Planning to Save Energy: How Information Format Affects Accuracy

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Abstract

This study examines how presenting energy information in different formats (kWh, %, USD) affects planning accuracy. Across two experiments, the kWh format generally led to better accuracy, while the USD format consistently led to the worst performance. These findings highlight the importance of effective information presentation to promote energy conservation.

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Introduction

Literature Review

Energy poverty continues to be a pervasive issue in the United States Memmott et al. (2021) . This challenge partly arises from difficulties in converting information across numerical formats, impeding the development of precise energy reduction plans Reimer et al. (2015). Prior research by Canfield et al. (2017) demonstrated that presenting energy information in tabular formats enhances comprehension relative to graphs.

Hypotheses

Building on these findings and informed by prior work showing that frequencies (like absolute units in kWh) are easier to comprehend and facilitate more precise decision-making compared to percentages, our study also utilizes a tabular format, but manipulates whether participants must consider energy information presented as absolute units (kWh), percentages (%), or monetary costs (USD). We hypothesize that presenting information in absolute units (kWh) will lead to more accurate household energy conservation planning.

Experiment 1

See Figure 1 for an example of a planning trial as it was seen by participants.

Methods

Participants

We implemented our task and surveys on Qualtrics, and recruited participants through Amazon Mechanical Turk. In Experiment 1, 252 participants were intially recruited, but data from 17 participants were corrupted due to experimenter error, leaving a final sample of 235 participants. Most participants (76%) reported using a calculator to complete the task.

Materials and Design

The study employed a mixed design with reference class (kWh, percentage, USD) as a between-subjects factor and state/family scenario as a within-subjects factor. Each participant completed energy reduction planning tasks for two different states, with state order counterbalanced across participants. The family scenarios featured four households in different climate regions: Texas (Smith family) and California (Adams family) representing warm climates, and Colorado (Wells family) and Massachusetts (Davis family) representing cold climates. We obtain average utility use from each state by CITE SOURCE FOR STATE AVGS?

Procedure

Participants received energy usage data for two hypothetical families and were tasked with creating action plans to meet specified reduction goals by allocating usage across five appliance categories: heating, cooling, water heating, refrigerator, and an other appliances (e.g., TV, lighting).

For each family scenario, the particpipants were shown a table containing the families utility usage from the prior year, alongside the state averages for each appliance category (both prior year usage and stage averages are always shown in kWh). For each scenario, participants were asked to create two possible action plans to achieve the target reduction in total household energy usage (see Figure 1). Depending on their reference class condition, the target reduction amount presented either in kilowatt-hours (kWh), as percentages of total household usage, or in U.S. dollars. In all conditions, the target reduction was equivalent to a 15% reduction in total household kWh.

The Wells family wants to reduce its household electricity use by 15% next year. Please complete two possible action plans that will help the Wells family achieve this goal. Please enter how many kWh should be used next year by each appliance and the total kWh each plan would use. **Enter only whole numbers.** Try to provide close estimations. You may use a calculator to complete the task.

Note: The Wells family used 9,233 more kWh than the average household in Colorado last year.

	Electricity Used Last Year by the Wells Family (kWh)	Average Electricity Used Last Year by Households in Colorado (kWh)	Action Plan 1	Action Plan 2
Cooling (Central A/C)	697	498		
Heating the Home	18,052	16,411		
Water Heating	11,667	5,832		
Refrigerator	1,370	1,142		
Other (Television, Lighting, Electronics, Washer/Dryer, etc.)	7,982	6,652		
Total kWh	39,768	30,535		

Figure 1: Example trial in the energy planning task. Participants are shown the prior year electricity use of a household, and are tasked with creating a plan for the next year that will meet the energy reduction goal. Study 1 manipulates the format of the reduction goal to be either a percentage (15% given as goal reduction), kilowatt hours (5965 kWh given), or USD ($656)

Additional data collected included:

- **Energy Literacy Quiz**: An 8-item questionnaire assessing participants' knowledge of energy consumption and conversion.
- **Calculator Usage Tracking**: Questions determined whether participants used a calculator, paper/pen, or other methods to complete the tasks.
- **Demographic Survey**: Collected information on gender, age, income, education, employment status, and state of residence.
- **Environmental Attitudes Survey**: Assessed participants' pro-environmental attitudes and perceived importance of energy conservation.

