Electrification: A Pathway to Improved Resilience and Economic Value

Moderator:

- Niek Veraart, Michael Baker International

Speaker:

- Siva Sankaranarayanan, Principal Technical Leader, EPRI

May 14, 2024, 10:30 a.m.

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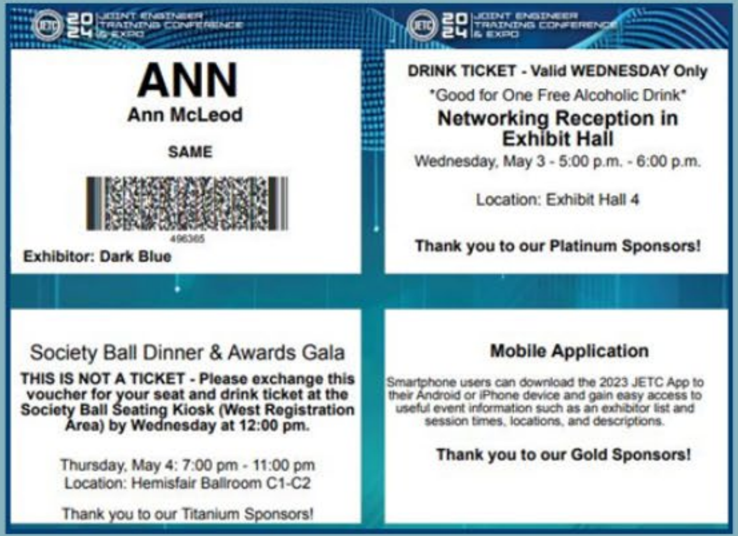

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MODERATOR

Niek Veraart, AICP, ENV SP
Michael Baker International

National Practice Lead | Planning
Senior Vice President

Fun Facts

- New Amsterdam resident (only 400 years late)
- Speed Skater
- Committed EV Driver

SPEAKER

Siva Sankaranarayanan

Electric Power Research Institute
Principal Technical Leader

Fun Facts

- My favorite Sports Team – Indian Cricket Team, of course!
- My favorite Vacation Spot – Anywhere in Hawaii, or just at home!
- Did you know… I have worked in 5 different industry verticals
- Hobbies – Cooking, Photography

Learning Objectives for Session

- What is Electrification? What does it entail? What are the best practices?
- What is the impact of federal, state, and city/local jurisdictional decarbonization policies on building operations?
- How do we assess the optimal set of technologies for building electrification for the stakeholders involved?
- How to sustain win-win outcomes for stakeholders in an evolving market?

Building Decarbonization Framework

DRIVERS (D)

Policy
- State, Local goals
- Corporate goals
- Federal policy

Market
- Customer interest
- Customer adoption

Technology
- Technology Readiness
- Product/Technology Support

STRATEGIES (S)

Efficiency
- Building Envelope
- Improved end-use efficiency

Electrification
- Space Conditioning
- Water Heating
- Appliances/Cooking
- EV Infrastructure

Flexibility
- Distributed Energy Resources
- GEB & Connected Communities

Low-Carbon Resources
- Dual-fuel pathways
- Hybrid strategies for cold-climate

ACTIONS (A)

Programs
- Reduced first cost
- Improve customer enrollment
- On-Bill Financing
- Equitable Decarbonization

Rates
- Rate Alignment with electrification

Codes & Standards
- EV Readiness for new construction
- End-use flexibility standards
- Special provisions for disadvantaged communities

Focusing on Policy Drivers – Building Performance Standards

Big shift: Energy Efficiency → GHG Emissions Accounting

- Helps to implement climate action plans at federal, state, and city/local level

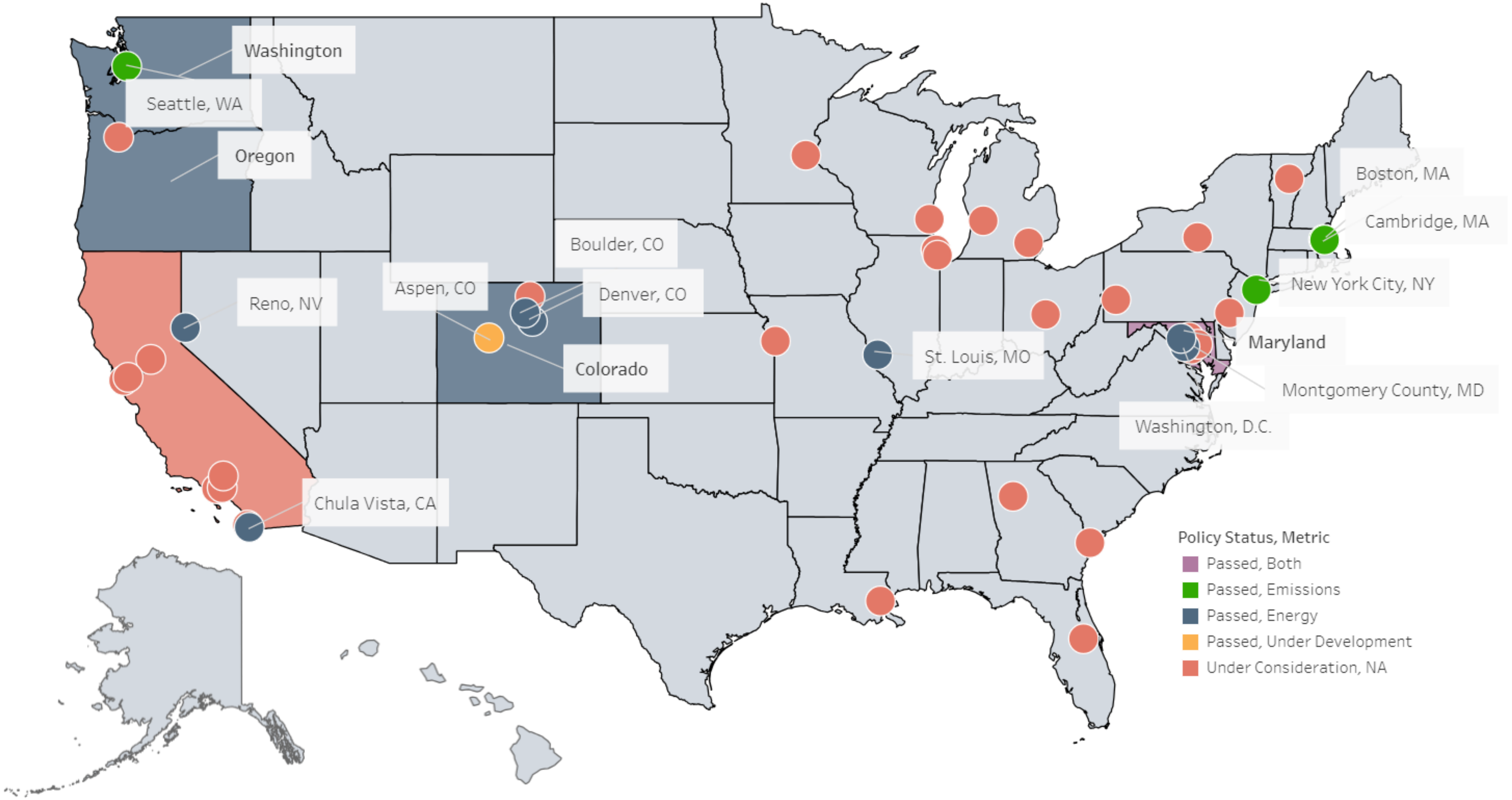
What is a Building Performance Standard & why should we care?

