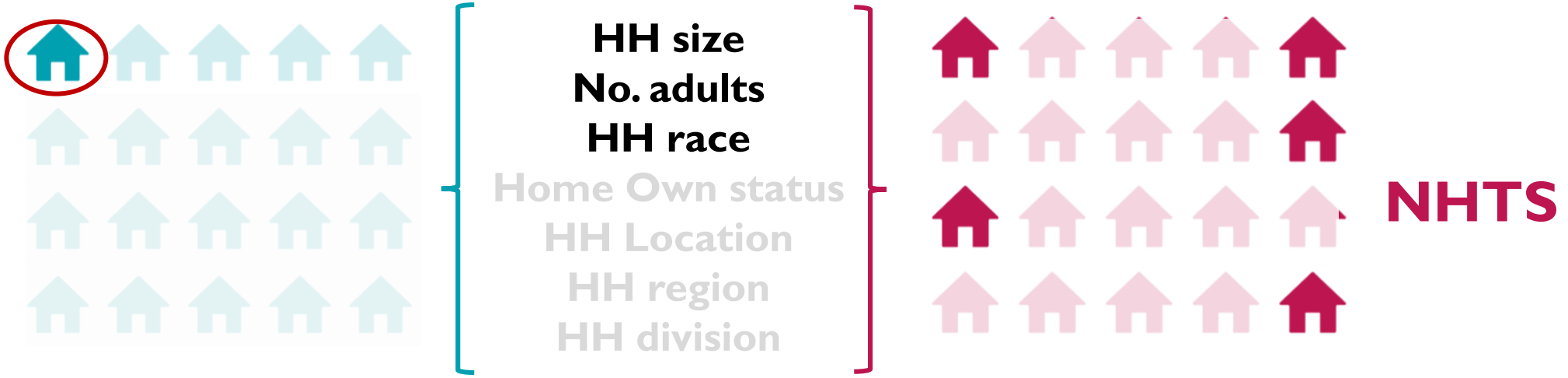
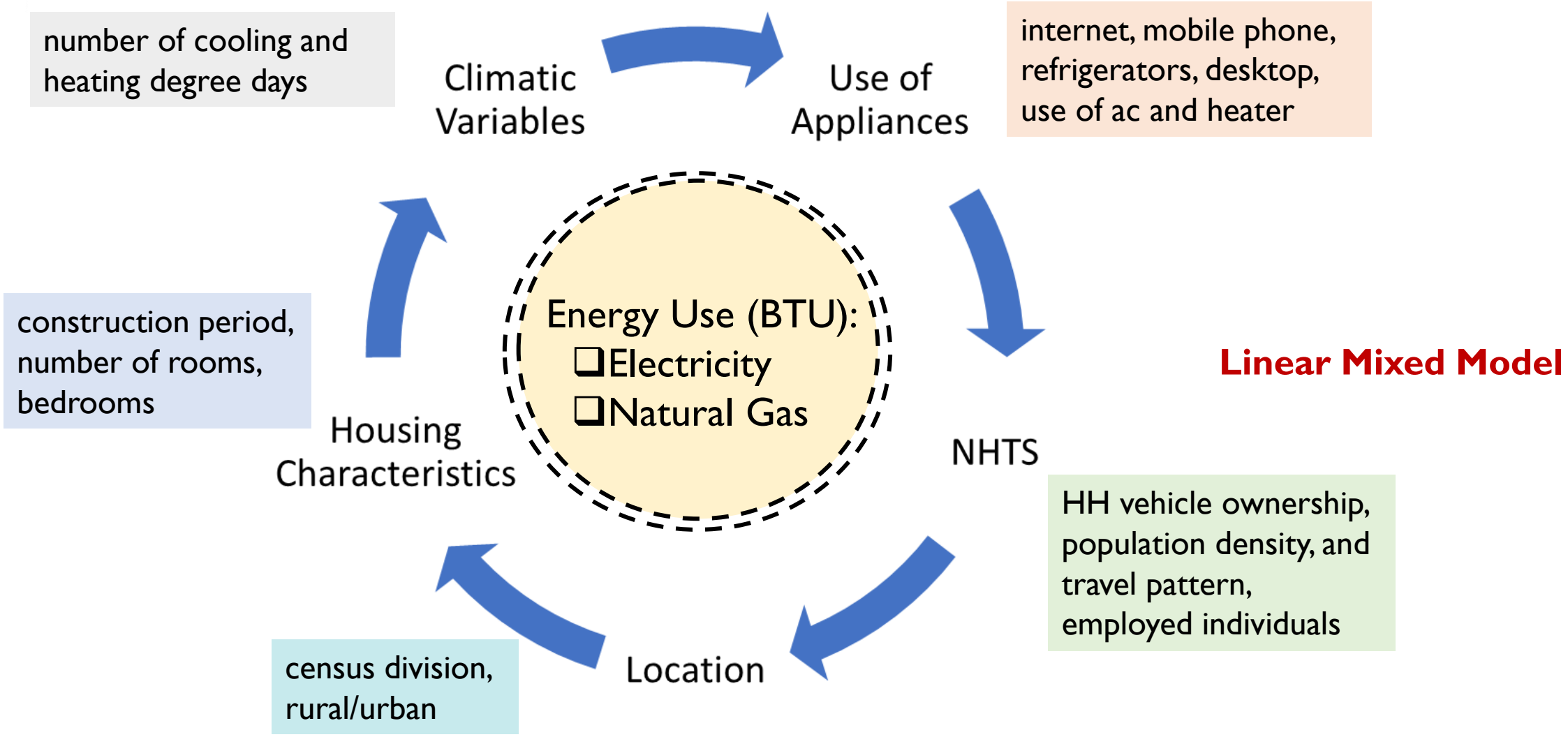


