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Center for Advanced Power Engineering Research

Customer-Oriented Planning Strategies for Active Distribution Systems

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Project Team

Clemson Team	
Role	**Name**
Faculty Advisor	Dr. Ramtin Hadidi & Dr. Jesse Leonard
Undergraduate Students	Joshua Smith, Jeffrey Miller, Garrett Bacon
Graduate Student	Roghieh Abdollahi

NCSU Team	
Role	**Name**
Faculty Advisor	Dr. David Lubkeman & Dr. Ning Lu
Undergraduate Students	Taylor Hill, Lilly Vang
Affiliated Graduate Student	Catie McEntee, David Mulcahy, Lisha Sun, Jiyu Wang, Asmaa Alrushoud, Ahmed Mohamed

Project Overview

- ✓ Current situation

  Current approach to distribution planning somewhat **utility-oriented** in that it assumes utility owns and operates most generation and customers are passive participants.

- ✓ New Technology and Market Initiatives

  In the future, customers owning distributed energy resources (DER) will result in an “active” distribution system, requiring new planning paradigms, with more focus on customer benefits and participation in the local energy market.

- ✓ Proposed Project

  This project aims to develop **customer-oriented** planning strategies for active distribution systems that incorporate customers’ expectations and future grid impacts.

Project Benefits

- Establish both customer-oriented and utility-oriented planning model.
- Develop continuous power flow calculation methods and model dynamic responses of the active distribution system.
- Develop new active distribution system planning criteria.
  - Integration of smart PV inverters
  - Integration of energy storages
  - Integration of demand response resources

Work Plan

Task 1: Identify features relevant to CAPER membership

Task 2: Define use case scenarios and architecture assumptions

Task 3: Build a test bed

Task 4: Develop models for customer-owned/operated DER and demand response

Task 5: Construct power flow/dynamic analysis methodology

Task 6: Characterize customer-oriented applications

Task 7: Planning criteria for customer-oriented distribution

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Task 1 – Identify Features

Define features of future customer-oriented active distribution systems

- Extract features from customer-oriented distribution systems considered in other part of the grids (New York, California, and Hawaii)

- Review European and other non-US customer-oriented planning initiatives

- Get Duke Energy’s and other CAPER participant feedback on which features should be considered in this study

Jan 27 Discussion with Duke Energy

- Duke Energy has several existing and past initiatives we could possibly get data from: Zero Energy House EPRI project, Duke Energy circuit with AMI data, possibly data collected for rate analysis.
- Duke Energy has issues modeling load with distributed generation. Limited ability to "disaggregate" to determine impact of the DG component.
- Duke Energy is current evaluating storage technologies. However there is currently no energy storage tariff.
- Would be value in looking at scenarios and business case for utility vs. customer owned storage. Work on evaluating tariff options ranging from flat rate to dynamic pricing structures.

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Presentation Outline

- Introduction - Dr. David Lubkeman
- Ongoing Initiatives
  - NY REV, Northeast - Catie McEntee
  - CA & HI vs. Duke Energy - Roghieh Abdollahi
- Analytical Modelling Tools Survey
  - HOMER - Taylor Hill
  - OpenDSS - Joshua Smith
  - GridLAB-D - Lisha Sun
- Customer Modeling - David Mulcahy
- Conclusions – Dr. Ramtin Hadidi

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Literature Review: Initiatives in the Northeast

Catie McEntee

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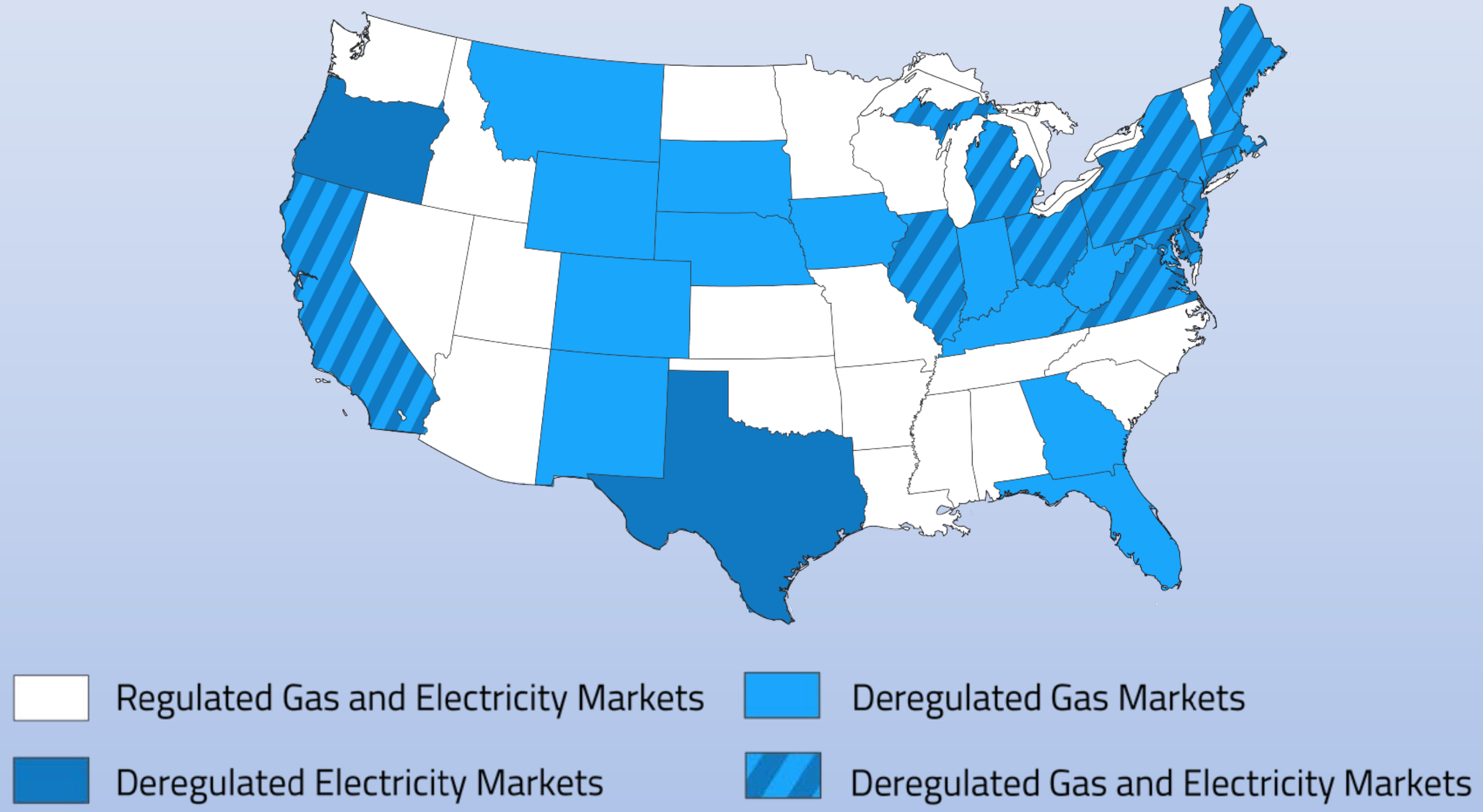
Northeastern Energy Markets

- Deregulated
- ISOs
- Higher Prices



While the industry landscape is different, we can learn from their projects

https://www.electricchoice.com/map-deregulated-energy-markets/

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Initiatives in the Northeast

NY REV directs utilities to create markets for distribution services provided by distributed generation (DG), demand response (DR) and energy storage (ES).

- Affects Consolidated Edison, National Grid, Central Hudson, Iberdrola, Orange & Rockland

Massachusetts Energy Storage Initiative aims to incorporate ES into the state's energy portfolio by creating a market for ES services.

Emerging Use Cases

- ES maximizes customer benefits of PV
- Increased resiliency as a premium service
- DG, DR and ES provide distribution services

These three concepts can be stacked for maximum benefits to customers and utilities

ES maximizes benefits of PV

- ES used with PV as **backup power**
- ES used for **self-consumption** of PV to reduce electric bills (useful when net-metering is not used)

Resiliency as a Premium Service

- Customers connected to a **microgrid** pay premium for increased reliability
- Customers buy or lease **energy storage** for backup power
- Commercial customers buy **generators** for backup power

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DG, DR and ES Provide Distribution Services

When dispatched properly, these can have positive impacts on the grid that reduce utility costs

- Use **price signals** to encourage use of devices to provide distribution services
- **Direct utility control** of devices behind-the-meter to provide distribution services

Stacking benefits

- Provide distribution services when the grid is on
- Provide backup power when the grid is out
- Improve benefit-cost ratio for both customer and utility

Green Mountain Power: Powerwall Sales

Customers can buy or lease Powerwalls under 3 pricing schemes

Option	Up-front cost	Monthly cost	Monthly Credit	Net Monthly Fee
Option 1: **Direct Purchase**	$6,501	$0	$0	$0
Option 2: **Direct Purchase with Utility Control**	$6,501	$0	$31.76	-$31.76
Option 3: **Rate Rider with Utility Control**	$0	$86	$48.50	$37.50

http://www.greenmountainpower.com/wp-content/uploads/2017/01/Hudson-12.02.2015-Tesla-Pilot-Filing.pdf

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Buffalo Niagara Medical Campus
Distributed System Platform Engagement Tool

- Medical buildings already have backup generators
- Utility will pay customers to generate power during peak times
- Pricing is based on distribution system benefits