Results

refClass	Avg. % meeting goal	Avg. Deviation From Goal
kWh	0.38	0.15
Percentage	0.22	0.16
USD	0.10	0.19

For our primary analyses of participants' ability to create accurate energy-saving plans, we employed an accuracy level binning approach by categorizing responses into four distinct levels: Exact match, 0.01–2% error, 2.01–15% error, and Over 15% error.

Accuracy Level	kWh	Percentage	USD	Combined Groups %
Exact match	37.5%	22.1%	9.8%	22.6%
0.01-2% error	15.1%	17.6%	11.2%	14.4%
2.01-15% error	26.3%	41.9%	47.8%	38.9%

Accuracy Level	kWh	Percentage	USD	Combined Groups %
Over 15% error	21.2%	18.4%	31.2%	24.1%

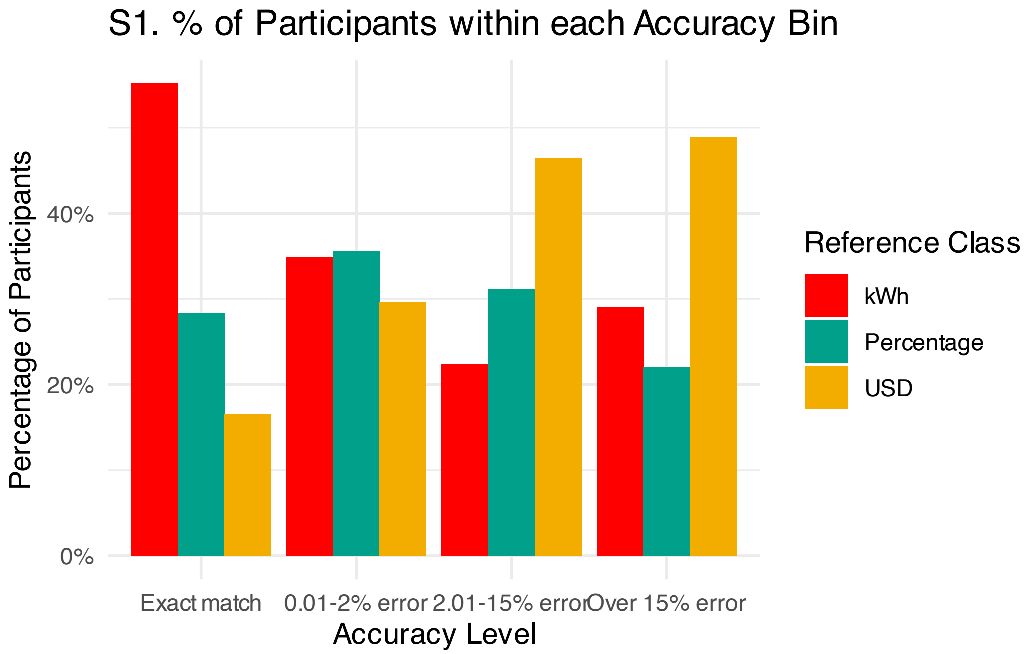
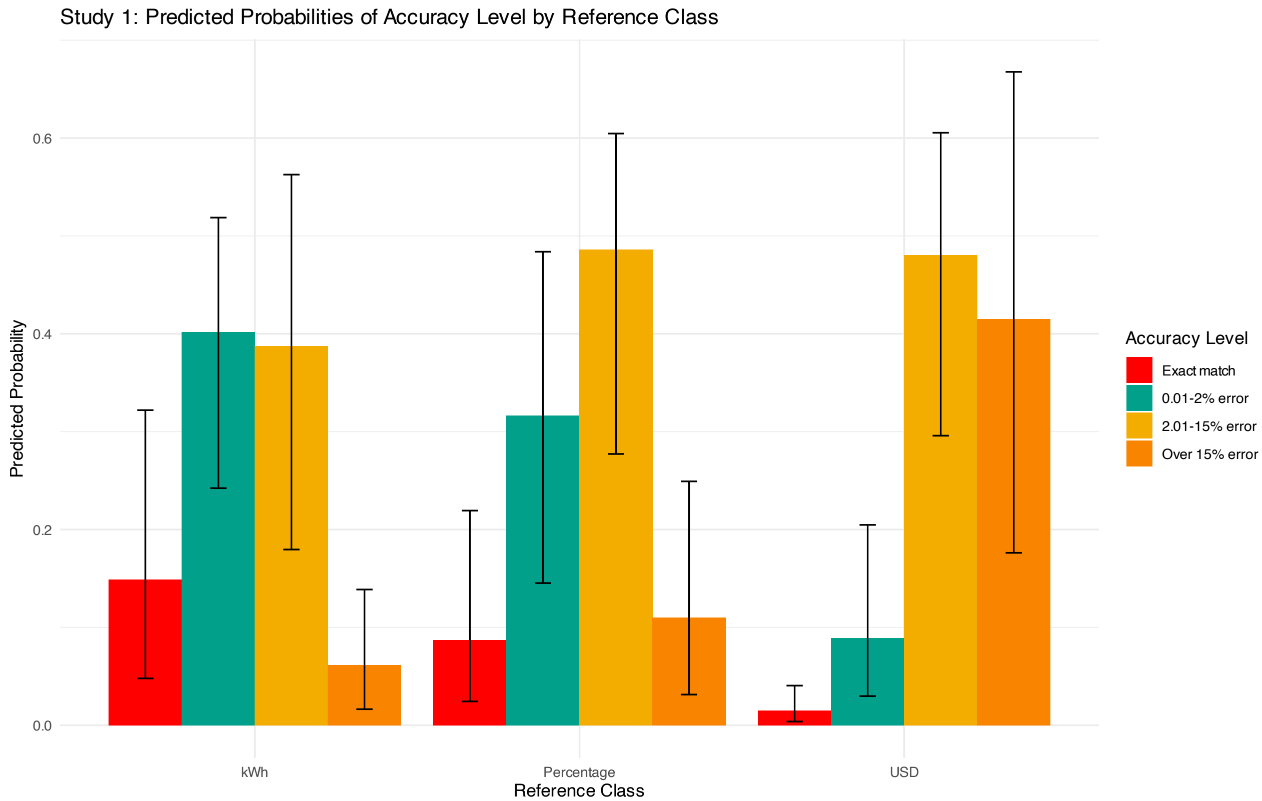
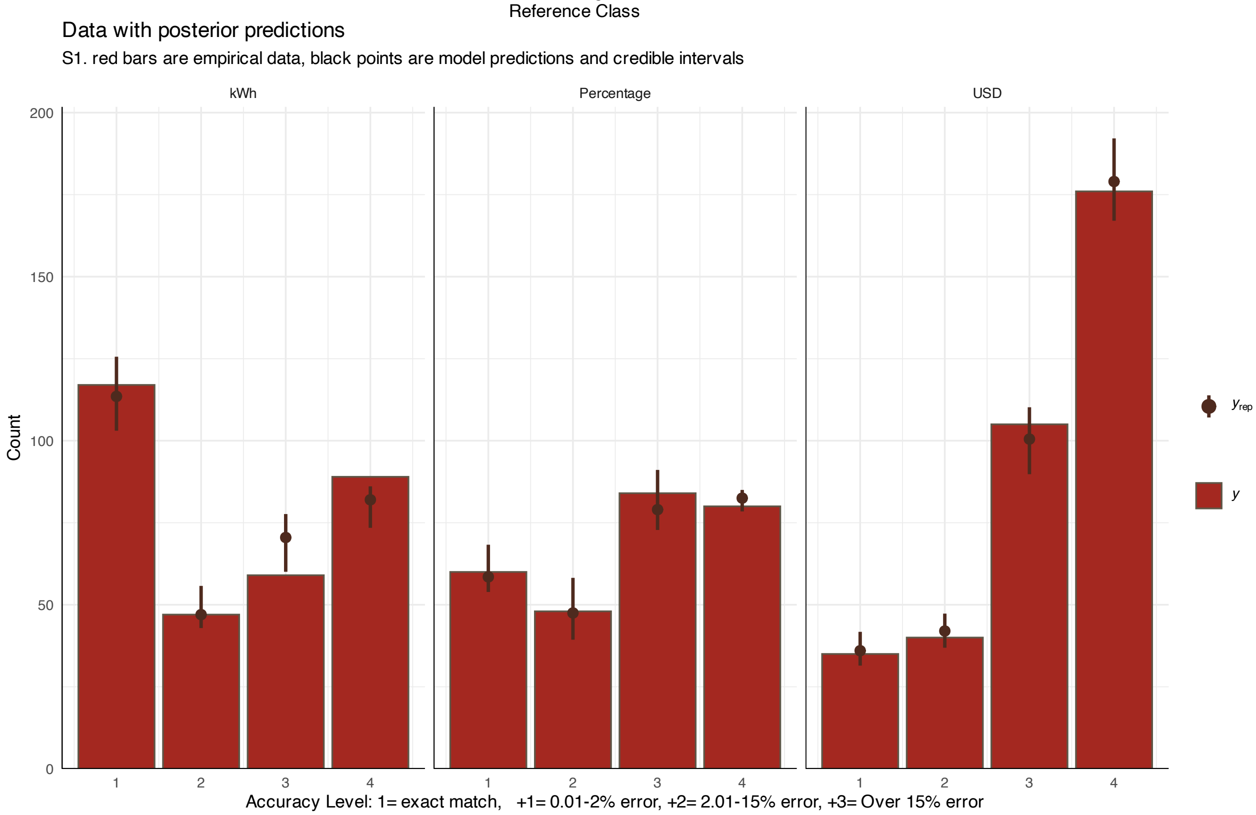


