The best of both worlds: Statistics and engineering working toward a good end (use)

Lullit Getachew, Ken Agnew, Steven Chang, DNV
Peter Franzese, CPUC

02 November 2022

Agenda

Background

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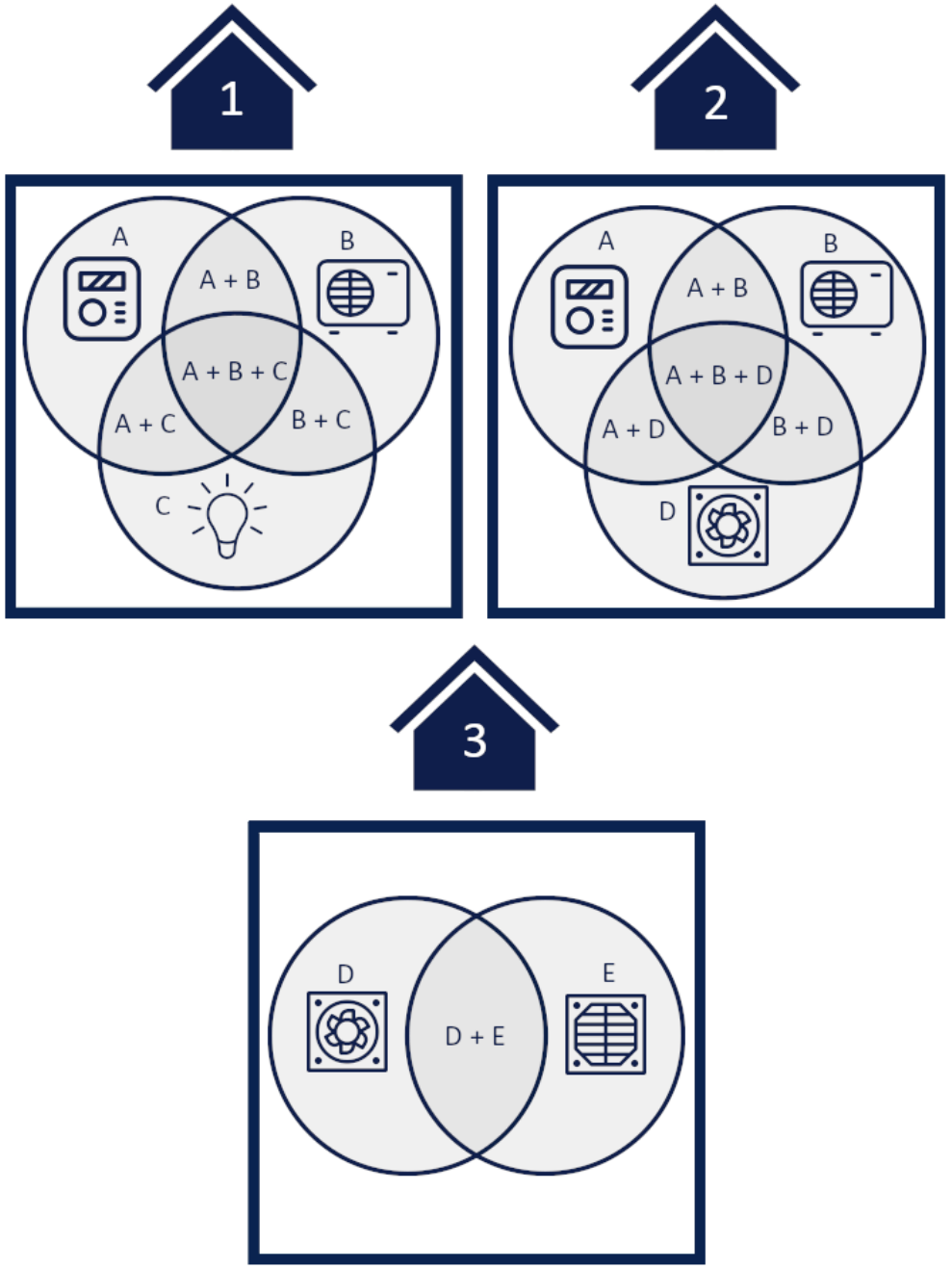
Background

Study motivation

- Attribute savings to individual measures in the context of multiple overlapping installations
  - Overlaps -> make it difficult to discern the contribution of individual measures
    - Each measure mix may be associated with unique participant characteristics
    - There are also overlaps in the installations that limit the information each measure provides (collinearity)
  - Interactive effects -> measure savings are non-additive
  - Competing functions -> make it difficult to attribute the savings to individual measures



Study approaches

Use a variant of statistically adjusted engineering (SAE) method

- leverages better engineering estimates to decompose savings

Disaggregate savings

- leverages engineering savings proportions that can be useful for similar programs