BMNC DSP pricing

LMP + D where D = d1 + d2 + d3 + d4 + d5

LMP: Locational Marginal Price

d1: Avoided Distribution Capacity Infrastructure Costs

d2: Avoided O&M Costs

d3: Avoided Distribution Losses

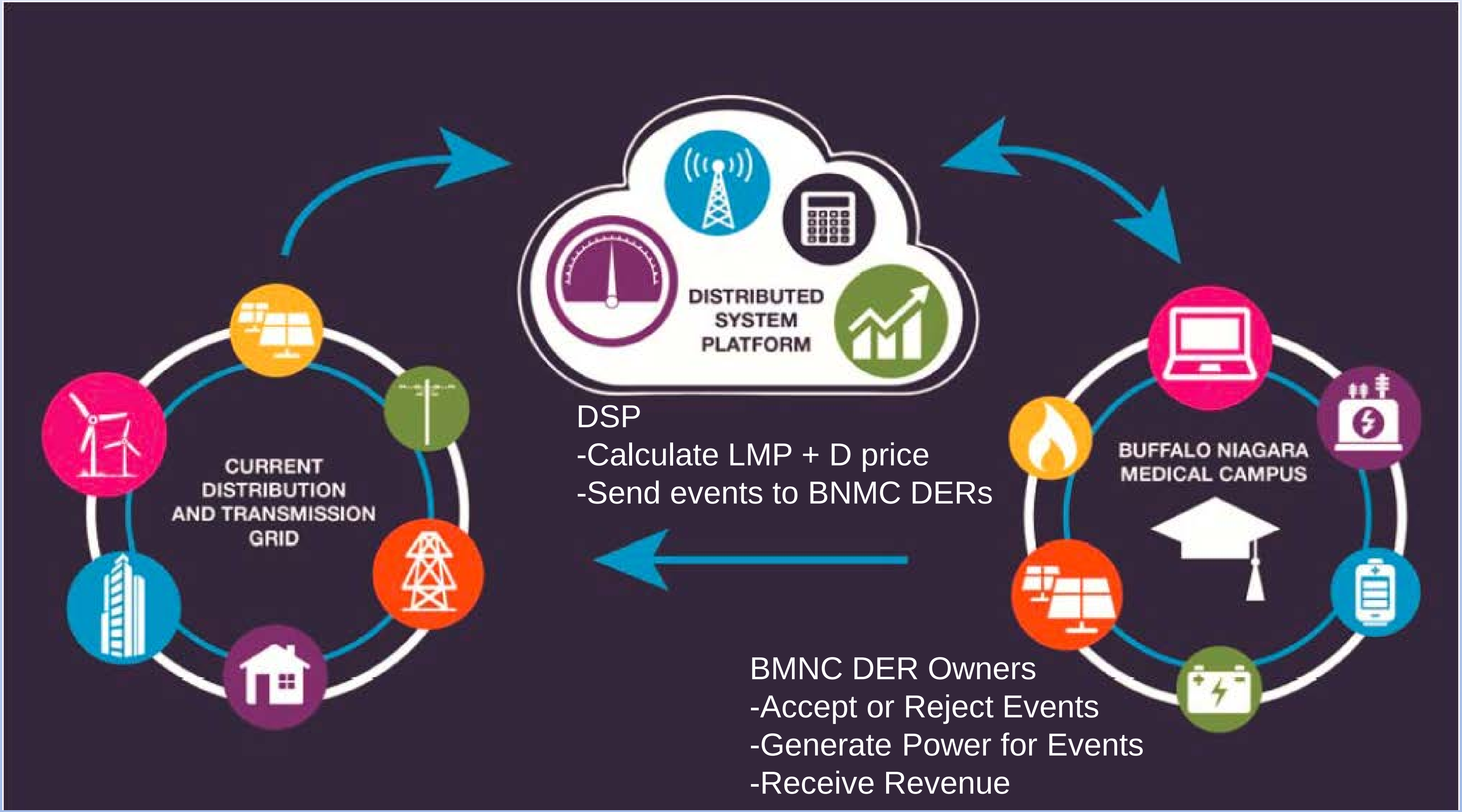
d4: Avoided Restoration Costs

d5: Avoided Outage Costs.

D costs calculated using equations from National Grid's Benefit Cost Analysis Handbook (August 2016)

http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BF0CC59D0-4E2F-4440-8E14-1DC07566BB94%7D

BMNC DSP Operation



http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B3F422A3A-BCC4-4B04-AA5C-9BDC6379E7F2%7D

Potsdam Resiliency Microgrid

A microgrid consisting of storm-hardened underground wires, generators and critical businesses will be installed

- Hydro Plants
- Combined Heat and Power Plants
- Gas Plants
- Solar Array
- Fire and Police
- Hospital
- National Grid Service Center
- Grocery & Drug Stores
- Water & Wastewater Plants
- College Campuses
- Hotel
- Bank

Customers connected to the microgrid share resiliency costs with surrounding customers who benefit from the operation of emergency services during outages

http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B20419D8D-C98E-4969-8EB9-536FF39B82C2%7D

Potsdam Resiliency Microgrid Pricing

Connection	Tier	Customers	Number of Customers	Cost Proportion
Direct	1a	Connected Generators	2	6%
	1b	Connected Businesses	10	1.5%
Indirect	2	Village of Potsdam Border	2,757	14%
	3	Town of Potsdam Border	3,709	18%
	4	Nearby towns	4,024	10%
	5	Surrounding Zip Codes	16,022	50%

Decreasing Cost Per Customer

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Projects Summary

Project	State/ Utility	Technology	Services	Pricing	Control
Powerwall Sales	VT/ Green Mountain Power	Energy Storage	Backup Power Peak Shaving	Rate Rider + Fixed credit	Utility Control (Optional)
BMNC DSP Engagement Tool	NY/ National Grid	Distributed Generation	Backup Power Peak Shaving	LMP + D	Customer Control with Price Signals
Potsdam Resiliency Microgrid	NY/National Grid	Microgrid (DG + underground cables)	Backup Power	Tiered Fixed Charge	Utility Control

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Next Steps

- Literature review on initiatives and projects outside the US (especially Europe)
- Narrow down use cases to model

Which use cases should we investigate?

- What constraints do we have due to regulations?
- Which services or customer behaviors are we interested in?
  - Peak Shaving
  - Voltage Support
  - Reduced Losses
  - Resiliency & Backup Power
- Which tariff structures are we interested in?
  - Flat vs. Time-of-use vs. Real-time pricing
  - Fixed payment to customers for allowing utility control
  - Utility ownership with rate riders for customer use

Literature Review on Rate Structure

Roghieh Abdollahi, Jeffrey Miller,
Garrett Bacon

EXPECTATIONS

What utilities want

- Smooth load profile
- Lower cost price
- Reasonable reliability
- High power quality to have lower possible generation

What customers want

- High power quality to have lower damage in electronic devices and lower payment bill
- Acceptable reliability
- Lower payment bill
- Clear policy and high level of customer services

Effective factors on customer behavior

- Home appliance efficiency including PEVs (Plug in Electric Vehicles)
- Weather (temperature , humidity ,…)
- Weekdays / weekends / holidays
- Renewables
- Storage

The effect of these factors can be summarized as electricity rates, so customer behavior can be directed by electricity rates.

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Northern California rates are based on:

- 10 different regions with different kwh of consumption baselines
- Two seasons for billing rates (summer and winter)
- Two different codes

  Code H: Customers with permanently installed electric heating as the primary heat source

  Code B: Basic quantities
- Regular or Time of Use (TOU) schedule
- Peak / part peak / off peak for TOU
- Clustering the customers to residential, agricultural, business, and so forth
- ***PEVs (plug in electric vehicle)***,according to submitted usage demand (kw) and energy consumption
- ***Small Renewables*** (less than 1.5 MW) , according to the Length of contract and Market-Price-Referent (MPR)

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Southern California rates are based on

- 9 different regions with different kwh of consumption baselines
- Two seasons for billing (summer and winter)
- Regular or Time of use (TOU) schedule
- Peak / off peak
- Week days, weekends , and holidays
- Clustering the customers to residential, business, and agricultural
- **Electric Vehicle has different rate option(TOU-D-EV-1)**, with separate metering
- **Renewables,** total capacity should not exceed 1,000 kW and NEM (net energy metering) system is used for measurements

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Duke Energy

- Duke Energy contains Six states.

  South Carolina, North Carolina, Indiana, Florida, Ohio, and Kentucky.

- Duke energy has different policy for different states.

South Carolina

- Two level of consumption are defined.
- Standard consumption or heating and air conditioner included
- Regular or Time of use (TOU) schedule
- Peak / off peak
  - Different rates for June-September and October-May
  - In peak time customer will be charged for both demand and energy
- Energy STAR certification (**ENERGY STAR** is a U.S. Environmental Protection Agency voluntary **program** that helps businesses and individuals save money and protect our climate through superior **energy** .)
- Clustering the customers to residential, industrial, and general.

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North Carolina

- Two level of consumption are defined
- Standard consumption or heating and air conditioner included (different rates for July-October and November-June and level of energy consumption)
- Regular or Time of use (TOU) schedule
- Peak (Monday-Friday) / off peak
  - In peak time customer will be charged for both demand and energy
  - Different rates for June-September and October-May
- Energy STAR certification (**ENERGY STAR** is a U.S. Environmental Protection Agency voluntary **program** that helps businesses and individuals save money and protect our climate through superior **energy** .)
- Clustering the customers to residential, industrial, and general.

