Better Buildings
U.S. DEPARTMENT OF ENERGY

Better Buildings Residential Network Peer Exchange Call Series

Earth Day Special: Electrification, Batteries, Storage & Residential Efficiency

April 22, 2021

Agenda and Ground Rules

- Agenda Review and Ground Rules
- Opening Poll
- Residential Network Overview and Upcoming Call Schedule
- Featured Speakers
  - **Anne Evens**, CEO, Elevate Energy
  - **Chris Bilby**, Research & Programs Engineer, Holy Cross Energy
  - **Tien Duong**, Sr. Technical Advisor, DOE Vehicle Technologies Office
- Open Discussion
- Closing Poll and Announcements

Ground Rules:

1. **Sales of services and commercial messages are not appropriate** during Peer Exchange Calls.
2. Calls are a safe place for discussion; **please do not attribute information to individuals** on the call.

The views expressed by speakers are their own, and do not reflect those of the Dept. of Energy.

Better Buildings Residential Network

Join the Network

Member Benefits:

- Recognition in media and publications
- Speaking opportunities
- Updates on latest trends
- Voluntary member initiatives
- One-on-One brainstorming conversations

Commitment:

- Members only need to provide *one number*: their organization's number of residential energy upgrades per year, or equivalent.

Upcoming Calls (2nd & 4th Thursdays):

- May 13: *Low Income, Market Rate Residential Efficiency: Reaching the Hard to Reach*
- May 27*: Decarbonization and Residential Buildings*
- Jun 10*: Environmental Justice and Residential Energy Efficiency*

Peer Exchange Call summaries are posted on the Better Buildings website a few weeks after the call

For more information or to join, for no cost, email bbresidentialnetwork@ee.doe.gov*, or go to* energy.gov/eere/bbrn *& click Join*

Anne Evens
Elevate Energy

U.S. DEPARTMENT OF ENERGY

Equitable Building Electrification

DOE Peer Exchange

April 22, 2021

Agenda

- Background: Elevate approach to Equitable Building Electrification
- Electrification pilot project
  - Property background
  - Energy Efficiency
  - Electrification
  - Rooftop Solar and First Year Utility Costs
  - Demand Response

Background – The Problem

- In order to have a chance of combatting the climate crisis, we need to eliminate fossil fuel use in the next one to two decades.

- Burning fossil fuels—typically oil or gas—to provide heating, cooling, and hot water in buildings can be a significant source of air pollution and greenhouse gas emissions.

- Lower income residents, renters, seniors, and other vulnerable groups are more likely to:
  - live in older, existing buildings,
  - disproportionally experience the effects of climate change, and
  - be left behind in climate mitigation efforts.

Background – The Solution

- Elevate seeks to invest capital resources into nonprofit-owned affordable housing in to end the on-site combustion of fossil fuels in buildings.
- The overall goal, shared by our funder, is to equitably electrify buildings and reduce carbon emissions to avert the worst impacts of climate change.
- Additionally, we strive to reduce utility costs, add central cooling, and improve indoor air quality.
- Our vision: affordable housing should be high quality and low-carbon, and we need to move as quickly as possible to combat the climate crisis.

Four Pillars of Decarbonizing Buildings

Energy Efficiency

Electrification

Renewable Electric Supply

Managed Electricity Loads

Elevate Research and Demonstration Projects

- Single family homes. US Department of Energy Advanced Buildings Construction Initiative. The goal is to assess the feasibility of a 50% energy reduction in Chicago's single family housing stock via combination of deep energy improvements and electrification. Pending funding in year 2 (June 2021), we will pilot measure packages in several home types (pre 1942 frame and brick, etc)
- Multifamily homes. Building Electrification Pilot provides whole-building electrification retrofits for affordable nonprofit-owned housing. Demonstration projects are underway in Chicago, Madison, and Detroit and will be completed by fall 2021.