Study setting

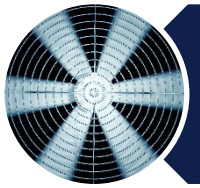
Study based on a large scale delivery of multiple measures across California

Year	**2018**
Program administrators	4 CA IOUs
Programs	14 direct install programs
End use targeted	Mostly HVAC use
Housing type targeted	Single family, multifamily, mobile homes
Participant cost	Low to none
Installed measures	About 200,000 electric- and 180,000 gas-saving measures

Technologies installed

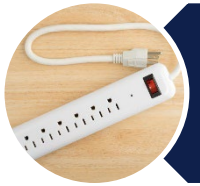
Smart Thermostat

Refrigerant charge adjustment (RCA)



Fan Controls

Condenser Coil Cleaning



Power strips

Duct Testing and Sealing

Lighting

Fan Motor Replacement

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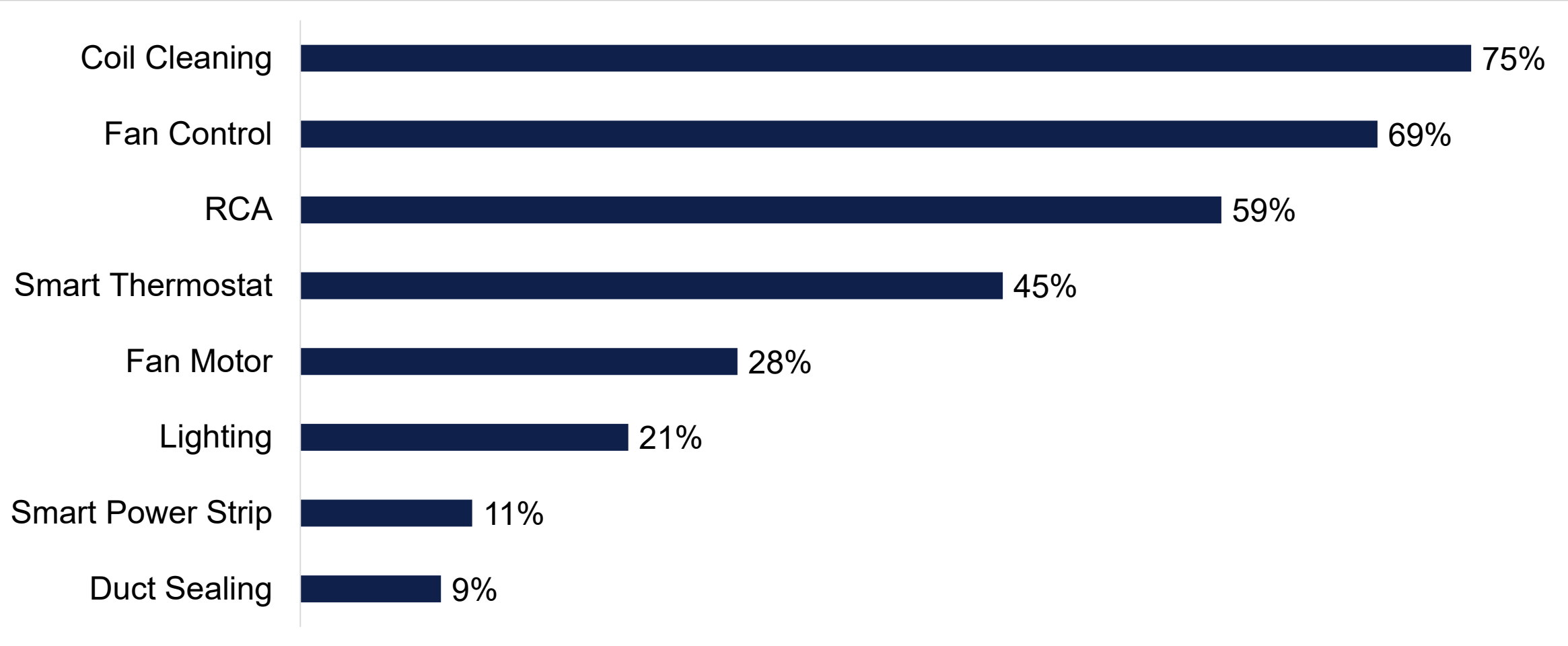
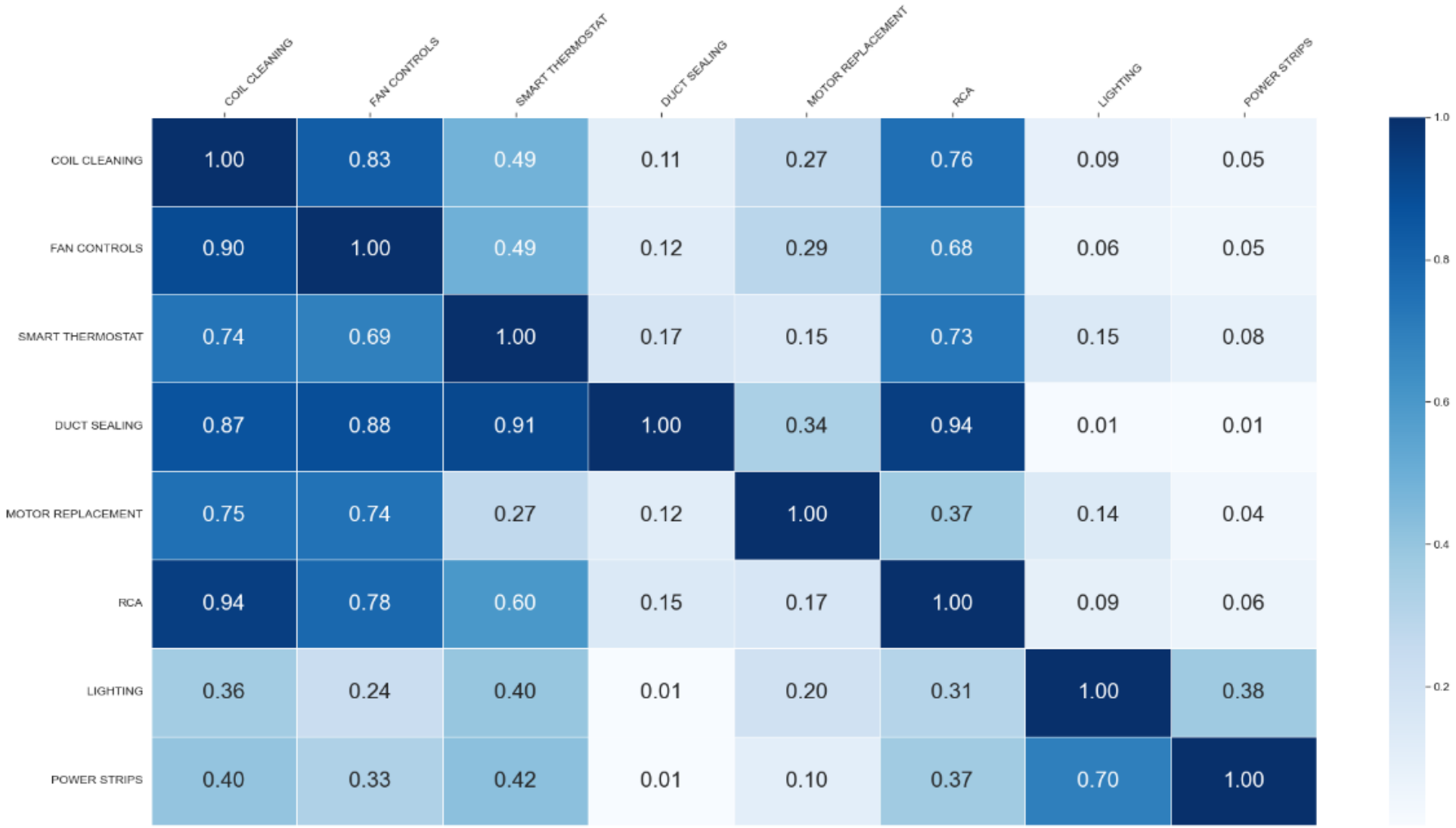
Percent of home receiving each technology – single family