- Set of energy and/or carbon emissions guidelines for buildings that are directed at various levels, e.g., Federal BPS, State-level, City-level
- Federal BPS – EO 14057; State-level – WA, MD state BPS; City-level Local Law 97, Seattle Building Emissions Performance Standard
- Carrot & Stick approach involves total operating carbon (Scope 1 & Scope 2)

Doesn't code take care of efficiency?

- Yes, but BPS is for existing buildings and is an annual compliance metric
- Virtually impacts all utilities because of BPS at various jurisdictional levels

Overview of BPS adoption across the US



Source: Pacific Northwest National Laboratory, 2024

Building Performance Standards – A Primer

Not all data is created equal: Data needed to meet reporting requirements may fall short of the depth of data necessary for continuous compliance

BPS are a driver of electrification: With many standards requiring a reduction in emissions, electrification readiness becomes critical, particularly for vulnerable segments.

BPS and grid resiliency: As electric demand increases due to the electrification of certain end-uses, it will become important for operators and utilities alike to understand how grid resiliency may be impacted.

This is just the tip of the iceberg: Federal and Industry initiatives are painting a clearer picture of how building performance standards may evolve as more jurisdictions adopt them.

EPRI Report Available at: https://restservice.epri.com/publicdownload/000000003002026790/0/Product

Building Electrification – What is our definition?

Efficient Building
- Must meet some efficiency standard or code, e.g., ASHRAE 90.1-2019 or IECC-2019

Electrified End-Uses
- Space Conditioning & Water Heating
- Electric Vehicle Charging
- Cooking

Resilient
- Offers a level of comfort for residents even when there is a short-term outage

Employ "Good Design Principles"
- Ability to provide positive outcomes for customer, service provider, and community/societal context

MUST HAVE

On-site Renewables
- Rooftop Solar
- Building-Integrate PV

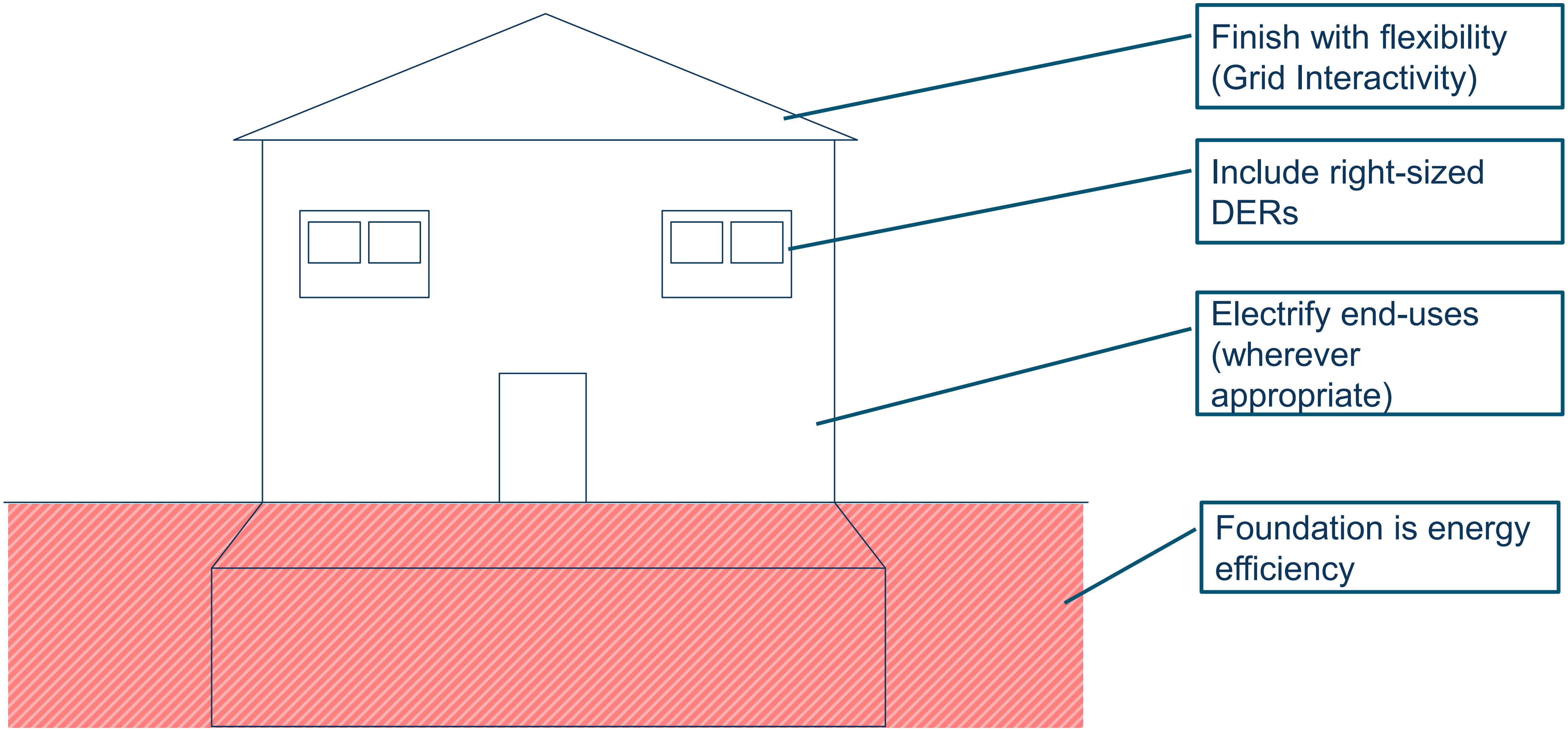
Energy Storage
- Batteries
- Thermal Energy Storage

Control System
- Building Automation System
- Building Energy Management System

Avoids "Bad Design Principles"
- A design that inherently disadvantages the customer in the process to achieve lose-win

NICE TO HAVE

The solution for Building Electrification



Pathways to Value Creation with Building Electrification

Building electrification entails the use of electrified end-uses such as space conditioning, water heating, cooking, and appliances in buildings.

- The use of heat pumps as an enabling technology for space conditioning and water heating is well documented in literature as well in prior EPRI research.

