Estimating the Potential Impact of Advanced Rate Designs in Hawaii: MAIN BODY OF REPORT

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THE Brattle GROUP

Agenda

Background

- Existing Rate Designs in Hawaii

Proposed Rate Designs

- Summary of Proposed Rate Designs
- Rate Calculation Methodology
- Residential and Commercial Class Attributes
- Sample Charges for the Proposed Rate Designs

Simulated Rate Design Impacts

Utilities in Hawaii are Offering the Following Residential Rate Designs Today

Residential rates offered by **Hawaiian Electric Co (HECO)**, **Hawaii Electric Light Co (HELCO)**, and **Maui Electric Co (MECO)**:

Schedule	Rate Design	Description
R	Tiered fixed volumetric	Standard residential rate
TOU-R	TOU + Tiered fixed volumetric	Pilot TOU rate; closed to new participants since 2016
Residential TOU EV	TOU + Tiered fixed volumetric	Pilot TOU EV rate; closed to new participants since 2016
TOU-RI	TOU	Interim TOU rate; also applies to customers with EVs (required to have separate meter); capped at 5,000 customers

Residential rates offered by **Kauai Island Utility Cooperative (KIUC)**:

Schedule	Rate Design	Description
D	Fixed volumetric	Standard residential rate
TOU-S	TOU	Capped at 300 customers

Utilities in Hawaii are Offering the Following Commercial Rate Designs Today

Commercial rates offered by **Hawaiian Electric Co (HECO)**, **Hawaii Electric Light Co (HELCO)**, and **Maui Electric Co (MECO)**:

Schedule	Rate Design	Description
G	Flat volumetric	General Servive Non-Demand
J	Demand + flat volumetric	General Service Demand
TOU-G	TOU	Small Commercial Time-of-Use
TOU-J	Demand + TOU	Commercial Time-of-Use Service
TOU-P	Demand + TOU	Large Commercial Time-of-Use Service
EV-F / EV-U	TOU	Commercial Public Electric Vehicle Charging Pilots
E-Bus-J / E-Bus-P	Demand + TOU	Commercial Electric Bus Charging Facility Service Pilot

Commercial rates offered by **Kauai Island Utility Cooperative (KIUC)**:

Schedule	Rate Design	Description
G	Fixed volumetric	General Light and Power Service
J	Demand + flat volumetric	General Light and Power Service
L / P	Demand + tiered fixed volumetric	Large Power Primary (L) / Secondary (P) Service

Our Proposed Rate Designs

We propose the following **three rate designs** for the residential and commercial classes:

- **3-period TOU rate**
- **3-period TOU rate with demand charge**
- **3-period TOU rate with CPP charge**

The next part of this presentation focuses on (1) providing sample charges that follow the rate structures proposed above and (2) describing the methodololgy used to calculate those charges.

We designed the sample rates to be **revenue-neutral**, meaning that each rate is designed to collect the same total revenue as the existing residential rate, in absence of any customer price response.

Rate Determination Methodology

Step 1: We gathered some data on the billing determinants (e.g. monthly electricity consumption*, monthly electricity sales*, monthly peak demand) for a typical residential/commercial customer in Hawaii. This data is summarized in the next two slides.

Step 2: We calculated the current average residential/commercial monthly bills in Hawaii (based on 2018 *sales* data**).

Step 3: We calculated revenue-neutral rates that would collect the same total revenue as the existing residential/commercial rates.

For a more detailed description of the methodology, please refer to Appendix ("Detailed Rate Calculation Methdology").

Notes:

**Sales* describe the kWh of electricity sold to the customer by the utility. *Consumption* describes a customer's total electricity needs, which might include self-consumption of electricity generated through the customer's solar PV systems. This distinction is particularly important to highlight for Hawaii given the high levels of distributed solar PV penetration in the residential sector.

**Average monthly bills and the revenue-neutral rates were calculated based on *sales,* not consumption, as electric rates are set by the utility and determined based on their electricity sales. Consumption data was not used in the rate determination analysis, but was used later on in the price response analysis to estimate customers' response to the new rate structures.

Residential and Commercial Class Consumption Summary

Preliminary Results
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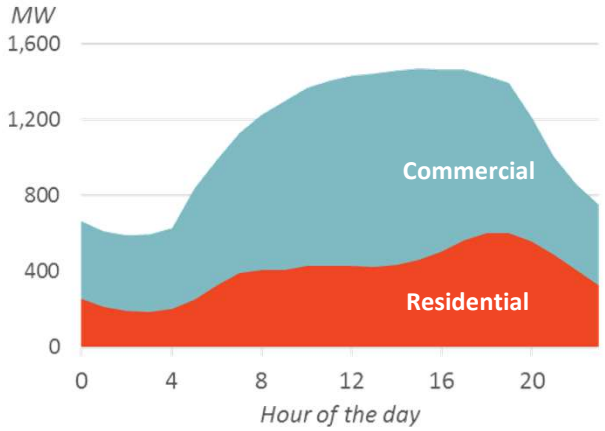
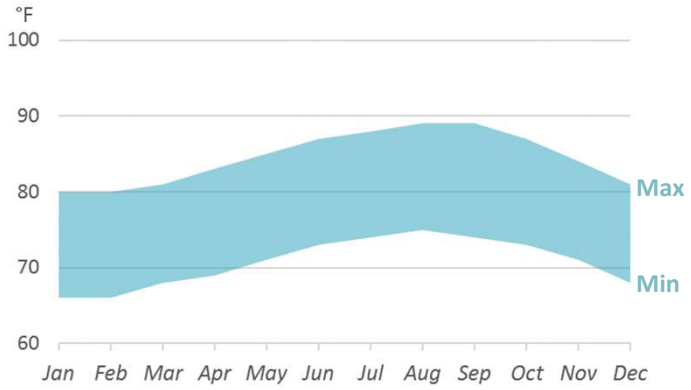
Residential and Commercial Average Annual Consumption Profiles *(Stacked)*

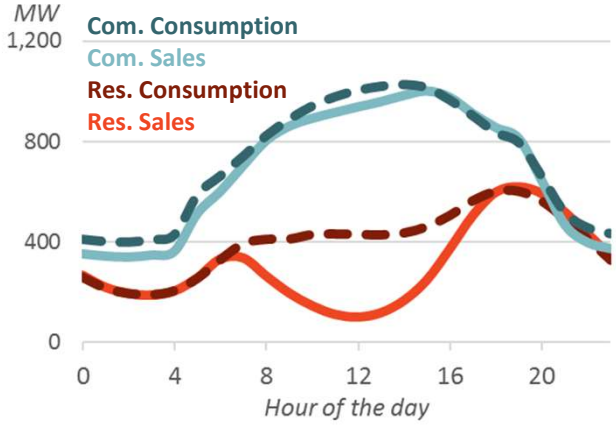


Avg. Temperature Range in Honolulu, HI



Source: https://www.rssweather.com/climate/Hawaii/Honolulu/

Average Annual Customer Consumption vs Sales Shapes

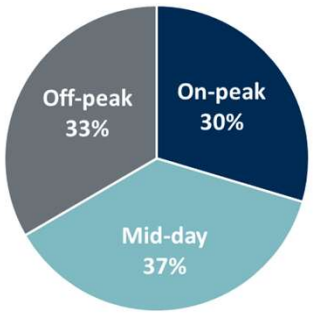


Source: Residential and commercial class consumption and sales shapes for 2018 provided by AEG.