Measure combinations – single family



Data and Methods

Data - sources

Tracking data

Customer information system data

AMI data

Weather data

Data - participant data

Participant Data Attrition	PG&E Electric	SCE Electric	SDG&E Electric
Customers with measures of interest in the 2018 tracking data	27,759	70,281	2,238
Customers with daily AMI data available for matching	13,715	28,948	1,151
Customers without on-site solar and sufficient AMI data for final analysis	13,473	28,727	635

Method – whole-home savings

Stage 1: model site-level data

Model pre- and post-period energy use as a function of weather

Generate normalized annual consumption (NAC)

Stage 2: model NAC

Model difference-in-difference (DID) in NAC from participants and matched comparators

Generate whole-home savings

Method – measure savings

The common dummy model

- Explains variation in pre-post NAC
- A model with multi-measure dummy variables
- Provides average measure savings estimates across all sites

The composite statistically adjusted engineering (SAE) model

- Explains variation in pre-post NAC
- A model with multi-measure dummy variables and *a priori* measure savings
- Provides measure savings that reflect variation by housing type and climate zone

The scaled SAE model

- Explains variation in pre-post % change in NAC
- A model with multi-measure dummy variables and *a priori* % measure savings
- Provides measure savings that reflect variation by housing type, climate zone, and HH size