Building electrification allows for significant value creation

- Eliminating emissions from on-site fossil-fuel use
- Reduced emissions attributed to electricity generation from reduced energy use arising from high efficiency of heat pumps
- Improved customer energy operating costs due to reduced energy use
- Better health from reduction in exposure to particulate matter and hazardous chemicals from burning fossil fuels

Mapping value creation with associated costs and impacts

Reduced emissions from on-site fossil-fuel use & grid electricity use

- Heat pump adoption is incentivized through policy actions, e.g., IRA funds
- Overall retrofit costs are important to consider.
- The electric grid needs to have enough capacity to support large-scale market adoption
- The distribution grid needs to be able to support additional electrical loads that may arise from heat pump adoption

Reduced customer's energy operating costs

- The customer's improved energy operating cost comes at the price of potentially higher up-front costs
- The distribution grid needs to be upgraded to support additional loads at the individual building level

Better health outcomes for building occupants

- Improved health outcomes of reduced emissions is a societal value generation pathway
- Overall improvement in emissions helps to achieve city, state, and utility-level decarbonization goals

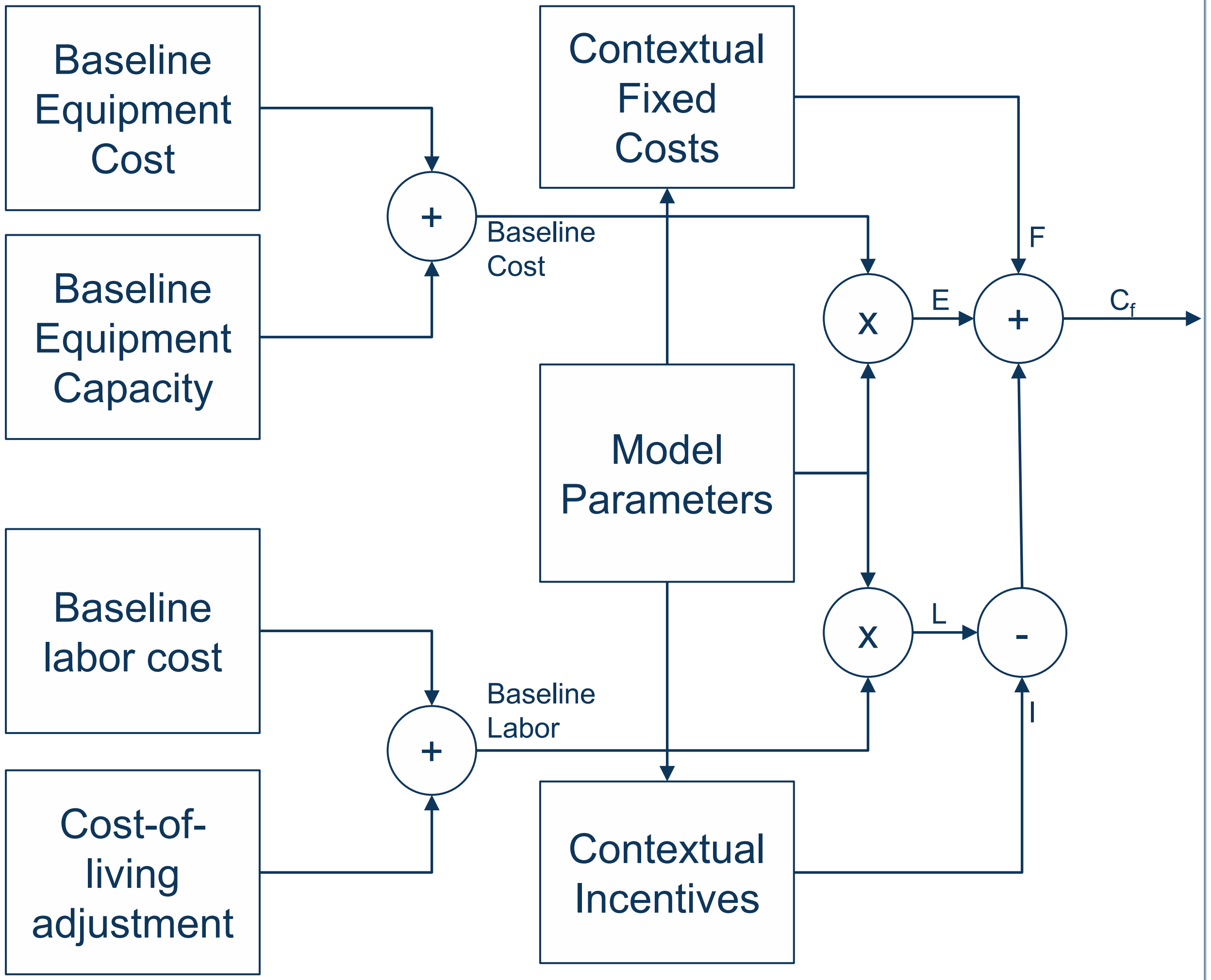
Systematically assessing Building Electrification – Cost-Benefit Analysis

	Customer	Utility	Society
First cost parameters (-)	✓ Equipment and labor cost of electrification measure ✓ Retrofit cost to enable electrification (wiring, panel upgrade, disposal of old equipment)	✓ Distribution upgrades needed to accommodate electrification ✓ Customer acquisition (incremental administrative costs) *(not included in value model)*	✓ Federal and state incentives *(not included in value model)*
Operating cost parameters (-/+)	✓ Increase/decrease in bills	✓ On-Bill Revenue	✓ Rates for electricity and natural gas ✓ Societal cost of carbon
Primary Value Dimension	Lifetime value of Electrified End-Use	Lifetime value of Infrastructure Upgrade Investment	Projected overall reduction in GHG emissions
Decision Tradeoff	First cost, operating cost savings	Incremental peak demand, On-bill revenues	Societal benefit, GHG reduction

Systematically Assessing Building Electrification – Computational Approach

- Model the cost picture from a customer's perspective as well as a utility perspective
  - Develop a parametric model for various electrification options
    - {Solar PV, Energy Storage, Level 1 & Level 2 EV chargers, HP, HPWH, HP+HPWH}
  - Adjust for relatively higher cost-of-living for Seattle
  - Explicitly account for equipment, labor, and maintenance costs as well as available federal, state, and utility incentives.

- Use the cost picture to establish strategies that provide win-win scenarios for customers and utility.

