Understanding Electric Rate Structures and Energy Markets

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Learning Objectives:

In this lesson, you will learn to:

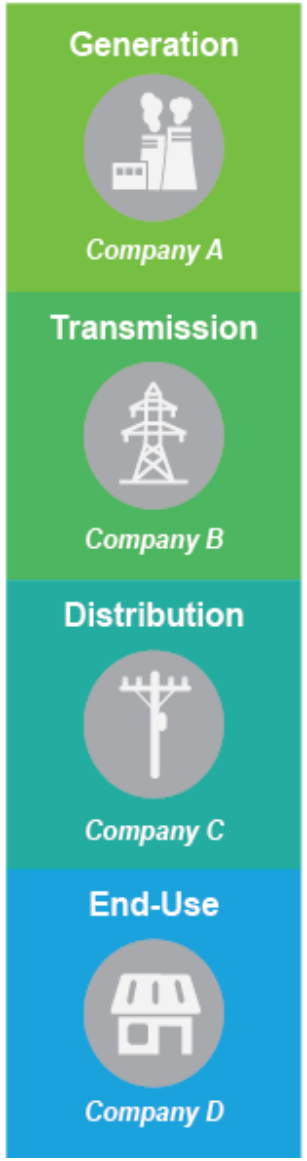
- Understand different types of electricity market structures
- Understand the components of retail rate structures
- Recognize how rate structure components affect total cost for different customer sectors
- Assess how utilities use rate structures to influence end-user behavior

Introduction to Traditional Electricity Markets

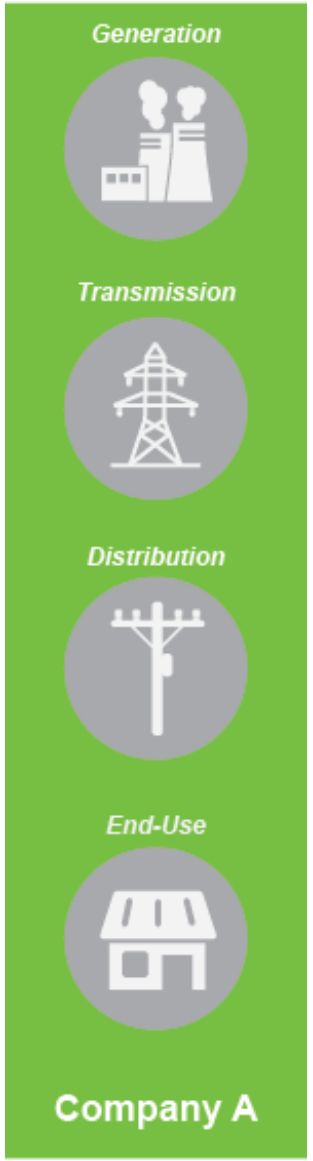
How People Deliver Power Across the World

- *Vertically integrated* – a single entity is responsible for generation, transmission, distribution, and sale to the customer.
  - Farm-to-table agriculture
  - Streaming services such as Netflix
  - Oil and Gas companies such as BP and Shell
- *Horizontally integrated* – more than one entity is responsible for generation, transmission, distribution, and sale to the end user.
  - Consumer products provided through supply chain (production, warehousing, distribution, sales)
  - Consumers goods such as snacks that pass through multiple entities before being sold

Horizontally Integrated Utility



Vertically Integrated Utility



Electricity Market Structures

- Generally, there are two types of market structures: the *wholesale* electricity market and the *retail* electricity market. This is similar to other market structures that sell products in bulk vs. individually.
  - Wholesale markets sell products in bulk to retailers
  - Retail markets sell products directly to customers
- Example: grocery store chains purchase goods from wholesale suppliers and sell those goods in smaller amounts at their retail stores to customers.

Retail Electricity Markets

- Retail generally refers to the sale of goods in small quantities directly to customers
  - “Customers” in this market are the direct end-user of electricity
  - “Retail Sellers” are utility companies
    - Emerging opportunities for end-users to participate in retail and wholesale energy market

Residential

Commercial

Industrial

Energy Regulation Committees

Regulatory committees oversee electricity, natural gas, oil, and other goods to ensure safe, reliable, and cost-efficient production from utilities to consumer. They can have either local or national jurisdiction.

- *Federal Energy Regulatory Commission* (FERC) – federal regulatory agency to set standards for safe and fair practices in the energy industry
  - https://ferc.gov/about/what-ferc
- *Arizona Corporation Commission* (ACC) – sets "just and reasonable" rates for public service corporations and ensure quality of service
  - Infrastructure approval, certificates, and safety enforcement
  - Set policies for the future of public service initiatives
  - Approves rates

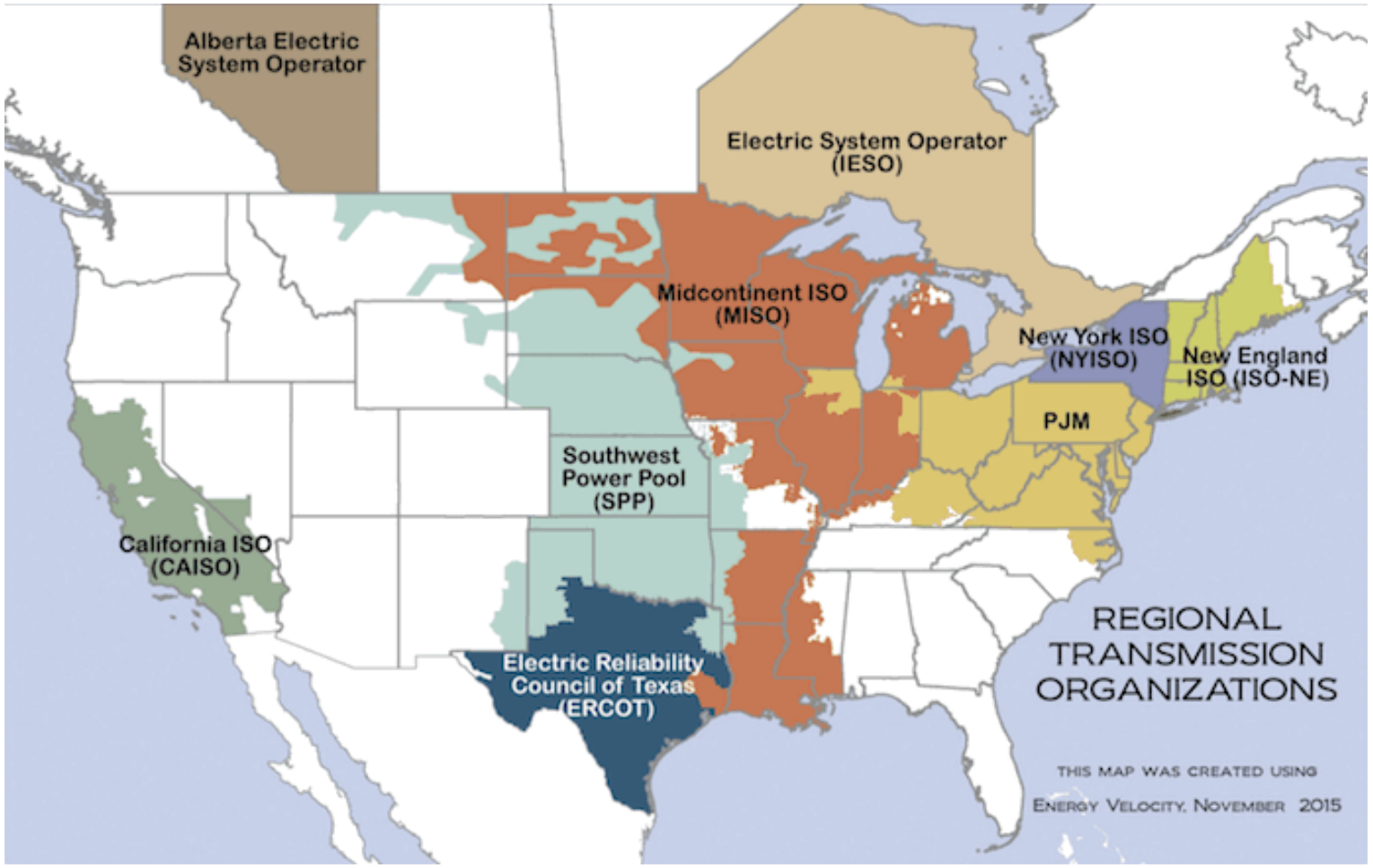
Wholesale Electricity Markets

- Traditionally, all aspects of the electricity market have been structured as *vertically integrated utilities*. These companies own and operate all assets:
  - Generation
  - Transmission
  - Distribution
  - Retail meters
- Some parts of the United States and international locations have moved towards a *deregulated* or *horizontally integrated* structure where generators compete to sell power:
  - ISOs/RTOs
  - IPPs
  - End Users

RTOs and ISOs

- *Regional Transmission Organizations* (RTOs) and *Independent Systems Operators* (ISOs) are organizations formed by the recommendation of the Federal Energy Regulatory Commission to *coordinate*, *control*, and *monitor* the multi-state electric power system.
  - Generally RTOs and ISOs are interchangeable terms
- From FERC: "Independent System Operators grew out of Orders Nos. 888/889 where the Commission suggested the concept of an Independent System Operator as one way for existing tight power pools to satisfy the requirement of *providing non-discriminatory access to transmission*"
- Introduction of these entities is considered the beginning of the *deregulation of the electric power industry*

RTOs and ISOs – United States



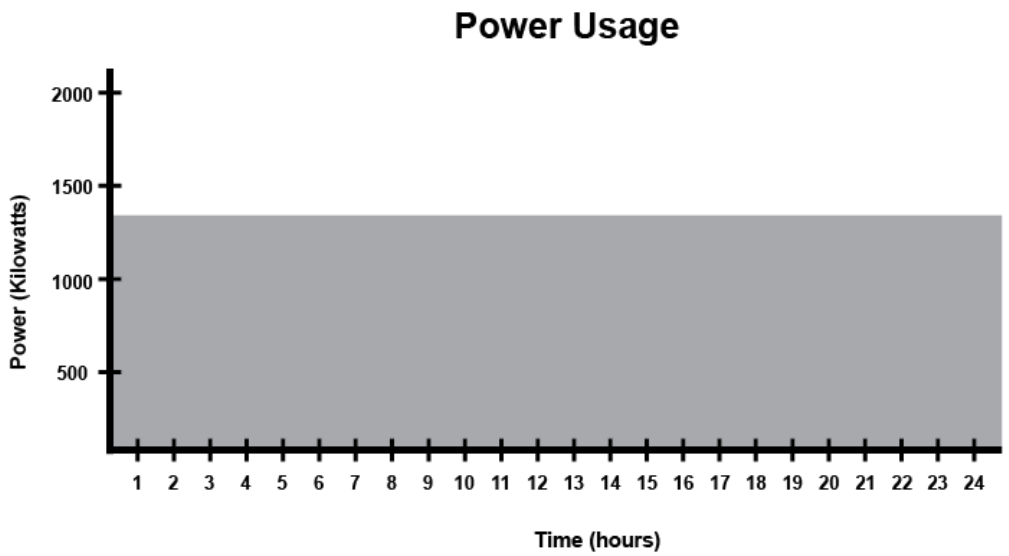
Retail Electricity Markets and Structures

Introduction to Electricity Pricing Structures

- Types of retail electricity charges:
  - **Fixed Charges** – charges that are applied on a monthly basis; usually to cover maintenance or metering costs, $\frac{\$}{\text{month}}$
  - **Energy Charges** – charges for the amount of *energy* consumed by the end user. Usually, the most common and largest expense across customer sectors, $\frac{\$}{\text{kWh}}$
  - **Demand Charges** – charges based the maximum *power* drawn by the customer throughout the billing period, $\frac{\$}{\text{kW}}$
  - **Additional Charges** – miscellaneous charges or fees for the utility's costs
    - Net-metering charge
    - Stand-by charge
    - Fuel adjustment fees or renewables fees

Power (Demand) vs. Energy (Demand Over *Time*!)