Measure savings models

Common Dummy Model

$$\Delta NAC_i = \alpha_0 + \sum_k \beta_k I_{ki} + \varepsilon_i$$

- ΔNAC_i: pre-NAC – post-NAC, premise *i*
- α_0: non-program-related change
- β_k: Measure *k* mean savings per premise
- I_{ki}: 1/0 for premises with/without measure *k*
- ε_i: Residual error, premise *i*

Composite Statistically Adjusted Engineering (SAE) model

$$\Delta NAC_i = \alpha_0 + \sum_k \beta_k I_{ki} + \sum_k \gamma_k E_{ki} + \varepsilon_i$$

- E_{ki}: Engineering savings estimate, measure *k*, premise *i*

Scaled SAE Model

$$\%\Delta NAC_i = \alpha_0 + \sum_k \beta_k I_{ki} + \sum_k \gamma_k \%E_{ki} + \varepsilon_i$$

- $\frac{\Delta NAC_i}{pre\text{-}NACi}$: non-program % change
- $\%E_{ki}$: Engineering % savings, measure *k*, premise *i*

Whole-home savings model

Collapsed Scaled SAE Model

$$\%\Delta NAC_i = \alpha_0 + \sum_i \beta\, I_i + \sum_k \gamma\, \%E_i + \varepsilon_i$$

- $\frac{\Delta NAC_i}{pre\text{-}NAC_i}$
- α_0: non-program % change
- $\sum_i \beta\, I_i$: 1/0 for participant/ nonparticipant
- $\sum_k \gamma\, \%E_i$: Engineering % savings, premise *i*
- ε_i

Estimate of measure k savings for participant i

$$\%\Delta \left(\left(\hat{\beta} + \hat{\gamma} \%E \right) * PreNAC_i \right) * \left(\frac{E_{ki}}{\sum_k E_{ki}} \right)$$