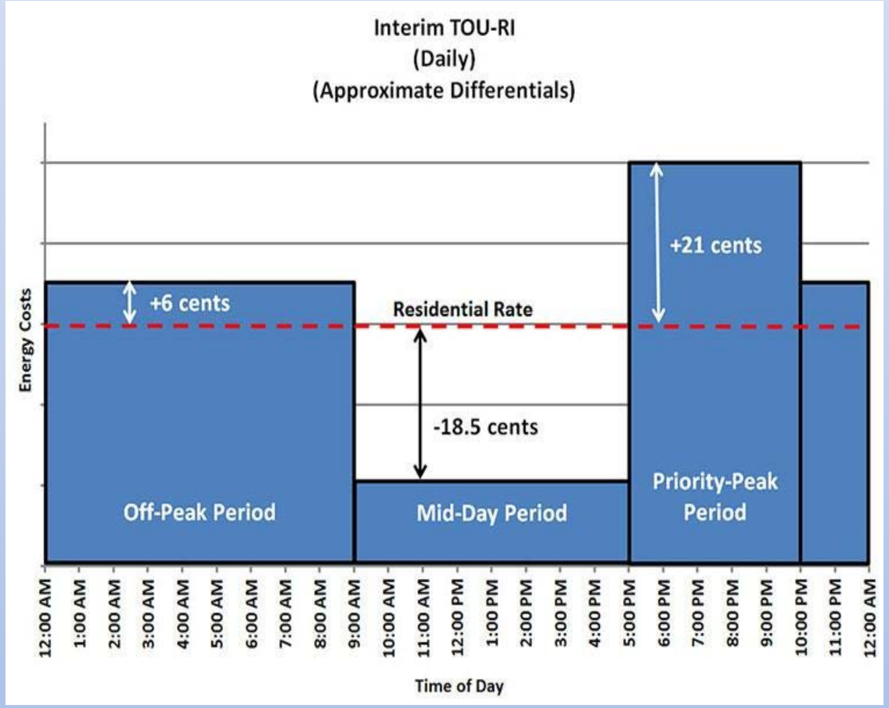
Hawaii Islands

- Electricity prices in Hawaii are generally higher than on the U.S. mainland due to the cost of imported oil used to power many of the islands' generators.

- Because of isolated geographic location, they can not draw power from nearby utility companies in the event of a problem, so they contribute to the higher cost of electricity.

Hawaii Public Utilities Commission (HPUC)

- Three level of consumption are defined, different limit for different Islands
- Regular or Time of use (TOU) schedule
- Peak / off peak and part peak for some Islands
- Clustering the customers to residential, commercial, and general.
- EV metering can be separated
- Customers get paied if they use less than their contracts



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Kauai

- **Monthly rates**
- Regular or Time of use (TOU) schedule
- Clustering the customers to residential, large power , commercial and general customers

Average rates for the 5 major islands served by HECO and KIUC

O'ahu	27.4 cents/kWh
Molokaii	34.4 cents/kWh
Lana'I	34.9 cents/kWh
Maui	29.3 cents/kWh
Big Island	32.9 cents/kWh

	Northern California	Southern California	South Carolina	North Carolina	Hawaii
Different regions	10 regions with daily baselines	9 regions with daily baselines	monthly baseline	monthly baseline	monthly rate
Different baselines	< 100%	< 100%	< 1000 Kwh and > 1000 Kwh	first 350 Kwh	first 200/350 Kwh
	100%< < 200%	100%< < 400%			next 700/850 Kwh
	> 200%	> 400%		> 350Kw	over than 1000/1200Kwh
Seasonal for billing	summer / winter	summer / winter		summer / winter	
Different codes	Regular / Heating and Air conditioner		Regular / Heating and Air conditioner	Seasonal Regular / Heating and Air conditioner	
Regular or Time of Use (TOU) schedule	for peak time	for peak time and weekdays	for peak time	for peak time	for peak time
Peak and off peak timing	three definitions	two definitions	two definitions	two definitions	two/three definitions
Clustering the customers	YES	detailed in business	YES	YES	YES
PEV	according to demand and consumption	according to consumption			according to consumption
Solar Panel	Net metering and contract length	Net metering			Net metering
Storage					

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Electric Company	Regions	Daily Baselines		Payment Bill ($)		
				500Kwh	1000 Kwh	1500 Kwh
Duke	South Carolina	1000/30		56.77	105.24	156.98
	North Carolina	350/30		58.53	105.26	151.99
Pacific Gas and Electric Company (Northern California)	P	13.8	12.3	123.78	404.29	604.99
	Q	7	12.3	203.60	404.29	604.99
	R	15.6	11	123.78	404.29	604.99
	S	13.8	11.2	123.78	404.29	604.99
	T	7	8.5	203.60	404.29	604.99
	V	8.7	10.6	123.78	404.29	604.99
	W	16.8	10.1	94.28	244.65	604.99
	X	10.1	10.9	123.78	404.29	604.99
	Y	10.6	12.6	123.78	404.29	604.99
	Z	6.2	9	203.60	404.29	604.99
Southern California Edison	5	13.7	15.2	120.90	240.90	360.90
	6	9.4	9.6	120.90	240.90	465.90
	8	10.4	9.1	120.90	240.90	465.90
	9	13.8	10.6	120.90	240.90	360.90
	10	16.2	10.8	120.90	240.90	360.90
	13	18.8	10.9	80.90	240.90	360.90
	14	16.1	10.5	120.90	240.90	360.90
	15	39.9	8.2	80.90	160.90	360.90
	16	12.1	10.8	120.90	240.90	465.90
Hawaii	Oahu	(350-850-1200)/30		141.98	279.00	421.66
	Maui	(350-850-1200)/30		147.05	293.50	441.88
	Lanai	(250-500-750)/30		176.85	353.20	531.30
	Molokai	(250-500-750)/30		173.69	348.38	525.95
	Hawaii	(300-700-1000)/30		165.04	329.64	499.74
	Kauai	No Baseline		175.97	341.35	506.74

Payment bill for three different level of energy consumption in Residential sector

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https://www.hawaiianelectric.com/my-account/rates-and-regulations

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Residential PV Modeling with HOMER

Taylor Hill

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Why Use HOMER?

- Advances in Distributed Energy Resource (DER) technologies are only beneficial if residential consumers buy and use them at the home
- We want to see the economic value of these technologies on the customer side
- Using HOMER as an economic tool to evaluate what it will take to make PV installation and storage at the home attractive to consumers
  - Analyze the economic incentives that will drive the increase in use of DERs

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What is HOMER and its Capabilities?

- Developed by the U.S. National Renewable Energy Laboratory (NREL)
  - Now a tool sold by HOMER Energy
- The HOMER Micropower Optimization Model is an economic tool used to assist in the design of micropower systems and find the least cost combination of components
- HOMER (Hybrid Optimization Model for Multiple Energy Resources) nests three functions:
  - **Simulation, Optimization, and Sensitivity analysis**
- HOMER allows the modeler to compare many different design options based on their technical and economic merits

Inputs and Outputs

Inputs:

- Location
- Discount Rate
- Average Daily Load (kWh/day)
- Load Profile
  - Residential
  - Commercial
  - Community
  - Industrial
- Grid Information
  - Power Price ($/kWh)
  - Sellback Rate ($/kWh)
  - Pricing Structure Options
- PV Capital Cost ($/kW)
- Battery Options
  - Type
  - Battery Cost ($/kWh)

Outputs:

- Sensitivity Cases
  - Optimization Results
- Within the Optimization Results:
  - System Architecture
  - Cost Summary
    - Total NPC
    - Levelized COE
    - Operating Cost
    - Cash Flow
  - Electrical Results
    - Renewable Production
    - Grid Purchases
    - Load Consumption
    - Excess Electricity
    - Renewable Fraction

*Homer identifies the electrical and economic characterics per Component

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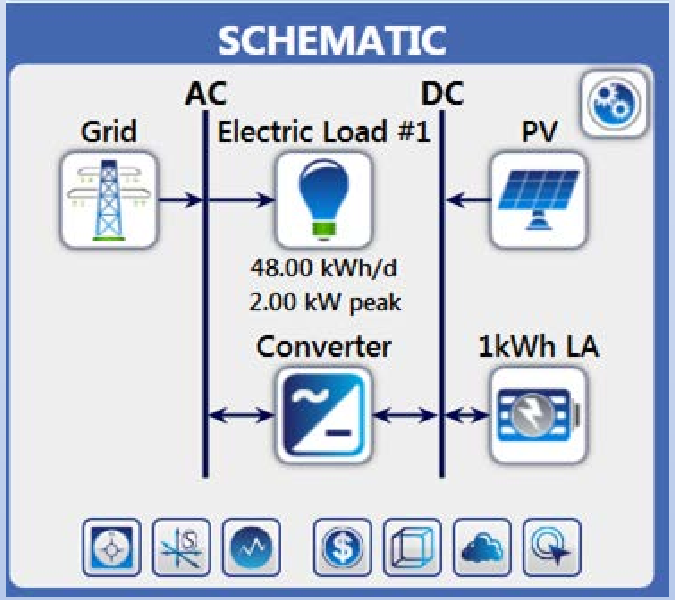
Residential PV + Storage Example

Inputs and Assumptions:

- Scaled Energy Consumption of 48 kWh/day
- Discount Rate of 8%
- 5kW PV at cost of 1950 $/kW
- 14 kWh of Lithium Ion Battery Storage at 100$/kWh
- Utility Energy price starting at $0.1/kWh
  - Sell-back price starting at $0.05/kWh
- All temperature and irradiance data downloaded from NASA surface meteorology and Solar Energy database for Raleigh, NC



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Residential PV + Storage Example

System Component Sizes

Total NPC , Operating Cost, and COE

Cost Type and Category Options

Graphical Representation of Cost Allocation

Cost Breakdown by Component

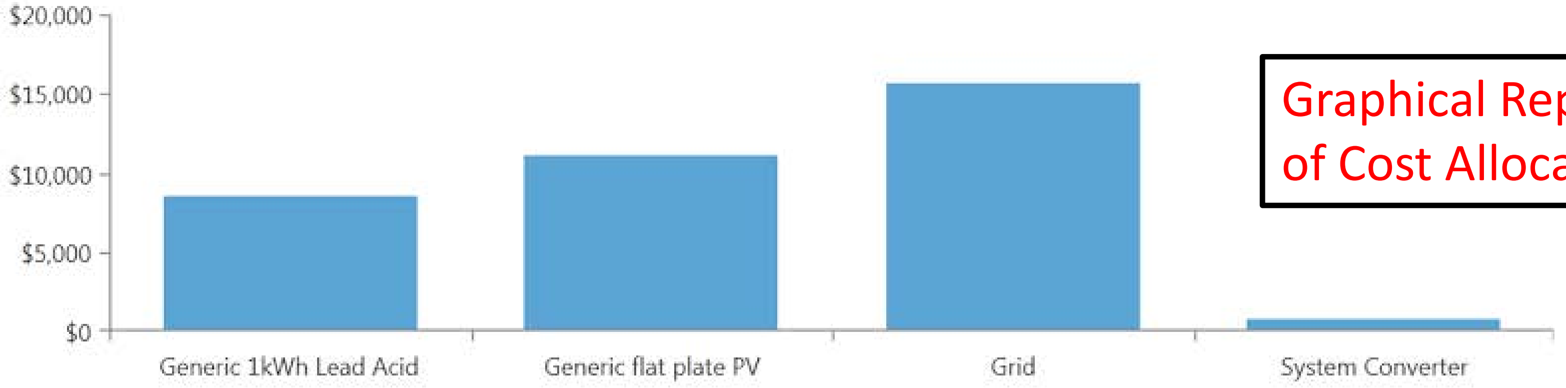
System Architecture: Generic flat plate PV (5.000000 kW) Grid (999999 kW)
Generic 1kWh Lead Acid (14 strings) HOMER Cycle Charging
System Converter (2.04 kW)

