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ENERGY + WATER + EFFICIENCY

A Test of Commercially Available Products for Estimating End Uses from Smart Meter Data

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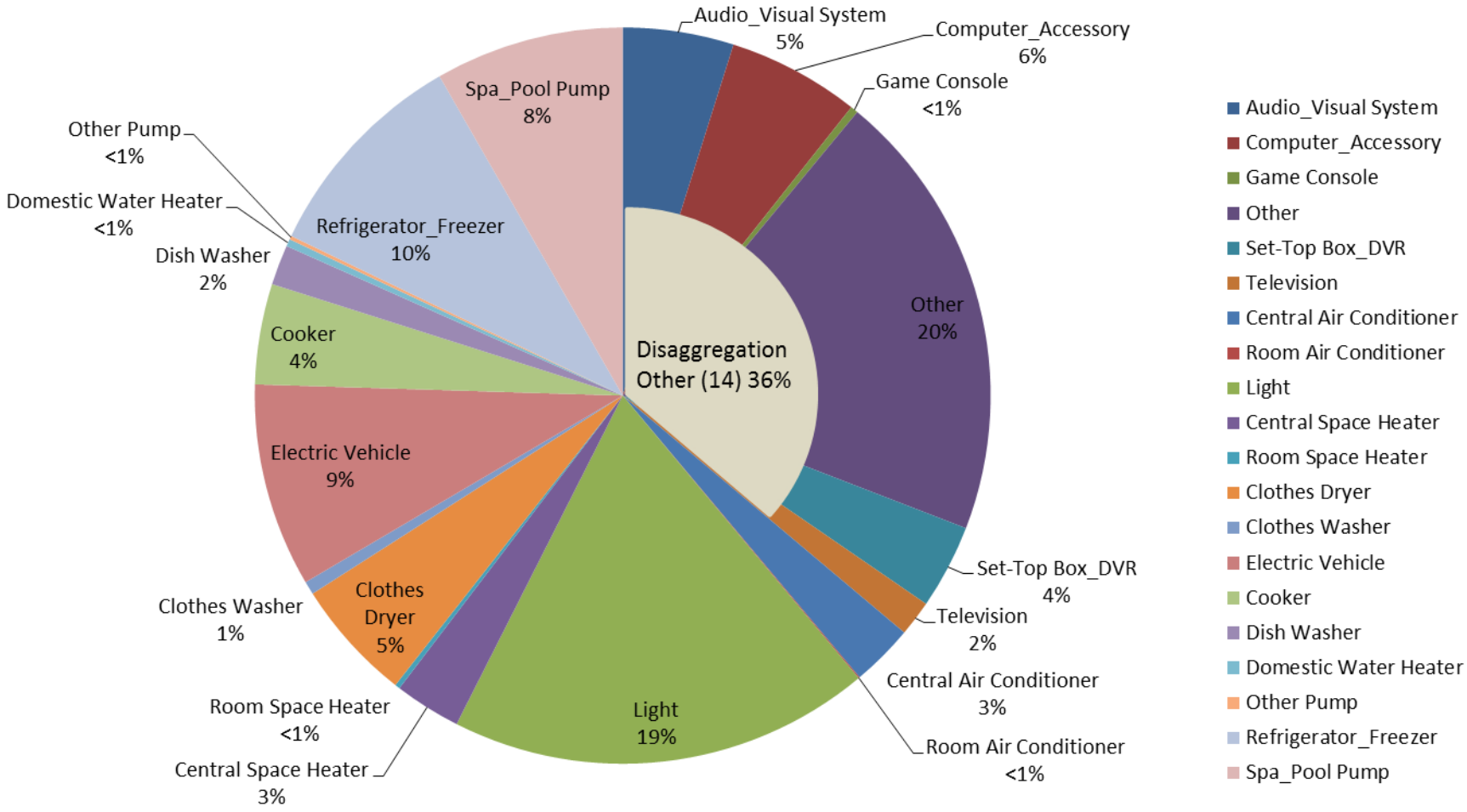
Objectives of the Test Bed