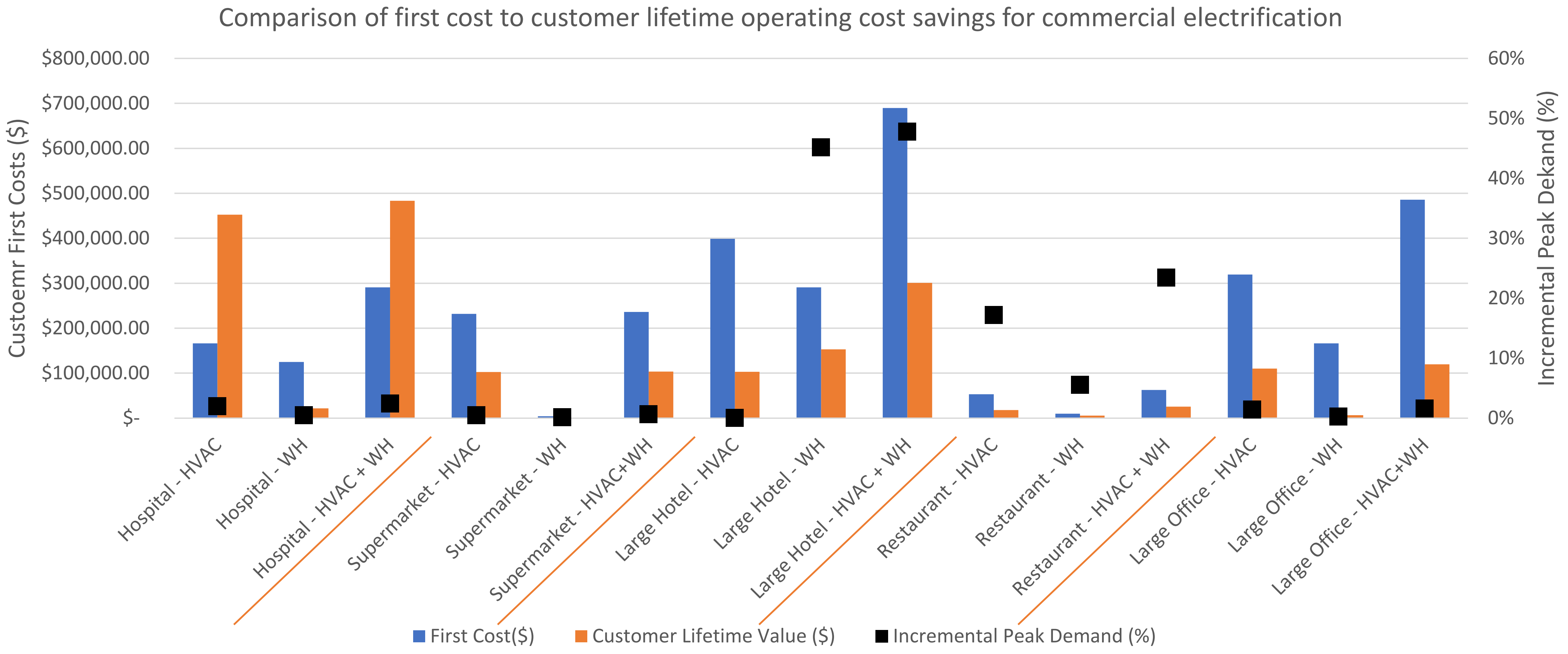


Systematically assessing Building Electrification – MFH retrofit results

Electrification Choice	Customer First Costs ($)	Lifetime Operating Cost Savings ($)	Incremental peak demand (%)	Site GHG Emissions Reduction (MTCO2e)	Societal Benefits ($ per upgrade)
3 Ton/SEER 15/2-zone Mini-split OR 2x 1-ton PTHP	$9,799 or $4,875	$1,165	39%	0.52 (49%)	$26
50G 240V OR 40G 120V HPWH	$6,144 or $3,551	$749	33%	0.53 (51%)	$27
HP+ HPWH	**$14,743 or $8,426**	**$1,244**	**48%**	**1.04 (100%)**	**$53**

- Economic value arising from heat pump-based water heating
- Space conditioning with heat pumps assumes gas furnace replacement with heat pumps which adds cooling loads in summer which causes savings to diminish.
- The use of 120V heat pumps reduces first cost for space conditioning and also reduces retrofit costs

Systematically Assessing Building Electrification – Extended Results



Learning by Doing: Solar + Storage + Demand Flexibility in MF Housing

Project Overview

Period of Performance: June 2017 – March 2022

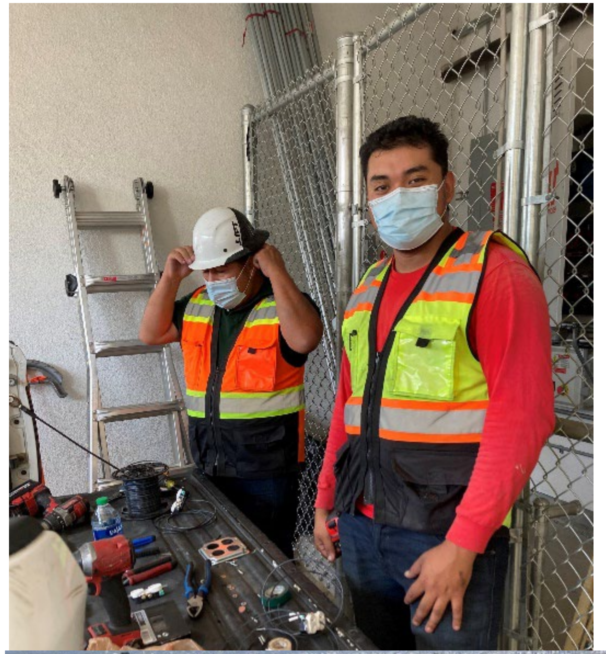
Demonstration Site: Mosaic Gardens at Willowbrook

61-unit Affordable Multifamily Property in Compton, CA

Developed and Owned by LINC Housing LLC

Project Scope: *Demonstration of community-level resource integration and controls at an affordable housing property in a low-income, disadvantaged neighborhood.*

- High-Efficiency Bifacial Solar PV
- Li-ion Battery Energy Storage
- AC/DC Bi-directional Smart Inverter
- Energy Efficient Direct Current Loads
- Multi-Level Controls Integration through Cloud-Based Platform
- Innovative Community-Sharing Business Model (VNEM)

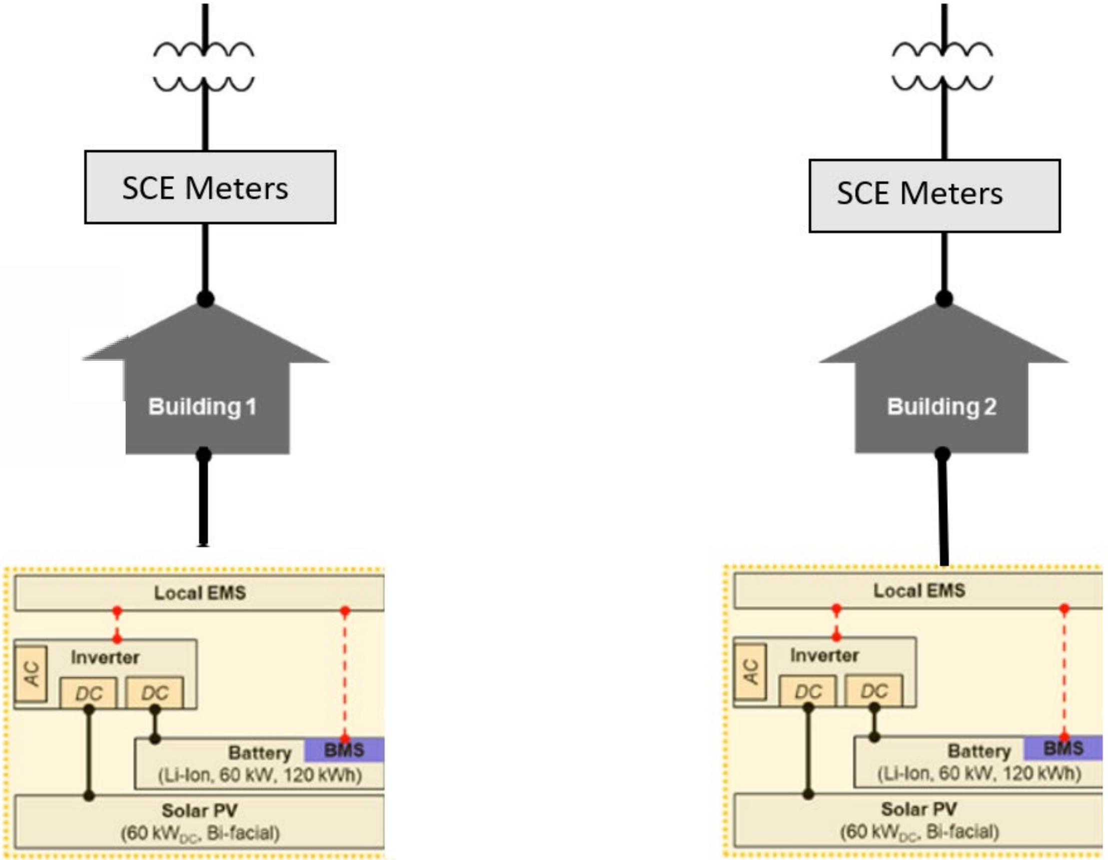


Project Objectives

- Identify scalable community models to maximize the economic and environmental benefits of solar PV for low-income populations and affordable housing facility operators
- Study how it will enable grid flexibility and that is beneficial to utilities and the entire rate base
- The levers being tested include batteries, direct current (DC) distribution and appliances and behavior and controls strategies
- Context: Onset of TOU rates for affordable housing residents that are entirely on CARE discount rates