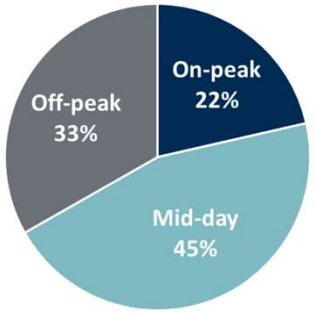
Average consumption by TOU period

Off-peak: 10pm-9am, mid-day: 9am-5pm, on-peak: 5pm-10pm

Residential



Commercial



Source: Residential and commercial class consumption profiles for 2018 provided by AEG. Note: Period definition based on HECO's TOU period definition for residential and commercial customers (same period definition for both classes).

Residential and Commercial Class Electricity Sales, Customers and Monthly Bills

Preliminary Results
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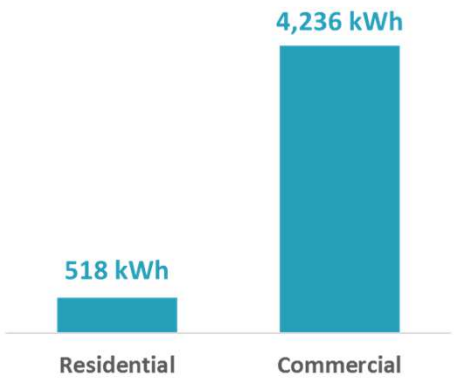
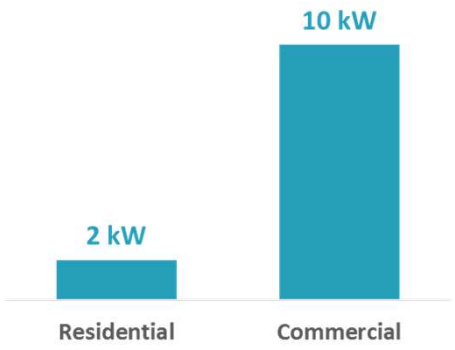
Avg. Monthly Sales per Customer in 2018

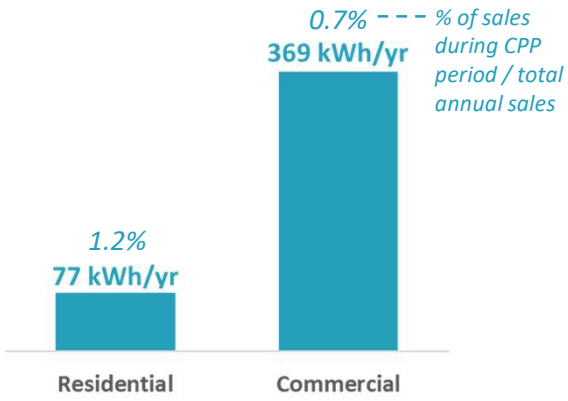


Avg. Monthly Peak Demand per Customer in 2018

(based on sales)



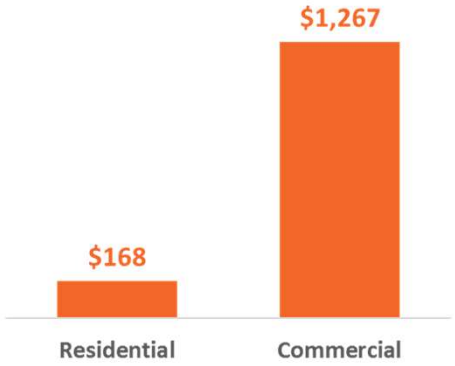
Avg. Sales during CPP Period* in 2018



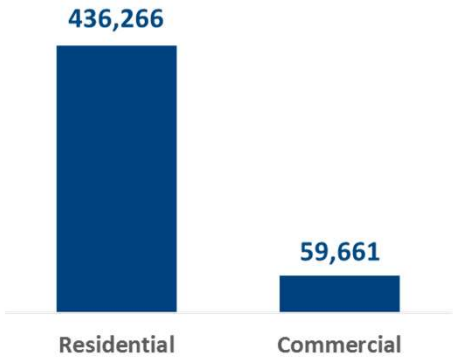
% of sales during CPP period / total annual sales

*CPP period = top 10 class sales days, 5 hour on-peak period (total of 50 hours/yr) .

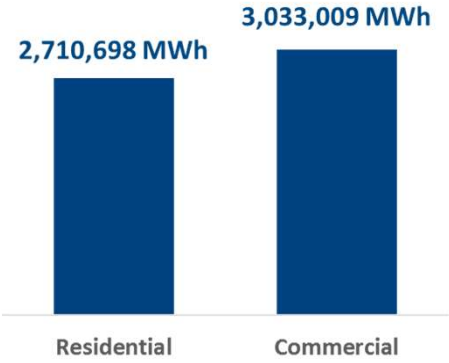
Avg. Monthly Bill per Customer in 2018



Total # of Customers by Class in 2018



Total Electricity Sales by Class in 2018



Source: EIA 2018 and sales profiles by class provided by AEG.

Rate Proposals for the Residential Class

The table below summarizes the proposed charges for three **revenue-neutral** rate designs for the residential class:

	Non-Fuel Energy Charges					Other Charges	
	TOU			Demand	CPP	Fixed Charge	Fuel + Other Charge
	On-peak	Mid-day	Off-peak	On-peak	On-peak		
Rate Design	5pm-10pm ¢/kWh	9am-5pm ¢/kWh	10pm-9am ¢/kWh	5pm-10pm $/kW	5pm-10pm* ¢/kWh	n.a. $/mo	All hours ¢/kWh
Existing Flat Vol.	11.83	11.83	11.83	n.a.	n.a.	11.50	18.42
Existing TOU	24.68	-4.48	15.85	n.a.	n.a.	11.50	18.42
TOU	25.00	1.00	5.00	n.a.	n.a.	11.50	18.42
TOU + Demand	19.85	1.00	5.00	6.33	n.a.	11.50	18.42
TOU + CPP	19.85	1.00	5.00	n.a.	174.28	11.50	18.42

Notes:

- *Only applies during the top 10 highest sales days of the year. During the on-peak period of those critical 10 days, the TOU on-peak charge gets replaced by the CPP on-peak charge.
- "Existing TOU" rate based on HECO Schedule TOU-RI and "Existing Flat Vol." rate based on HECO Schedule R. The non-fuel energy charges of the "Existing Flat Vol." rate are tiered: 10.6812¢/kWhr for the first 350 kWh, 11.8347¢/kWhr for the next 850 kWh, and 13.7121¢/kWhr for all kWh over 1,200 kWh.
- Monthly fixed charge of $11.50 based on HECO's Schedule TOU-RI and Schedule R fixed charge for single-phase service.
- Fuel charge of $0.18/kWh estimated based on the difference between the avg. residential all-in electricity price and the fixed and non-fuel energy charges.
- The demand and CPP charges collect 20% of the total revenue collected from on-peak hours in the "TOU" rate.