- Assist in the development of end use estimation tools
  - Online service offering to customers – help them in recognizing potential of energy efficiency within their homes
  - Potential advisory service to customers – help contractors identify high use areas and identify possible opportunities for efficiency upgrades
- Test accuracy of commercial software products that disaggregate Smart Meter data
- Other applications
  - Development of better tools for modeling the impact of energy efficiency measures

Measurement System

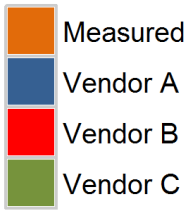
- One-minute data
  - PG&E modified their Smart Meters to record at this level
  - All active circuits – True power at breaker panel(s)
    - Used potential transducers and current transducers
  - Plug in appliances – Wireless plug load energy measurement
    - Used to separate out different end uses on a single circuit
- Wireless data collection
  - Data all sent to hub wirelessly and collected over cellular networks
  - Virtual channels – Addition and subtraction of measurements to create an end use channel equation
  - End use virtual channels compared to vendor estimates at an hourly level
- Integration of end use measurements with Vendor supplied hourly end use estimates

Total Electric Consumption All Sites (Dec-Apr)

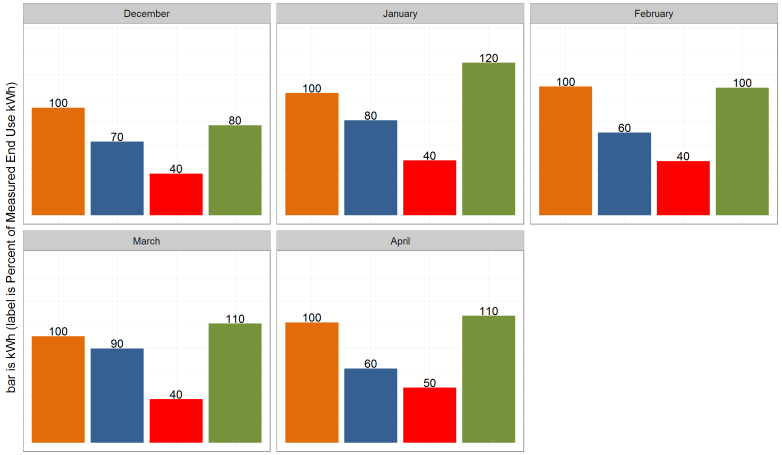


Percent of Measured Use by End Use

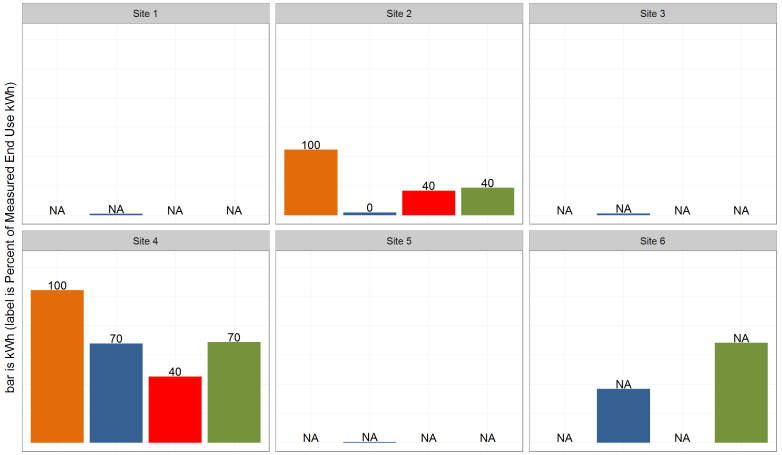
Accuracy by Month and Site



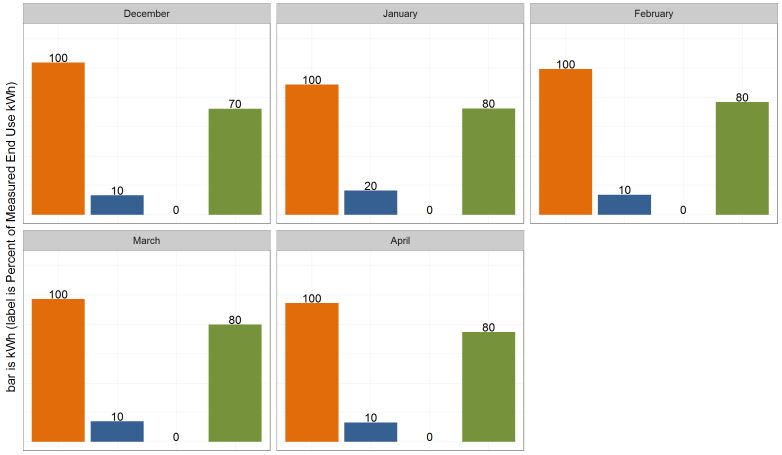
Pool Pump by Month



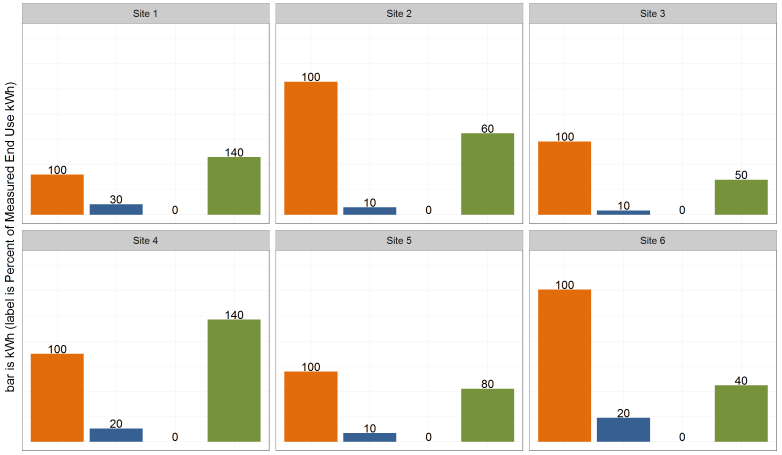
Pool Pump by Site



Lighting by Month



Lighting by Site



Conclusions

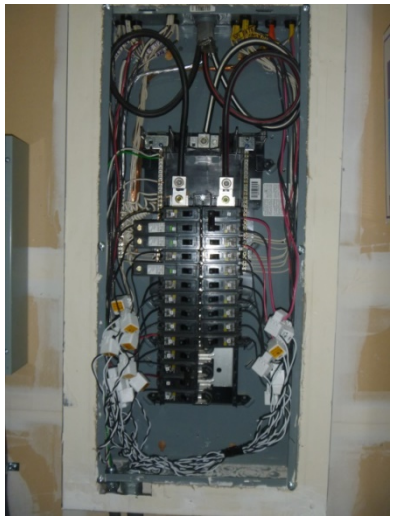
- None of the vendors were able to consistently identify all the end uses
- Some vendor estimates that were accurate over the whole test period, we not accurate for individual months or sites
- End uses with multiple device types (e.g. cooker) proved difficult for most vendors
- No clear winner. Who is best would depends on the criteria, e.g. no false positives, matching large energy uses, number of end uses reported
- All of the vendors have a lot of room for improvement