RECS HH: 1 ← *5 records* → *optimal solution : 5 here*

Deterministic weight: 1/5

Probabilistic weight — Home Own status, HH Location, HH region, HH division

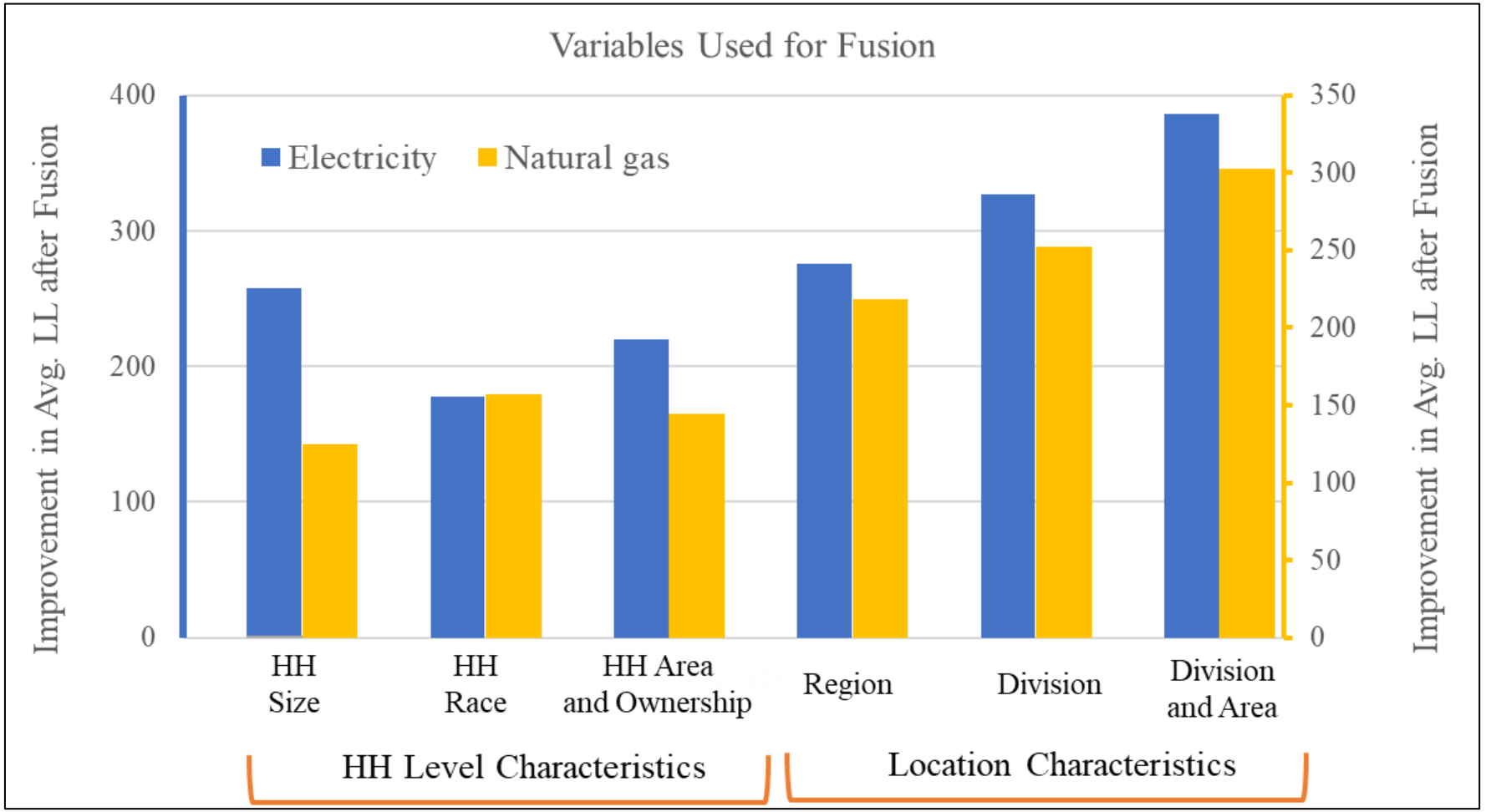
Data Description



Linear Mixed Model