Rate Proposals for the Commercial Class

The table below summarizes the proposed charges for three **revenue-neutral** rate designs for the commercial class:

	Non-Fuel Energy Charges					Other Charges	
	TOU			Demand	CPP	Fixed Charge	Fuel + Other Charge
	On-peak	Mid-day	Off-peak	On-peak	On-peak		
	5pm-10pm	9am-5pm	10pm-9am	5pm-10pm	5pm-10pm	n.a.	All hours
Rate Design	¢/kWh	¢/kWh	¢/kWh	$/kW	¢/kWh	$/mo	¢/kWh
Existing Flat Vol.	9.60	9.60	9.60	n.a.	n.a.	35.00	18.42
Existing Demand	5.32	5.32	5.32	13.00	n.a.	66.00	18.42
Existing TOU	14.60	6.60	11.60	n.a.	n.a.	35.00	18.42
TOU	30.00	1.00	8.50	n.a.	n.a.	35.00	18.42
TOU + Demand	18.00	1.00	8.50	11.42	n.a.	35.00	18.42
TOU + CPP	24.00	1.00	8.50	n.a.	210.45	35.00	18.42

Notes:
- "Existing Flat Vol." based on HECO Schedule G, "Existing Demand" based on HECO Schedule J, and "Existing TOU" rate based on Schedule TOU-G for HECO.
- CPP on-peak charge is in addition to the TOU charge during that period.
- Monhtly fixed charges based on HECO's Schedule J charge for single-phase service.
- Assumed same fuel charge as for the residential class.
- The demand and CPP charges collect 40% and 20%, respectively, of the total revenue collected from on-peak hours in the "TOU" rate.

Estimating Consumption Impacts from Change in Rate Design

Once we calculated the sample charges for the proposed rate designs, we estimated customers' response to the change in rate structure.

In particular, we estimated customers' average change in:

- Overall consumption
- On-peak consumption
- Off-peak consumption
- Super-off-peak consumption

Finally, we estimated the % impact that the new rate designs would have on total residential consumption under three adoption scenarios: opt-in, opt-out and mandatory.

Estimating the Impact of New Rate Designs

To estimate the average customer's change in overall consumption in response to the new rate structures, we reviewed a wide range of TOU, demand, and CPP pilot studies, which are summarized in the next slide. No Hawaii-specific studies are available on the topic.

Then, we fed that parameters into the Price Response Impact Simulation Model (PRISM) to model the shift in energy consumption across periods.

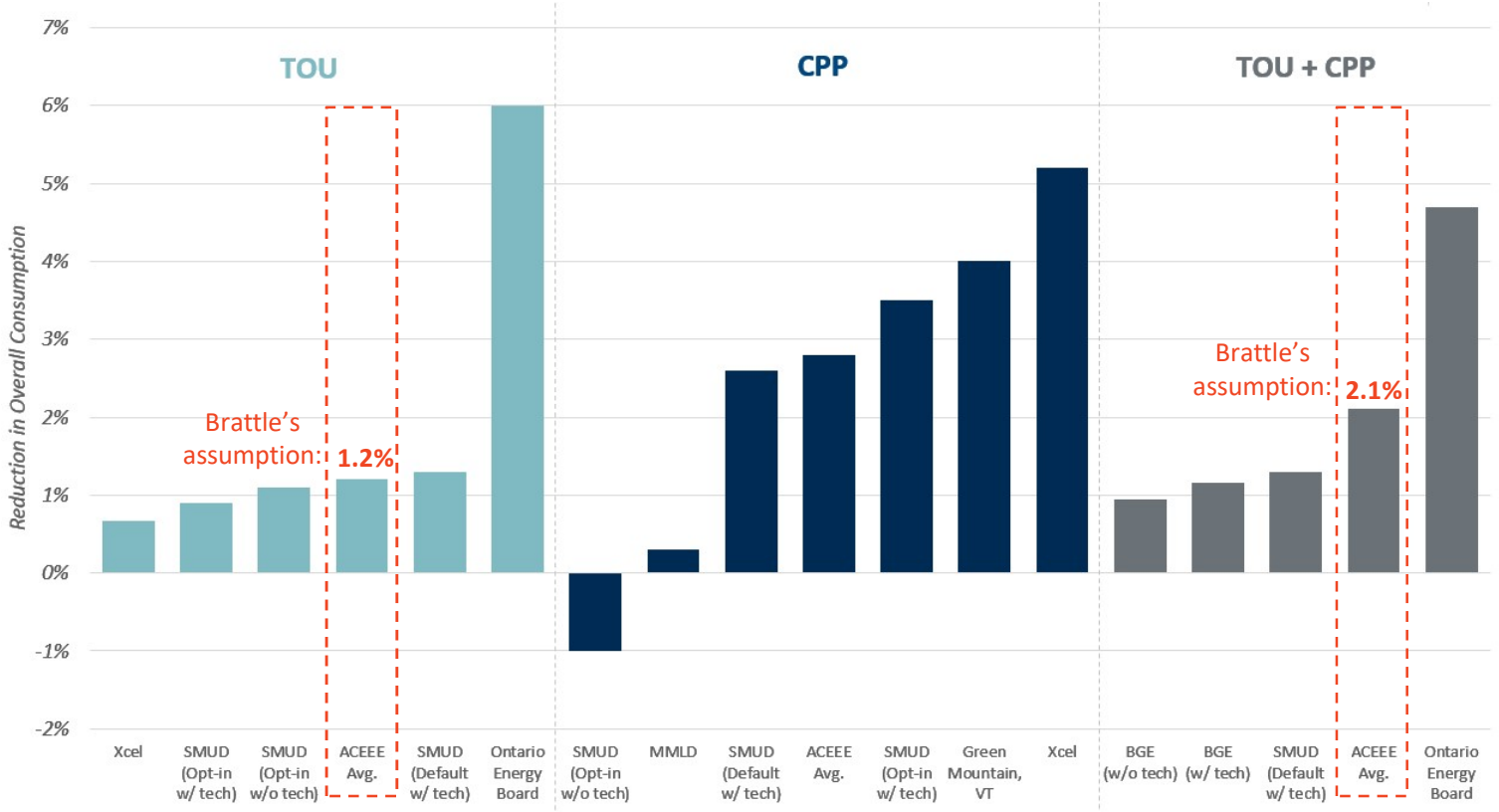
- The inputs to PRISM were:
  - Change in total energy consumption (based on literature review)
  - Average customer 8760 consumption profile (provided by AEG)
  - Proposed new rates (derived by Brattle)
  - Elasticities of substitution (based on literature review)
- Based on those inputs, PRISM outputs the change in energy consumption for each TOU period.

Notes: The equations used by PRISM can be found in the appendix.

Change in Total Energy Consumption
(Based on Literature Review)

The figure below summarizes a sample of studies reviewed that evaluate the change in overall consumption from TOU, CPP and demand rates.