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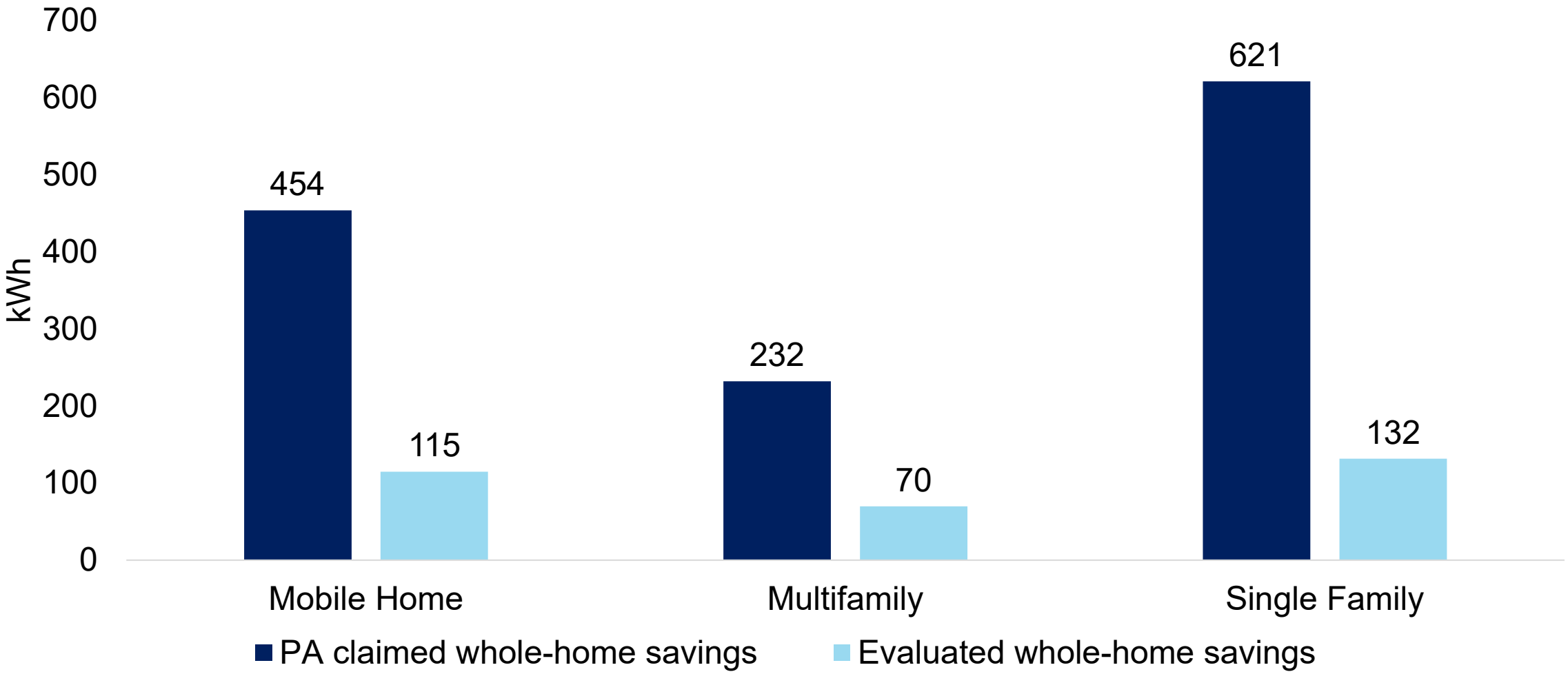
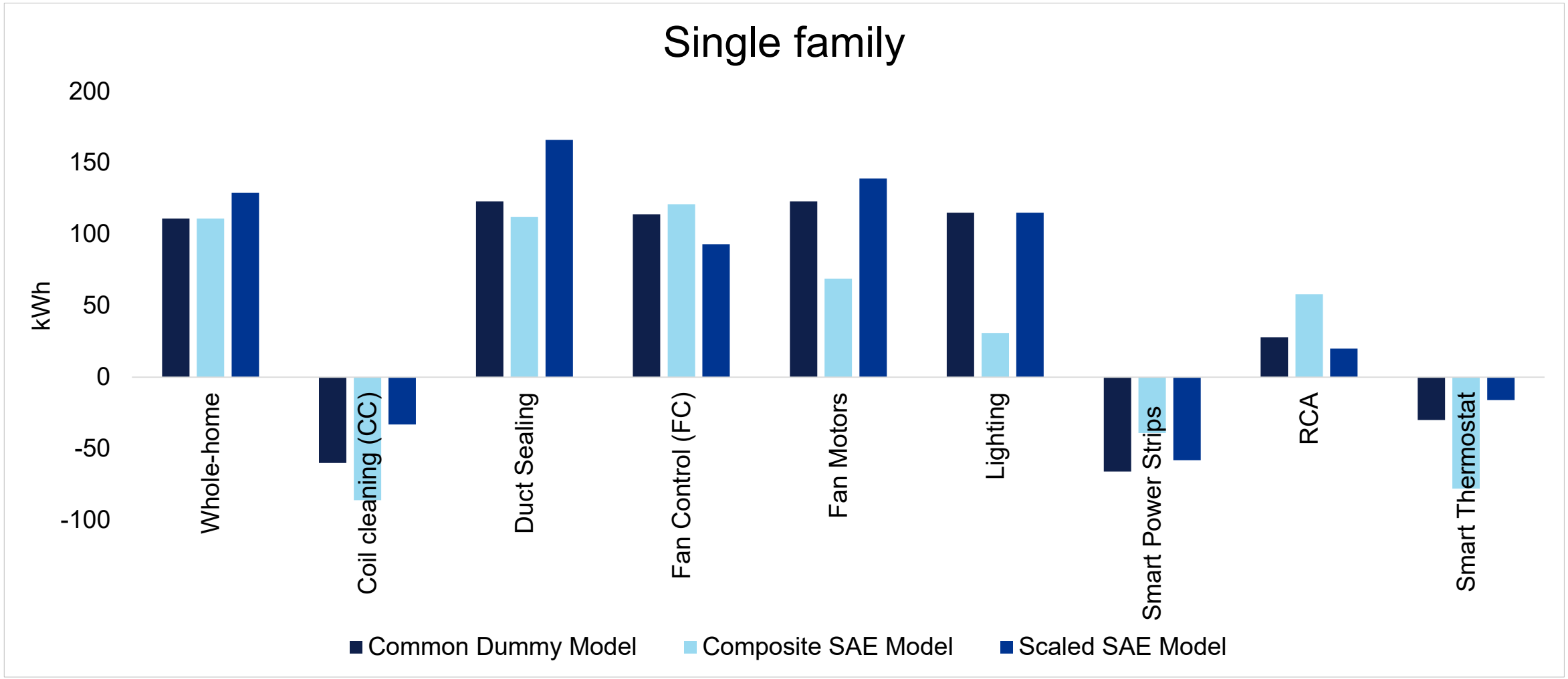
Results