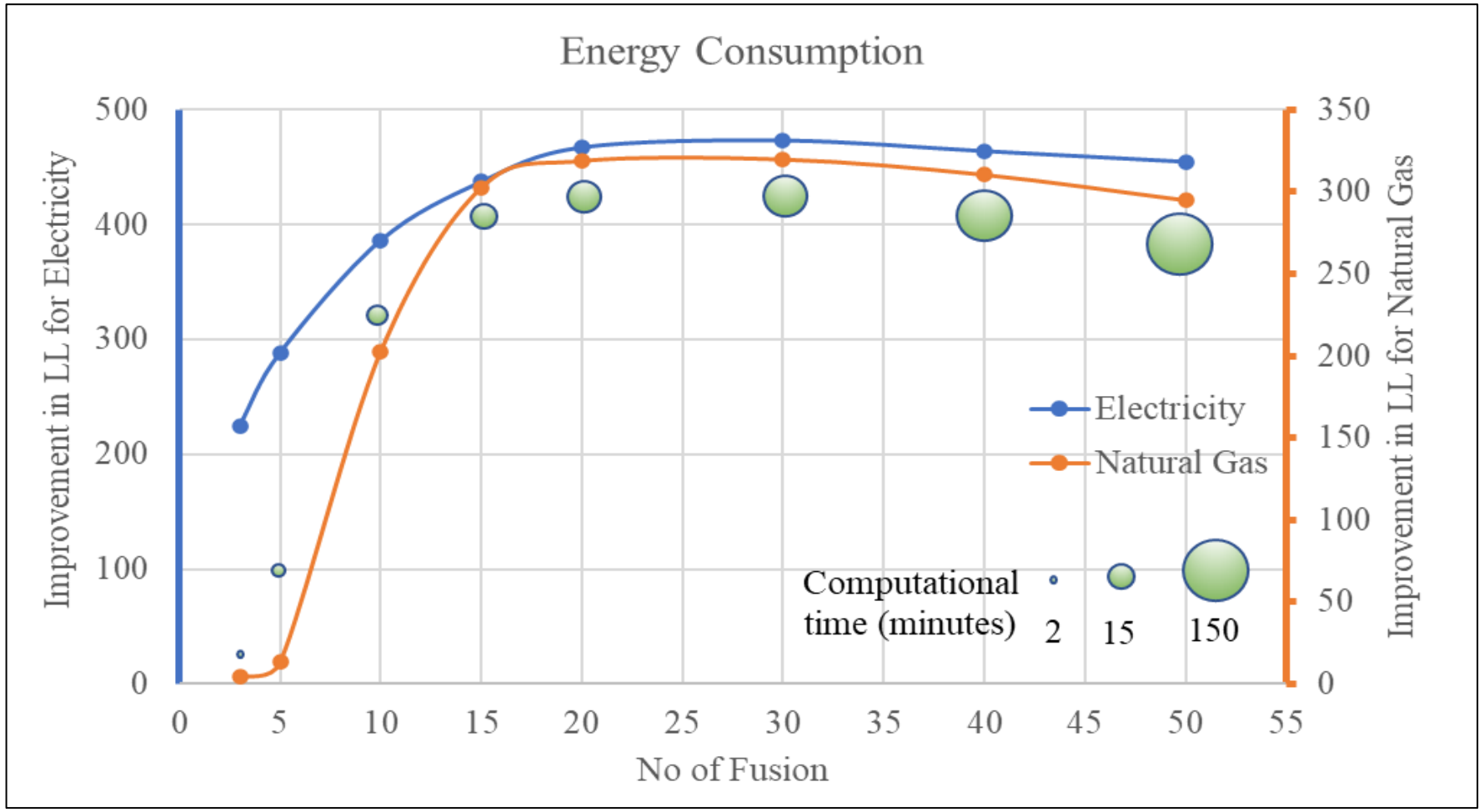
Fusion Analysis

- **What variables to use for fusion???**
- **Base Model**: model with RECS data only
- **Best improvement**: Fusing two dataset with common census division and location