Source: LINC Housing

Technology Concept



Solar + Storage Demo at Buildings 1

60 kW Bifacial PV array

60 kW 120 kWh Li-ion BESS

30 kW AC/DC Power Converter

4-ton Gree VRF DC split system and 24 V DC Lighting

DC Minigrid at Building 2

Controls Objectives

01

Support vulnerable populations through rate changes

02

Provide solar balancing that mitigates need for distribution upgrades

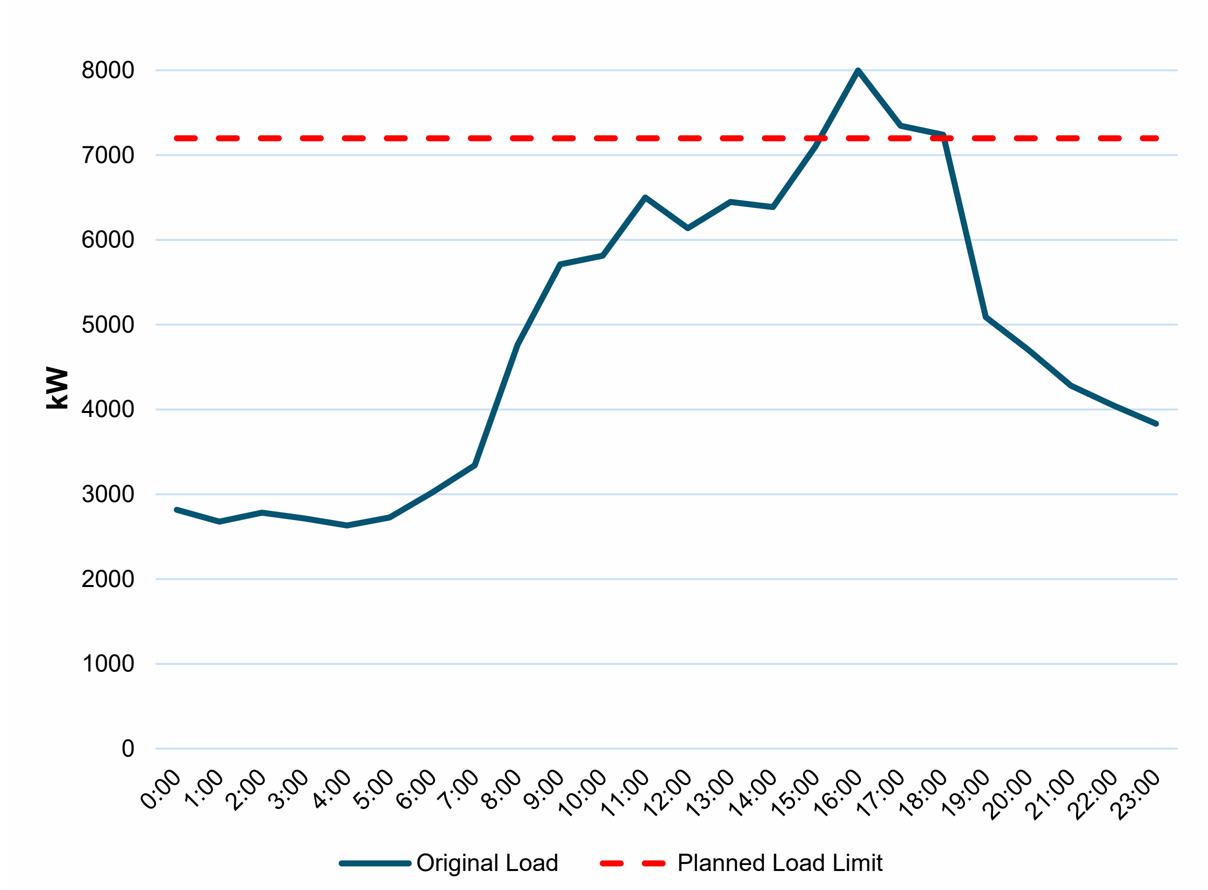
03

Reduce GHG from the CA Electric system during hours of high marginal carbon emissions

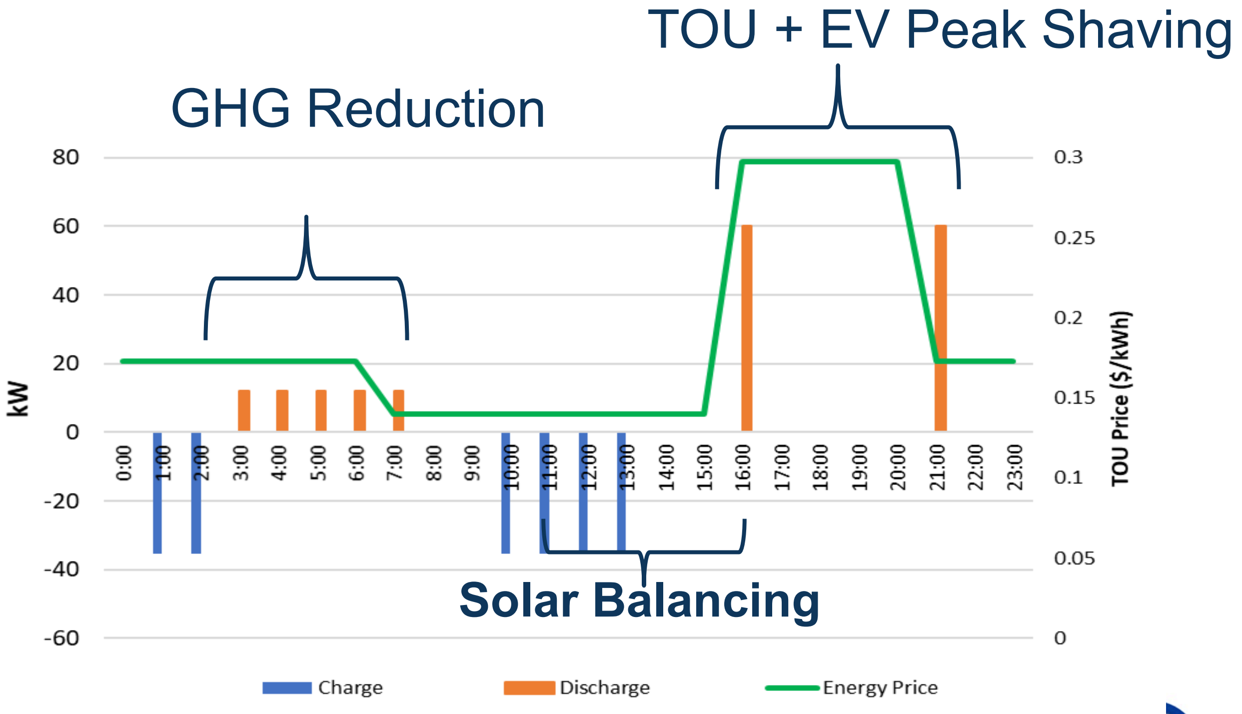
04

Manage bulk-system capacity based on participation in Demand Response Auction Market