Figure 2

We analyzed planning accuracy using Bayesian ordinal regression. The dependent variable, plan error, was computed by binning the goal deviation into four ordered levels: exact match (0% error), minor deviations (0.01-2% error), moderate deviations (2.01-15% error), and major deviations (>15% error). For each comparison, we provide posterior odds ratios (OR) and their 95% CIs.

comparison	odds_ratio	ci_lower	ci_upper
Percentage vs kWh	2.27407	0.6177874	6.14783
USD vs kWh	14.09463	4.0796697	38.03732


Study 1: Predicted Probabilities of Accuracy Level by Reference Class
Predicted Probability
0.0
0.2
0.4
0.6
kWh
Percentage
USD
Reference Class
Accuracy Level
Exact match
0.01-2% error
2.01-15% error
Over 15% error


Data with posterior predictions
S1. red bars are empirical data, black points are model predictions and credible intervals
kWh
Percentage
USD
Count
0
50
100
150
200
1
2
3
4
Accuracy Level: 1= exact match, +1= 0.01-2% error, +2= 2.01-15% error, +3= Over 15% error
y_{rep}
y

List of 1

```
 $ legend.background: list()
  ..- attr(*, "class")= chr [1:2] "element_blank" "element"
 - attr(*, "class")= chr [1:2] "theme" "gg"
 - attr(*, "complete")= logi FALSE
 - attr(*, "validate")= logi TRUE
```

Experiment 2

Methods

The experimental procedures in study 2 are quite similar to those in study 1, but we also included a rounding manipulation (rounded vs. not rounded), and a manipulation of the goal (10% reduction vs. 15% rediction). We recruited 206 participants from Amazon Mechanical Turk, but data from from 10 participants were corrupted due to experimenter error, leaving a final sample of 196 participants.

Note that reference class remains a between-subjects variable, while percent goal, rounding, and state are within-subjects variables. In study 2, the new design is a 4 state temperature (2 warm vs. 2 cold states) X 2 task goal (10% vs. 15%) X 2 last year's usage for the family and the state average (exact vs. rounded numbers) within X 3 task reference class (USD vs. Percentage vs. kWh) between.

Results

refClass	Avg. % meeting goal	Avg. Deviation From Goal
kWh	0.44	0.13

refClass	Avg. % meeting goal	Avg. Deviation From Goal
Percentage	0.27	0.16
USD	0.18	0.17

Accuracy Level	kWh	Percentage	USD	Combined Groups %
Exact match	43.5%	26.8%	18.5%	30.2%
0.01-2% error	8%	13.8%	9.1%	10.3%
2.01-15% error	21%	33.3%	38.4%	30.5%
Over 15% error	27.5%	26.1%	34.1%	29%