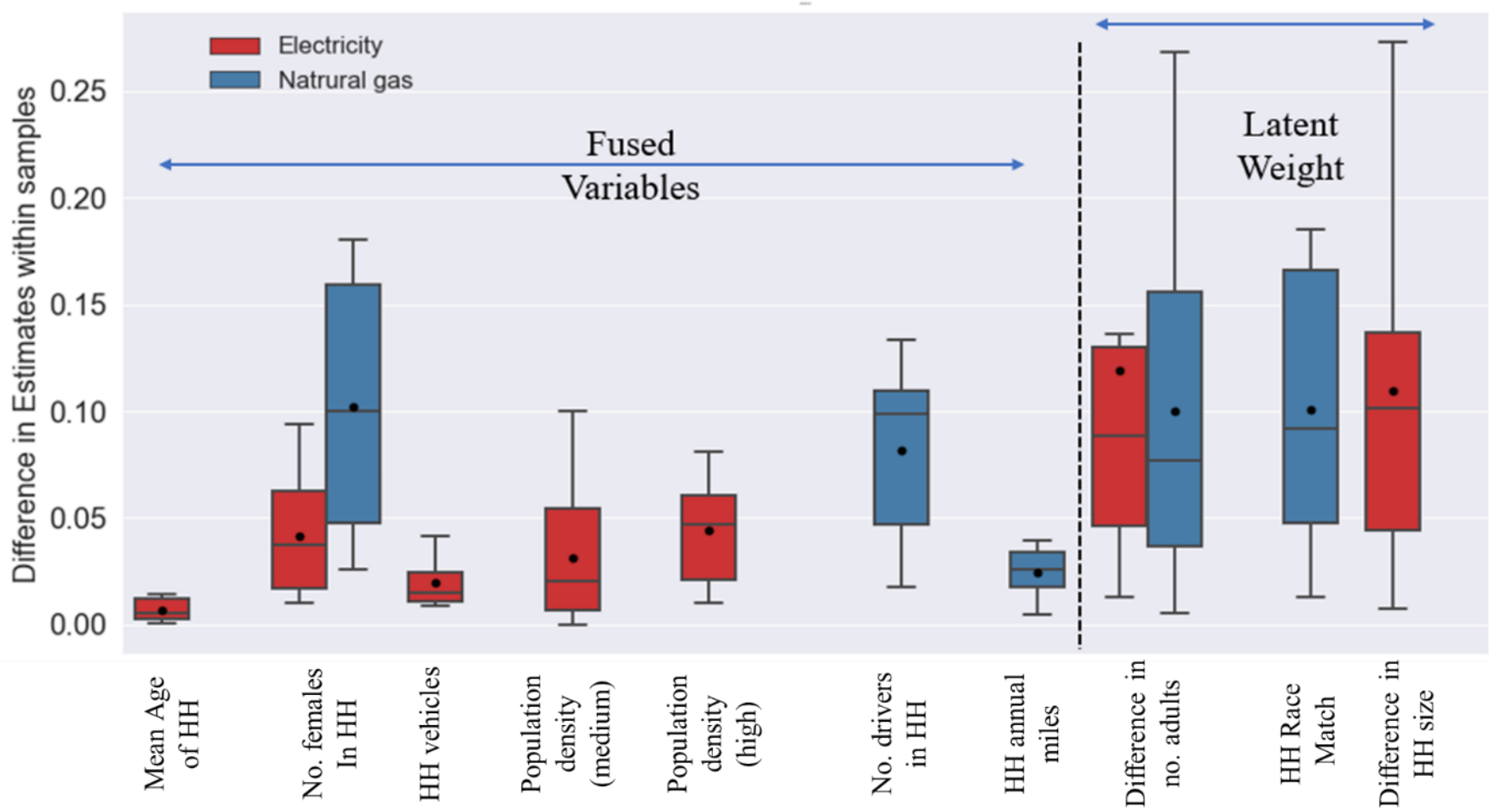
Fusion Analysis

- **How many records will we fuse???**
- **Base Model**: model with RECS data only
- **Best improvement**: Fusing two dataset with 15 matching records
- **Optimal choice**: 10 records