- When we measure or talk about power, we're generally referring to *instantaneous power*. This is a continuous value that changes all the time. Utilities measure *power* in kilowatts (kW)
- Power consumption (over a period of time) is called *energy* (kWh)
- Example: A 1300 kilo-Watt Inductor Motor, on for 24 hours/day:



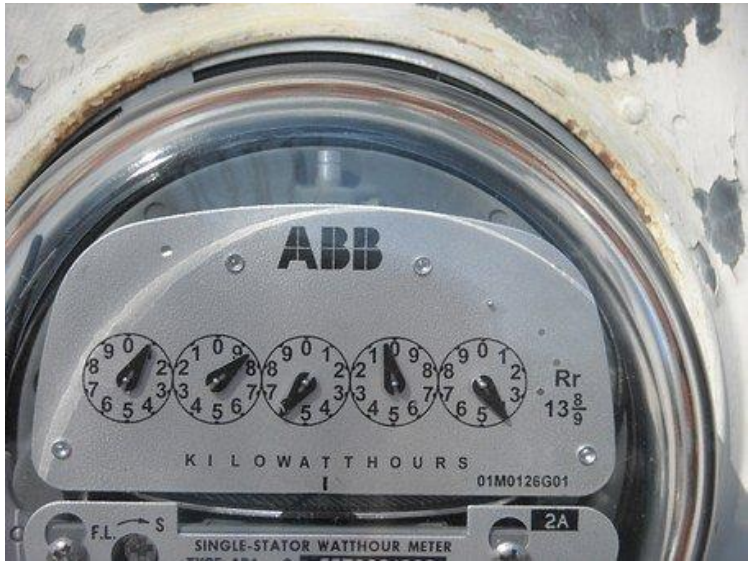
$$\text{Power} = 1300\ \text{kW}$$
$$\text{Time} = 24\ \text{hours}$$

$$\text{Energy} = \text{Power} \times \text{Time}$$
$$= 1300\ \text{kW} \times 24\ \text{hours}$$
$$= 31{,}200\ \text{kilowatt hours [kWh]}$$
$$= 31.2\ \text{MWh}$$

(Also equal to the total area under the curve of a power vs. time graph)

Fixed Charges

- *Fixed charges* are fixed monthly (or daily) charges applied to the utility bill. They cover costs such as:
  - Meter infrastructure
  - Meter data service
  - Billing and processing



Standard Disk Meter

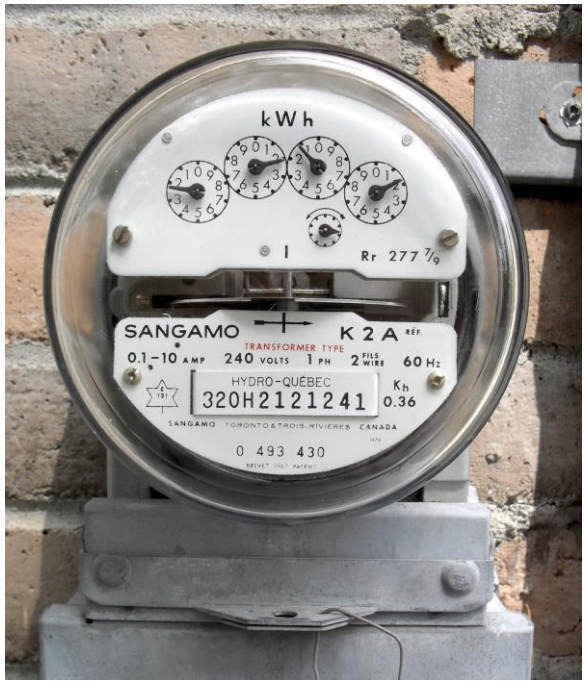
Smart Meter

Energy Charges

- *Energy charges* – are determined by the number of kilowatt-hours (kWh) consumed by the end-user throughout the billing period. $\left[\frac{\$}{\text{kWh}}\right]$
- *Fixed rates* – the amount charged for energy purchased does not change at any point in time. Often thought of as the simplest pricing structure.
- *Tiered (step) rates* – the price of electricity varies by the amount used during the billing period.
  - *e.g., 0-50 kWh* @ $0.1058 \frac{\$}{\text{kWh}}$
    51-100 kWh @ $0.1578 \frac{\$}{\text{kWh}}$
    100+ kWh @ $0.1701 \frac{\$}{\text{kWh}}$
  - This is an indirect way to charge higher prices to customers with higher usage, to pay more for the infrastructure required for transferring higher amounts of power (demand).

Introduction of Smart Meters

Advanced Metering Infrastructure (AMI)