Total NPC:	$36,179.27
Levelized COE:	$0.1615
Operating Cost:	$1,632.34

Cost Summary | Cash Flow | Compare Economics | Electrical | Renewable Penetration | Generic 1kWh Lead Acid | Generic flat plate PV | Grid | System Converter | Emissions

Cost Type
- Net Present
- Annualized

Categorize
- By Component
- By Cost Type



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic 1kWh Lead Acid	$4,200.00	$2,923.87	$1,789.69	$0.00	($391.44)	$8,522.12
Generic flat plate PV	$10,500.00	$0.00	$639.17	$0.00	$0.00	$11,139.17
Grid	$0.00	$0.00	$15,697.51	$0.00	$0.00	$15,697.51
System Converter	$612.50	$255.57	$0.00	$0.00	($47.57)	$820.50
System	$15,312.50	$3,179.44	$18,126.37	$0.00	($439.01)	$36,179.30

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Residential PV + Storage Example

System Architecture: Generic flat plate PV (5.000000 kW) Grid (999999 kW)
Generic 1kWh Lead Acid (14 strings) HOMER Cycle Charging
System Converter (2.04 kW)

Total NPC: $36,179.
Levelized COE: $0.16
Operating Cost: $1,632.

t Summary | Cash Flow | Compare Economics | Electrical | Renewable Penetration | Generic 1kWh Lead Acid | Generic flat plate PV | Grid | System Converter | Emiss

Yearly Energy Production by Source

Production	kWh/yr	%
Generic flat plate PV	7,011	36.34
Grid Purchases	12,280	63.66
Total	19,291	100.00

Load per Year by Electrical Bus Type

Consumption	kWh/yr	%
AC Primary Load	17,520	100.00
DC Primary Load	0	0.00
Total	17,520	100.00

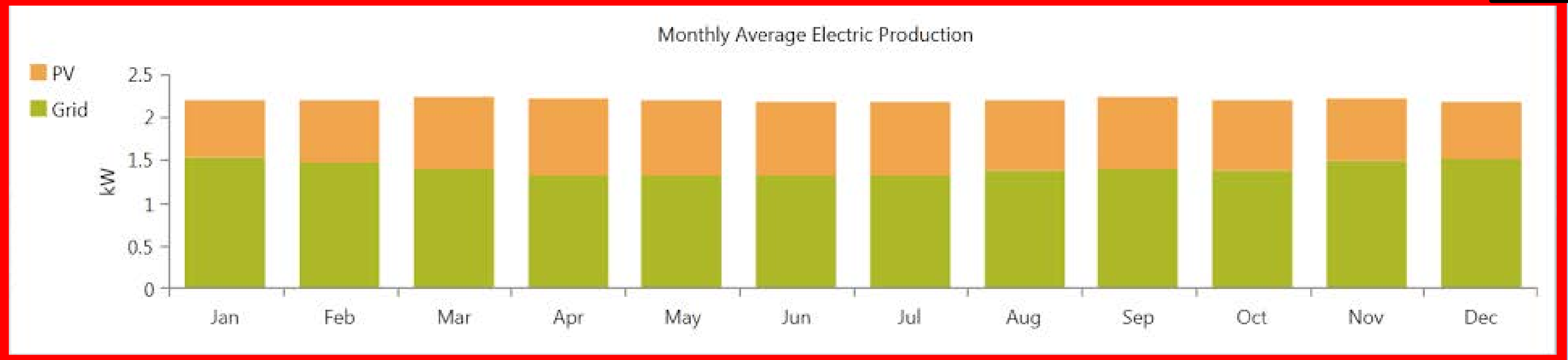
Excess Electricity Production per Year

Quantity	kWh/yr	%
Excess Electricity	1,495.0	7.7
Unmet Electric Load	0.0	0.0
Capacity Shortage	0.0	0.0

Max Renewable Penetration and Renewable Fraction

Quantity	Value
Renewable Fraction	29.9
Max. Renew. Penetration	257.9

Monthly Average Energy Production



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Summary of Results

	Total NPC	Energy Production (kWh/yr)
Storage	$8,522.12	
PV	$11,139.17	7,011
Grid	$15,697.51	12,280
Converter	$820.50	
System	$36,179.27	19,291

- Levelized COE = $0.1615
- Excess Electricity = 1,495 kWh/yr.
- Renewable Fraction = 30%

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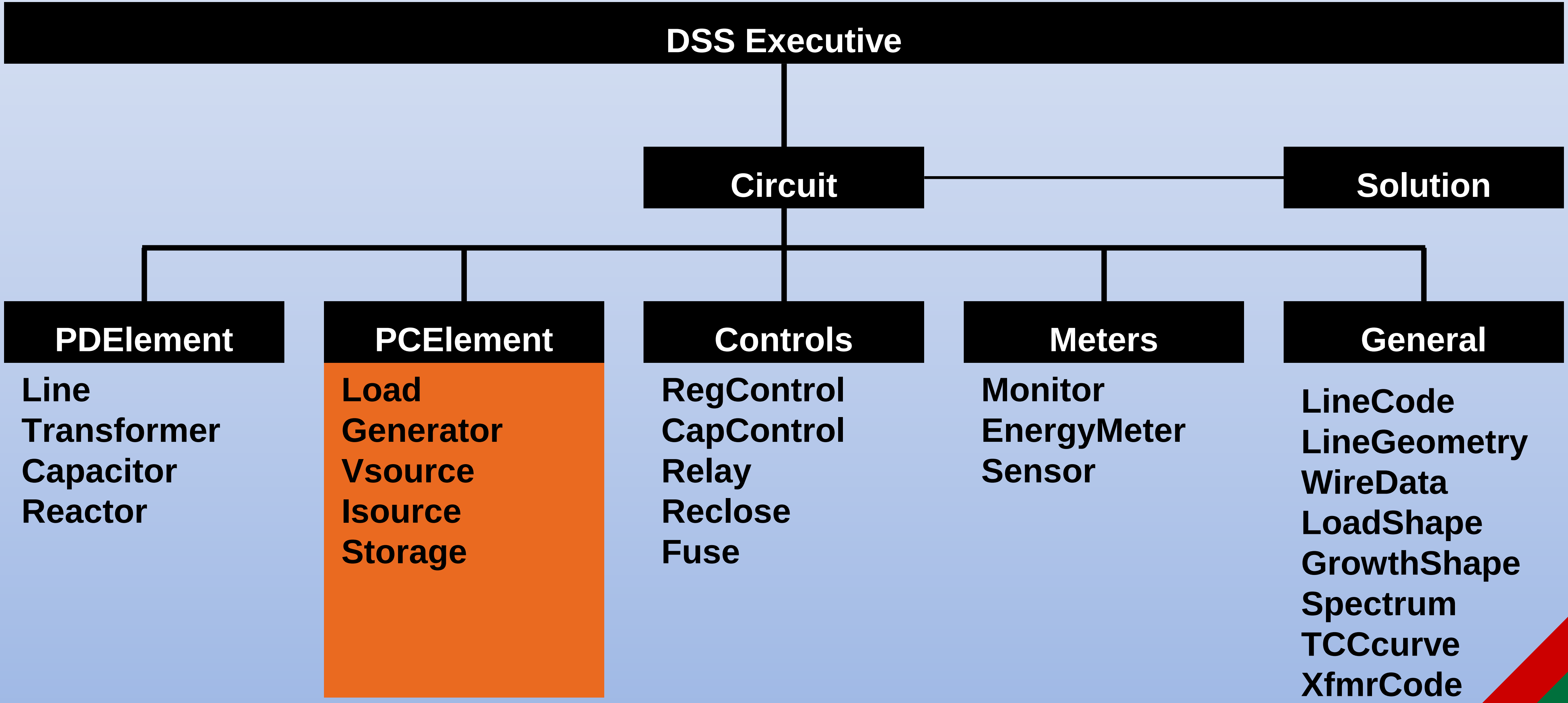
Summary and Considerations

- HOMER outputs realistic system models that provide credible system sizes and cost estimations of microgrid systems
  - Given specific and user approriate inputs
- Can implement different rate structures to analyze different uses of renewables
  - Simple (constant) rate
  - Net Metering (Monthly and Annually)
  - Real Time Rates
  - Demand Rates
- Does Duke currently use a tool to analyze value of PV and energy storage to the customer?
- Are there specific incintive stratigies that customers seem to respond to more over others?