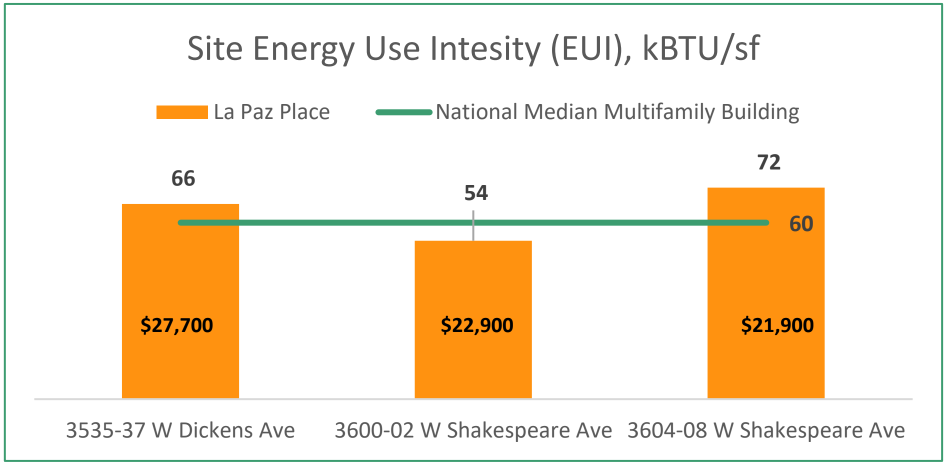
Project Background – Chicago Multifamily Property

- 3-building property totaling 44 units on Northwest side of Chicago.
- It is a masonry courtyard-style building, which is typical of the pre-War vintage.
- Of the 44 units at La Paz Place, 31 are affordable to families at 50% Area Median Income (AMI) or $44,550, and 13 are affordable at 30% AMI ($26,730).
- Provides housing development and preservation, economic empowerment, leadership development, and tenant organizing.

Energy Efficiency Strategies

Energy Efficiency

- In 2013, all 3 properties upgraded their air sealing and insulation of roof cavities/attics
- In 2015-2016, all 3 properties installed aerators and showerheads
- Similar energy performance to the national median
- Energy costs are relatively similar