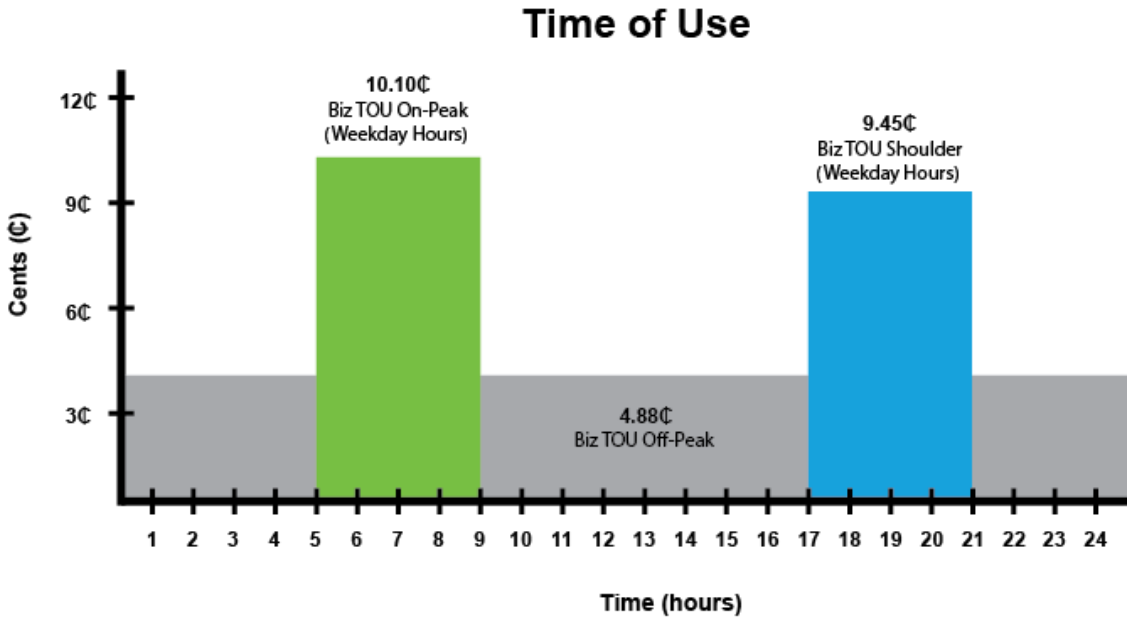


Legacy pricing

Dynamic pricing

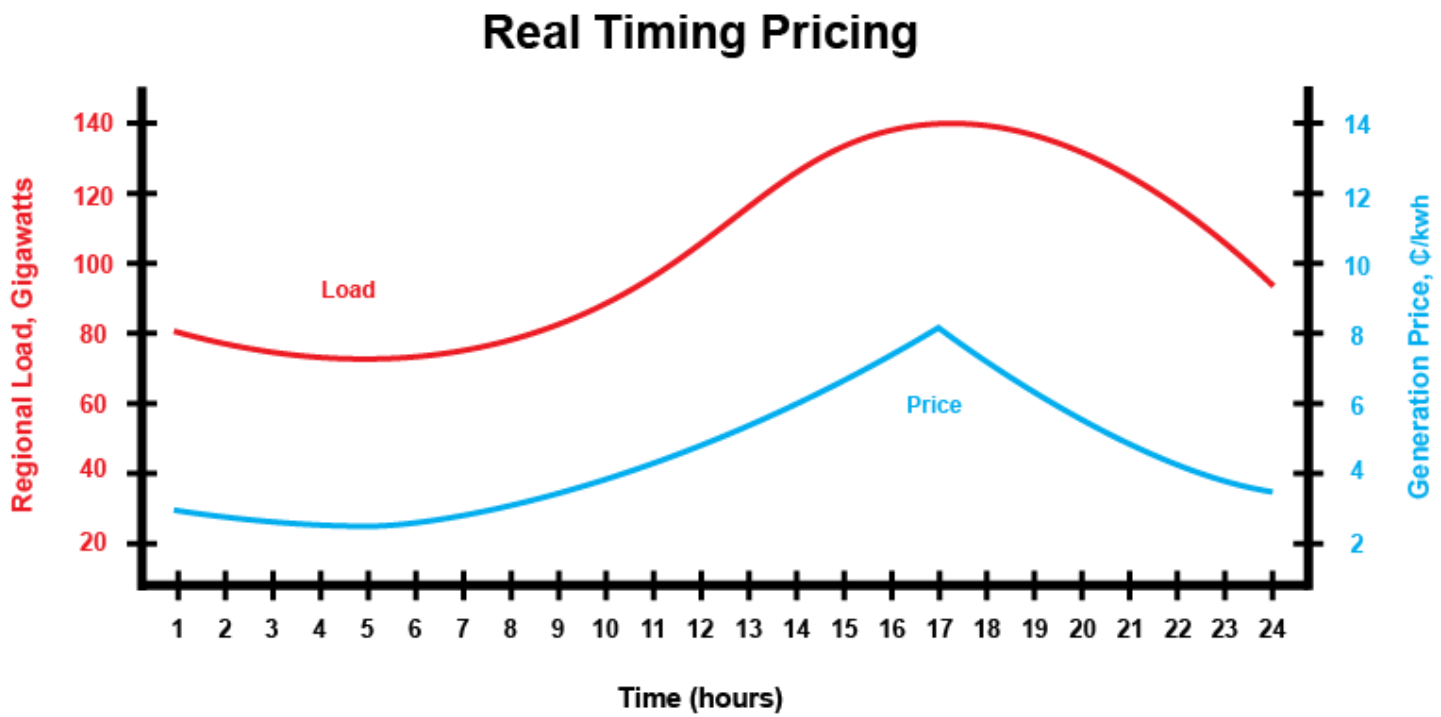
Energy Charges, continued

- *Time of Use (TOU)* – price of electricity varies throughout the *day.* It may also change by day of week (e.g., weekend vs. weekday)
  - Can be multiple TOU periods, varies greatly by utility provider
  - Usually rate has off-peak and on-peak
  - TOU pricing structures can vary by season
  - Incentivize users to limit demand during periods of peak system-wide usage



Energy Charges, continued

- *Real-Time Pricing (RTP)* – price of electricity varies at a smaller time scale than TOU pricing and is directly correlated to the price of system-wide energy.
  - Not common in retail markets. Structure is mainly used for ISOs during energy trading.
  - Common time scales: 5 minute, 15 minute, 1 hour



Energy Charges, continued

- *Pay-as-you-go*
  - Pre-paid plan, goal is to allow users to better manage and understand usage
  - Intended for income-constrained customers or those without credit.
  - Hardware inside the end-user's home that manages electricity access, tells user how much money is left on their account
  - Salt River Project (SRP) in Arizona has the largest prepaid electricity program in the US, with over 100,000 customers

Energy Charges – Additional Information

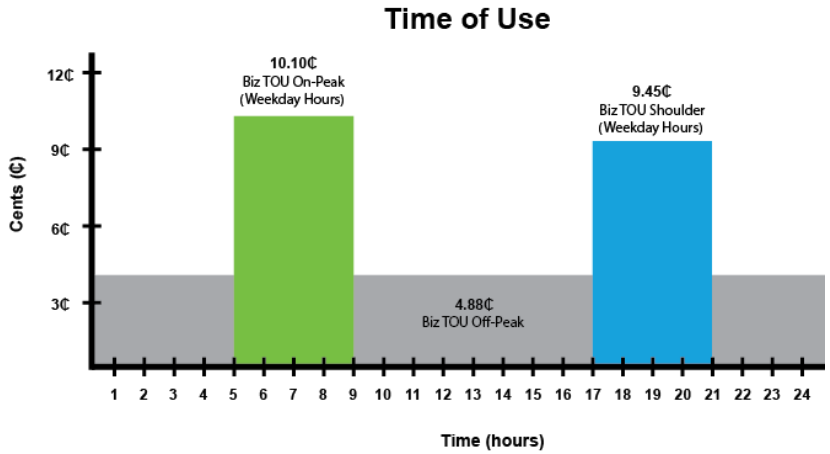
- *Seasonal Rates* – price of electricity varies based on *season*.
  - Demand-Side Management (DSM) – incentivize users to limit usage based on seasonal trends
  - Example: rates are higher in Arizona during the summer because of increased system load from air conditioning units, which requires more generating stations to be turned on and ready to dispatch, and those assets are more expensive to operate than base loading generation
  - You can have *both* seasonal rates and TOU/tiered rates, meaning that you can have a different TOU or tiered rate structure for each season
- *Weekends/Holidays*
  - Utilities usually treat weekends and holidays with the lowest price structure (off-peak or lowest pricing tier)
  - The intraday load profile is generally flatter, meaning there is naturally less variation in weekend loads relative to weekday loads, and hence generally no incentives established to change user behavior

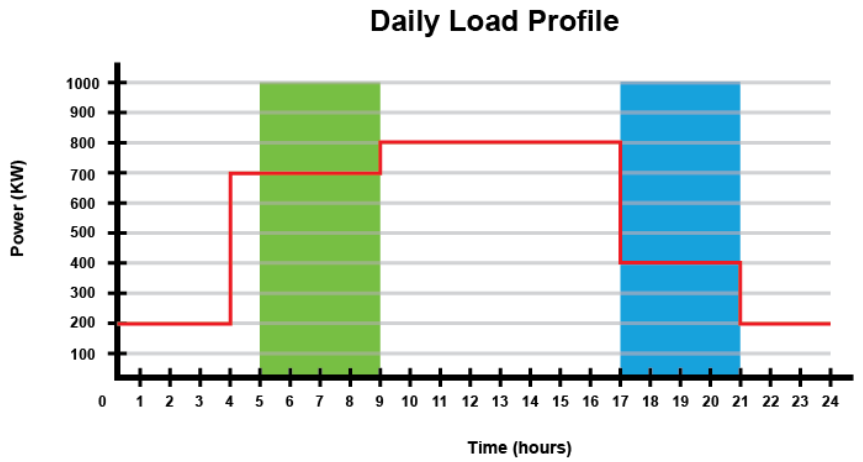
Electricity Rate Structure Exercise

Problem: An electrical conductor manufacturer purchases their electricity from Unified Electric Company, under a large-business TOU plan. The figures show the customer's TOU pricing structure (top) and the load profile for June 23, 2020 (bottom).

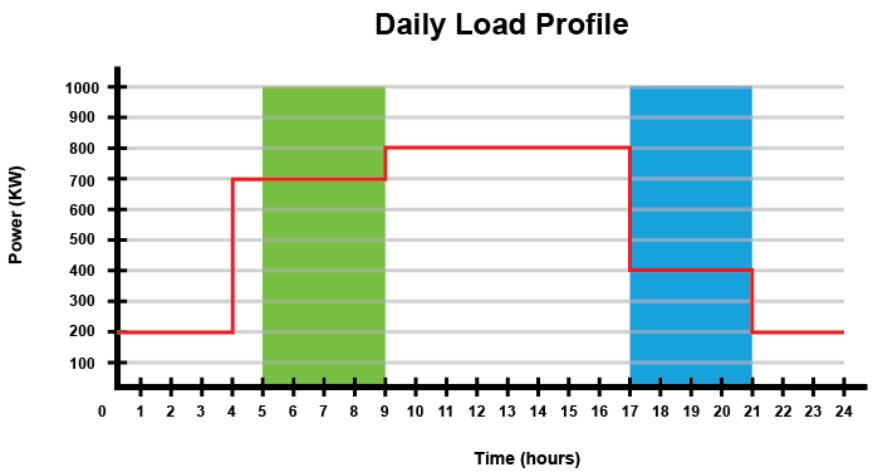
Question: Calculate the total OFF-PEAK energy cost, and the total energy cost for the day.

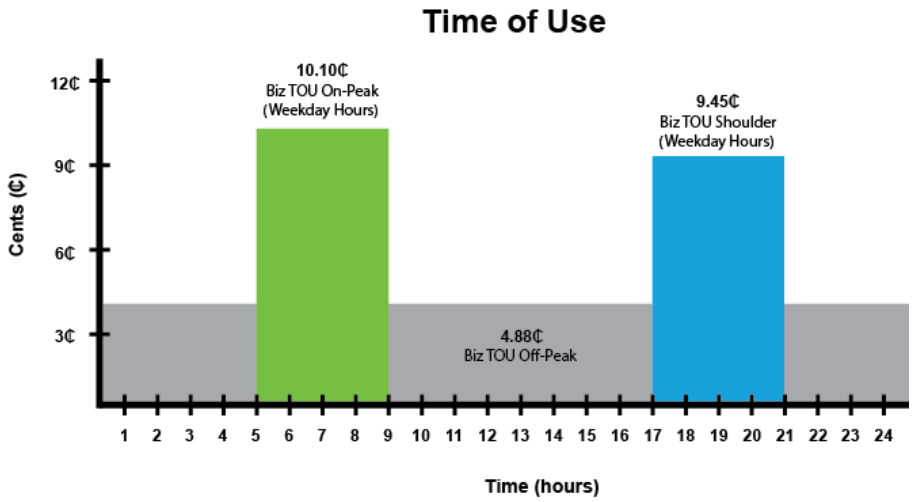
Summer on-peak demand charge: $5.29
Summer peak on-peak demand charge: $6.99
Winter on-peak demand charge: maximum of $4.69
Summer, summer-peak and winter shoulder and off-peak demand charge: $1.05
Monthly service charge: $22.72 plus meter charge (CT/PT $16.88 or demand $6.11)
*All weekend hours are off peak.