Fusion Analysis

- **Stable or not**
- Perform a **t-test**
- No variable go over the **critical limit**
- **Stable analysis**



Model Fit

Model (Electricity)	No. Parameters	BIC
Model with RECS data only	16	6,126.73
Model with Fused data, deterministic/equal weight	21	5,859.04
Model with Fused data, probabilistic weight	23	5,806.38

Model (Natural gas)	No. Parameters	BIC
Model with RECS data only	9	9,882.92
Model with Fused data, deterministic/equal weight	12	9,685.34
Model with Fused data, probabilistic weight	14	9,635.35

Result

Variables (RECS)	Electricity Consumption	Natural Gas Consumption
HH Characteristics		
Ln (Total square footage)	▲	▲
Total number of rooms	▲	▲
Housing type - Mobile home	▲	
Housing type - Apartment		▼
Construction year 1981 - 2000	▲	
Construction year 2001 - 2010	▲	▼
Construction year after 2010	▲	▼
High income HH (>120k)		▲

Result

Variables (RECS)	Electricity Consumption	Natural Gas Consumption
Appliance Use		
AC Used	▲	
Number of refrigerators used	▲	
Number of desktop computers	▲	
Space heating used	▲	
Number of smart phones	▲	
Humidifier used	▼	
Climatic Variables		
Ln (Total cooled square footage)	▲	
Ln (Total heating square footage)		▲

Result

Variables (NHTS)	Electricity Consumption	Natural Gas Consumption
Population Density (Medium)	▼	
Population Density (High)	▼	
Number of females in HH	▲	▲
Number of vehicles in HH	▲	
Proportion of EV in HH	▲	
Number of drivers in HH		▼
Mean age of HH members	▼	
No. people work from home	▲	▲
HH average annual miles		▲

Result

Weight	Electricity	Natural Gas
HH member difference	▼	
No. of adult differences	▼	▼
HH race match		▲

Validation Analysis

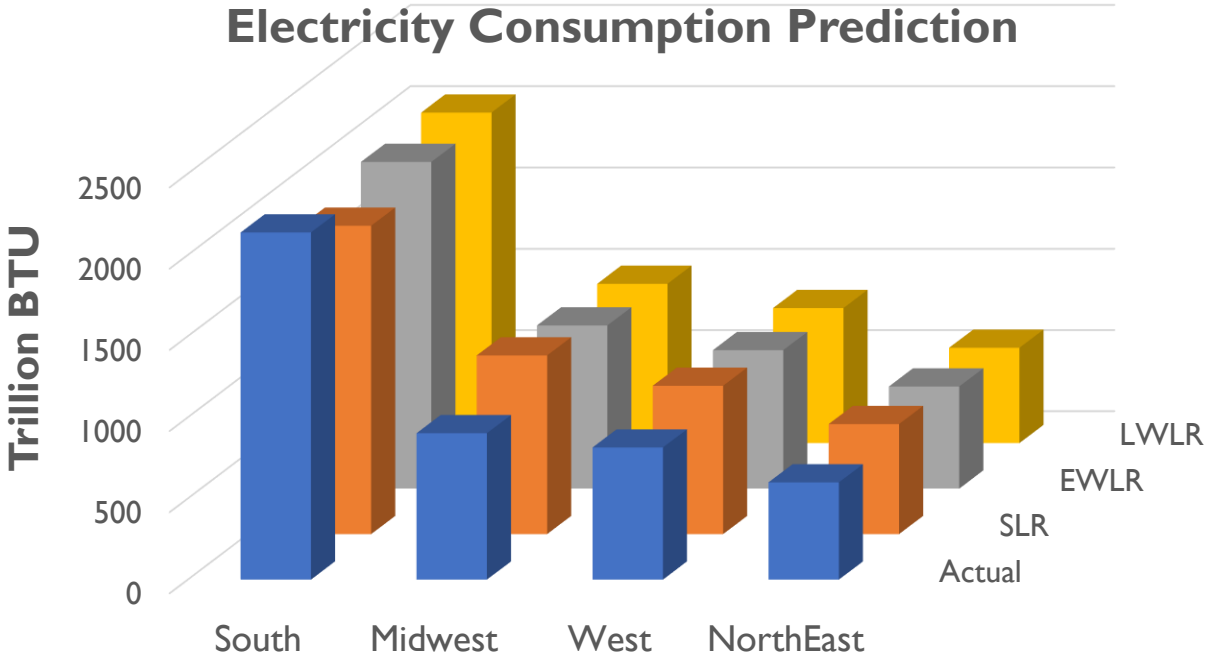
Energy Source	Sample size	Avg. LL comparison for Estimation Sample		Avg. LL comparison for Validation Sample	
		Improvement (EWLR~SLR)	Improvement (LWLR~EWLR)	Improvement (EWLR~SLR)	Improvement (LWLR~EWLR)
Electricity	Est.* 1000 Val** 4686	97.80	18.22	337.00	92.73
	Est. 2000 Val. 3686	143.61	40.21	282.16	71.49
	Est. 3000 Val. 2686	254.29	54.62	189.31	65.22
	Est. 4000 Val. 1686	366.02	74.66	86.26	23.67
	Est. 5000 Val. 686	392.19	103.76	59.86	18.61
Natural Gas	Est. 1000 Val. 4686	57.78	3.45	364.48	13.01
	Est. 2000 Val. 3686	106.72	9.69	354.26	10.59
	Est. 3000 Val. 2686	224.78	13.53	196.95	6.19
	Est. 4000 Val. 1686	339.01	18.98	178.48	4.14
	Est. 5000 Val. 686	410.30	21.16	16.03	3.41