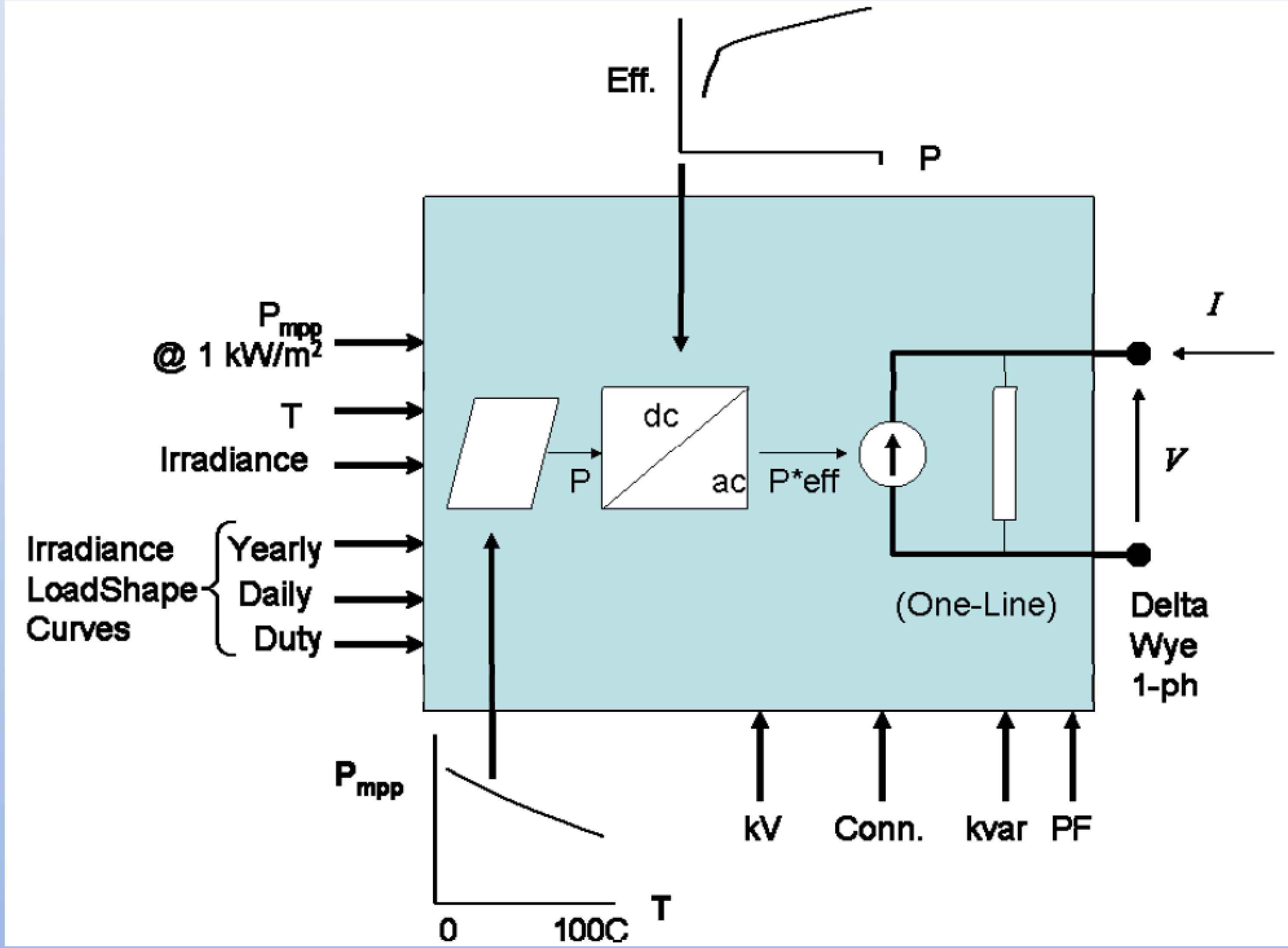
Active Distribution Systems: Modelling in OpenDSS

Joshua Smith

Feeder Modeling in OpenDSS



PV Modeling



Block Diagram of the PVSystem Element Model

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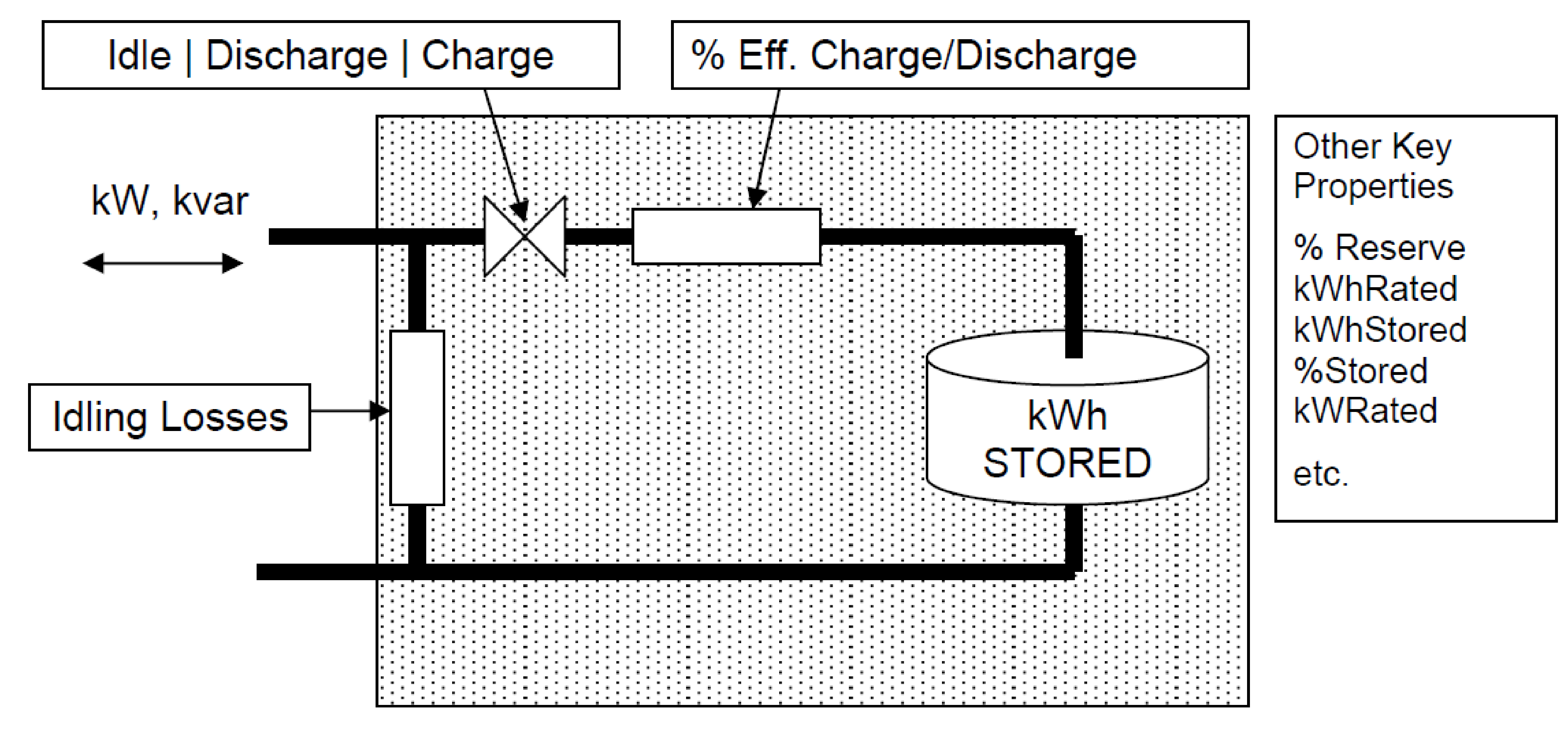
Storage Modeling



Block Concept of the Storage Element

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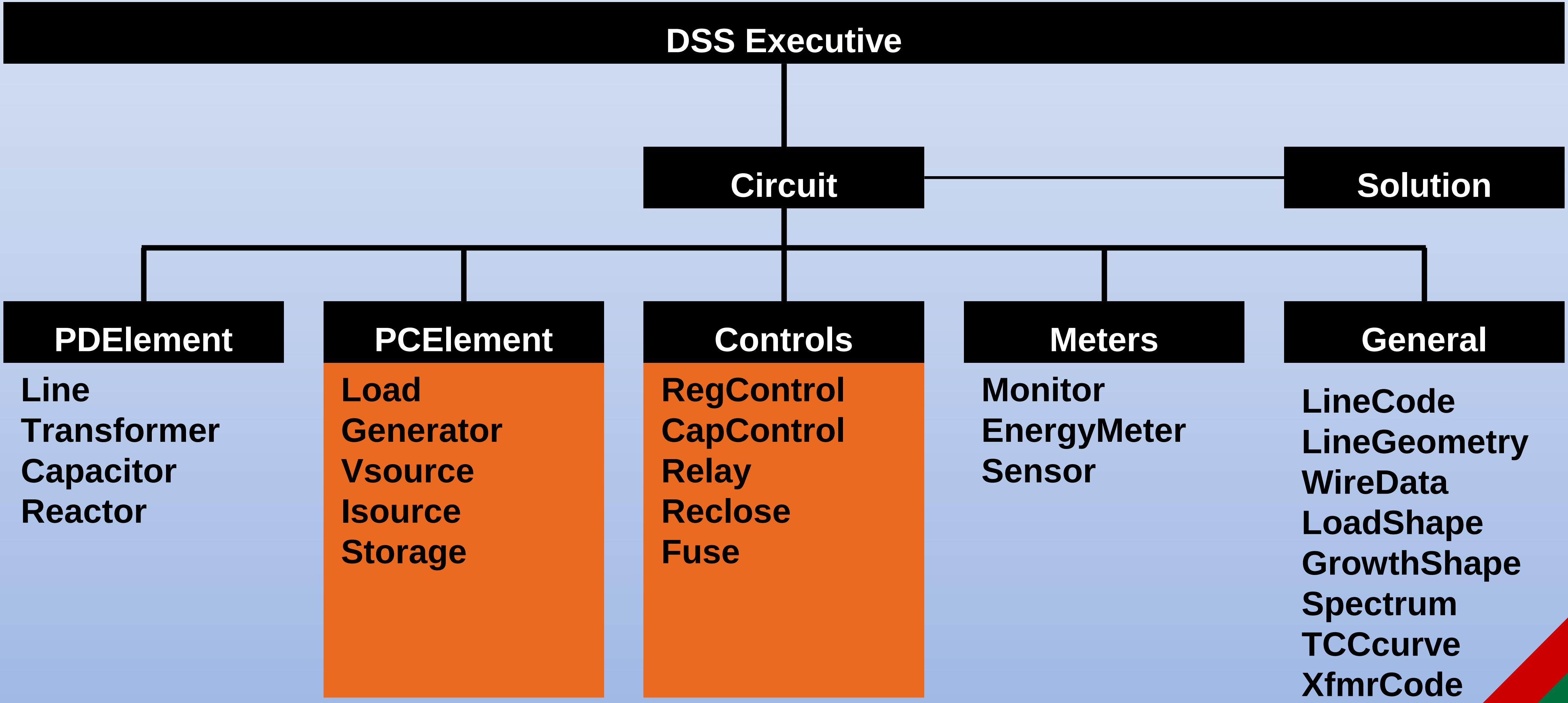
PEV Modeling

