Co-Design of Electricity Tariffs

1.144: Applied Category Theory for Engineering Design
Project Presentation

Daniel Shen

Dec 1 2025

Total Charges for Electricity

Supplier (CAMBRIDGE COMM ELEC DIRECT ENERGY)

Meter 5507686

Generation Service Charge	445 kWh X .14810	$65.90
Subtotal Supplier Services		$65.90

Delivery

R1-Residential Non-Heating

Meter 5507686

Customer Charge		$10.00
Distribution Charge	445 kWh X .09655	$42.96
Transition Charge	445 kWh X -0.00095	-$0.42
Transmission Charge	445 kWh X .04545	$20.23
Net Meter Recovery Surcharge	445 kWh X .01622	$7.22
Revenue Decoupling Charge	445 kWh X -0.00085	-$0.38
Distributed Solar Charge	445 kWh X .00431	$1.92
Renewable Energy Charge	445 kWh X .00050	$0.22
Energy Efficiency Charge	445 kWh X .02506	$11.15
Electric Vehicle Program	445 kWh X .00238	$1.06
Subtotal Delivery Services		$93.96
Total Cost of Electricity		**$159.86**

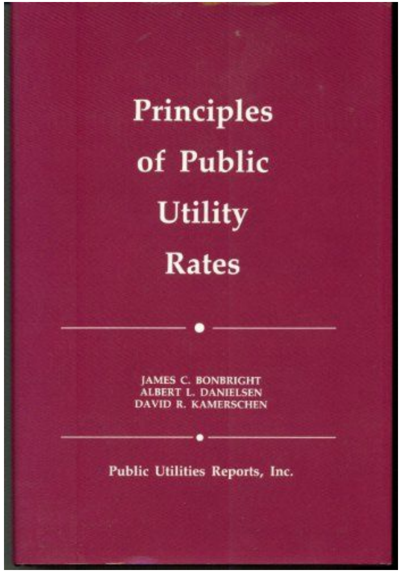
Total Current Charges	**$159.86**

Electricity Tariffs: What is a desirable rate structure?

Key principles:

- Recovers all revenues.
- Discourages wasteful use of services.
- Reflects the costs of providing a service.
- “Practical”
  - simple, understandable, publicly acceptable

  … and more



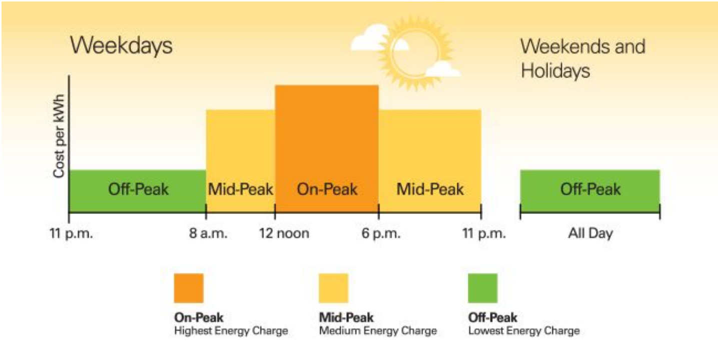
Tariff Design has Tradeoffs

A more complex design might allow us to more closely reflect the cost of service…

> … but it might not be very practical to administer nor understandable by customers…

Structure of a Tariff

- Residential bills usually have at least two components:
  - A *volumetric charge* reflecting the amount (volume) of electricity used.
  - A *fixed charge* which is constant regardless of the consumption.
- Some localities are switching to *time of use* tariffs where the volumetric charge varies depending on the time of day.



https://www.greenconvergence.com/blog/what-is-time-of-use

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“Fair” Tariff Design as a MCDP

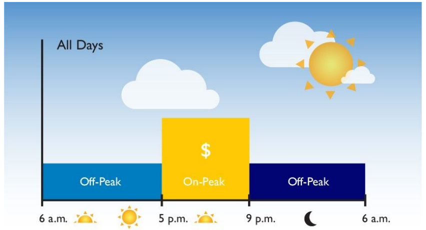
Functionality:

- Customer approval
  - Total bill
  - Carbon emissions
  - Tariff “simplicity”
- Profit (for the utility)