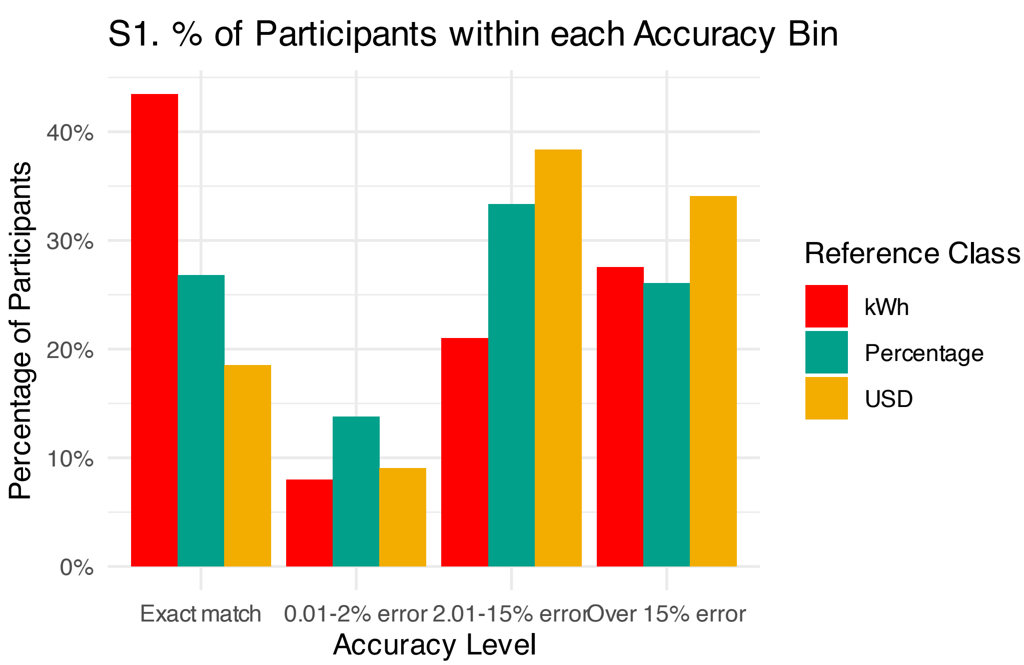


Figure 3

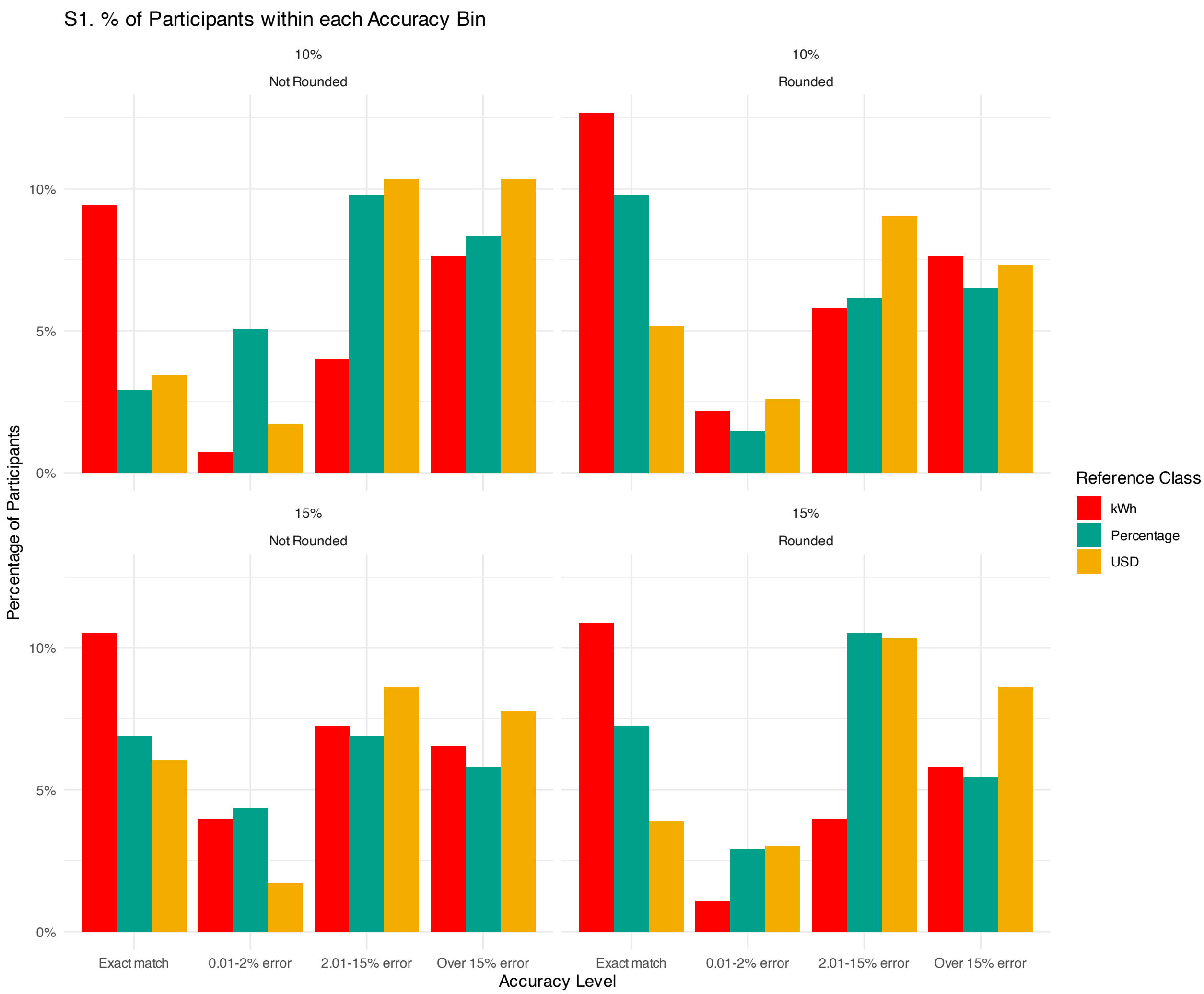

S1. % of Participants within each Accuracy Bin
10%
Not Rounded
10%
Rounded
15%
Not Rounded
15%
Rounded
Percentage of Participants
0%
5%
10%
Exact match
0.01-2% error