Whole-home savings



Measure savings – full models



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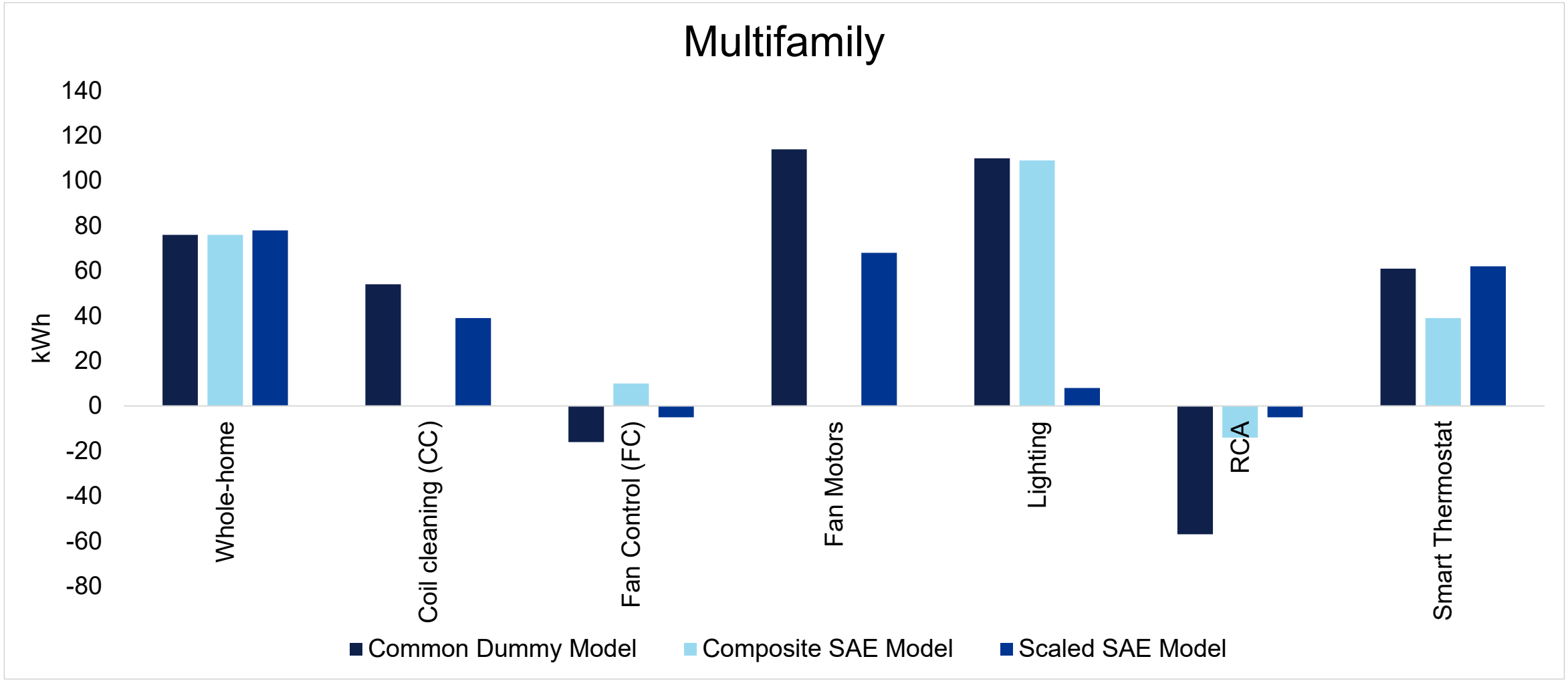
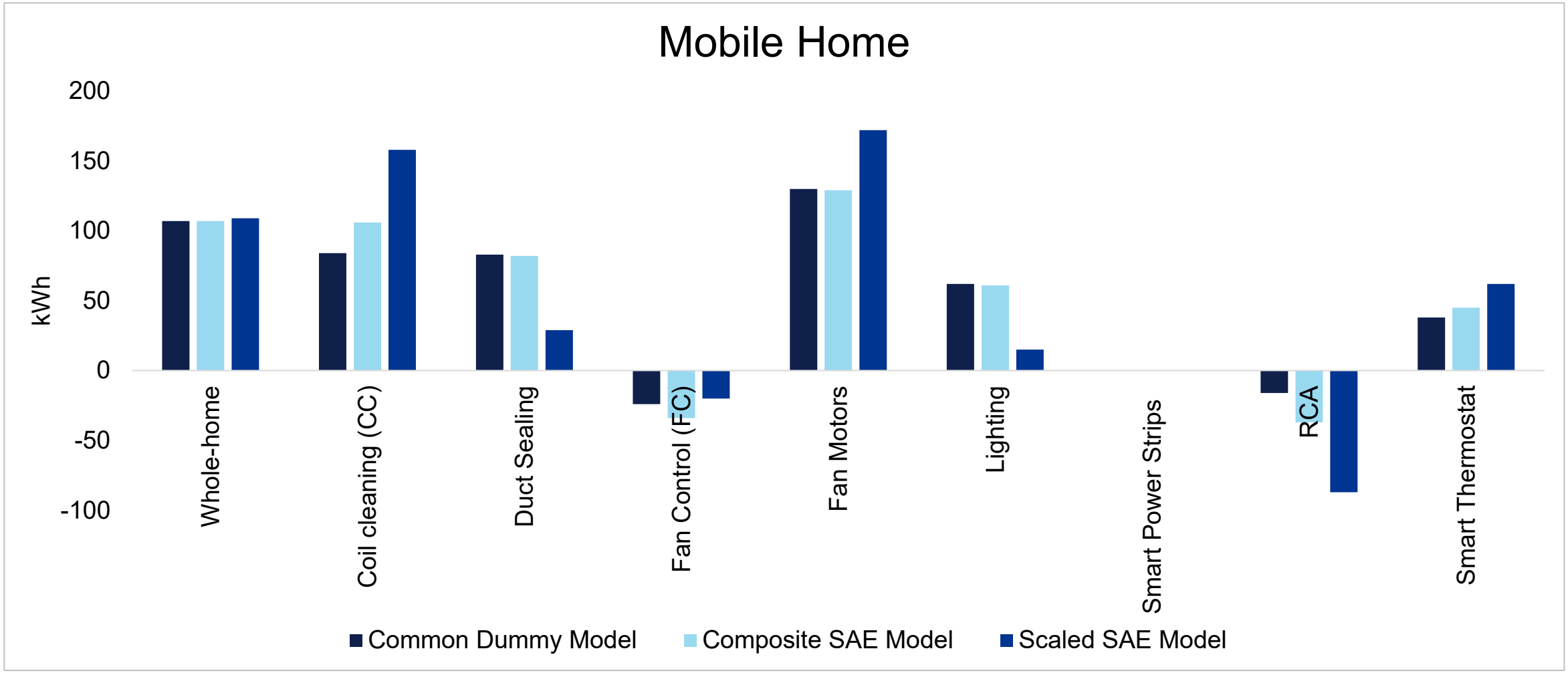