Controls and DR in Operation

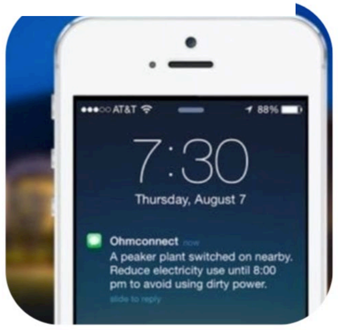


Residential Distribution Circuit Load Profile



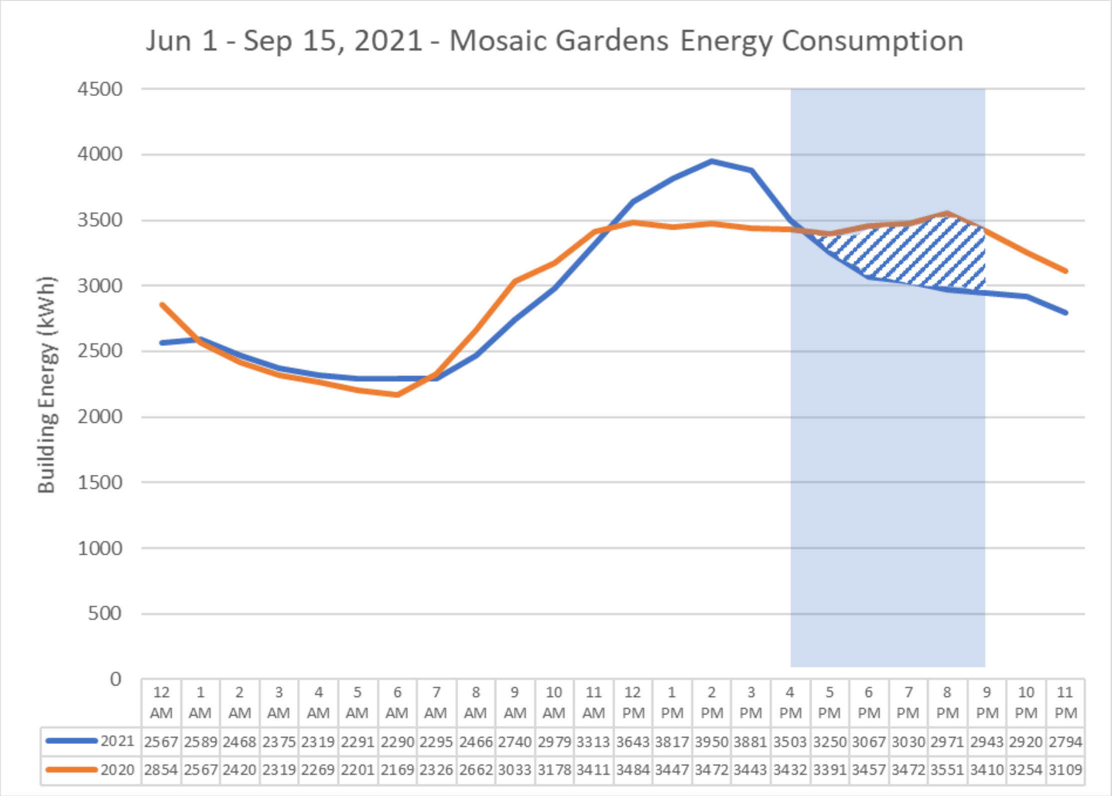
Battery Deployment Protocol

Behavioral DR →



Aggregate Project Performance (Summer)

- Post-installation energy performance peaked well before the 4-9 pm timeframe but was otherwise quite similar in trend compared to 2020
- Load shifting is apparent during the 4-9 pm timeframe and before noon with a new peak around 2 pm
- The reduction in energy use between June – Sept of 2020 and June to Sept 2021 is ~1.48 MWh
- 9% reduction in energy usage from just the behavioral energy management during the 4-9 pm window

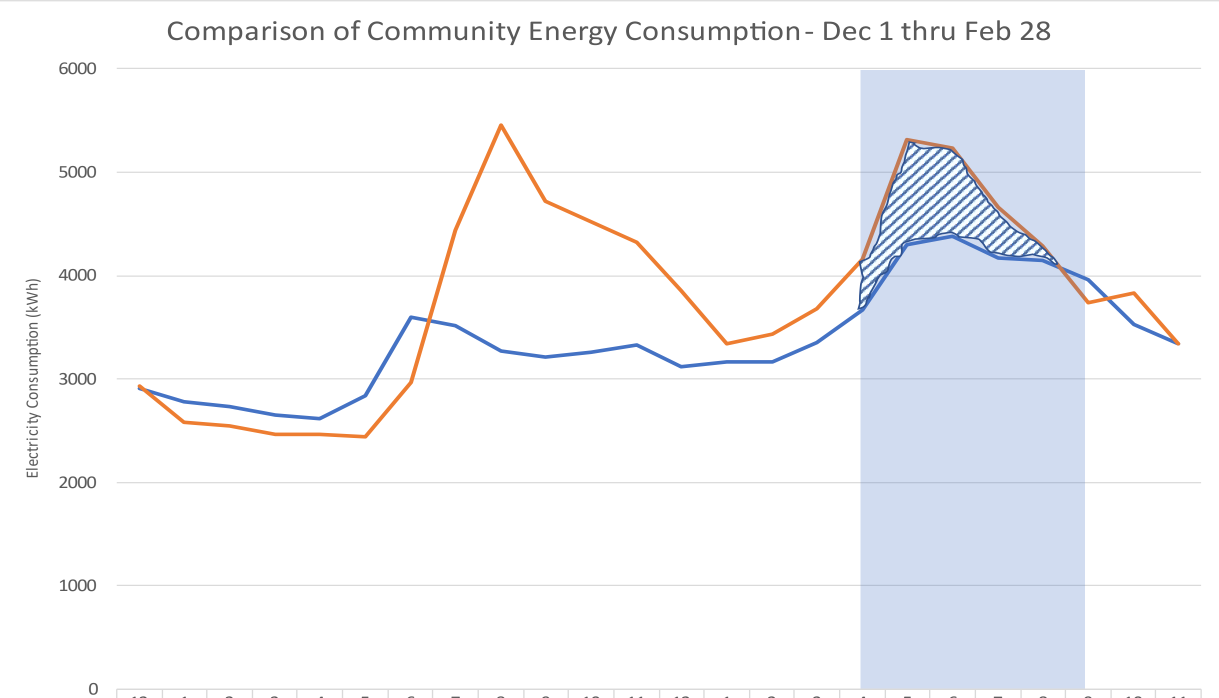


	12 AM	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM
2021	2567	2589	2468	2375	2319	2291	2290	2295	2466	2740	2979	3313	3643	3817	3950	3881	3503	3250	3067	3030	2971	2943	2920	2794
2020	2854	2567	2420	2319	2269	2201	2169	2326	2662	3033	3178	3411	3484	3447	3472	3443	3432	3391	3457	3472	3551	3410	3254	3109

Pre-retrofit (2020) vs. Post-retrofit (2021)
Energy Performance June 1-Sep 1

Project Performance (Winter)

- Peak shifts from the morning to the evening hours but is also lower in 2021 compared to 2020
- Overall reduction in load (over 24 hours) is 11% (9.7 MWh) and 13% (2.9 MWh) during the 4-9pm timeframe.