Comparison across Studies of Reduction in Overall Consumption for Residential Customers



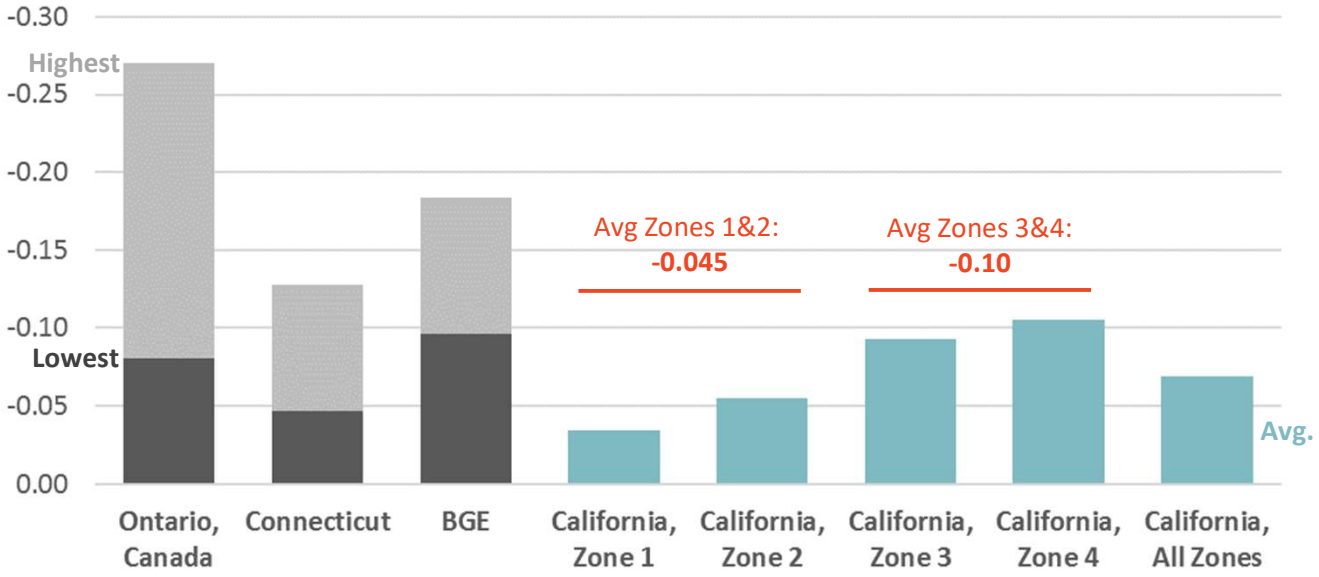
Sources: listed in Appendix. Note: We assumed the same reduction in overall consumption for the TOU and the TOU+Demand rates.

PRISM Inputs

The inputs to PRISM were:

- Change in total energy consumption (based on literature review)
- Average customer 8760 consumption shapes (provided by AEG)
- Proposed new rates (derived by Brattle)
- Elasticities of substitution (based on literature review, **summarized below**)
  - The elasticity of substitution measures a customer's willingness to shift consumption across periods in response to the price differences across those periods.

Comparison of Elasticities of Substitution Across Residential Rate Design Pilots



We based our elasticity parameters on the results from a study in California, given the similarity in climate to Hawaii compared to other regions in the US. We tested two elasticities values: the averages from the two mild climate zones in California (Zone 1 and Zone 2) and from the two hot climates zones (Zone 3 and Zone 4).

Sources: listed in Appendix.

Summary of Average % Consumption Impact per Customer

Period	Consumption *kWh/yr* [A]	Three-Period TOU **Estimated Impact** *%* [B]	Three-Period TOU Estimated Usage *kWh/yr* [C]	Three-Period TOU + Demand Charge **Estimated Impact** *%* [D]	Three-Period TOU + Demand Charge Estimated Usage *kWh/yr* [E]	Three-Period TOU + CPP Charge **Estimated Impact** *%* [F]	Three-Period TOU + CPP Charge Estimated Usage *kWh/yr* [G]
Elasticity of Substitution = -0.045							
On-Peak	2,390	**-3.3%**	2,310	**-3.3%**	2,310	**-4.0%**	2,290
Off-Peak	2,690	**-0.7%**	2,670	**-0.7%**	2,670	**-1.8%**	2,640
Mid-Day *(Super-Off-Peak)*	2,990	**0.1%**	2,990	**0.1%**	2,990	**-1.1%**	2,960
CPP On-Peak	72	n.a.	n.a.	n.a.	n.a.	**-10.4%**	64
Peak Demand	n.a.	n.a.	n.a.	**-3.3%**	n.a.	n.a.	n.a.
All periods	**8,070**	**-1.2%**	7,970	**-1.2%**	7,970	**-2.1%**	7,900
Elasticity of Substitution = -0.10							
On-Peak	2,390	**-5.8%**	2,250	**-5.8%**	2,250	**-6.3%**	2,240
Off-Peak	2,690	**-0.2%**	2,690	**-0.2%**	2,690	**-1.4%**	2,650
Mid-Day *(Super-Off-Peak)*	2,990	**1.6%**	3,040	**1.6%**	3,040	**0.3%**	3,000
CPP On-Peak	72	n.a.	n.a.	n.a.	n.a.	**-19.7%**	58
Peak Demand	n.a.	n.a.	n.a.	**-5.8%**	n.a.	n.a.	n.a.
All periods	**8,070**	**-1.2%**	7,970	**-1.2%**	7,970	**-2.1%**	7,900

Note: All consumption results (in kWh) are rounded to the nearest ten except for CPP On-Peak.

Summary of Average % Consumption Impact per Customer: Key Takeaways

- Using Hawaii-specific residential consumption shapes and customer elasticities of substitution between -0.045 and -0.010, we estimated that residential customers would on average reduce **consumption** during the **on-peak period** by **3.3%-5.8%,** from **2,390** kWh/yr to **2,250-2,310** kWh/yr under a **TOU rate** design, assuming an on-peak/off-peak ratio of 2. **Overall energy consumption** would be reduced by an average of **1.2%**, from **8,070** kWh/yr to **7,970** kWh/yr.

- The change in overall and on-peak consumption by switching to a **TOU rate with a demand charge** (assuming revenue neutrality) would be expected to be similar to that of the simple TOU rate on average. In addition, we would also expect customers to reduce their **peak demand** by **3.3%-5.8%**, from **1.8 kW** to **1.70-1.75 kW**.

- Under a revenue neutral **TOU+CPP rate**, we estimate that **on-peak consumption** would decrease by **4.0%-6.3%** on average, from **2,390** kWh/yr to **2,240-2,290** kWh/yr. In addition, consumption during the **on-peak hours** of the **critical peak days** would be reduced by **10%-20%**, from **72** kWh/yr to **58-64** kWh/yr.

Modeling Residential Class Consumption Impact under Three Adoption Scenarios

Once we modeled the average % consumption impact per customer, we estimated the aggregate impact of the proposed rate designs on consumption under three adoption scenarios: opt-in, opt-out, and mandatory.