Measure savings – full models



Measure savings – full model

Mostly consistent savings across models for a given measure and home type

Some savings estimates are statistically insignificant – plausible

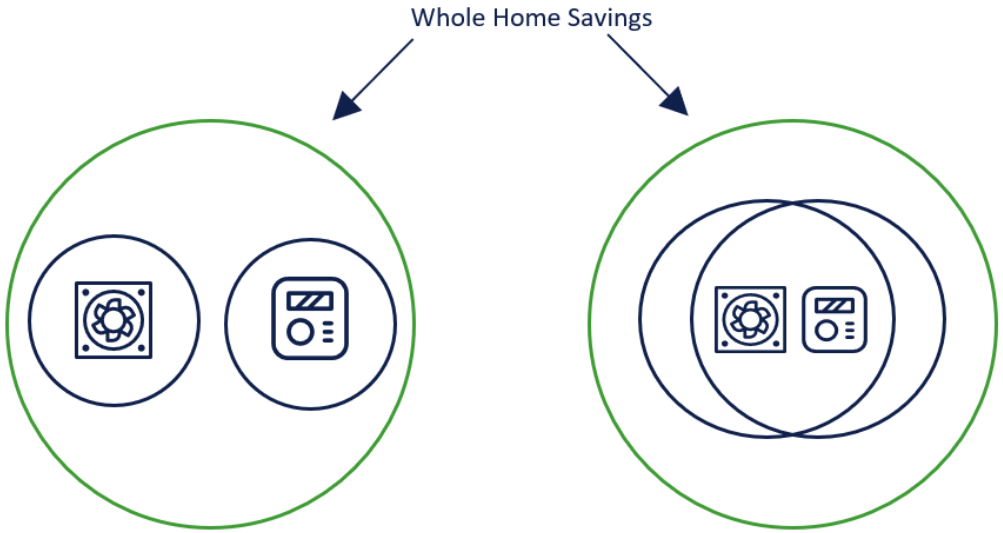
Some savings estimates are negative – implausible

Negative savings estimates indicate inability to isolate effects (correlated variables)

A priori information and scale (consumption level) do not fully overcome limitations of the simple model

Measure savings - full model

- Reasons for ill-determined measure savings estimates
  - Absence of (significant) savings due to “take-back”
  - Interactive effects between measures
  - Competing functions (e.g., SCTs and fan controls)
  - Significant overlap in installations making it difficult to identify separate effects of measures (figure on the right illustrates this)



Measure overlaps – single family

Significant overlap among some measures, for example:

SCTs overlap with fan controls in 69% of SF homes, with RCA in 73% of SF homes, with coil cleaning in 74% of SF homes

Coil cleaning overlaps with RCA in 76% of SF homes, with fan controls in 83% of SF homes

Overlaps prevent a statistical delineation of the marginal or individual measure savings contribution

Measure savings – reduced models

Given the challenges above, we bundled correlated measures and estimated reduced scaled SAE models