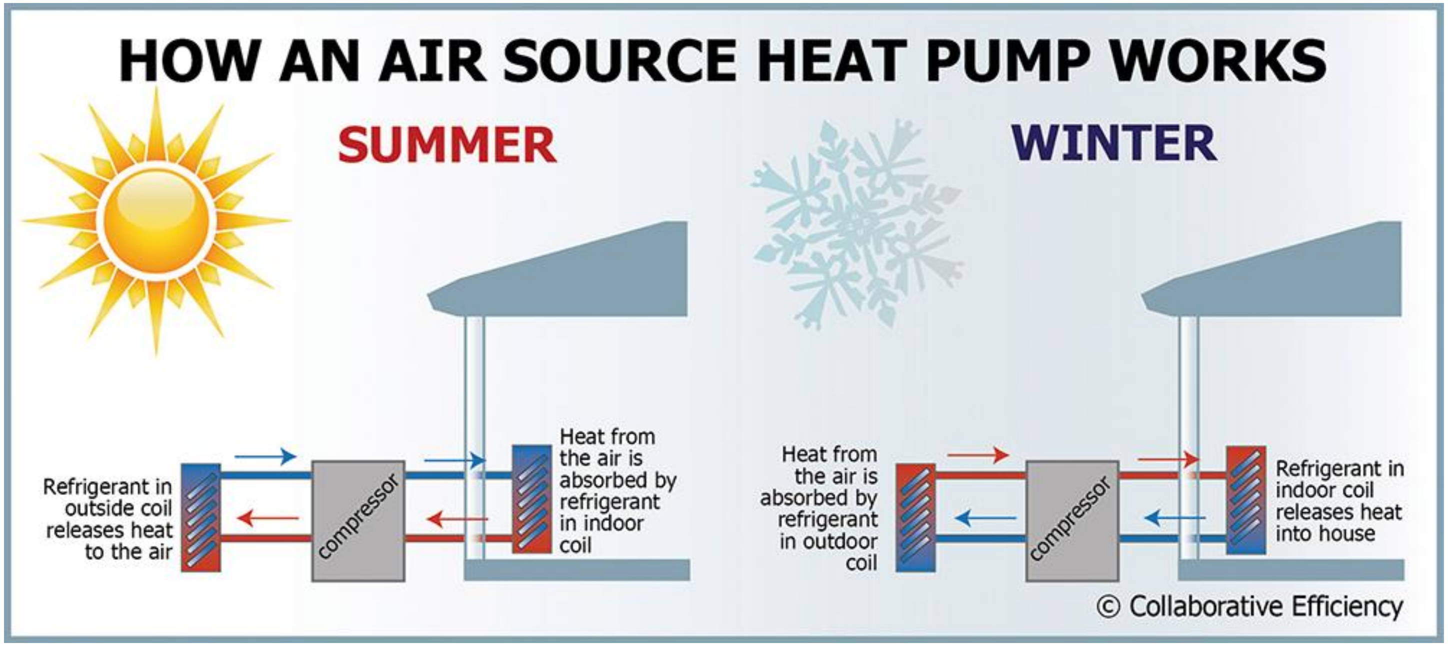
Electrification Strategies

Electrification

- Upgrade all building equipment and systems that use natural gas:
  - Space Heating → heat pumps
  - Water Heating → heat pumps
  - Appliances (stoves, clothes dryers)→ all-electric

- Upgrade electrical service to withstand new/added electrical loads, including additional cooling (if needed)

Electrification Strategies
Heat Pump Technology – Space & Water Heating



Proposed Space Heating & Cooling Technology

- High-efficiency individual heat pumps for each unit provide heating in winter and cooling in summer
- Would not trigger major electrical upgrades (except for 4-bedroom units)
- LG technology shown, also available from Daikin, Mitsubishi and others
- Average COP of 200-300% versus 70-80% efficiency furnaces
- Reduces total energy 50-60%

System Riser
(one per unit)

Proposed Water Heating Technology

Energy Performance:

- Average COP of 2.5, means 250% of the heat is moved per unit of input energy
- Provides “free” basement cooling in summer

Installation/Maintenance:

- Simplified installation, no flues or additional roof/wall penetrations
- Typical life 5 years longer than traditional gas heater

Heat Pump Hot Water Heater

Storage Tank behind

Proposed Stoves & Laundry Equipment

- Stoves drive tenant savings because they are the ‘last mile’ to eliminate tenant gas service, thereby eliminating the high fixed charges.
- Ceramic flattop stoves and heat pump dryers are the recommended technologies
- Stoves would require in-unit electrical work to run conduit from panels to kitchens and coordination with tenants
- Impacts to utility costs are minimal compared to HVAC and hot water

Heat Pump Dryer

Electric Stove/Oven

Solar & Demand Response

- The property is applying for funding via Illinois Solar for All
- Electrification will save 3% on annual utility costs, and the addition of solar brings total cost savings to 15% annually
- Storage and demand response have additional cost and emissions savings potential, and are being explored with the building owner

Renewable Electric Supply

Managed Electricity Loads

What have we learned?

- Electrification must be integrated with the other pillars of building decarb, especially energy efficiency
- Affordable owners are focused on their tenants, their operating costs, not widgets or technology
- Added cooling, resiliency, and health improvements are huge selling points
- Policy is needed to fill gaps and address first costs
- Diverse contractors need help to pivot to electrification

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Chris Bilby
Holy Cross Energy

U.S. DEPARTMENT OF ENERGY

Earth Day Special

Electrification, Batteries, Storage & Residential Efficiency

April 22, 2021

Holy Cross Energy

Chris Bilby
Research & Programs Engineer

Holy Cross Energy is leading the responsible transition to a clean energy future.

Holy Cross Energy (HCE) provides safe, reliable, affordable and sustainable energy and services that improve the quality of life for our members and their communities.

Founded in 1939, we serve more than 44,000 members in scenic Western Colorado with:

- *265 MW peak demand*
- *3,000 miles distribution*
- *120 miles transmission*
- *165 employees*

In 2020, 44% of our power supply came from wind, solar, biomass and hydroelectric power, as well as coal mine methane recovery.

Our "Journey to 100%"

These actions will allow HCE to achieve its vision of

100% carbon-free power supply by 2030

Carbon-neutral or better across the enterprise by 2035

in a way that does not sacrifice affordability, safety, or reliability for the sake of sustainability