Rate of adoption (%) under opt-in, opt-out and mandatory scenarios

Opt-in	20%
Opt-out	80%
Mandatory	100%

Residential Results

Estimated Residential Class Consumption Impact for **Opt-in** Scenario

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		Opt-in					
		TOU		TOU + Demand		TOU + CPP	
		Estimated Impact	Estimated Load	**Estimated Impact**	Estimated Load	**Estimated Impact**	Estimated Load
	Consumption	*%*	*GWh/yr*	*%*	*GWh/yr*	*%*	*GWh/yr*
Period	*GWh/yr*	[A]	[B]	[C]	[D]	[E]	[F]
Elasticity of Substitution = -0.045							
On-Peak	1,030	-0.7%	1,025	-0.7%	1,025	-0.8%	1,020
Off-Peak	1,160	-0.1%	1,160	-0.1%	1,160	-0.4%	1,155
Mid-Day *(Super-Off-Peak)*	1,290	0.0%	1,290	0.0%	1,290	-0.2%	1,285
CPP On-Peak	31	n.a.	n.a.	n.a.	n.a.	-2.1%	30
Peak Demand	n.a.	n.a.	n.a.	-0.7%	n.a.	n.a.	n.a.
All periods	**3,480**	**-0.2%**	**3,470**	**-0.2%**	**3,470**	**-0.4%**	**3,465**
Elasticity of Substitution = -0.10							
On-Peak	1,030	-1.2%	1,020	-1.2%	1,020	-1.3%	1,015
Off-Peak	1,160	0.0%	1,160	0.0%	1,160	-0.3%	1,155
Mid-Day *(Super-Off-Peak)*	1,290	0.3%	1,295	0.3%	1,295	0.1%	1,290
CPP On-Peak	31	n.a.	n.a.	n.a.	n.a.	-3.9%	30
Peak Demand	n.a.	n.a.	n.a.	-1.2%	n.a.	n.a.	n.a.
All periods	**3,480**	**-0.2%**	**3,470**	**-0.2%**	**3,470**	**-0.4%**	**3,465**

Note: All consumption results (in kWh) are rounded to the nearest five except for CPP On-Peak.

Estimated Residential Class Consumption Impact for **Opt-out** Scenario

		Opt-out					
		TOU		TOU + Demand		TOU + CPP	
Period	Consumption *GWh/yr*	**Estimated Impact *%*** [A]	Estimated Load *GWh/yr* [B]	**Estimated Impact *%*** [C]	Estimated Load *GWh/yr* [D]	**Estimated Impact *%*** [E]	Estimated Load *GWh/yr* [F]
Elasticity of Substitution = -0.045							
On-Peak	1,030	-2.6%	1,005	-2.6%	1,005	-3.2%	995
Off-Peak	1,160	-0.6%	1,155	-0.6%	1,155	-1.4%	1,145
Mid-Day *(Super-Off-Peak)*	1,290	0.0%	1,290	0.0%	1,290	-0.9%	1,280
CPP On-Peak	31	n.a.	n.a.	n.a.	n.a.	-8.4%	28
Peak Demand	n.a.	n.a.	n.a.	-2.6%	n.a.	n.a.	n.a.
All periods	**3,480**	**-1.0%**	**3,445**	**-1.0%**	**3,445**	**-1.7%**	**3,420**
Elasticity of Substitution = -0.10							
On-Peak	1,030	-4.7%	980	-4.7%	980	-5.0%	980
Off-Peak	1,160	-0.1%	1,160	-0.1%	1,160	-1.1%	1,145
Mid-Day *(Super-Off-Peak)*	1,290	1.3%	1,305	1.3%	1,305	0.2%	1,295
CPP On-Peak	31	n.a.	n.a.	n.a.	n.a.	-15.8%	26
Peak Demand	n.a.	n.a.	n.a.	-4.7%	n.a.	n.a.	n.a.
All periods	**3,480**	**-1.0%**	**3,445**	**-1.0%**	**3,445**	**-1.7%**	**3,420**

Note: All consumption results (in kWh) are rounded to the nearest five except for CPP On-Peak.

Residential Results

Estimated Residential Class Consumption Impact for **Mandatory** Scenario

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		Mandatory					
		TOU		TOU + Demand		TOU + CPP	
Period	Consumption *GWh/yr*	**Estimated Impact *%*** [A]	Estimated Load *GWh/yr* [B]	**Estimated Impact *%*** [C]	Estimated Load *GWh/yr* [D]	**Estimated Impact *%*** [E]	Estimated Load *GWh/yr* [F]
Elasticity of Substitution = -0.045							
On-Peak	1,030	-3.3%	995	-3.3%	995	-4.0%	990
Off-Peak	1,160	-0.7%	1,150	-0.7%	1,150	-1.8%	1,140
Mid-Day *(Super-Off-Peak)*	1,290	0.1%	1,290	0.1%	1,290	-1.1%	1,275
CPP On-Peak	31	n.a.	n.a.	n.a.	n.a.	-10.4%	28
Peak Demand	n.a.	n.a.	n.a.	-3.3%	n.a.	n.a.	n.a.
All periods	**3,480**	**-1.2%**	**3,440**	**-1.2%**	**3,440**	**-2.1%**	**3,405**
Elasticity of Substitution = -0.10							
On-Peak	1,030	-5.8%	970	-5.8%	970	-6.3%	965
Off-Peak	1,160	-0.2%	1,160	-0.2%	1,160	-1.4%	1,145
Mid-Day *(Super-Off-Peak)*	1,290	1.6%	1,310	1.6%	1,310	0.3%	1,295
CPP On-Peak	31	n.a.	n.a.	n.a.	n.a.	-19.7%	25
Peak Demand	n.a.	n.a.	n.a.	-5.8%	n.a.	n.a.	n.a.
All periods	**3,480**	**-1.2%**	**3,440**	**-1.2%**	**3,440**	**-2.1%**	**3,405**

Note: All consumption results (in kWh) are rounded to the nearest five except for CPP On-Peak.

Estimated Residential Class Consumption Impact: **Key Takeaways**

- Under the assumptions laid out in this presentation, we estimate that **residential consumption** during **on-peak hours** could be reduced on average by
  - **0.7%-1.3%** under **opt-in** rates, from **1,030** to **1,015-1,025** GWh/yr
  - **2.6%-5.0%** under **opt-out** rates, from **1,030** to **980-1,005** GWh/yr
  - **3.3%-6.3%** under mandatory rates, from **1,030** to **965-995** GWh/yr
- We estimate that **total residential consumption** could be reduced on average by
  - **0.2%-0.4%** under **opt-in** rates, from **3,480** to **3,465-3,470** GWh/yr
  - **1.0%-1.7%** under **opt-out** rates, from **3,480** to **3,420-3,445** GWh/yr
  - **1.2%-2.1%** under **mandatory rates**, from **3,480** to **3,405-3,440** GWh/yr.

Commercial Class Analysis

We used the same methodology for estimating the consumption impacts for the commercial class as for the residential class.