SLR = Model with RECS data only

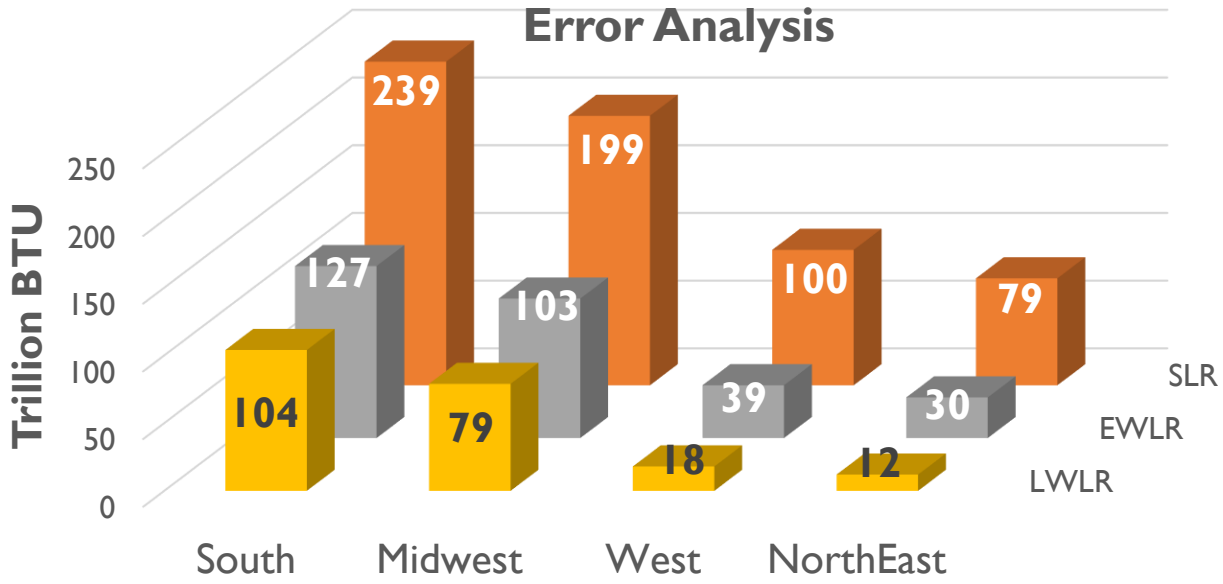
EWLR = Model with fused data, equal weight