Electricity Rate Structure Exercise, continued





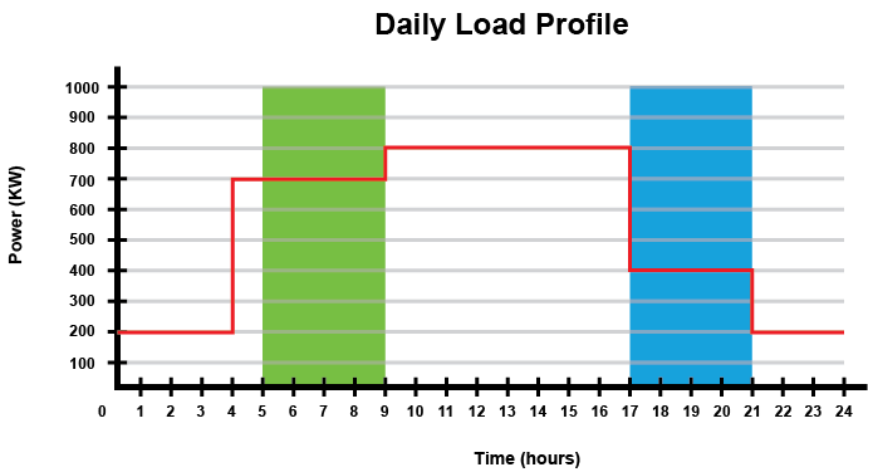
$$\text{Off Peak Energy (kWh)} = (200\ \text{kW} \times 4\ \text{hour}) + (700\ \text{kW} \times 1\ \text{hour}) + (800\ \text{kW} \times 8\ \text{hour}) + (200\ \text{kW} \times 3\ \text{hour})$$

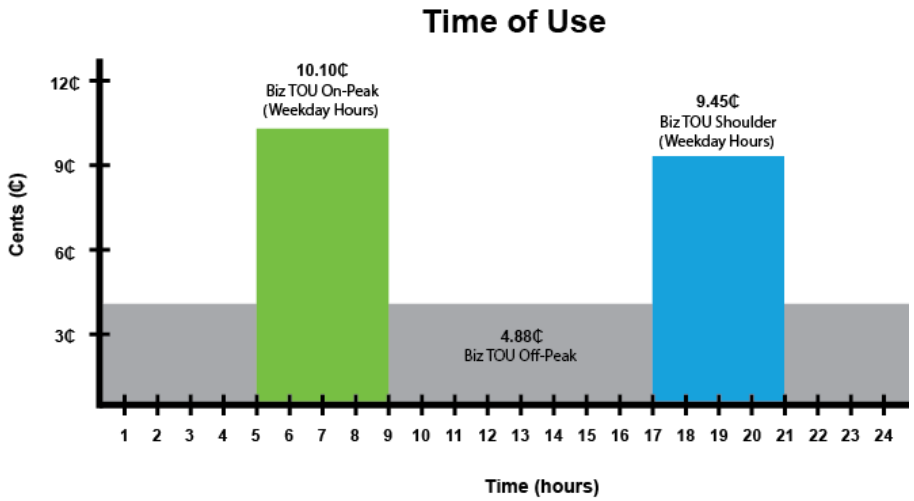
$$\text{Total Energy} = 8{,}500\ \text{kWh}$$

$$\text{Off Peak Energy Cost} = 8{,}500\ \text{kWh} \times \frac{\$0.0488}{\text{kWh}}$$

$$\textbf{Off Peak Energy Cost} = \$\mathbf{414.80}$$

Electricity Rate Structure Exercise, continued





$$\text{On Peak Energy} = (700\ \text{kW} \times 4\ \text{hour}) = 2{,}800\ \text{kWh}$$

$$\textbf{On Peak Energy Cost} = \textbf{2,800 kWh} \times \frac{\textbf{\$0.1010}}{\textbf{kWh}} = \textbf{\$282.80}$$

$$\text{Shoulder Peak Energy} = (400\ \text{kW} \times 4\ \text{hour}) = 1{,}600\ \text{kWh}$$

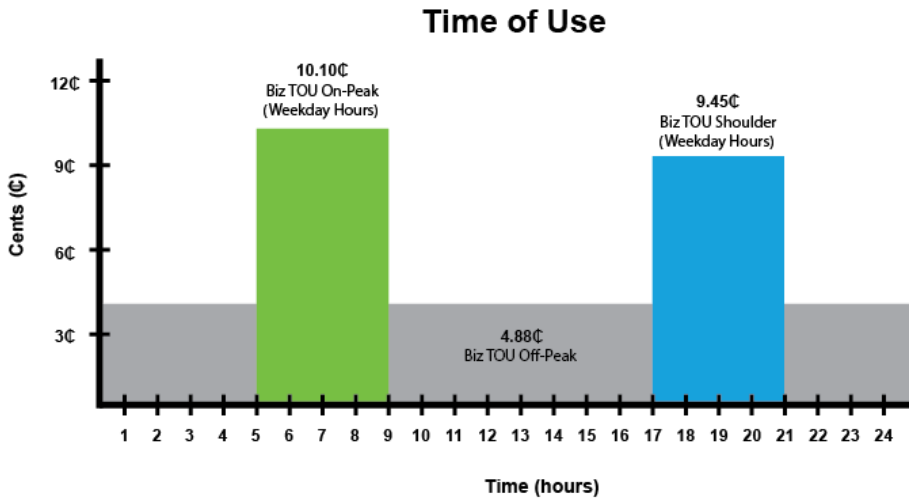
$$\textbf{Shoulder Peak Energy Cost} = \textbf{1,600 kWh} \times \frac{\textbf{\$0.0945}}{\textbf{kWh}} = \textbf{\$151.20}$$

Electricity Rate Structure Exercise, continued

Total Energy Cost
= Off Peak Energy Cost + On Peak Energy Cost
+ Shoulder Peak Energy Cost

Total Energy Cost = $414.80 + $282.80 + $151.20

Total Energy Cost = $848.80



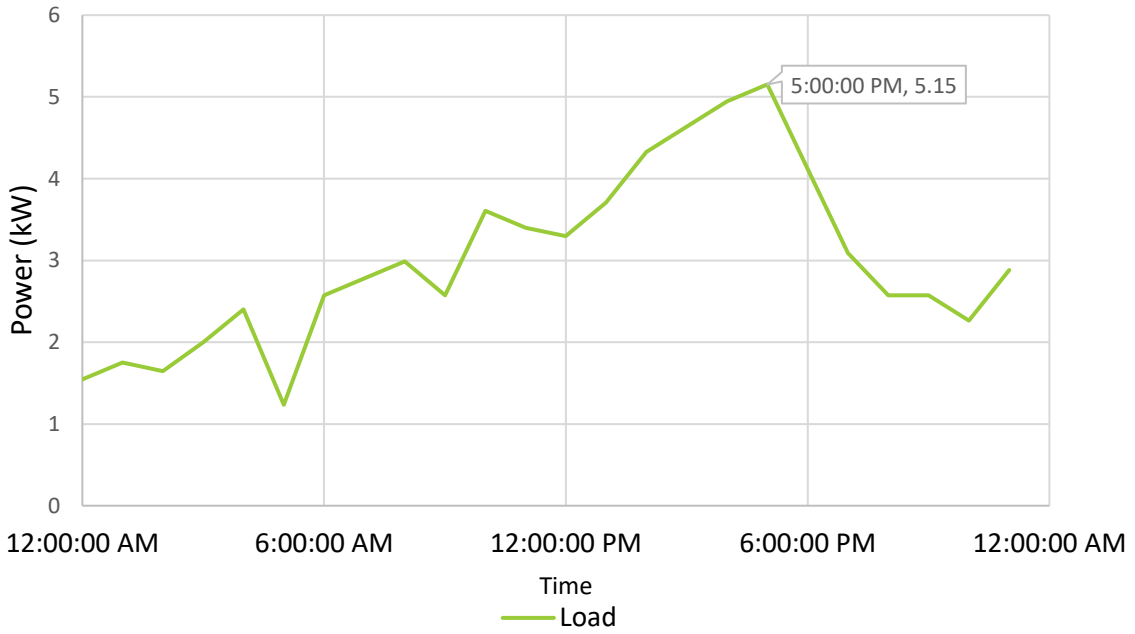
Total Energy Cost
= Off Peak Energy Cost + On Peak Energy Cost
+ Shoulder Peak Energy Cost

Total Energy Cost = $414.80 + $282.80 + $151.20

Total Energy Cost = $848.80

Demand Charges

- *Demand Charge* – charge for the *maximum instantaneous power* used by a customer, and is measured differently by each utility
  - Although power is a continuous, instantaneous value, demand charges are not reported as such due to the high amount data collection and memory required <1 second intervals
  - Commonly reported as the maximum 15-min average power use over a billing period
    - Can also be a 30-min, 1 hour, etc.



$$\text{Demand Charge} = \frac{\$}{\text{kW}} \times \text{Max Power}$$

$$= 4.2\frac{\$}{\text{kW}} \times 5.15\ \text{kW} = \$21.63$$

Demand Charges, continued

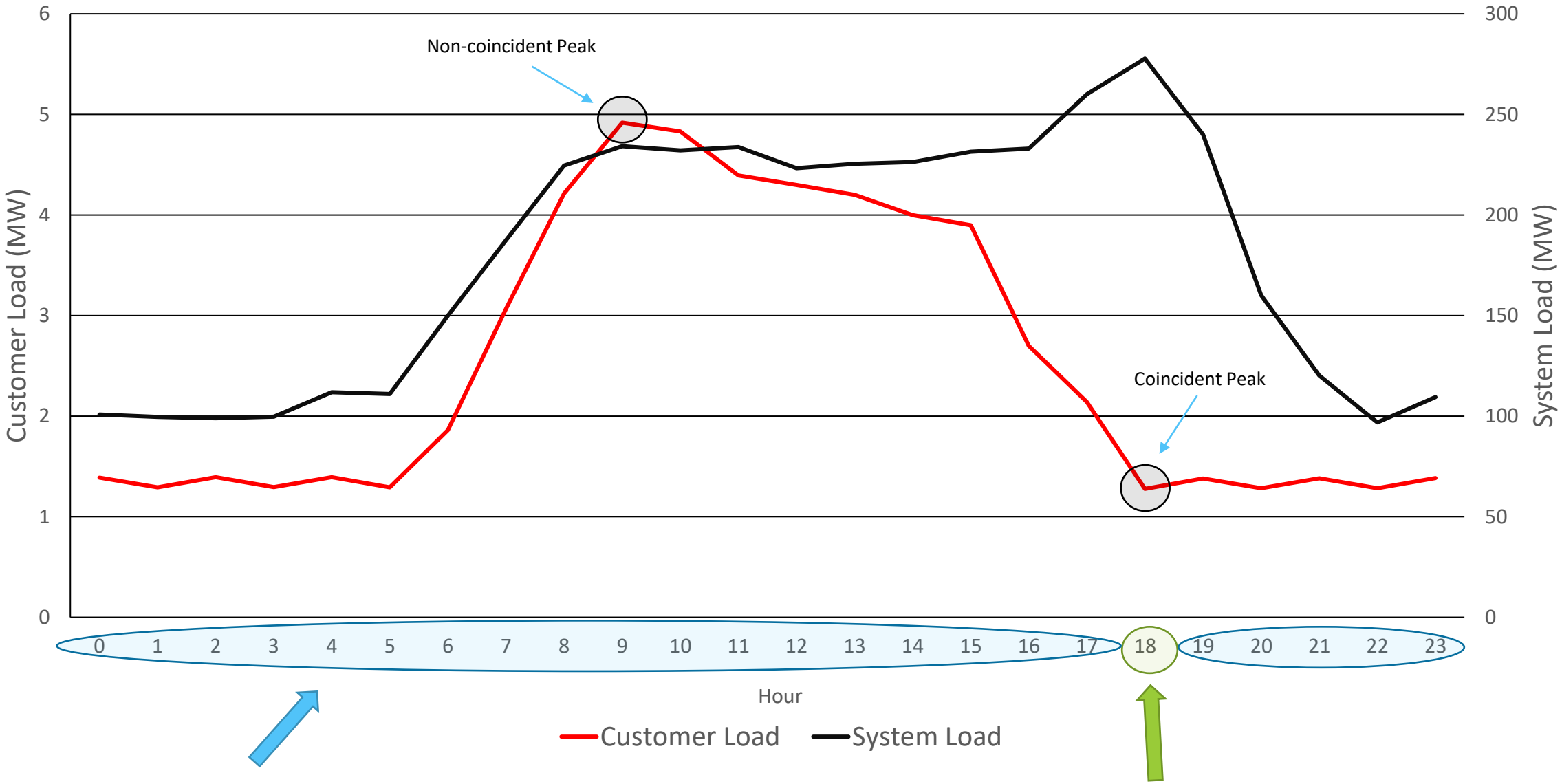
- Demand charges are common for commercial and industrial customers, uncommon for residential customers
- Demand charges can also vary by time of day (TOU) and season, and also be tiered or “ratcheted” to increase as the customer uses more power
- An emerging method to reducing demand charge is by using microgrids and distributed energy resources (solar PV, battery storage)
  - Supply own load during periods of high demand, so that utility import is reduced