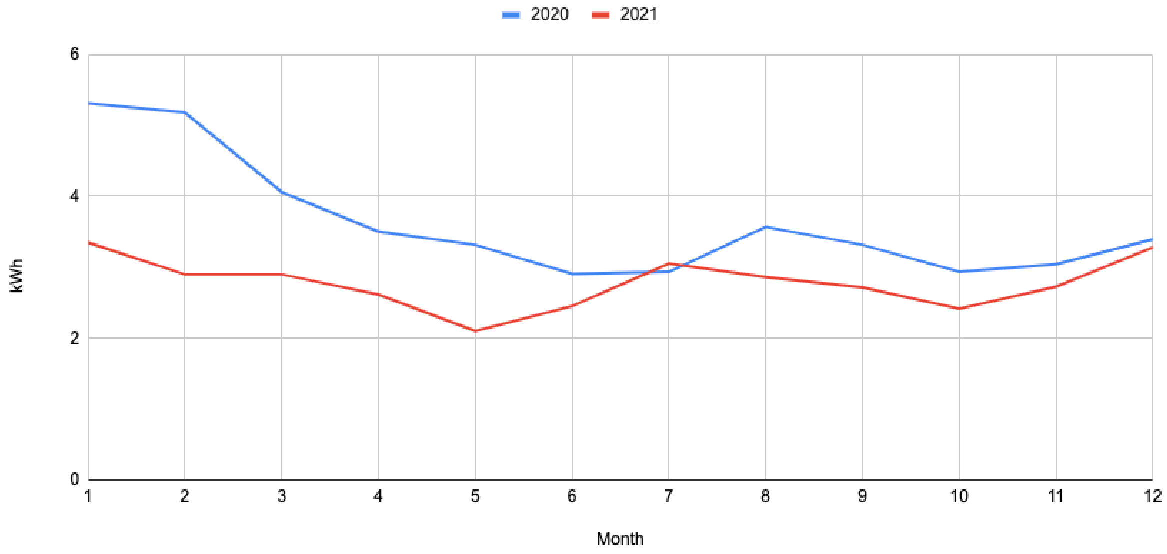
	12 AM	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM
2021	2914	2785	2735	2657	2620	2843	3593	3512	3273	3207	3263	3331
2020	2932	2586	2550	2470	2465	2437	2967	4438	5455	4722	4520	4324

	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM
2021	3120	3165	3167	3350	3673	4304	4384	4171	4143	3958	3532	3340
2020	3861	3346	3430	3675	4165	5310	5232	4656	4286	3737	3834	3345

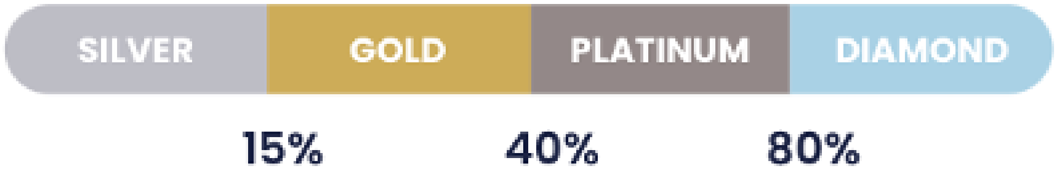
Pre-retrofit (2020) vs. Post-retrofit (2021) Energy Performance for Dec 1 – Feb 28

Behavioral DR with TOU Messaging

- 1/3 of the property's residents are actively enrolled
- 53 unique events, with 765 resident opt-ins or an average of 16 opt-ins per event
- 45% have achieved Gold or Platinum status, suggesting they are consistently saving between 15-80% compared to their historic baseline during Ohmhour events
- Sampled participants participated in at least 50% of DR events and saved up to 50% compared to their historic baseline
- Energy consumption in 2021 between the 4-9 TOU window fell compared to the previous year by an estimated ~15%



Monthly Average of Daily Energy Consumption per Resident Between 4-9pm



Recognition Status based on Energy Improvement

Implementation Lessons Learned

- There is a significant approvals process for multifamily property owners to conduct solar and storage projects
- Economics of solar + storage for low-income communities is nascent
- Dual sided PV is a good technology, unless there is insufficient space on reflective flat roofs
- Permitting and interconnection is still a challenge, but there are emerging solutions
- Integration of solar, storage and loads (DR) is not as easy as it seems on paper

Source: K&A

But what about Cold Climates?

Cold Climates require additional engineering to ensure that they can maintain higher performance under colder ambient conditions

- Use different refrigerants that have lower boiling points
- Increased compressor capacity
- Variable speed as opposed to one or two-speed configurations

U.S. Department of Energy launched a cold-climate heat pump challenge.

- The aim is to develop new technology specifications for CCHP
- Understand and alleviate installation challenges and address market transformation through utility program collaborations

CCHP Technology Challenge Timeline

CCHP Technology Challenge Specifications

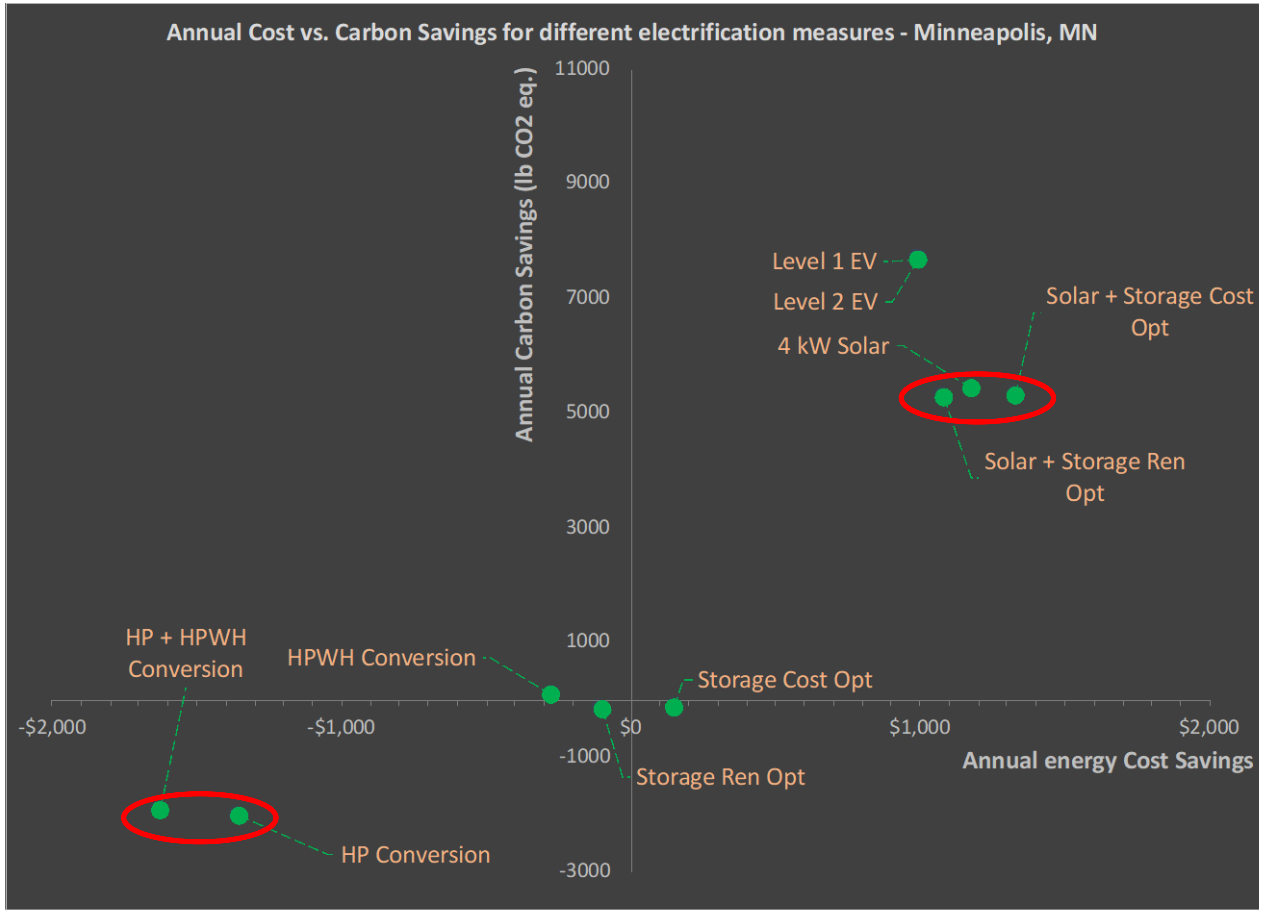
The CCHP Challenge specifications represent a best-in-class heat pump product that provides high-efficiency heating performance in cold climates, employs environmentally friendly low-GWP refrigerants and is designed to be grid interactive. **Learn more about the Challenge specifications.**