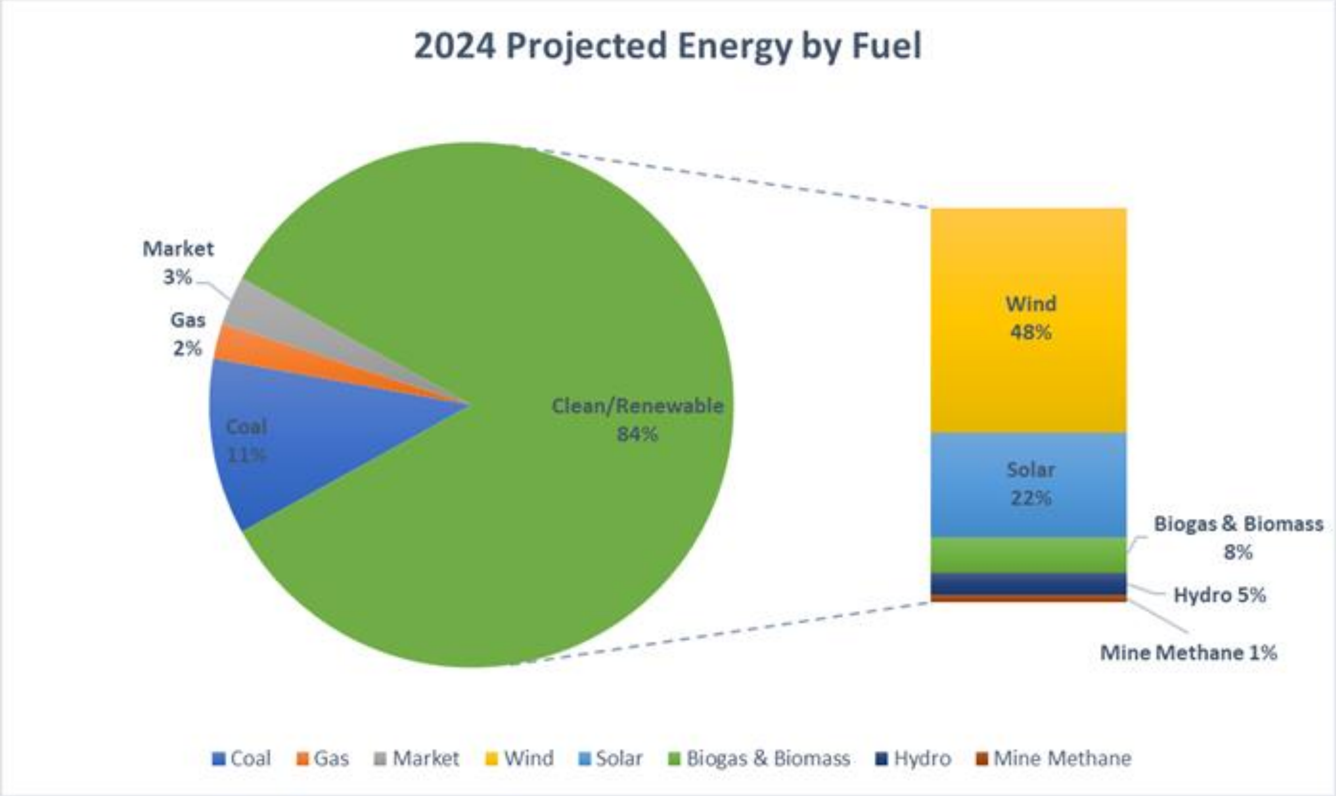
- **Energy Efficiency:** obtain an additional 0.25% per year of energy efficiency improvements
- **Cleaner Wholesale Power Supply:** incorporate new, clean, dispatchable resources into HCE's power supply mix
- **Local Clean Energy Resources:** continue our existing agreements for energy from local biomass, hydro, solar, and coal mine methane projects
- **Distributed Energy Resources:** support installation of at least 2 MW per year of new rooftop solar systems and 1 MW of BTM storage per year
- **Smart Electric:** encourage the expanded use of electricity for transportation, building heating and cooling, and industrial processes

Progress to Date

New Resources Under Contract:

Eastern Colorado
- 100 MW wind
- 30 MW solar

HCE Service Area
- 5 MW solar
- 4.9 MW hydro
- 4.5 MW/15 MWh solar+storage
- 10 MW/20 MWh solar+storage
- 10 MW/20 MWh solar+storage



Fostering DERs for Grid Flexibility

2018

Charge at Home

Free EV home charger and an optional EVSE Rider that allow on-bill payments for the installation cost.

2018

Basalt Vista House Project

An all-electric affordable housing project to demonstrate the value of DER to consumers and the grid.