- Modeled as a Load:
  - the Loadshape reflects the charging characteristic
- Modeled as a Generator
- Modeled as a Storage Element
  - OpenDSS will limit charge/discharge

Feeder Modeling in OpenDSS



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Modelling in GridLAB-D

Lisha Sun

GridLAB-D

- A power distribution system simulation and analysis tool
- Provide valuable info to utilities that wish to take advantage of the latest energy technologies
- Developed by DOE at Pacific Northwest National Laboratory

	CYME (Base)	OpenDSS	GridLAB-D
Snap Shot Power flow	X	X	X
Time Series Analysis		X	X
Distributed Energy Resources	X	X	X
Physical House/Building Model			X
End-use Model			X
Customer Price-responsive Model			X
Reliability			X

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Process

Step1: Feeder Conversion

- Convert Cyme to GridLAB-D Model (GLM)
- Test static power flow run
- Python & PERL

Step2: Load Addition

- Residential Physical House Model
- Commercial & Industrial
- MATLAB

Step3: Technology Addition

- Distributed Energy Resources (PV, Energy Storage etc.)
- Controllers & Price signal
- Secondary System
- MATLAB

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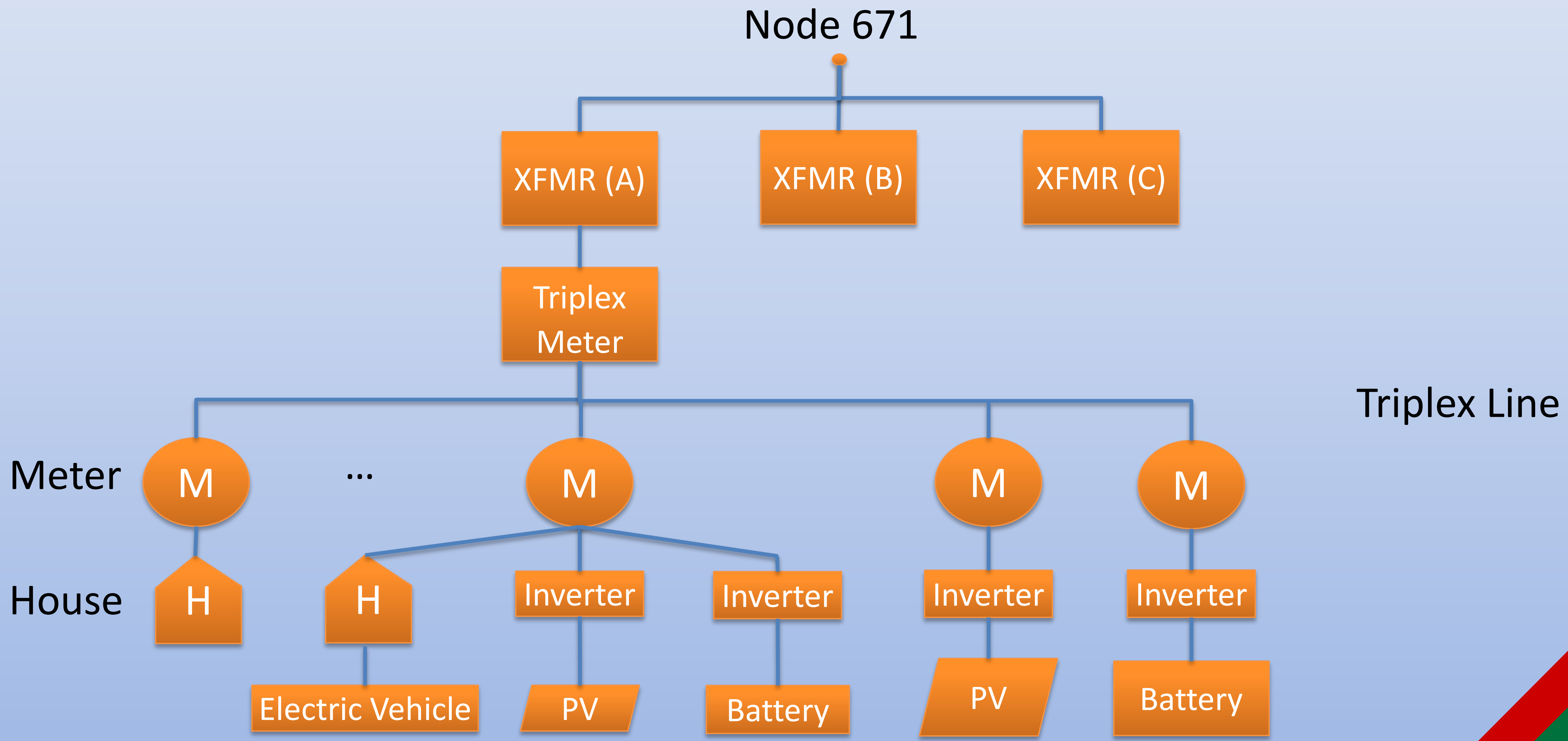
Customer Modelling Components



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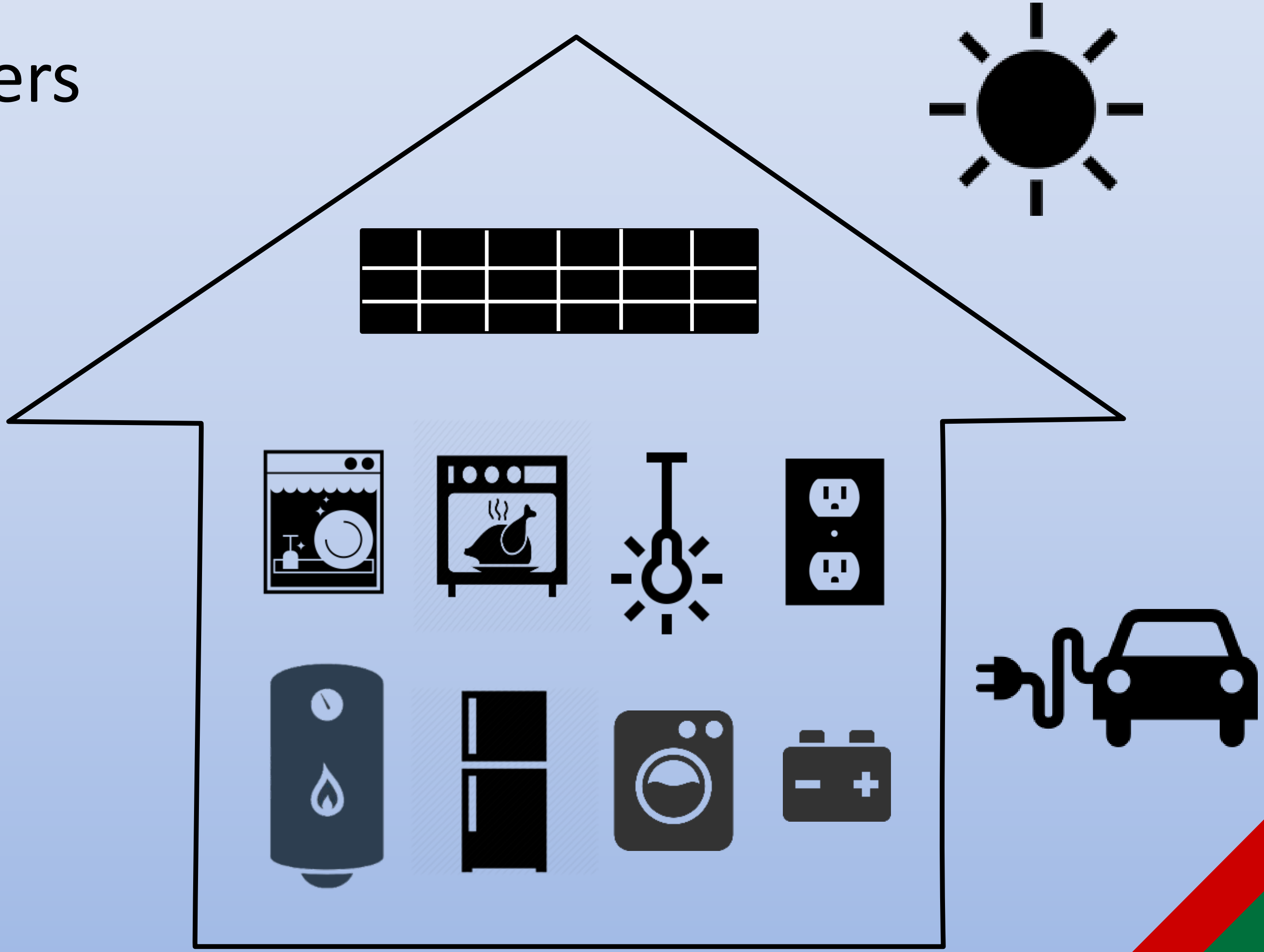
Physical-based Residential House

- House Design Parameters
  - Floor area (sf)
  - Thermal integrity
  - Cooling system type
  - Heating system type
  - Number of stories
  - Number of doors
  - …
- House Appliance & Controller
- ZIP Load