From DOE website…

https://www.energy.gov/eere/buildings/residential-cold-climate-heat-pump-challenge

Let's build out a model… in Minneapolis, MN

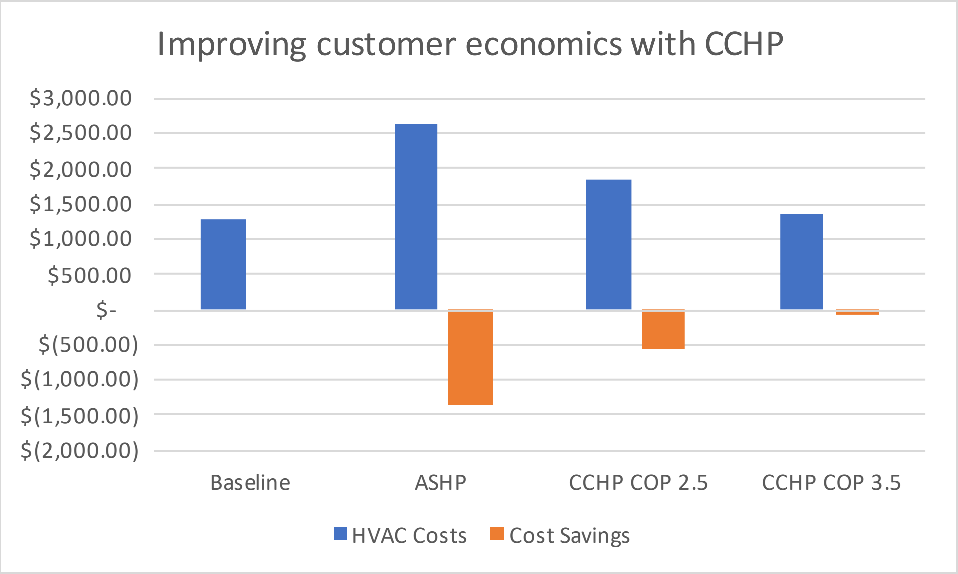
- 2400 Sq. Ft. 3 BR/ 2 BA house in Minneapolis, MN
  - Built to the 2015 ICC Code
  - Gas Furnace (0.8 AFUE), Central A/C (SEER 15)
  - Gas 50G Water Heater
  - Gas cooking range, Energy Star appliances
- Electrification Options
  - 5kW Solar
  - 10kW Battery
  - 3T ASHP (SEER 16/HSPF 9)
  - 50G HPWH
  - Level 1 & Level 2 EV Chargers
- Assumptions around economics
  - TOD Rate (9am-9pm peak ~ \$0.20/kWh, offpeak ~ \$0.04/kWh)
  - The battery may be profiled either to optimize Renewable Energy – so charge only when solar is on, or optimize cost – so discharge during peak TOD
  - 15000 miles a year @ \$3/gal; EV is charged every night



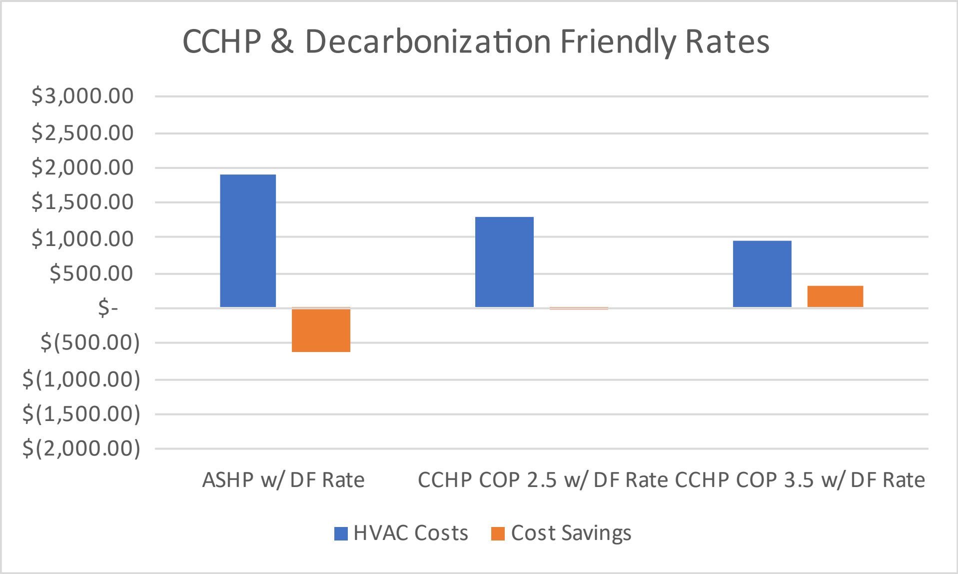
X axis: Annual Cost Savings; Y axis: Annual GHG Savings

How can the economic and carbon outcomes be improved?

- Using a Cold Climate Heat Pump increases the Coefficient of Performance of Heating.
  - SEER 16 – 9 HSPF ASHP: COP of HVAC: 1.72
  - Typical COP of CCHP: 2.5 to 3.5



- Using a decarbonization-friendly rate structure:
  - Baseline effective rate: $0.10/kWh
  - Decarbonization Friendly: $0.07/kWh



Final Takeaways

Electrification of end-uses is a viable path for building decarbonization but the right set of conditions are necessary

The need for flexibility in building loads is an emerging strategy for decarbonization

Cold Climate Heat Pumps are an emerging technology that can help address heating needs

On-site renewables and energy storage have an important role in improving economic outcomes for customers while contributing to decarbonization

Electrification is viable but stakeholder support is vital

THANK YOU

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Q&A

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