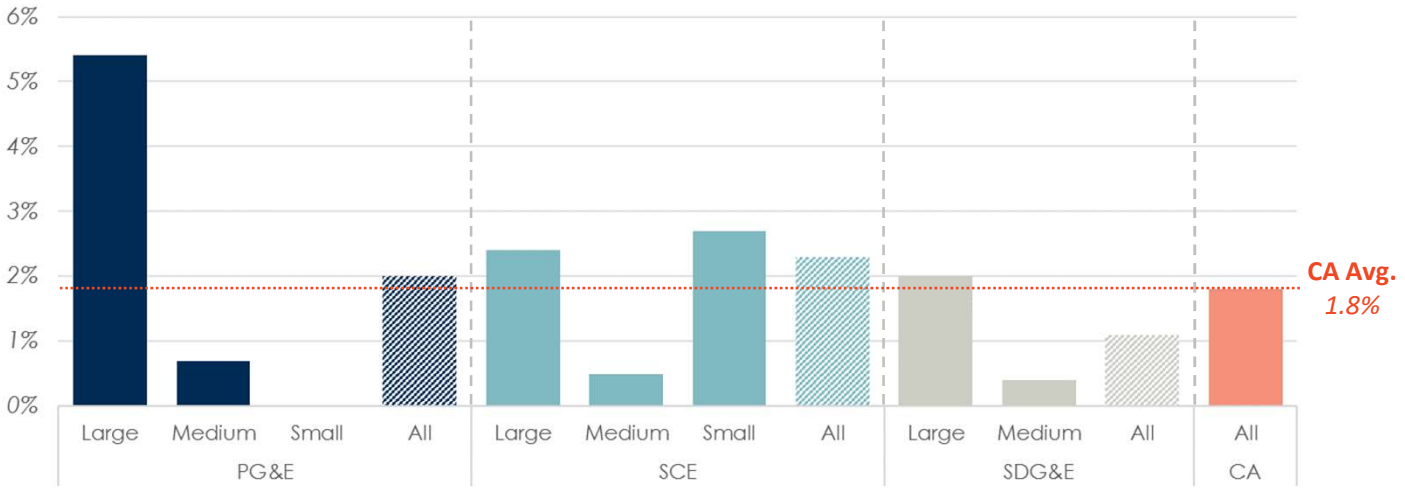
We used commercial consumption data (provided by AEG) and the proposed commercial rates presented earlier to estimate the commercial class consumption impacts.

Given the lack of information available about the possible range of customer elasticities for the commercial class, we have used the same change in total energy consumption and the same elasticities of substitution as for the residential analysis.

Commercial Class Consumption Impact Studies

- We reviewed a range of consumption impact studies for the commercial sector, including the CPP load impact study for non-residential customers in California (results summarized below).
- Overall, the consumption impact studies available for the commercial class are limited. As a result, we used PRISM to model the shift in consumption across periods based on the HI-specific commercial class consumption shapes and commercial rates, and assumed the same change in total energy consumption and the same elasticities of substitution for the commercial analysis as for the residential analysis.

% Consumption Impact Results for CPP Programs in 2018 in California



Source: Applied Energy Group, "2018 Statewide Load Impact Evaluation of California Non-Residential CPP Programs", April 2019.

Summary of Average % Consumption Impact per Customer

Period	Consumption *kWh/yr* [A]	Three-Period TOU **Estimated Impact** *%* [B]	Three-Period TOU Estimated Usage *kWh/yr* [C]	Three-Period TOU + Demand Charge **Estimated Impact** *%* [D]	Three-Period TOU + Demand Charge Estimated Usage *kWh/yr* [E]	Three-Period TOU + CPP Charge **Estimated Impact** *%* [F]	Three-Period TOU + CPP Charge Estimated Usage *kWh/yr* [G]
Elasticity of Substitution = -0.045							
On-Peak	11,500	**-4.0%**	11,030	**-4.0%**	11,030	**-4.5%**	10,990
Off-Peak	17,800	**-1.2%**	17,580	**-1.2%**	17,580	**-2.3%**	17,400
Mid-Day *(Super-Off-Peak)*	24,320	**0.2%**	24,360	**0.2%**	24,360	**-0.9%**	24,110
CPP On-Peak	377	n.a.	n.a.	n.a.	n.a.	**-11.6%**	334
Peak Demand	n.a.	n.a.	n.a.	**-4.0%**	n.a.	n.a.	n.a.
All periods	**53,620**	**-1.2%**	52,980	**-1.2%**	52,980	**-2.1%**	52,490
Elasticity of Substitution = -0.10							
On-Peak	11,500	**-7.4%**	10,640	**-7.4%**	10,640	**-7.6%**	10,630
Off-Peak	17,800	**-1.3%**	17,560	**-1.3%**	17,560	**-2.5%**	17,360
Mid-Day *(Super-Off-Peak)*	24,320	**1.8%**	24,770	**1.8%**	24,770	**0.6%**	24,480
CPP On-Peak	377	n.a.	n.a.	n.a.	n.a.	**-21.9%**	294
Peak Demand	n.a.	n.a.	n.a.	**-7.4%**	n.a.	n.a.	n.a.
All periods	**53,620**	**-1.2%**	52,980	**-1.2%**	52,980	**-2.1%**	52,490

Note: All consumption results (in kWh) are rounded to the nearest ten except for CPP On-Peak.

Summary of Average % Consumption Impact per Customer: Key Takeaways

- Using Hawaii-specific commercial consumption profiles and customer elasticities of substitution between -0.045 and -0.010, we estimated that commercial customers would **reduce consumption during the on-peak period by 4.0%-7.3**% under a **TOU rate structure**, from **11,500** kWh/yr to **10,640-11,030** kWh/yr, assuming an on-peak/off-peak ratio of 2. **Overall energy consumption would be reduced** by an average of **1.2%**, from **53,620** kWh/yr to **52,980** kWh/yr.

- The change in overall and on-peak consumption by switching to a **TOU rate with a demand charge** (assuming revenue neutrality) would be expected to be similar to that of the simple TOU rate. However, we would also expect **peak demand to reduce by 4.0%-7.4**%, from **11.2 kW** to **10.2-10.7 kW**.

- Under a revenue neutral **TOU+CPP rate**, we estimate that **on-peak consumption would decrease by 4.5%-7.6%**, from **11,500** kWh/yr to **10,630-10,990** kWh/yr**.** In addition, consumption during the on-peak hours of the **critical peak days would reduce by 11%-22%**, from **377** kWh/yr to **294-334** kWh/yr.

Modeling Commercial Class Consumption Impact under Three Adoption Scenarios

Similarly to the residential class analysis, we estimated the aggregate impact of the proposed rate designs on consumption under three adoption scenarios: opt-in, opt-out, and mandatory.

Rate of adoption (%) under opt-in, opt-out and mandatory scenarios

Opt-in	20%
Opt-out	80%
Mandatory	100%

Commercial Results

Estimated Commercial Class Consumption Impact for **Opt-in** Scenario

Preliminary Results
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		Opt-in					
		TOU		TOU + Demand		TOU + CPP	
Period	Consumption *GWh/yr*	**Estimated Impact *%*** [A]	Estimated Load *GWh/yr* [B]	**Estimated Impact *%*** [C]	Estimated Load *GWh/yr* [D]	**Estimated Impact *%*** [E]	Estimated Load *GWh/yr* [F]
Elasticity of Substitution = -0.045							
On-Peak	1,350	-0.8%	1,340	-0.8%	1,340	-0.9%	1,340
Off-Peak	2,090	-0.2%	2,085	-0.2%	2,085	-0.5%	2,080
Mid-Day *(Super-Off-Peak)*	2,855	0.0%	2,855	0.0%	2,855	-0.2%	2,850
CPP On-Peak	44	n.a.	n.a.	n.a.	n.a.	-2.3%	43
Peak Demand	n.a.	n.a.	n.a.	-0.8%	n.a.	n.a.	n.a.
All periods	**6,295**	**-0.2%**	**6,280**	**-0.2%**	**6,280**	**-0.4%**	**6,270**
Elasticity of Substitution = -0.10							
On-Peak	1,350	-1.5%	1,330	-1.5%	1,330	-1.5%	1,330
Off-Peak	2,090	-0.3%	2,085	-0.3%	2,085	-0.5%	2,080
Mid-Day *(Super-Off-Peak)*	2,855	0.4%	2,865	0.4%	2,865	0.1%	2,860
CPP On-Peak	44	n.a.	n.a.	n.a.	n.a.	-4.4%	42
Peak Demand	n.a.	n.a.	n.a.	-1.5%	n.a.	n.a.	n.a.
All periods	**6,295**	**-0.2%**	**6,280**	**-0.2%**	**6,280**	**-0.4%**	**6,270**

Note: All consumption results (in kWh) are rounded to the nearest five except for CPP On-Peak.