LWLR = Model with fused data, latent weight

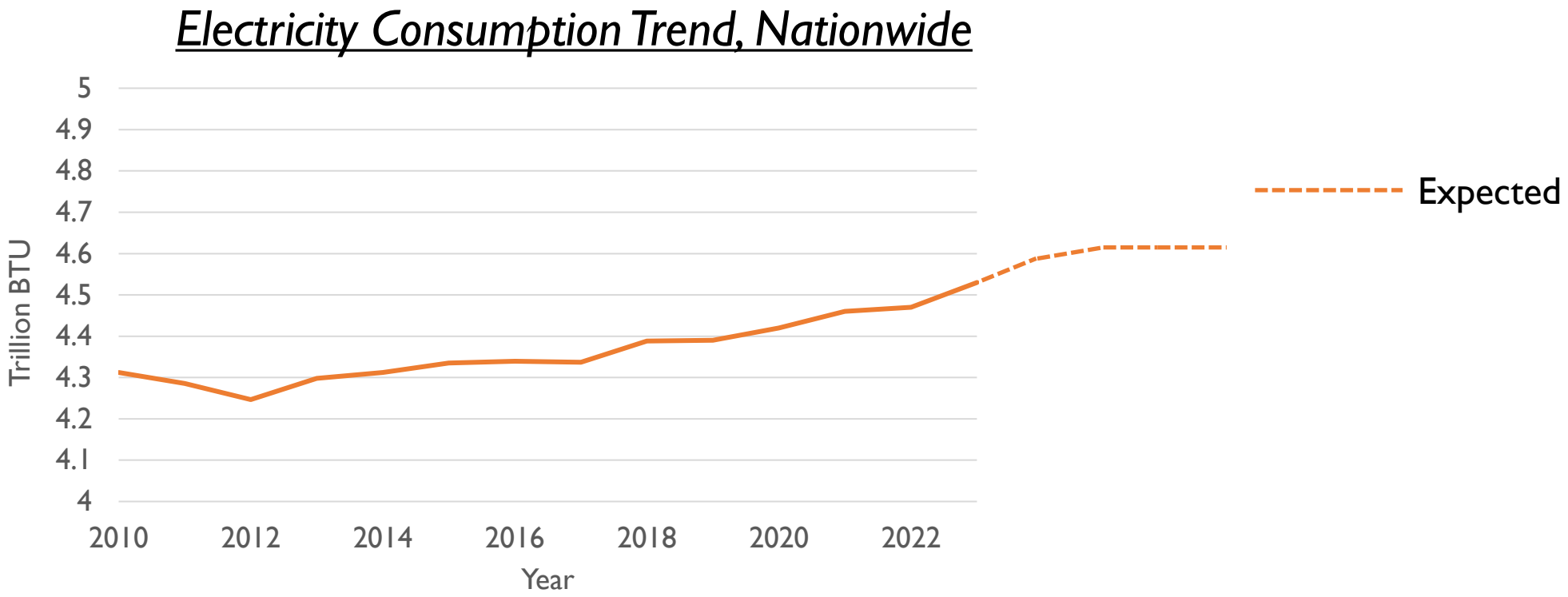
Prediction Analysis



- 202RECS data is recently available
- Predict using our model



Policy Analysis



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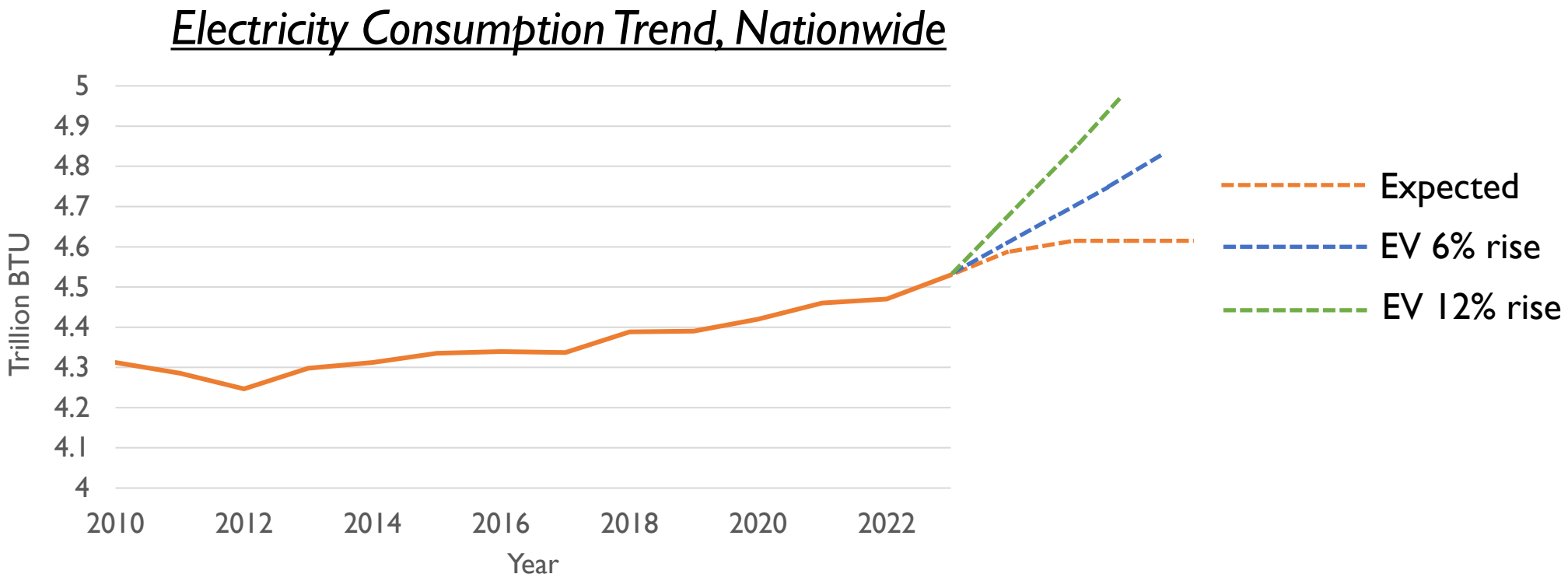