Demand Charges, continued

- *Coincident charge* – charge based on the customer's demand at the time of the system-wide peak during a billing period
  - Charging for the customer's demand that is "coincident" with utility peak demand
- *Non-coincident charge* – charge based on the customer's highest demand over the billing period
  - This charge occurs regardless of the timing of system-wide peak demand

- Utilities may utilize both charges, and customers will see each charge separately on a statement

Load Profile



Electricity Rate Structure Exercise

Problem: An electrical conductor manufacturer purchases their electricity from Unified Electric Company, under a large-business TOU plan. The figures show the customer's TOU pricing structure (top) and the load profile for June 23, 2020 (bottom).

Question: Calculate the ON-PEAK non-coincident demand cost (assume June 23 is when the peak demand occurs for the month of June).

Summer on-peak demand charge: $5.29
Summer peak on-peak demand charge: $6.99
Winter on-peak demand charge: maximum of $4.69
Summer, summer-peak and winter shoulder and off-peak demand charge: $1.05
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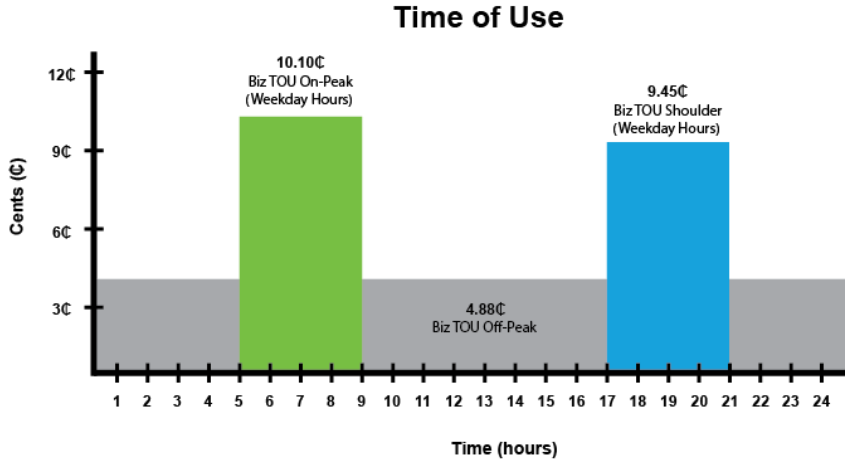
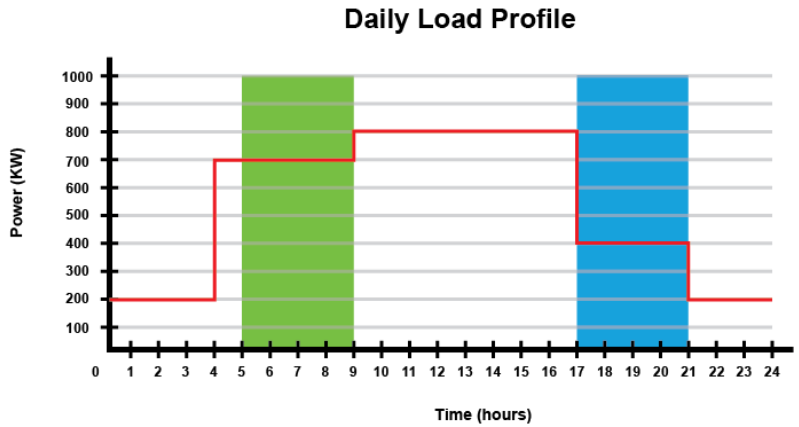
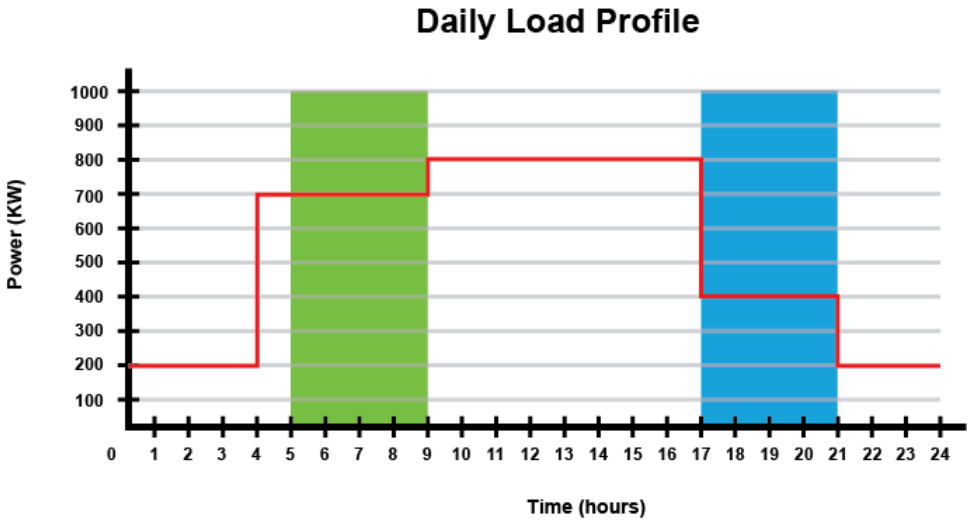
*All weekend hours are off peak.





Demand Cost



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Monthly service charge: $22.72 plus meter charge (CT/PT $16.88 or demand $6.11)

*All weekend hours are off peak.

$$\text{On peak demand} = 700\ \text{kW}$$

$$\text{On peak demand cost} = 700\ \text{kW} \times \frac{\$6.99}{\text{kW}}$$

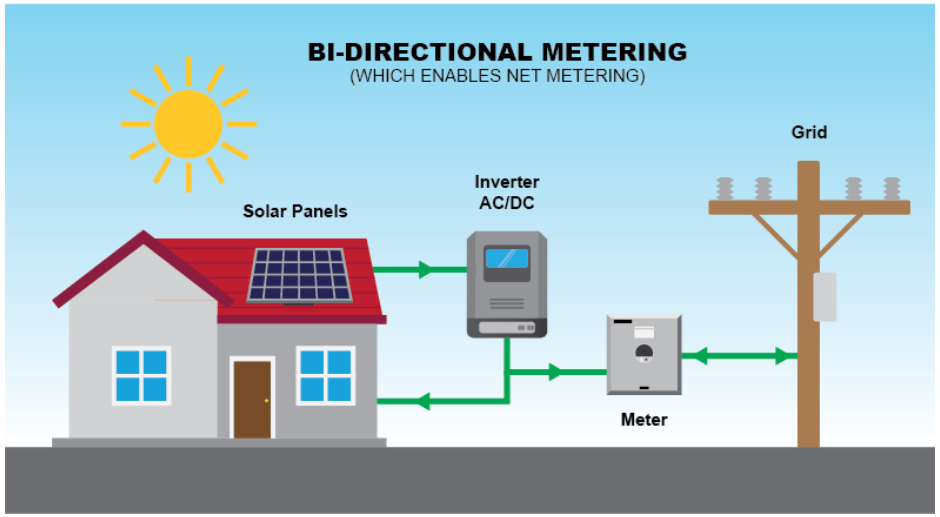
$$\text{On peak demand cost} = \$4{,}893$$

Additional Line Items on Electricity Bill

- Charges can be added to bill based on additional costs and tariffs seen by the utility company.
  - Feed-in tariff
  - Net metering credit
  - Environmental fee
  - Fuel fee
  - Stand-by charge
  - Power Factor charge
  - Distribution fees
  - Other “rate riders”

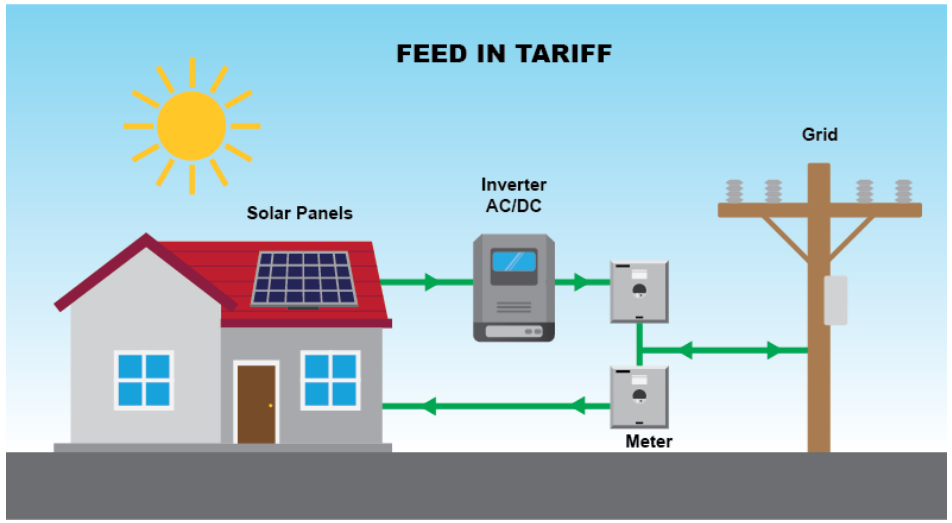
Net metering (common in the United States)

- Net metering is a type of billing agreement between the electrical utility and the consumer.
- Consumer power systems that produce electricity are credited for excess electricity (kWh) that is not used at the time of production.
- This electricity is sent back to the grid and the electrical meter runs backwards generating credits.
- With net metering the consumer is charged for the net power they consume over a designated period (typically monthly or annually).