Acknowledgements

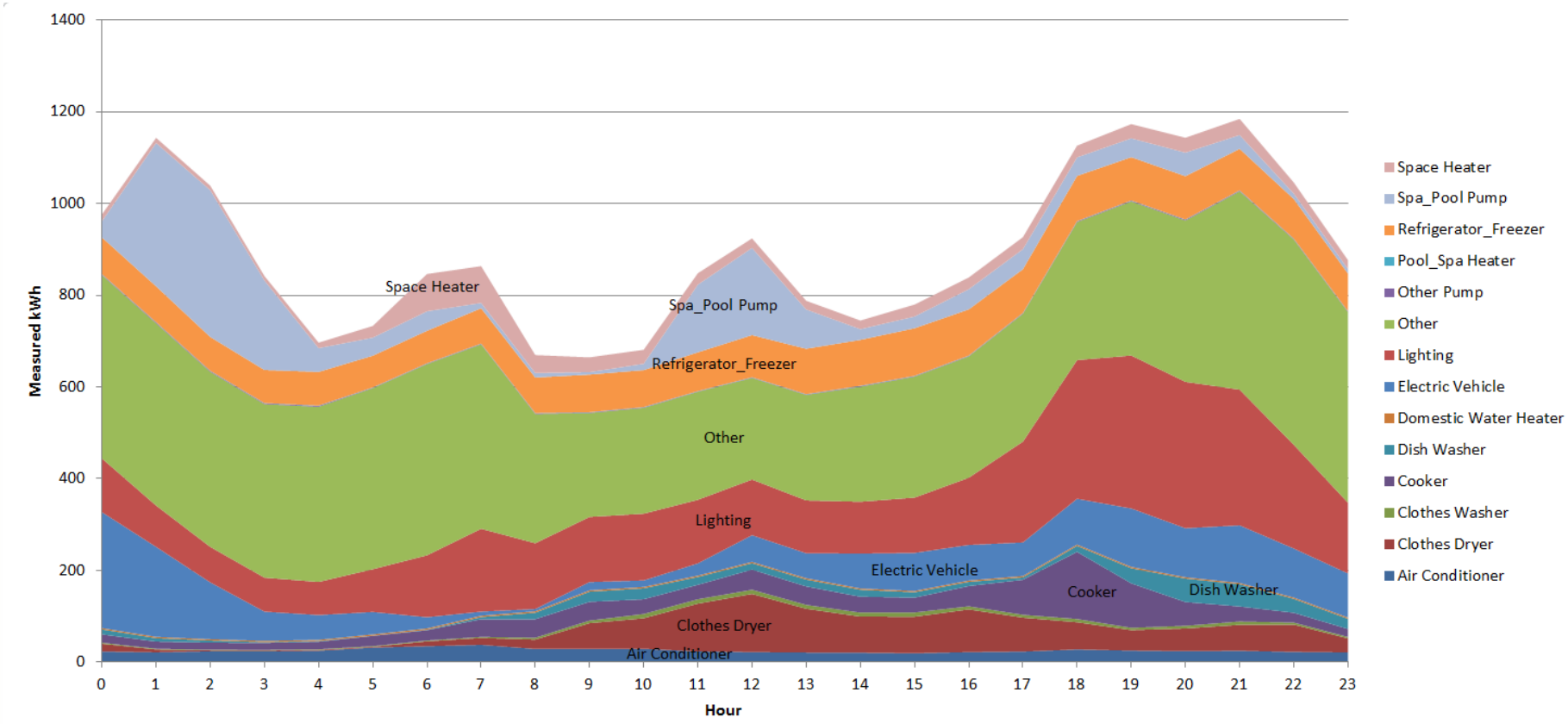
- We could not have done this without
  - Unwavering cooperation of all the homeowners
  - Determination of PG&E to get real data
  - Cooperation of the Vendors
  - Skills and inventiveness of our plumbers and electricians
- We appreciate all the work that everyone did to make this study possible