Commercial Results

Estimated Commercial Class Consumption Impact for **Opt-out** Scenario

Preliminary Results
CONFIDENTIAL

		Opt-out					
		TOU		TOU + Demand		TOU + CPP	
Period	Consumption *GWh/yr*	**Estimated Impact *%*** [A]	Estimated Load *GWh/yr* [B]	**Estimated Impact *%*** [C]	Estimated Load *GWh/yr* [D]	**Estimated Impact *%*** [E]	Estimated Load *GWh/yr* [F]
Elasticity of Substitution = -0.045							
On-Peak	1,350	-3.2%	1,305	-3.2%	1,305	-3.6%	1,300
Off-Peak	2,090	-1.0%	2,070	-1.0%	2,070	-1.8%	2,050
Mid-Day *(Super-Off-Peak)*	2,855	0.1%	2,860	0.1%	2,860	-0.7%	2,835
CPP On-Peak	44	n.a.	n.a.	n.a.	n.a.	-9.2%	40
Peak Demand	n.a.	n.a.	n.a.	-3.2%	n.a.	n.a.	n.a.
All periods	**6,295**	**-1.0%**	**6,235**	**-1.0%**	**6,235**	**-1.7%**	**6,190**
Elasticity of Substitution = -0.10							
On-Peak	1,350	-6.0%	1,270	-6.0%	1,270	-6.1%	1,270
Off-Peak	2,090	-1.1%	2,070	-1.1%	2,070	-2.0%	2,050
Mid-Day *(Super-Off-Peak)*	2,855	1.5%	2,895	1.5%	2,895	0.5%	2,870
CPP On-Peak	44	n.a.	n.a.	n.a.	n.a.	-17.5%	37
Peak Demand	n.a.	n.a.	n.a.	-6.0%	n.a.	n.a.	n.a.
All periods	**6,295**	**-1.0%**	**6,235**	**-1.0%**	**6,235**	**-1.7%**	**6,190**

Note: All consumption results (in kWh) are rounded to the nearest five except for CPP On-Peak.

Commercial Results

Estimated Commercial Class Consumption Impact for **Mandatory** Scenario

Preliminary Results
CONFIDENTIAL

Period	Consumption *GWh/yr*	Mandatory					
		TOU		**TOU + Demand**		**TOU + CPP**	
		Estimated Impact *%* [A]	Estimated Load *GWh/yr* [B]	**Estimated Impact *%*** [C]	Estimated Load *GWh/yr* [D]	**Estimated Impact *%*** [E]	Estimated Load *GWh/yr* [F]
Elasticity of Substitution = -0.045							
On-Peak	1,350	-4.0%	1,295	-4.0%	1,295	-4.5%	1,290
Off-Peak	2,090	-1.2%	2,065	-1.2%	2,065	-2.3%	2,045
Mid-Day *(Super-Off-Peak)*	2,855	0.2%	2,860	0.2%	2,860	-0.9%	2,830
CPP On-Peak	44	n.a.	n.a.	n.a.	n.a.	-11.6%	39
Peak Demand	n.a.	n.a.	n.a.	-4.0%	n.a.	n.a.	n.a.
All periods	**6,295**	**-1.2%**	**6,220**	**-1.2%**	**6,220**	**-2.1%**	**6,165**
Elasticity of Substitution = -0.10							
On-Peak	1,350	-7.4%	1,250	-7.4%	1,250	-7.6%	1,245
Off-Peak	2,090	-1.3%	2,060	-1.3%	2,060	-2.5%	2,040
Mid-Day *(Super-Off-Peak)*	2,855	1.8%	2,910	1.8%	2,910	0.6%	2,875
CPP On-Peak	44	n.a.	n.a.	n.a.	n.a.	-21.9%	35
Peak Demand	n.a.	n.a.	n.a.	-7.4%	n.a.	n.a.	n.a.
All periods	**6,295**	**-1.2%**	**6,220**	**-1.2%**	**6,220**	**-2.1%**	**6,165**

Note: All consumption results (in kWh) are rounded to the nearest five except for CPP On-Peak.

Estimated Commercial Class Consumption Impact: **Key Takeaways**

- Under the modeled assumptions, we estimate that **commercial consumption during on-peak hours** could be reduced on average by
  - **0.8%-1.5%** under **opt-in** rates, from **1,350** to **1,330-1,340** GWh/yr
  - **3.2%-6.1%** under **opt-out** rates, from **1,350** to **1,270-1,305** GWh/yr
  - **4.0%-7.6%** under **mandatory** rates, from **1,350** to **1,245-1,295** GWh/yr
- We estimate that **total commercial consumption** could be reduced on average by
  - **0.2%-0.4%** under **opt-in** rates, from **6,295** to **6,270-6,280** GWh/yr
  - **1.0%-1.7%** under **opt-out** rates, from **6,295** to **6,190-6,235** GWh/yr
  - **1.2%-2.1%** under **mandatory** rates, from **6,295** to **6,165-6,220** GWh/yr

Summary and Conclusions

- We developed several time-varying rates for the residential and commercial classes in Hawaii
- These rates reflected the sales profiles of these two classes in Hawaii and were designed to recover the same revenue as the rates that are in place today
- We estimated the impact of time-varying rates on energy consumption by pricing period for the two customer classes using:
  - Elasticities of substitution and daily conservation impacts for time-varying rates derived from the mainland
  - Customer participation rates across alternative deployment scenarios derived from the mainland
  - The Price Response Impact Simulation Model (PRISM)

Conclusions: Residential Class

- We estimate that **residential consumption** during **on-peak hours** could be reduced on average by
  - **0.7%-1.3%** under **opt-in** rates, from **1,030** to **1,015-1,025** GWh/yr
  - **2.6%-5.0%** under **opt-out** rates, from **1,030** to **980-1,005** GWh/yr
  - **3.3%-6.3%** under mandatory rates, from **1,030** to **965-995** GWh/yr

- We estimate that **total residential consumption** could be reduced on average by
  - **0.2%-0.4%** under **opt-in** rates, from **3,480** to **3,465-3,470** GWh/yr
  - **1.0%-1.7%** under **opt-out** rates, from **3,480** to **3,420-3,445** GWh/yr
  - **1.2%-2.1%** under **mandatory rates**, from **3,480 3,405-3,440** GWh/yr