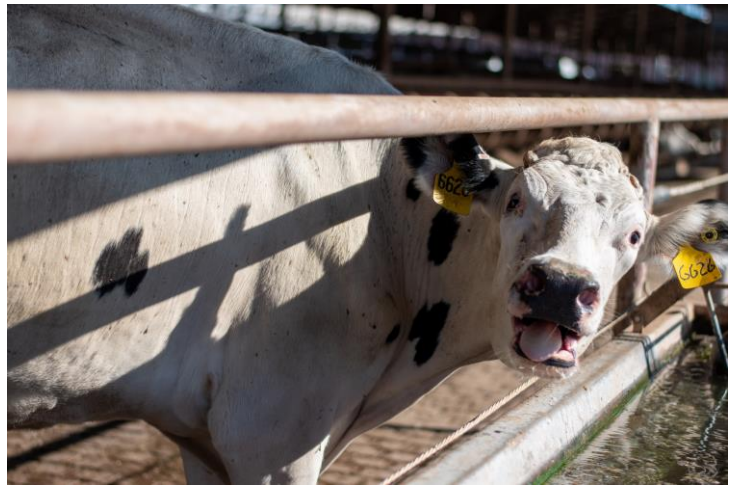
Feed-in-tariff (common in most countries)

- All renewable energy is sold ($) to the utility.
  - Regardless of how much energy you consume.
  - Sometimes this is a fixed rate $/kWh.
  - Requires a separate “revenue” energy meter.
- Sometimes called “sell back” if available in conjunction with net metering… excess energy is sold at the end of each billing period.
  - This is at a substantially lower price (e.g., 0.03$/kWh) than the purchase price (e.g., 0.10$/kWh).
  - It is very rare to “make money” off selling power to the grid… you still have connection charges, etc.



Custom Rate Structures

- Sometimes utility companies will create customized rate structures for end-users in unique situations.
  - Businesses in isolated or remote areas such as farms or mining.
  - Large areas or governmental jurisdictions with many energy meters
- Utilities may also create rate structure based on *type* of end-use.
  - Water pumping and electric resistance heating are commonly separated from general energy use, and require a separate meter



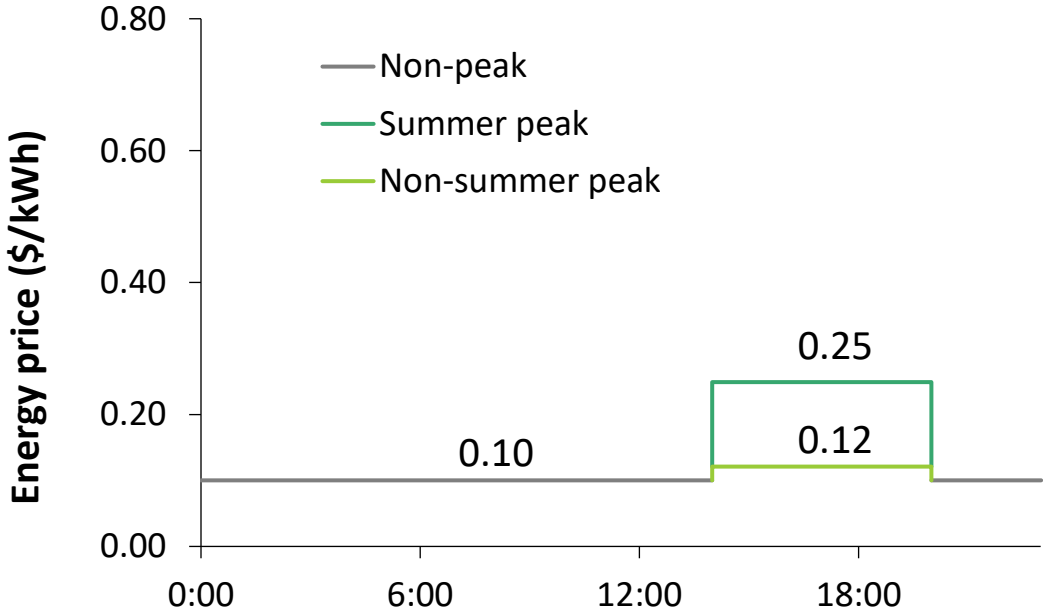
Example: Energy Shifting

Question: Given a household with a constant power consumption of 2 kW, how much money can be saved per year by shifting 25% of energy consumption from peak hours to non-peak hours?

Peak hours: 2pm-8pm

Summer: June 1 – Sept 30

Winter: Oct 1 – May 31



$$E_{shifted} = P \times t = \left(2\ \text{kW}\right) \times \left(25\%\right) \times \left(\frac{6\ \text{hr}}{\text{day}}\right) = 3\ \frac{\text{kWh}}{\text{day}}$$

Example: Energy Shifting

Summer peak: June 1 – Sept 30, 2pm-8pm, $0.25/kWh

Winter peak: Oct 1 – May 31, 2pm-8pm, $0.12/kWh

Off-peak: all other times, $0.10/kWh

$$C_{savings} = C_{savings,summer} + C_{savings,winter}$$

$$E_{shifted} = 3\ \frac{\text{kWh}}{\text{day}}$$

Summer

$$C_{savings,summer} = C_{energy,summer} - C_{energy,off\text{-}peak} = E_{shifted,tot} \times \left(c_{energy,summer} - c_{energy,off\text{-}peak} \right)$$

$$= \left(3\ \frac{\text{kWh}}{\text{day}} \right) \times \left(122\ \text{day} \right) \times \left(\left(0.25 - 0.10 \right) \frac{\$}{\text{kWh}} \right)$$

$$= \$54.90$$

Example: Energy Shifting

Summer peak: June 1 – Sept 30, 2pm-8pm, $0.25/kWh

Winter peak: Oct 1 – May 31, 2pm-8pm, $0.12/kWh

Off-peak: all other times, $0.10/kWh

Winter

$$C_{savings,winter} = C_{energy,winter} - C_{energy,off\text{-}peak} = E_{shifted,tot} \times \left(c_{energy,winter} - c_{energy,off\text{-}peak} \right)$$

$$= \left(3 \ \frac{\text{kWh}}{\text{day}} \right) \times \left(243 \text{ day} \right) \times \left(\left(0.12 - 0.10 \right) \frac{\$}{\text{kWh}} \right)$$

$$= \$14.58$$

$$C_{savings} = C_{savings,summer} + C_{savings,winter} = \$54.90 + \$14.58 = \underline{\underline{\$69.48 \text{ per yr}}}$$

XENDEE Utility Tariff Creation

Create a Fijian Business Rate

Use the following link to identify the appropriate rate for a customer with a peak load of 479 kW.

https://efl.com.fj/your-business/electricity-tariffs-and-rates/maximum-demand-tariffs/

These tariffs cannot be accessed by small business customers whose Demand is less than 75KW.

Maximum Demand between 75kW – 500kW

This tariff has a charge for the total amount of electricity used (Energy Charge in kWh), plus a Demand Charge (kW), for the relevant billing period. The demand is a measure of the maximum amount of electricity used at any one time. The chargeable demand in any month is the maximum demand recorded in that month. For customers whose Maximum Demand is between 75kW – 500kW the following tariff is applied.

Demands between 75kW – 500kW	Tariff Price – VAT Exclusive
Demand Charge – dollars per kW per month	$35.33
Energy Charge cents per kWh per month	27.81 cents
Excess Reactive Energy – cents per kVarh per month	42.95 cents

Maximum Demand > 500kW and < 1000kW

This tariff has a charge for the total amount of electricity used (Energy Charge in kWh), plus a Demand Charge (kW), for the relevant billing period. The demand is a measure of the maximum amount of electricity used at any one time. The chargeable demand in any month is the maximum demand recorded in that month. For customers whose Maximum Demand is more than 500kW and less than 1000kW the following tariff is applied.

Demands between 500kW and < 1000 kW	Tariff Price – VAT Exclusive
Demand Charge – dollars per kW per month	$37.57
Energy Charge cents per kWh per month	30.26 cents
Excess Reactive Energy – cents per kVarh per month	42.95 cents

Maximum Demand > 1000kW

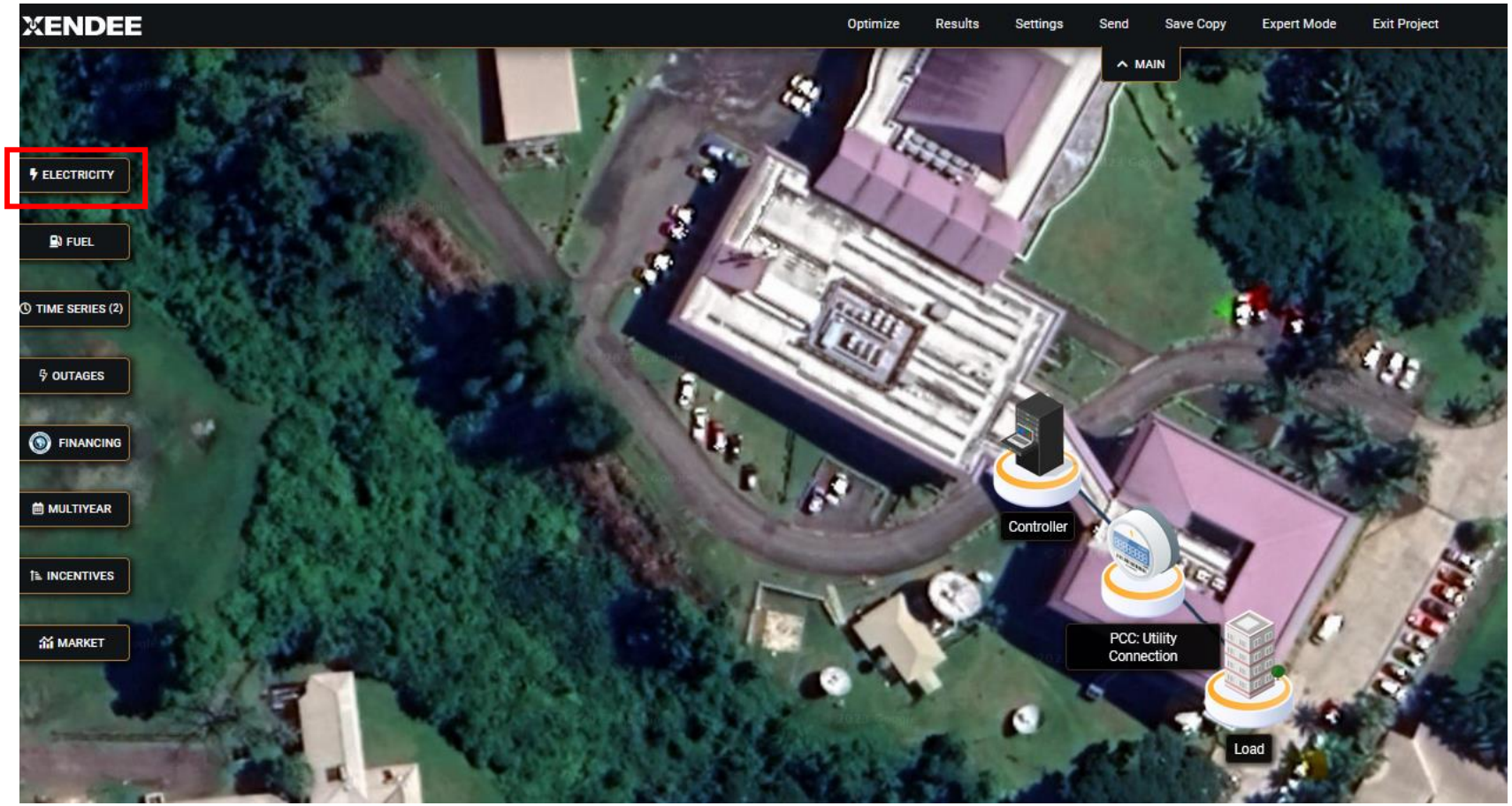
This tariff has a charge for the total amount of electricity used (Energy Charge in kWh), plus a Demand Charge (kW), for the relevant billing period. The demand is a measure of the maximum amount of electricity used at any one time. The chargeable demand in any month is the maximum demand recorded in that month. For customers whose Maximum Demand is more than 1000kW the following tariff is applied.