Supplemental Slides

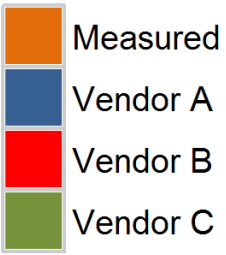
Installation



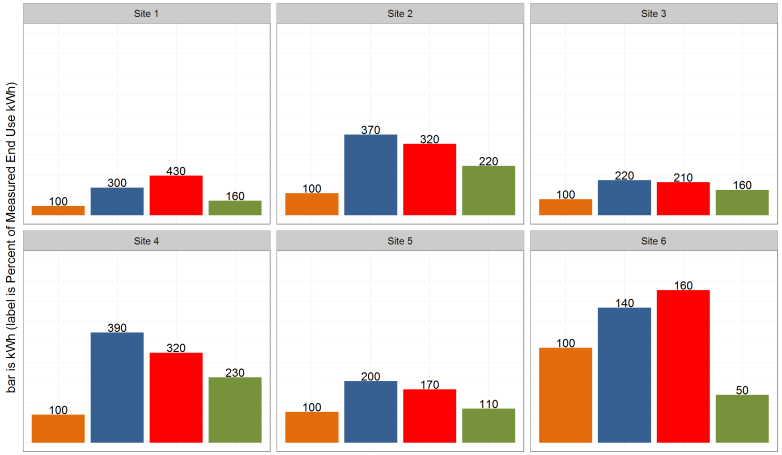
Hourly End Use Profile - All Sites (Dec-Apr)