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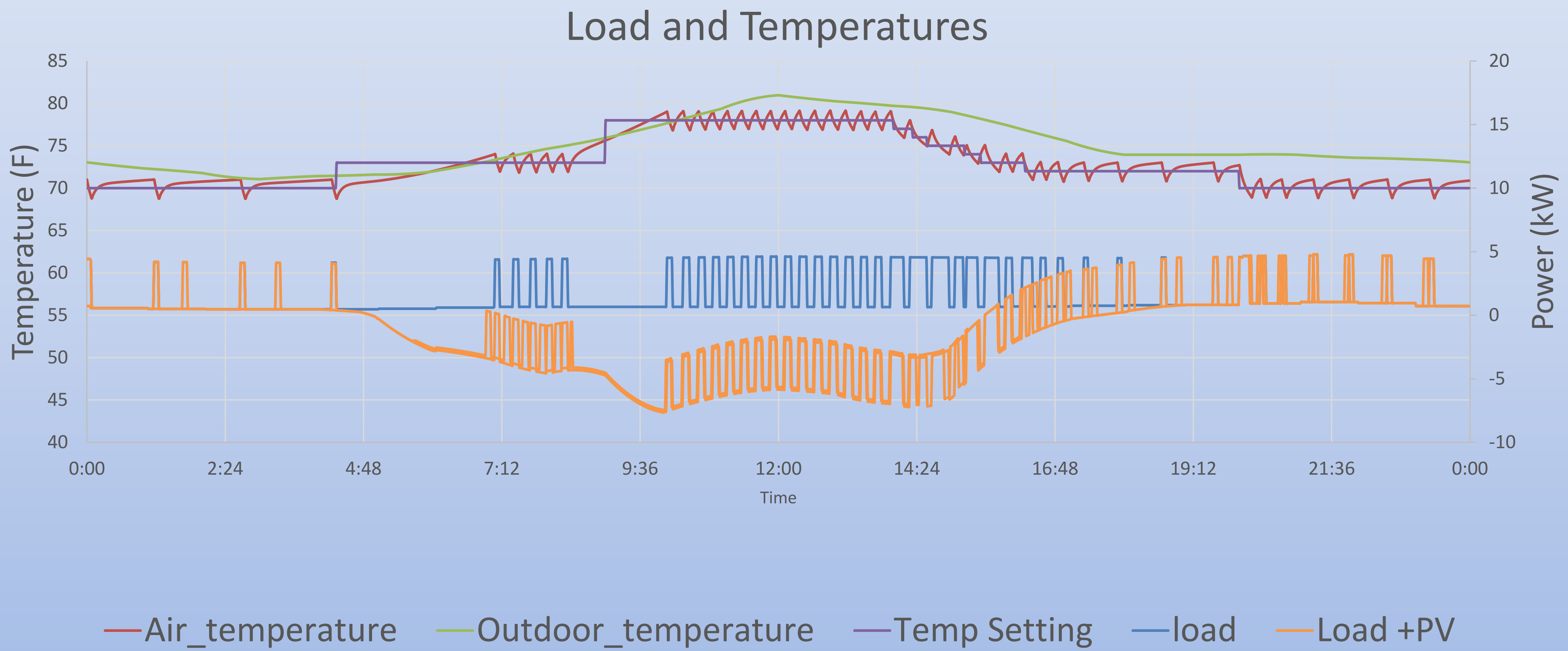
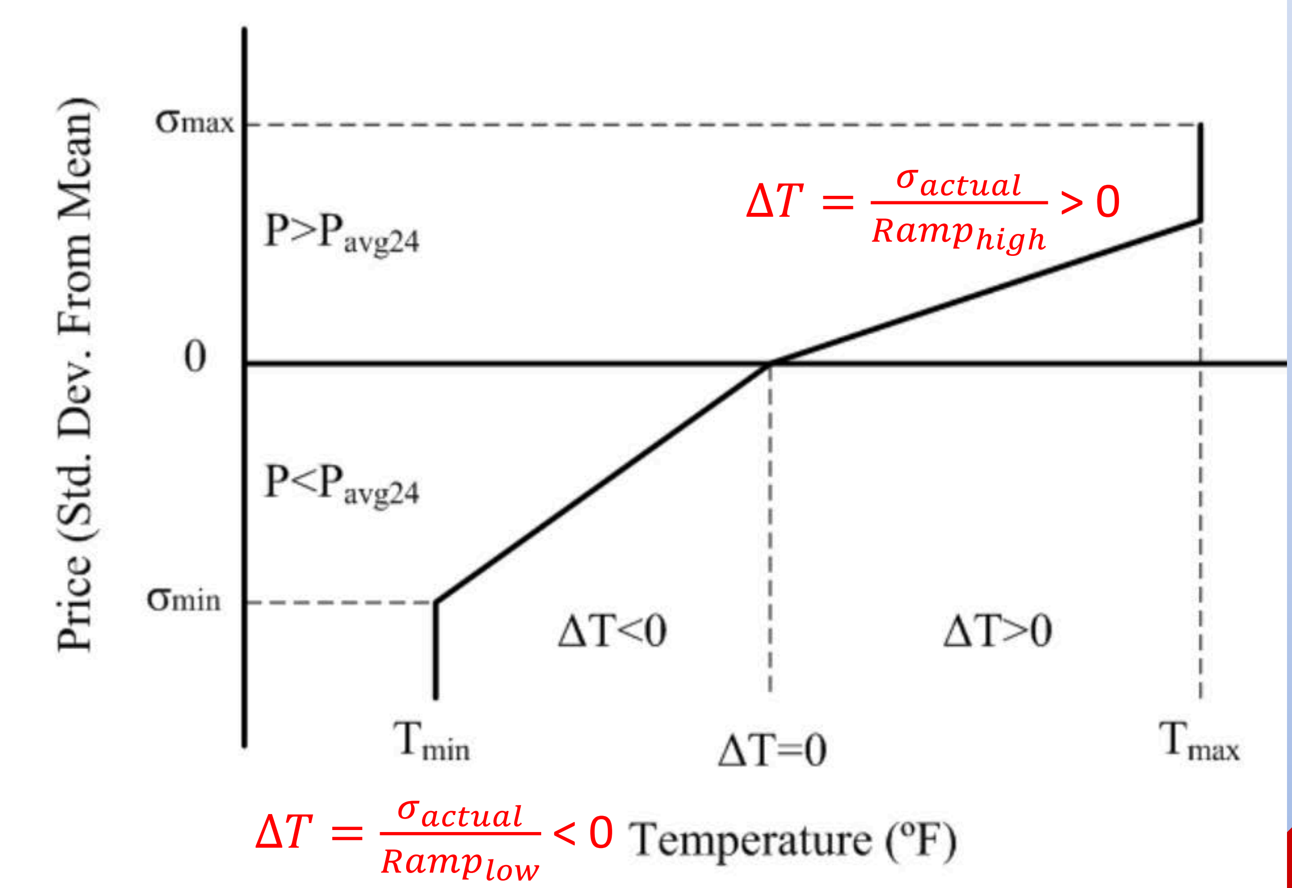
Single House Load Profile



Market Model

Market Objects

EXAMPLE: HVAC Controller



Auction

- Read Price
- Collects, Processes & Clear bids – Market Clearing Price

Controller

- Price Response
- Perform Bid
- 24 hour Market Value moving window (average and standard deviation)

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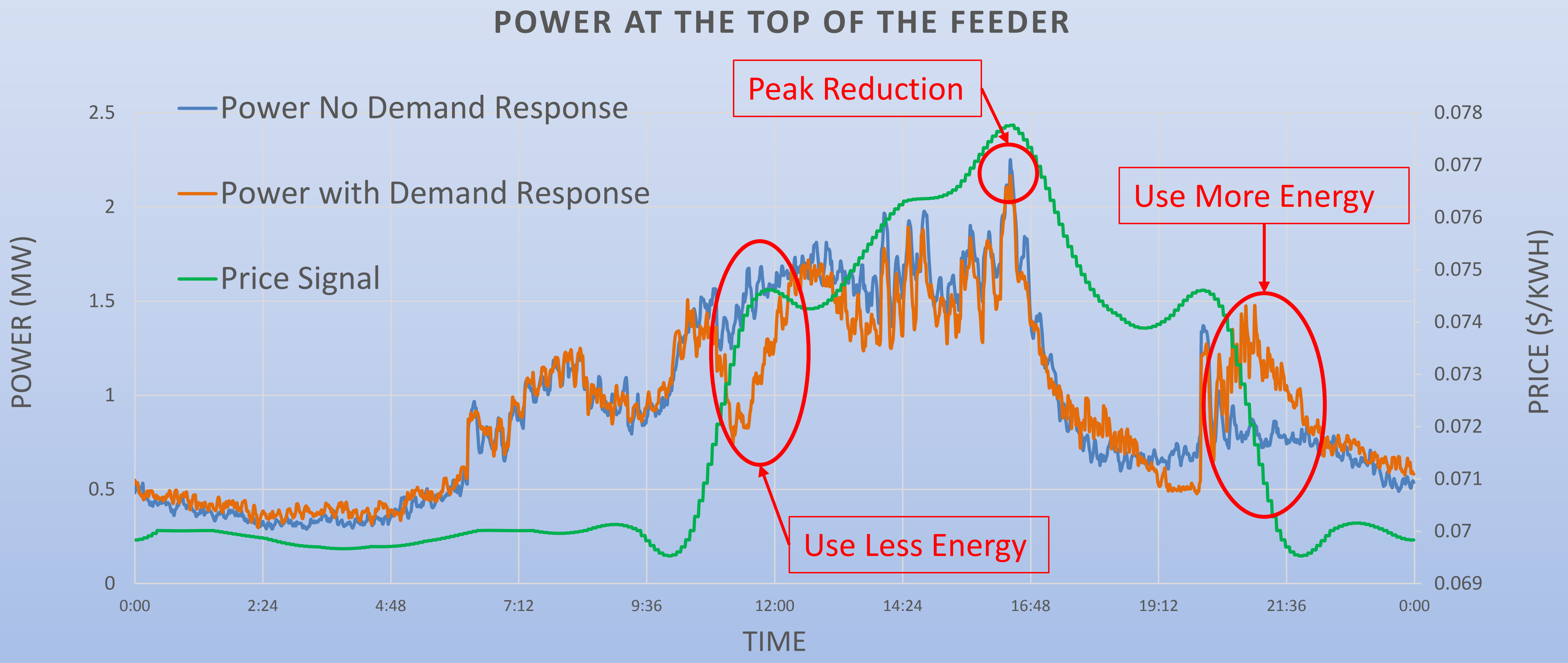
Price-Based Demand Response