Demands > 1000 kW	Tariff Price – VAT Exclusive
Demand Charge – dollars per kW per month	$39.24
Energy Charge cents per kWh per month	32.70 cents
Excess Reactive Energy – cents per kVarh per month	42.95 cents

Create a Fijian Business Rate

Open the previously create “Fiji Activities” project in your XENDEE account.

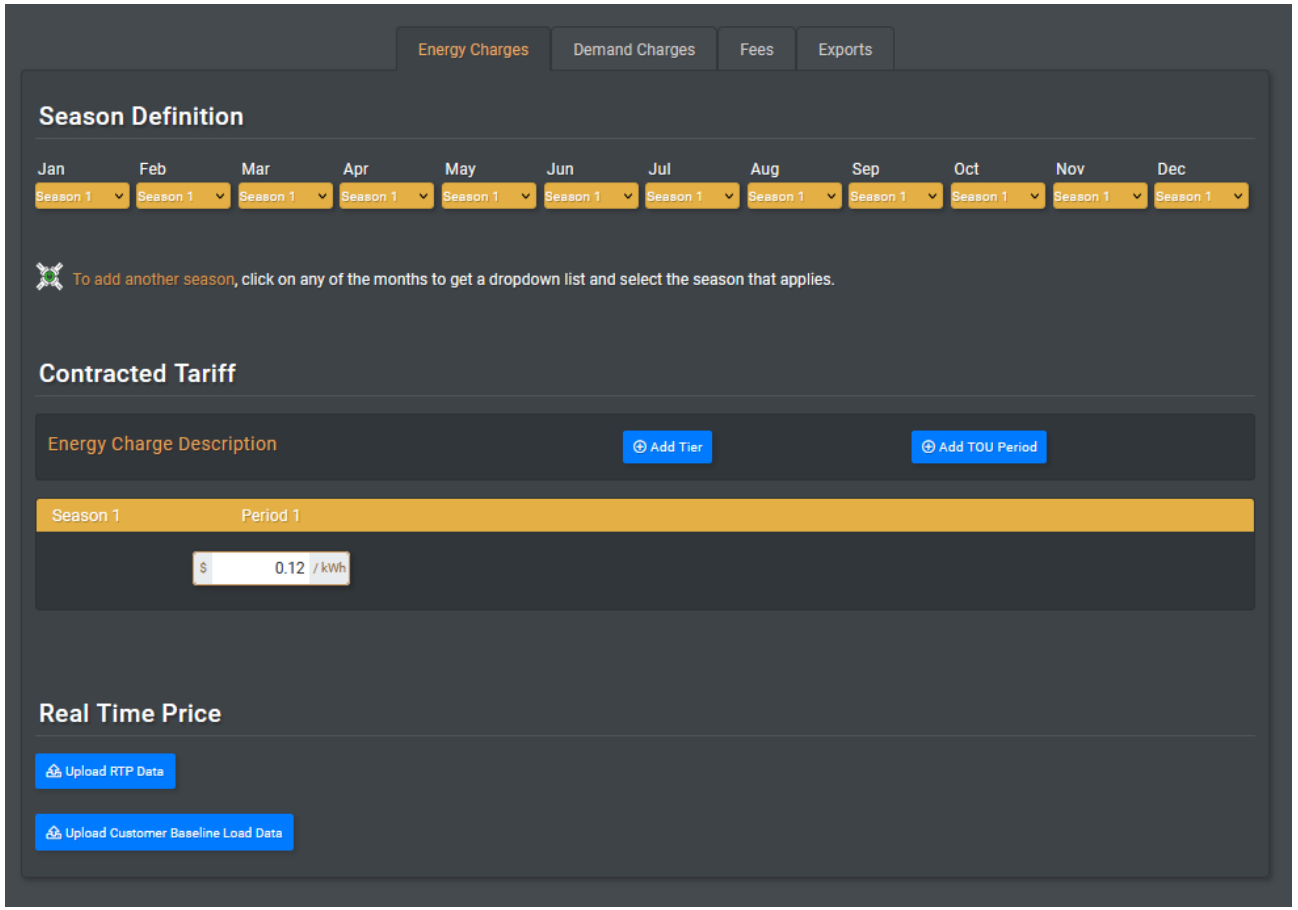
Navigate to the ELECTRICITY button on the left-hand side and select.



Create a Fijian Business Rate – Energy Charges

Convert the energy charges from FJD to USD and input into appropriate XENDEE fields.