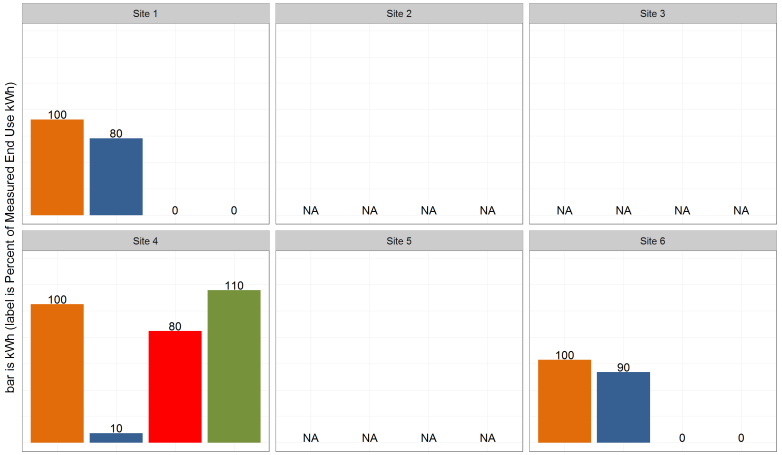
Other Site Level Results



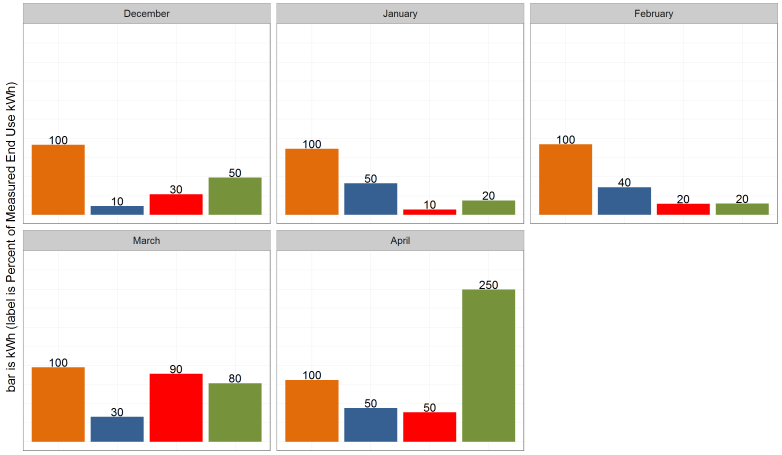
Other - Site



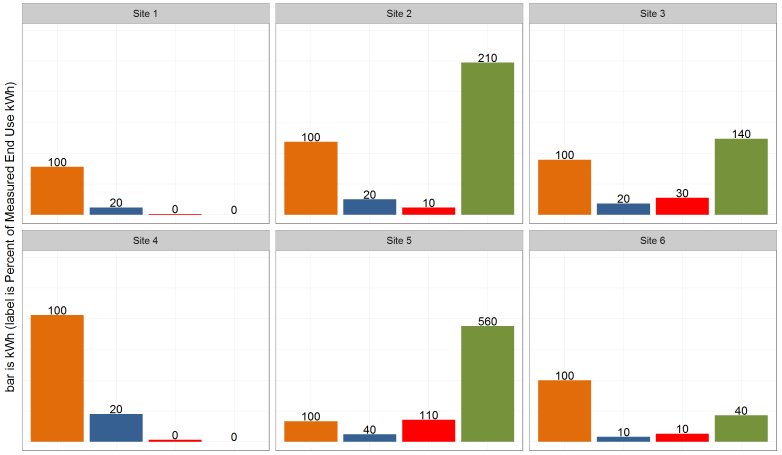
Electric Vehicle - Site



Air Conditioner - Monthly



Cooker - Site



Physical Monitoring Points

End Use #	End Use	Circuit Transducer (CT)	Gas	Plug	Grand Total
14	Audio/Visual System			31	31
2	Central Air Conditioner	15		2	17
1	Central Space heater	5	9	1	15
8	Clothes dryer	11	1		12
9	Clothes washer	4		2	6
14	Computer/Accessory	1		43	44
7	Cooker	23	5	7	35
10	Dish washer	4		2	6
11	Electric Vehicle	6		1	7
14	Game Console			8	8
5	Light	60		5	65
14	Other	26		73	99
6	Refrigerator/Freezer	6		7	13
2	Room Air Conditioner	1		1	2
1	Room Space Heater	1	5	2	8
14	Set-top box/DVR			11	11
14	Television			11	11
NA	Meter Total	12			12
3	Domestic Water Heater	1	7	1	9
13	Other Pump	1		2	3
12	Spa/Pool Pump	4			4
4	Pool / SPA Heater	1	1		2
	Grand Total	**182**	**28**	**210**	**420**

Home Characteristics – Electric

Site ID	13	21	27	32	40	45
City	Redwood City	El Macero	Crockett	Orinda	Union City	Lafayette
CEC Climate Zone	San Francisco	Stockton	Stockton	Stockton	San Francisco	Stockton
Floor Area	2,200	3,000	2,100	2,600	2,400	2,600
Year Built	1999	1972	1984	1937	2007	1950
Occupants - Adults	2	2	2	2	5	2
Occupants - Children	-	1	-	-	-	1
# Refrigerators (of all sizes)	1	1	1	1	2	4
Cooktop / Stove - Electric	-	1	1	-	-	-
Oven - Electric	1	1	1	1	1	2
Microwave / Convection Oven	1	2	2	1	1	1
Dishwasher	1	1	1	1	1	1
Clothes Washer	1	1	1	1	1	1
Clothes Dryer - Electric	1	1	1	1	1	1
Cooling - Central A/C	-	1	-	1	1	1
Cooling - Wall/Window Mounted	-	-	-	-	-	-
Water Heater - Electric	-	-	-	-	-	-
Pool / Spa Pump	-	1	-	1	-	-
Electric Vehicle Charging	1	-	-	1	-	-
# TV	2	1	1	1	2	2

Disaggregation (Red) and Detailed End Uses (Blue)

1 Space heater
- Room Space heater
- Central Space heater

2 Air conditioner
- Room Air Conditioner
- Central Air Conditioner

3 Domestic Water Heater

4 Pool / SPA Heater

5 Light

6 Refrigerator/Freezer

7 Cooker

8 Clothes dryer

9 Clothes washer

10 Dish washer

11 Electric vehicle

12 Spa/Pool Pump

13 Other Pump

14 Other
- Audio/Visual system
- Television
- Set-top box/DVR
- Game console
- Computer/Accessory
- Other

Virtual Measurements

- Add 2 phases for (240 v) devices
- Measurements by subtraction
  - Subtract one or more plug loads from a circuit total or power strip total to obtain a residual that is an end use, such as light
  - Same can be done for circuits that serve a subpanel
- Add measurements to form end uses
  - Detailed end uses
  - Disaggregation target end uses
- Add all circuits and compare to electrical mains to detect missing use.