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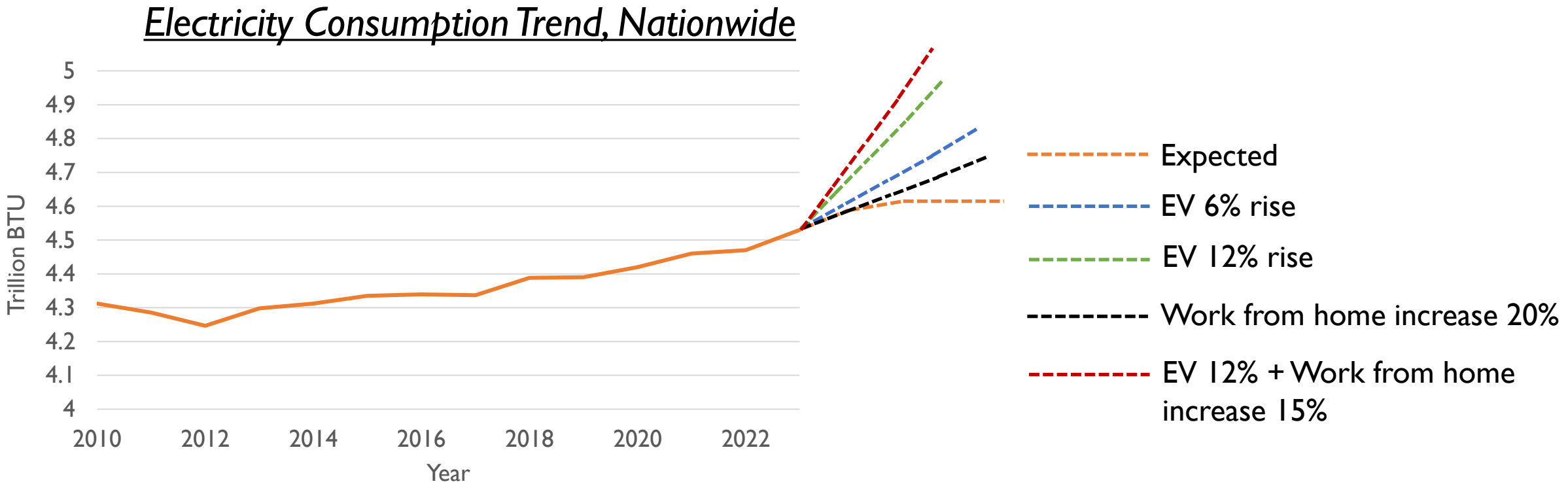

Summary

- ❑ Generate an Energy Model
- ❑ Propose a novel fusion algorithm, that can be applied in multiple energy and transportation sectors
- ❑ Fusing RECS data with NHTS data
  - ➢ Improve the energy model
  - ➢ Incorporate additional information missing from RECS data
  - ➢ Incorporate the effect of emerging technology in residential energy consumption

The work is currently Under Review in Applied Energy

Limitation and Future Work

- The current analysis focused on 2017 NHTS data, electric vehicle and working from home % are very few
  - 2022 NHTS data with 2020 RECS data
- Simulate the framework considering both residential and commercial energy demand
- Integrated framework
  - Who will buy EV?
  - Who will prefer charging at home?
  - Impact on residential and commercial energy

Vision

A meaningful and positive impact through
my research and inspire the next generation

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Thank you!