Conclusions: Commercial Class

- We estimate that **commercial consumption** during **on-peak hours** could be reduced on average by
  - **0.8%-1.5%** under **opt-in** rates, from **1,350** to **1,330-1,340** GWh/yr
  - **3.2%-6.1%** under **opt-out** rates, from **1,350** to **1,270-1,305** GWh/yr
  - **4.0%-7.6%** under **mandatory** rates, from **1,350** to **1,245-1,295** GWh/yr.
- We estimate that **total commercial consumption** could be reduced on average by
- **0.2%-0.4%** under **opt-in** rates, from **6,295** to **6,270-6,280** GWh/yr
- **1.0%-1.7%** under **opt-out** rates, from **6,295** to **6,190-6,235** GWh/yr
- **1.2%-2.1%** under **mandatory** rates, from **6,295** to **6,165-6,220** GWh/yr

Recommendations

- The results of our analysis are a function of the elasticities assumed in our analysis.
  - These parameters can vary widely across regions and customer types.
- To validate our analysis, we recommend that scientific experiments (pilots) be carried out in Hawaii to generate state-specific elasticities for various time-varying rates.
  - These experiments should test alternative rate designs and alternative enabling technologies and behavioral treatments.
- We also recommend that market research (focus groups and conjoint analysis) be carried out to determine likely customer participation rates under alternative scenarios of deployment.

Appendix

I. Detailed Rate Determination Methodology

II. Detailed Rate Impact Simulation Methodology

Appendix: Detailed Rate Determination Methodology

Steps and Calculations

- Calculated existing revenue from residential class
  - Based on EIA, the average all-in residential rate in Hawaii in 2018 was $0.32/kWh, and average sales were 6,216 kWh/yr/customer
  - Estimated total residential revenue per customer = $0.32/kWh x 6,216 kWh/yr/customer = **$2,000/yr/customer**
- We estimated the share of total revenue by component
  - Rev. from fixed charge: $11.50/month/cust x 12 months/yr = **$138/yr**
  - Rev. from non-fuel energy charge: $0.12/kWh x 6,216 kWh/yr/cust = **$736/yr**
  - Rev. from all other charges: $0.18/kWh x 6,216 kWh/yr/cust = **$1,145/yr**
    - Levelized fixed charge = $11.50/mo x 12 mo/yr / 6,216 kWh/yr = $0.02/kWh
    - Other charges = ($0.32/kWh – $0.12/kWh - $0.02/kWh) = $0.18/kWh
- The new rates have the same fixed charge and “other” charges as the existing rates, thus only the non-fuel energy charges will have a different rate design, even though they will collect the same amount of revenue as the existing rate, i.e. they’re revenue neutral

Appendix: Detailed Rate Determination Methodology

Steps and Calculations

- The new non-fuel energy charges should collect the same amount of revenue as the existing residential rate, that is, $736/yr
- We defined non-fuel energy TOU price ratios of 5 for on-peak/off-peak and 25 of on-peak/super-off-peak to create a price differential large enough for customers to react to
- Using the total non-fuel energy revenue requirement, the TOU price ratios, and the customer sales patterns, we were able to calculate the values of the TOU prices (without demand or CPP charges)
  - We used the same TOU period definitions as currently used (peak: 5pm-10pm, off-peak: 10pm-9am, super-off-peak: 9am-5pm)
  - We estimated the following charges: on-peak = $0.25/kWh, off-peak = $0.05/kWh, super-off-peak = $0.01/kWh

Steps and Calculations

- To estimate the values of the demand and CPP charges, we assumed that 20% of the TOU on-peak revenue (TOU on-peak charge x TOU on-peak consumption) would be collected by demand or CPP charges.
  - The % of on-peak revenue collected through demand and CPP charges was established to be 20% so that the resulting demand and CPP charges would be within the range of similar charges offered by other utilities
  - 20% of TOU on-peak revenue = 20% x $0.25/kWh x 2,400 kWh/yr/cust = $120/yr/cust
  - **Demand charge** = $120/yr/cust / 18.8 kW = $6.33/kW/mo
    - Demand billing determinant: sum of monthly maximum coincident demand during on-peak period = 1.57 kW/mo x 12 mo = 18.8 kW
  - **CPP charge** = $120/yr/cust / XX kWh CPP = $1.54/kW/mo
    - CPP billing determinant: sum of consumption during peak hours of top 10 highest sales days
    - This charge is <u>in addition</u> to the TOU on-peak charge applicable during that period
  - **On-peak charge** = $0.25/kWh x 20% = $0.20/kWh

Estimating Consumption Impacts

This section summarizes the assumptions and methodology used to estimate the impact on customer electricity consumption in response to the introduction of the proposed rate designs.

First, we estimated the change in overall energy consumption based on a literature review of TOU, CPP and demand-based rate studies. The results from those studies are summarized in the main section of the slides, and the source is provided below:

- Brendon Baatz, "Rate Design Matters: The Intersection of Residential Rate Design and Energy Efficiency", American Council for an Energy-Efficient Economy (ACEEE), March 2017.

Modeling Shifts in Consumption Across Periods

Next, we used PRISM to model the shift in energy consumption across periods.

- The inputs to PRISM were:
  - Change in total energy consumption (based on literature review)
  - Average customer 8760 consumption shape (provided by AEG)
  - Proposed new rates (derived by Brattle)
  - Elasticities of substitution (based on literature review)
- Based on those inputs, PRISM outputs the change in energy consumption for each TOU period

The equations used in the PRISM model are shown in the next few slides.

PRISM Equations for Three-Period TOU

Old and new average consumption:

$$\overline{K} = \frac{h_1 K_1 + h_2 K_2 + h_3 K_3}{24}$$

$$\overline{K'} = \overline{K} \times (1 + d)$$

Where:

$\overline{K}$	= old daily kWh/hr usage
$\overline{K}'$	= new daily kWh/hr usage
K_i	= old kWh/hr usage in period i
h_i	= hours in period i
d	= % change in daily usage

PRISM Equations for Three-Period TOU (cont'd)

Consumption during each TOU period:

$$K_1' = e^{A_{12}} K_2'$$

$$K_2' = \frac{24\overline{K'}}{e^{A_{12}} h_1 + h_2 + e^{-A_{23}} h_3}$$

$$K_3' = e^{-A_{23}} K_2'$$

Where:

K_i	= old kWh/hr usage in period i
K_i'	= new kWh/hr usage in period i
$\overline{K}'$	= new daily kWh/hr usage
h_i	= hours in period i
A_{12}	*See next slide for formula*
A_{23}	*See next slide for formula*

PRISM Equations for Three-Period TOU (cont'd)

Constants:

$$A_{12} = \ln\left(\frac{K_1}{K_2}\right) + b_{12}\left(\ln\left(\frac{P_1'}{P_2'}\right) - \ln\left(\frac{P_1}{P_2}\right)\right)$$

$$A_{23} = \ln\left(\frac{K_2}{K_3}\right) + b_{23}\left(\ln\left(\frac{P_2'}{P_3'}\right) - \ln\left(\frac{P_2}{P_3}\right)\right)$$

Where:

K_i = old kWh/hr usage in period i

P_i = old daily price per kWh

$\overline{P'}$ = new daily price per kWh

b_{12} = constant elasticity of substitution between periods 1 and 2

b_{23} = constant elasticity of substitution between periods 2 and 3

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