Variables	Scaled SAE Reduced Model 1			Scaled SAE Reduced Model 2			Scaled SAE Reduced Model 3		
	Mobile home	Multi-family	Single family	Mobile home	Multi-family	Single family	Mobile home	Multi-family	Single family
CC, RCA	66	37	-30						
CC, RCA, FC				14	-1	59			
CC, RCA, FC, SCT							40	26	49
Duct Sealing	20		158	37		171	33		161
FC		-6							
Fan Motors	159	67	155	153	86	148	149	53	155
Lighting, SPS	67	17	52	61	17	56	63	17	53
SCT, FC	9		78						
SCT		62		62	62	-17			

Beige-shaded values represent statistically significant results

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Disaggregating measure savings

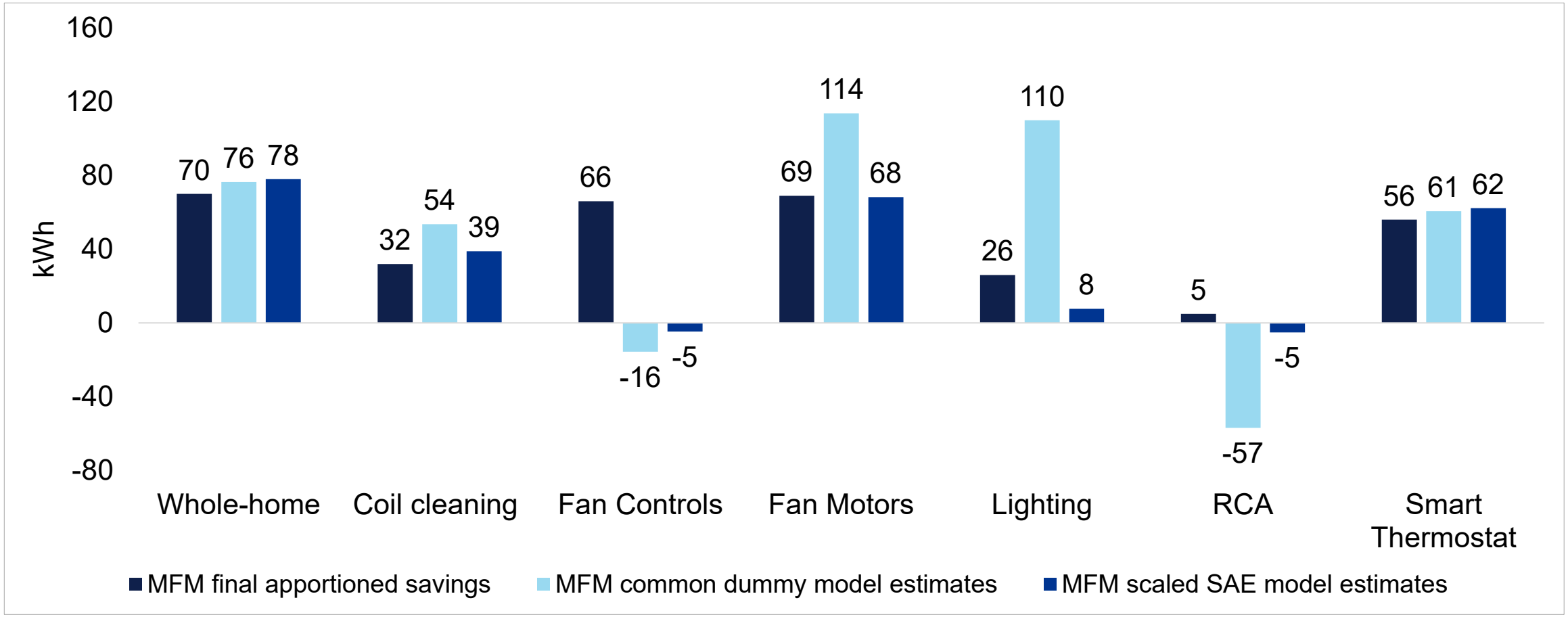
Given the limitations noted, we estimated whole-home savings and disaggregated these into measures savings using the engineering measure savings estimates

For each participant, we used the measure-level proportion of the total engineering savings to disaggregate to measure level savings

For example, if the total estimated savings for a household were 100 kWh and a smart thermostat made up 50% of the total engineering savings, the estimated savings for the smart thermostat would be 50 kWh (100 kWh x .50).

Comparison of different measure savings

Comparison of measure savings estimates based on different approaches including savings apportioned using engineering savings proportions are presented for MF installations below



Conclusions

- Getting separate realization rates by measure has always been a challenge
- Our efforts suggest that it could be useful to combine either similar or highly overlapping measures prior to estimating measure-specific savings
- Our approach avoids nonsensical measure-level estimates from high overlap among measures
- It uses regression to determine program-level realization rate, and the engineering estimates to allocate to individual measures

Thank you.

Lullit.Getachew@dnv.com

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