2.01-15% error
Over 15% error
Accuracy Level
Reference Class
kWh
Percentage
USD

Figure 4

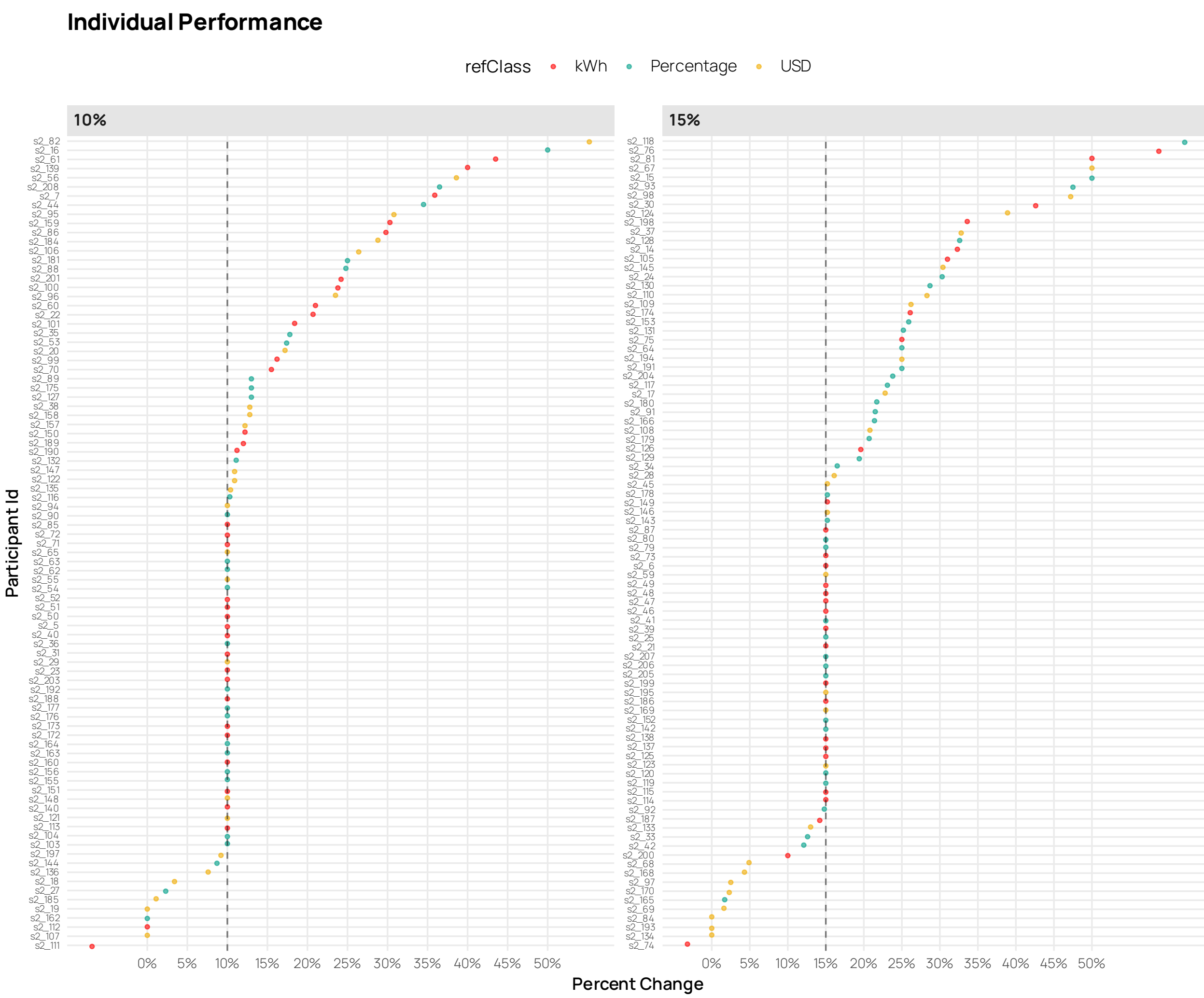

Individual Performance
refClass kWh Percentage USD
10%
15%
Participant Id
Percent Change
0% 5% 10% 15% 20% 25% 30% 35% 40% 45% 50%