Reduction: 85kW(4%) Peak; 10MWh(1%) Energy

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Reliability

Grouped
- Meter
- Triplex Meter

"Scheduled" or Random Faults → Perform Faults → Collects Outage info and Metrics

- Manual
- Random

Distribution (For Random)
- Failure
- Restoration

Metrics
- SAIFI, MAIFI
- SAIDI, CAIDI
- ASAI

Underlying event types:
- Momentary ≤ 5 minutes; Sustained > 5 minutes

Example Report				
New Metric Interval started at 2000-01-01 05:00:00				
Annual Event #	16		...	22
Metric Interval Event #	2		...	8
Starting Date Time	1/1/2000 5:05		...	1/1/2000 8:06
Ending DateTime	1/1/2000 5:10		...	1/1/2000 8:06
Object type	underground_line		...	underground_line
Object Name	node711-741		...	node781-701
Inducing Object	ManualEventGen		...	RandEventGen
Protective Device	sectionalizer_838_838b		...	reg799-781
Desired Fault type	SLG-A		...	DLG-X
Implemented Fault Type	SLG-A		...	DLG-CA
# of customers affected	3		...	26
Secondary # of customers affected	8		...	0
SAIFI = 1.23	SAIDI = 0.14	CAIDI = 0.12	ASAI = 1	MAIFI = 11.7

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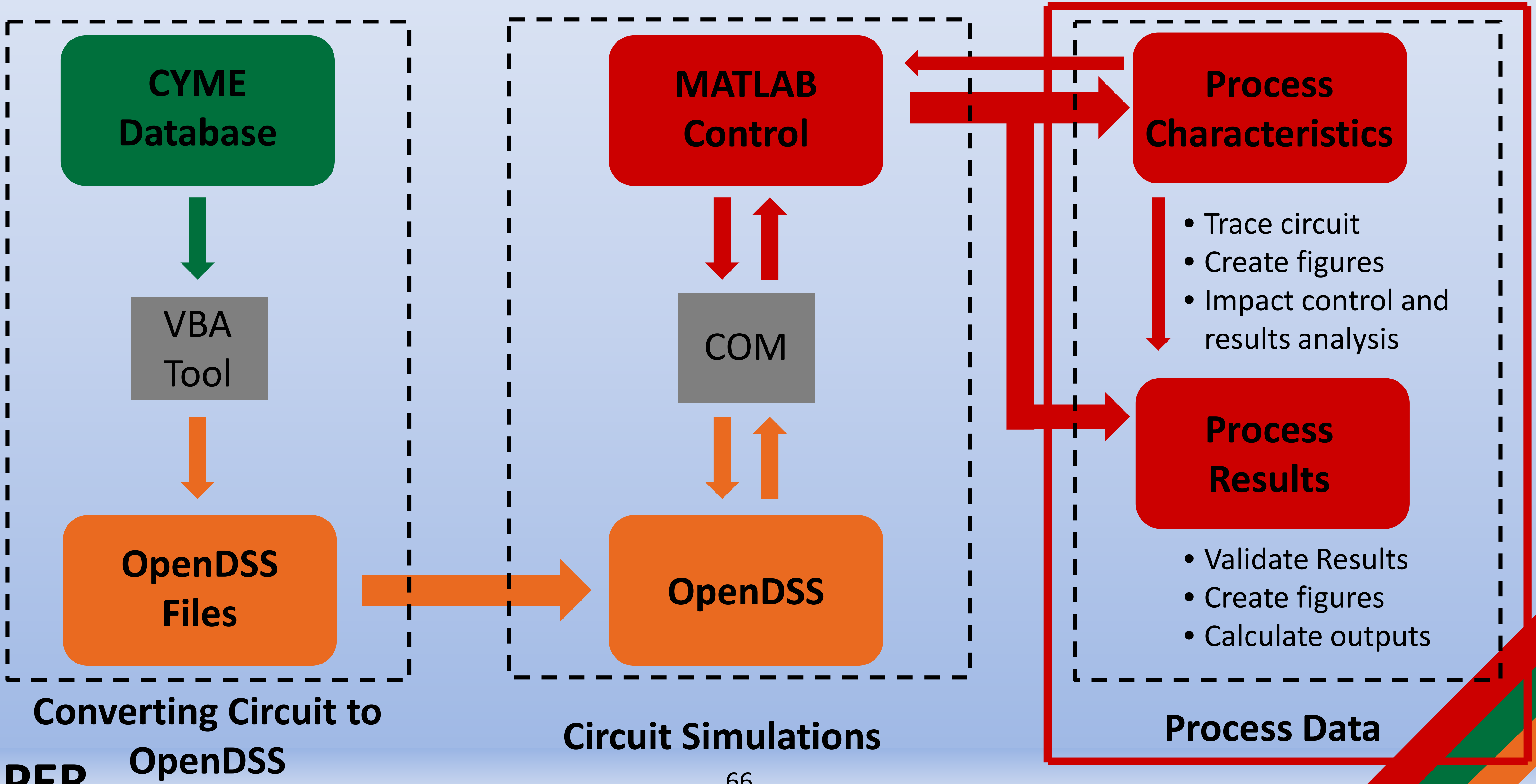
Questions

- Any of the CAPER members using the same methodologies?
- Which features of GridLAB-D should we implement in this project?
- Is it reasonable for us to have access to customer information?

Customer Modeling

David Mulcahy

Previous Project Study Methodology



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Recap: Needs for DER Planning

Infrastructure Improvement	Advanced Control	Modeling Improvement
• Reconductor • Regulator Placement • Distribution Transformer Sizing	• Volt-VAR • Energy Storage • Smart Inverter	• PV Forecasting • Full Costs and Benefits • Operational Impacts

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Building on Needs from DER Project

Infrastructure Improvement	Advanced Control	Modeling Improvement
• Reconductor • Regulator Placement • Distribution Transformer Sizing	• Volt-VAR • Energy Storage • Smart Inverter	• PV Forecasting • Full Costs and Benefits • Operational Impacts

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Need for Customer Models

- Short-run planning (Customer Operation)
  - Changes in operational behavior
  - Responsiveness to price
- Long-run planning (Customer Investment)
  - Participation in new rate structures or incentives schemes
  - Technology adoption
  - Customer capital investment

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Customer Modelling Framework

Scenarios

- Technology
  - PV + Energy Storage
  - HEMS (DR)
  - Electric Vehicle
- Ownership
  - Customer Owned
  - Utility Owned

Tariff Structure

- Existing Flat & TOU
- Existing Variation
- New rates or Rebates

Σ

Customer Model

Physical Model

- Residential House
- Commercial Building
- Technology

Behavior Model

- Price Sensitivity
- Technology Adoption

Utility Model

Distribution Model

- Demand reduction
- Efficiency improve
- Upgrade deferral

Time Frame

- One year
- Five to Ten years

Potential Modeling Tools

HOMER ENERGY

Customer equipment sizing based on incentives and controls

GridLAB-D

Distribution grid modelling with individual loads and behaviors modeled

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

OpenDSS

Detailed modeling of distribution operation. Calculate effects on utilities' system.

Questions

- What kind of incentives need to be examined?
  - Purely rates, investment incentives or utility installed equipment programs, etc.?
- What models are helpful to utility engineers?
  - Could CYME with Python be used?
  - Could OpenDSS be used?
- How do utility engineers see customer behavior changing?
- How is the long term adoption of these technologies considered?

Conclusions

Dr. Ramtin Hadidi

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Technical Approach

Customer Information

Customer location
Type of costumer
Type of loads
Daily, Weekly, Monthly load profile
Usage patterns
Any PV installed?
PV manufacturer
PV size
PV efficiency
Any Battery Installed?
Battery manufacturer
Battery size (energy, power)
Battery controller
Battery efficiency
Battery Application
Any PEV/PEHV?
Type of PEV/PEHV
PEV/PEHV demand
Type of Charger installed
Customer rate plan
Other rates availability
...

Customer Objects

Load

Residential vs Commercial/
Power vs Time /
...

PV

Size /
Irradiance/
Efficiemcy/
...

BESS

Power /
Energy /
Efficeicy /
...

PEV/PEHV

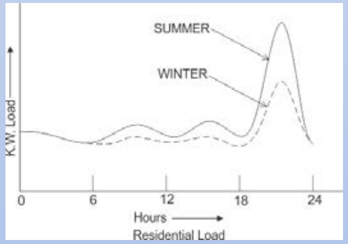
Model/
Charger Type /
...

Rate Options

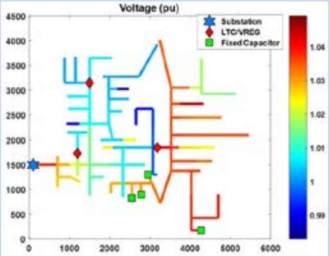
Rate 1/
Rate 2/
...

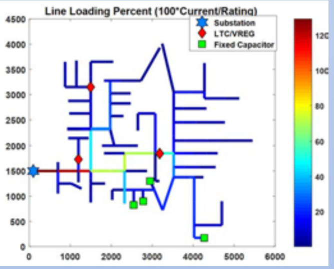
Customer Load Modeling

Power vs Time data with proper resolution



Feeder analysis with customer models included





Planning Strategies and Tools

Objective

- Enables customers to install roof PV,BESS, EV without adverse affects to distribution system.

How does this boil down to utility decisions?

- Cables: bigger lines, additional lines, etc.
- Transformers: best outcome - buy the right size transformer the first time.
- Help balance the circuit.

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Data and Other Requirements

- Customer Information
- Feeder Information
- Software and Licensing
- Factors to consider for planning studies

Thanks !

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