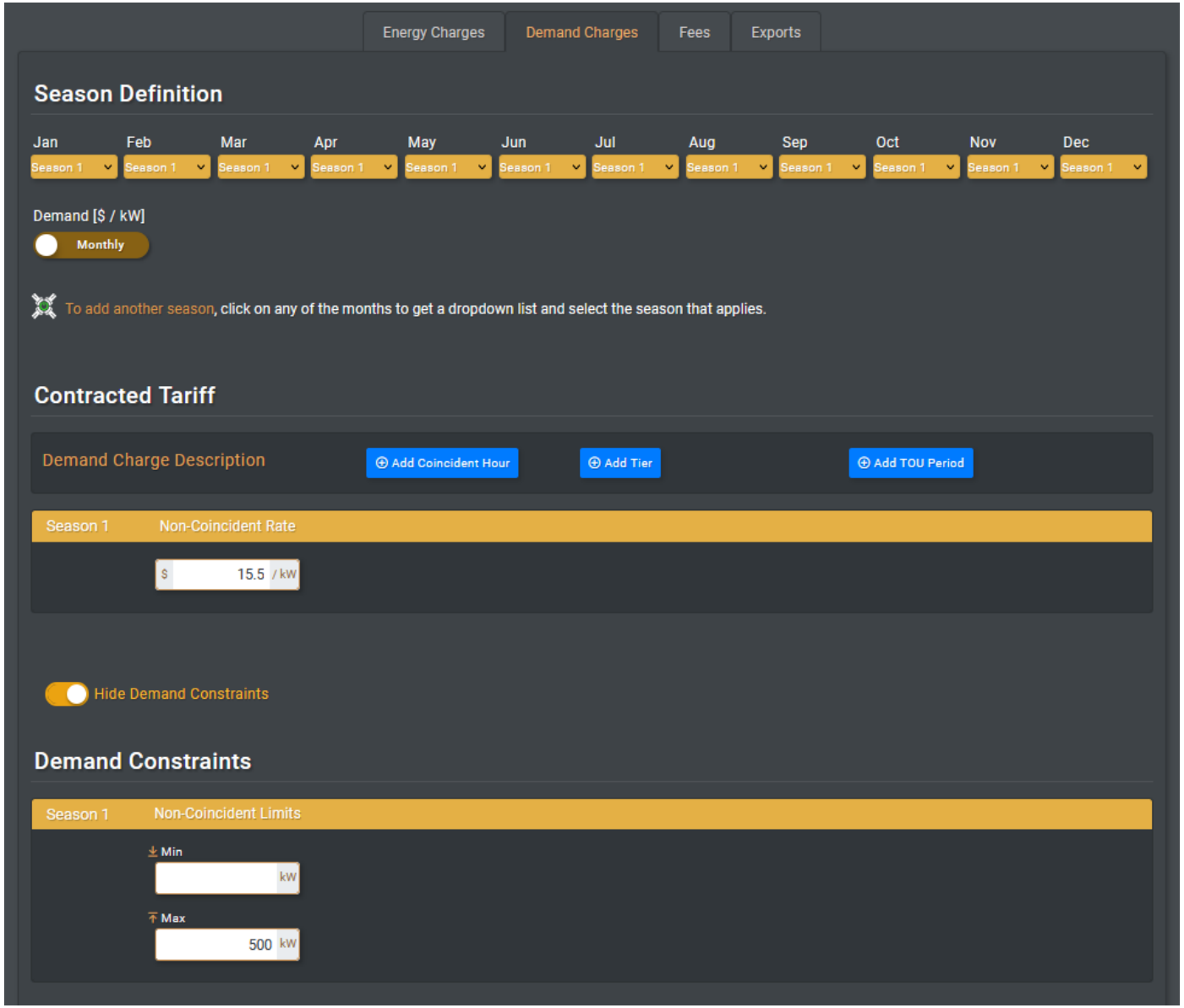
0.2781 FJD/kWh = 0.12 USD/kWh



Create a Fijian Business Rate – Demand Charges

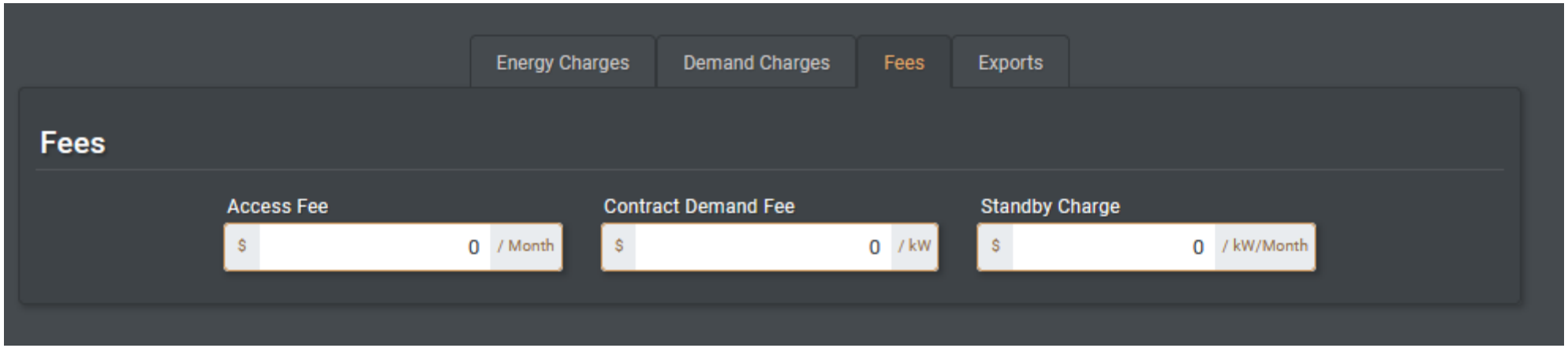
Convert the demand charges from FJD to USD and input into appropriate XENDEE fields. Also enforce a maximum demand constraint of 500 kW to ensure tariff eligibility.

35.33 FJD/kW = 15.50 USD/kW



Create a Fijian Business Rate – Fees

The web page indicates no type of fixed charges or fees. Ensure all field in XENDEE are zero.

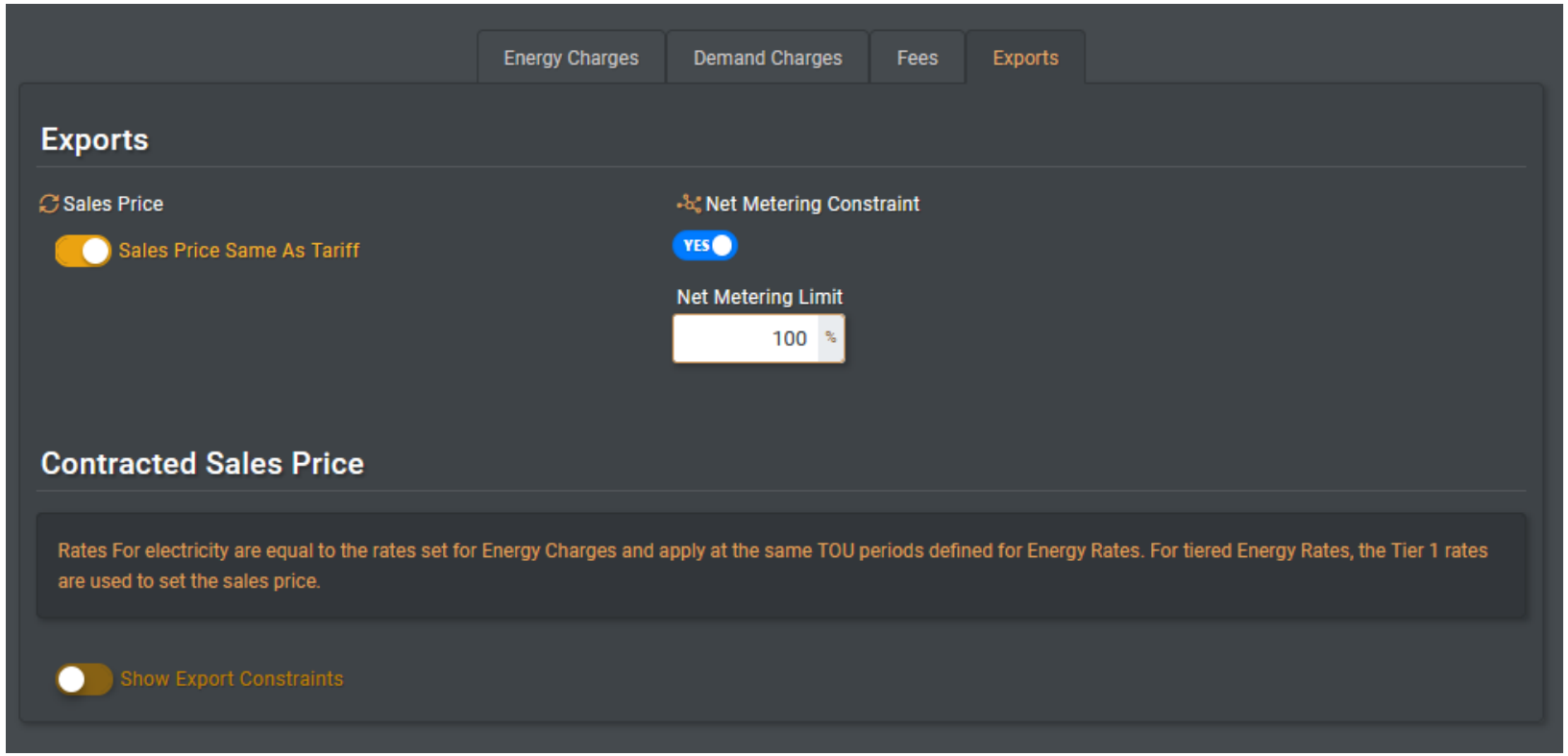


Create a Fijian Business Rate – Exports

Assume a net metering type of export regulation/system.

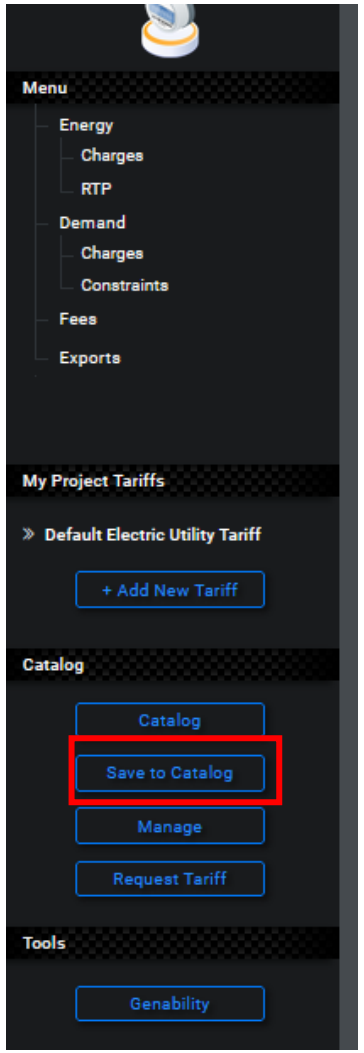
Assume the export sales prices as the same as the tariff.

Enable the Net Metering Constraint in XENDEE to ensure that the total annual exports (kWh) to the utility can not exceed imports (kWh).

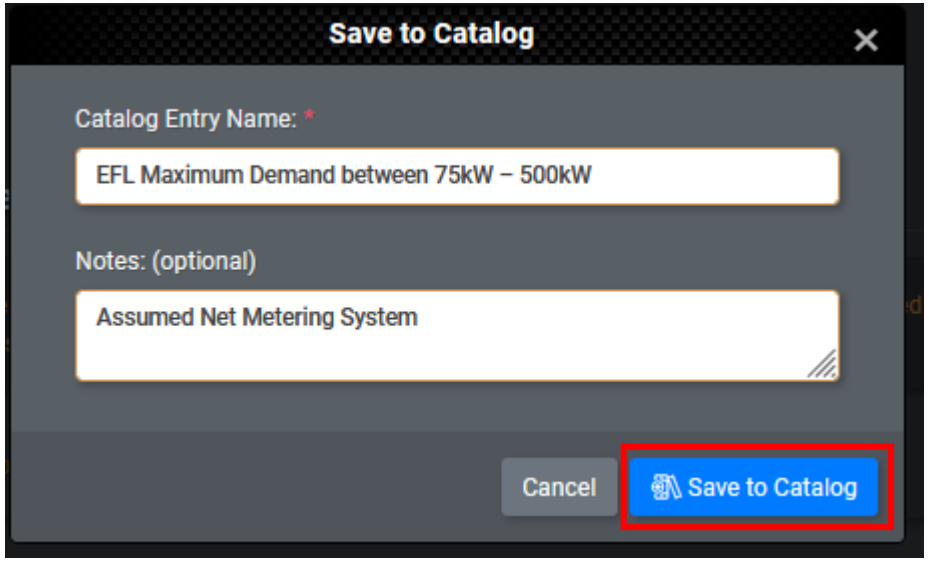


Create a Fijian Business Rate – Save to Catalog

Select “Save to Catalog” on the left side of the screen to save the tariff for future use in different projects.

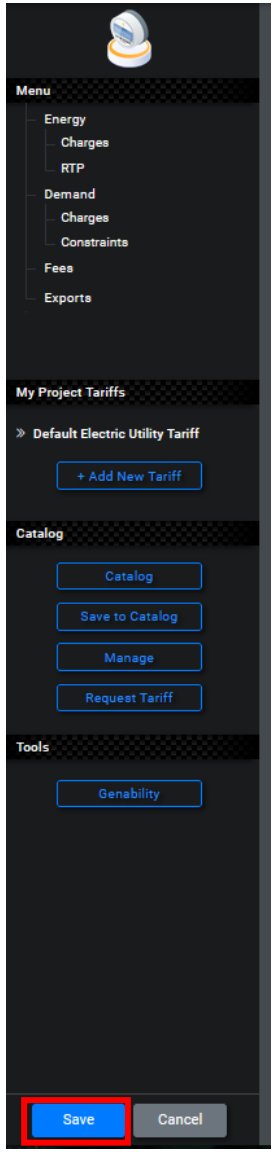


Provide a representative name for the saved tariff and any important notes and select “Save to Catalog”.



Create a Fijian Business Rate – Save Project Tariff

Select “Save” on the bottom left side of the screen to save the tariff for the project.



Lesson Summary

Lesson Summary

- How are energy charges calculated?
- How are demand charges calculated?
- What are the differences between net metering and feed-in tariff, and what are the implications to customer electric bills?
- What are the different ways to input electricity rate data into XENDEE?