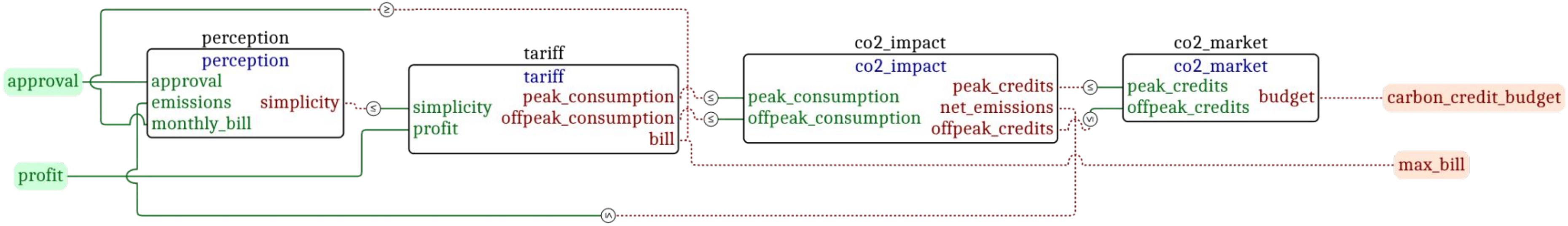
Resources:

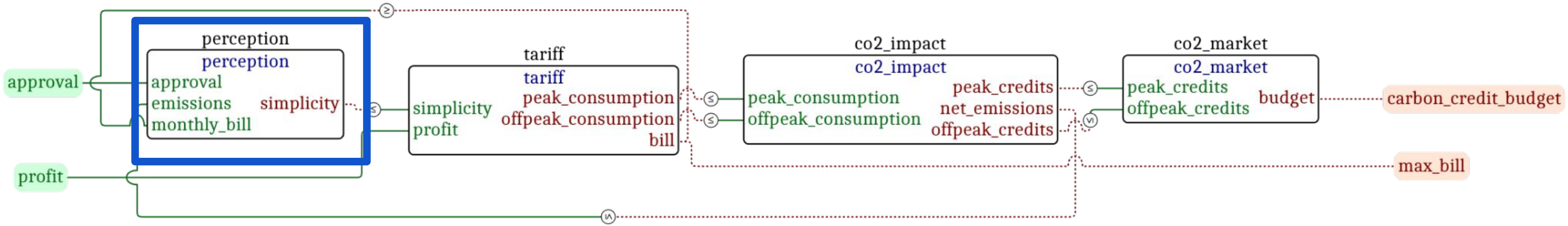
- Carbon credit budget
- Maximum tolerable bill