Figure 5

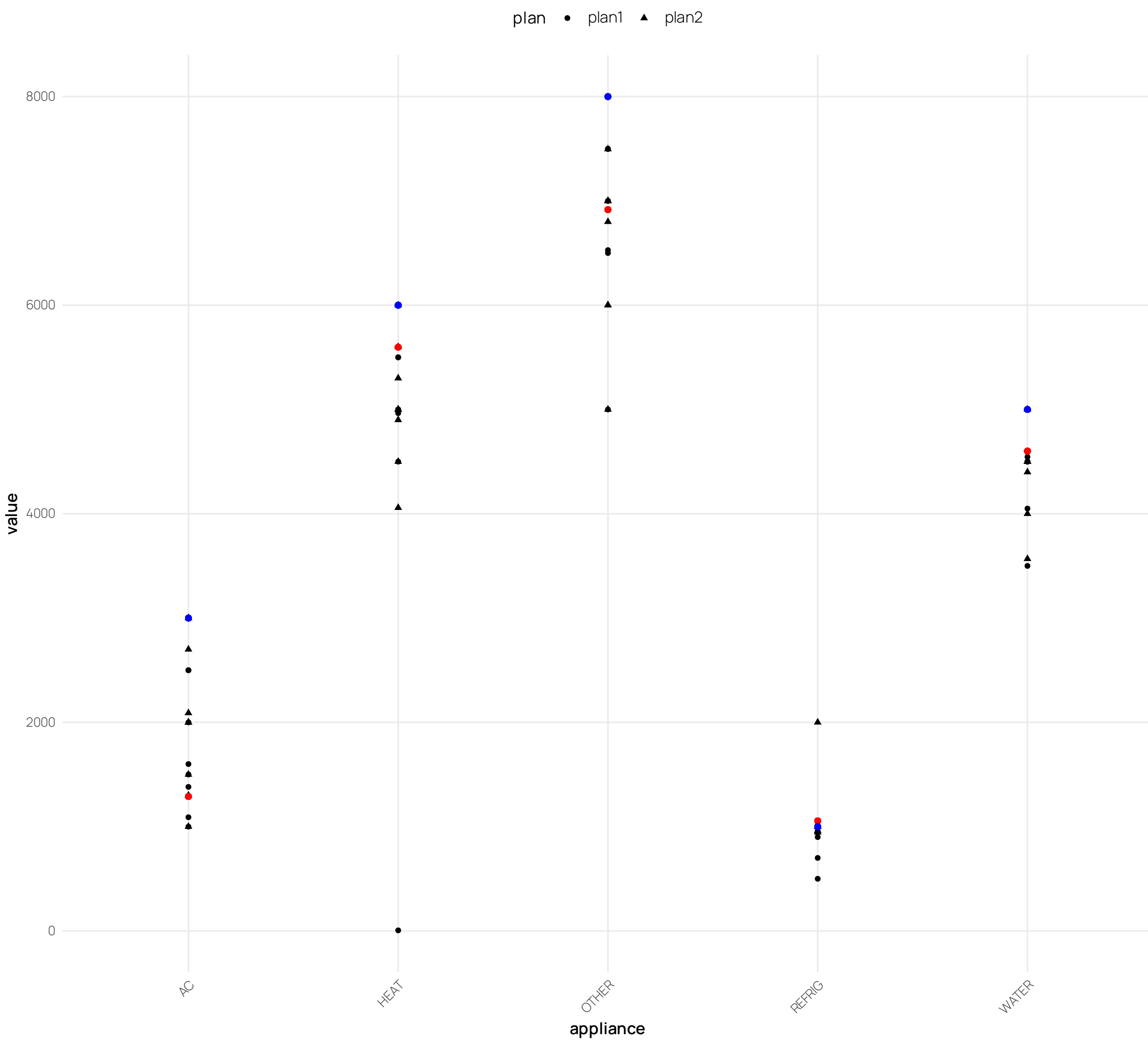
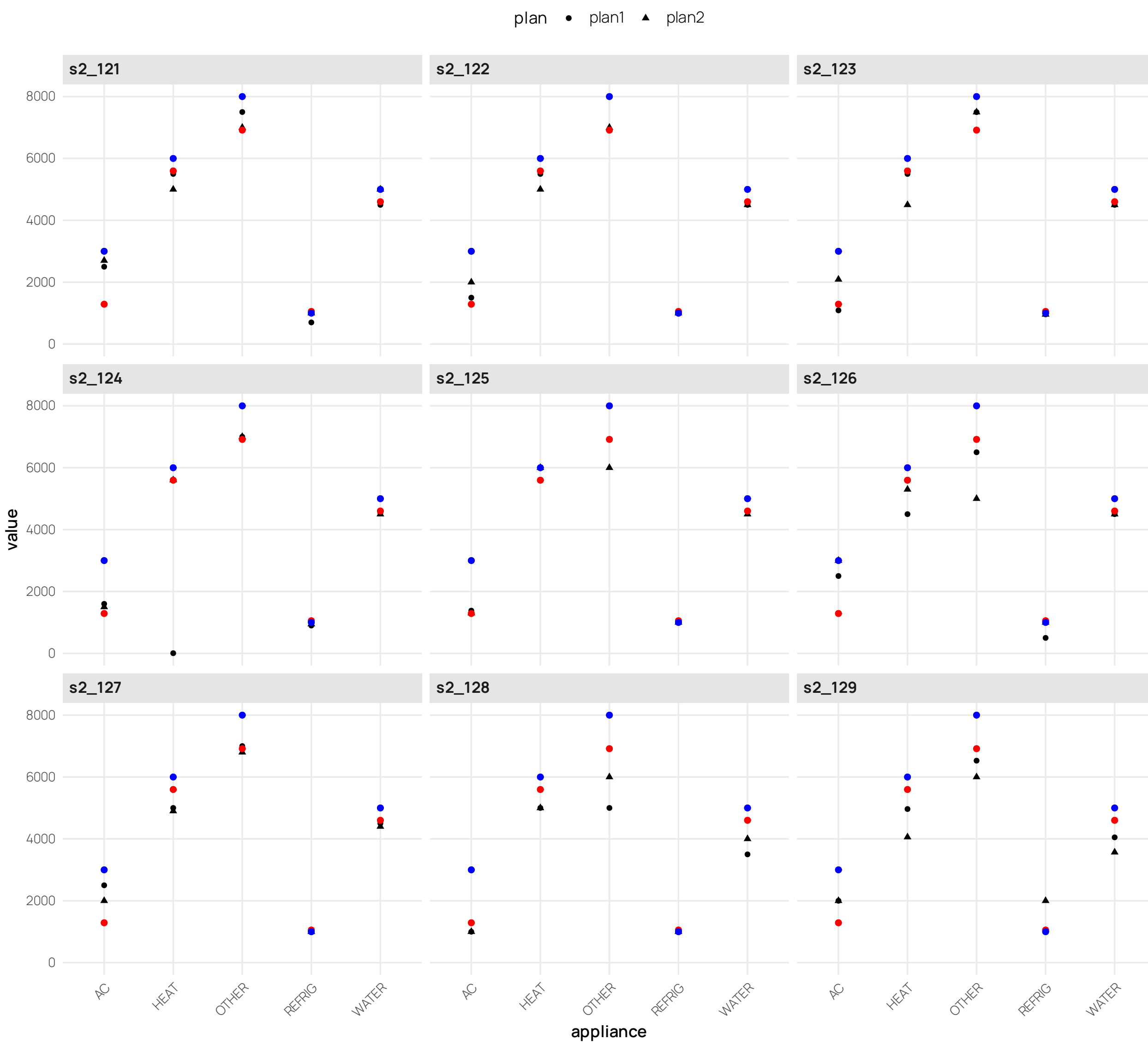

plan
plan1
plan2
value
8000
6000
4000
2000
0
AC
HEAT
OTHER
REFRIG
WATER
appliance

Figure 6



plan
plan1
plan2
s2_121
s2_122
s2_123
s2_124
s2_125
s2_126
s2_127
s2_128
s2_129
value
0
2000
4000
6000
8000
AC
HEAT
OTHER
REFRIG
WATER
appliance

Figure 7

Individual Differences

Discusion

References

Canfield, C., Bruine De Bruin, W., & Wong-Parodi, G. (2017). Perceptions of electricity-use communications: Effects of information, format, and individual differences. *Journal of Risk Research*, *20*(9), 1132–1153. https://doi.org/10.1080/13669877.2015.1121909

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