- On- & off-peak volumetric charge
- Fixed charge



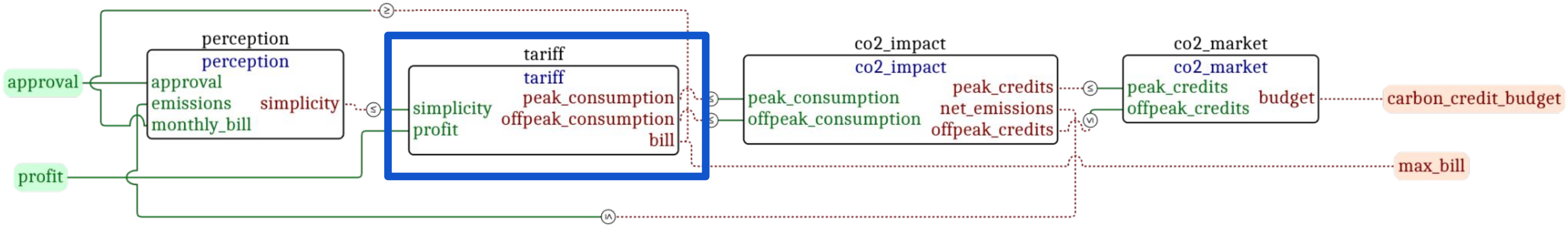
Tariff Design Wiring Diagram



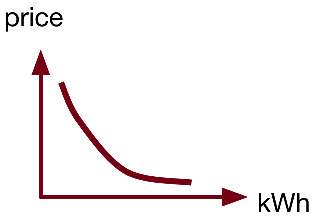


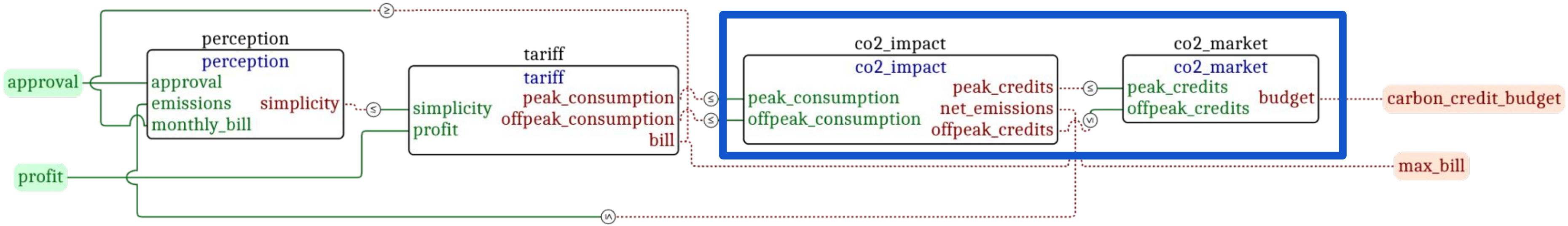
approval + co2_emissions + total_bill <= tariff_simplicity

- Customer is happy when they pay less for electricity.
- Customer is happy when utility's CO2 emissions from producing power are lower.
- Customer is happy when the tariff is "simple" (fewer prices, smaller price differentials).



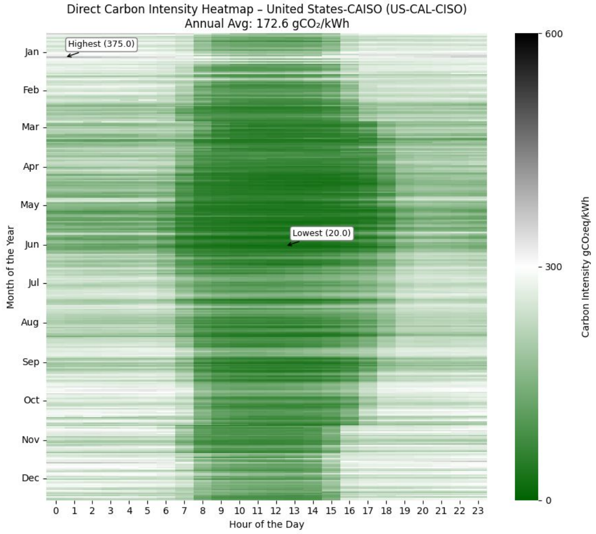
- Customer consumption is calculated offline based on an on-peak and off-peak demand function
- Tariffs are rated for simplicity based on their structure:
  - Only fixed charge, no volumetric = **100**
  - Constant volumetric charge (any fixed charge) = **90**
  - High on-peak price relative to off-peak price: low score

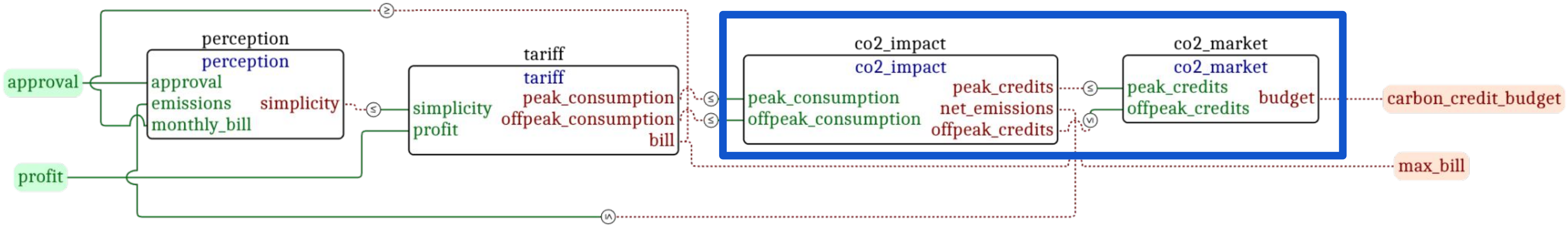




emissions <= consumption * co2_intensity - credits

- On- and off-peak hours have different CO2 intensity
- Utility can purchase CO2 credits using a carbon credit budget to improve consumer perception of the emissions component.
- Off-peak credits cannot be applied to on-peak hours and vice versa.





FixFunMinRes

Find the tariff structure which minimizes the customer bill and:

- Generates at least $20 of profit
- Has at least an approval rating of 20 units
- Utilizes less than $10 of carbon credits

Optimistic soln: Volumetric price of 25c/kWh, fixed charge of $40/mo
Pessimistic son: Volumetric price of 10c/kWh, fixed charge of $50/mo

Summary

- An utility tariff needs to fulfill several principles, some of which are in contradiction to each other.
- I utilize a MCDP approach to evaluate the tradeoffs in utility tariff design when considering customer approval and cost recovery.
- The optimal bill utilizes **volumetric charges** to discourage wasteful consumption.

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Thanks!

Questions?

oski@mit.edu