2018

Time of Day Rate

An optional rate structure to encourage load shifting. Tailored for DCFC and Transit.

- **24c/kWh on-peak (4-9 pm)**
- **6c/kWh off-peak**

2019

Distribution Flexibility Tariff (DFT)

Created an on-bill credit to allow HCE to manage behind-the-meter DER assets.

2019

DER Service Agreement

Expanded the EVSE Rider to allow for a broader application of the tariff-based (service agreement) financing model.

2019

Peak Time Payback & Green Up

Launched programs that pay members for a measured reduction or increase in usage compared with their baseline during a limited number of demand response event hours.

2020

Camus Energy

HCE begins effort on a Zero Carbon Grid Orchestration combining system visibility with DER signaling.

2021

Power+

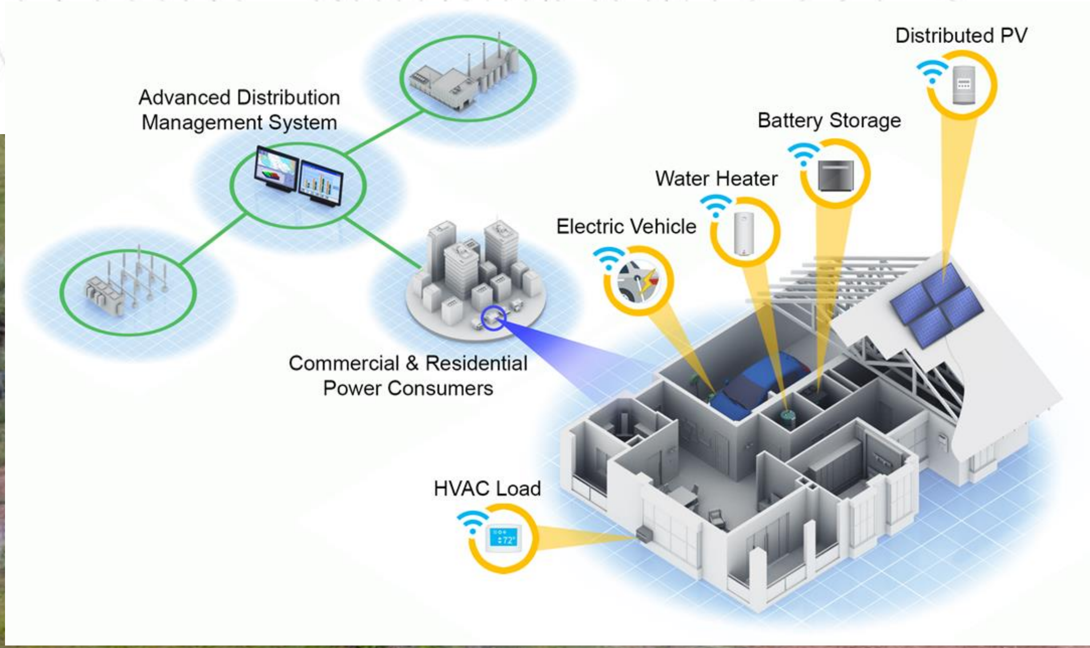
Combines DER Service Agreement and DFT to offer members a new resilience option using Battery Energy Storage Systems with a 5MW goal.

“Basalt Vista” Affordable Housing Project

- Habitat for Humanity, Pitkin County, Basalt School District
- 27 homes for teachers and local service workers
- Designed net-zero energy with *all electric* construction
- Adjacent to Lake Christine Fire affected area
- Cost-shared partnership with NREL and DOE Office of Electricity
- Demonstrate value of DERs to consumer *and* grid

<u>Four</u> homes with controllable loads

- 8kW rooftop solar PV
- Battery storage
- L2 EV charging
- Heat pump water heater
- Air source heat pump



Basalt Vista Case Study

Project Goal: Demonstrate the ability for a distribution utility to control and dispatch Distributed Energy Resources (DERs) to provide value to the grid as well as to the individual consumer.

- **Microgrid controllers coupled with DER**
  - Flexible
  - VPP at All Levels
    - Feeder, Community or Individual Buildings
- **ADMS: Simple Management and Visibility of DER**
- **Studied High Penetration of DERs**
- **Interoperability of different "Systems"**
- **Resilient Soft Microgrid**

Distributed Controls of DERS

Advanced Distribution Management System (ADMS)

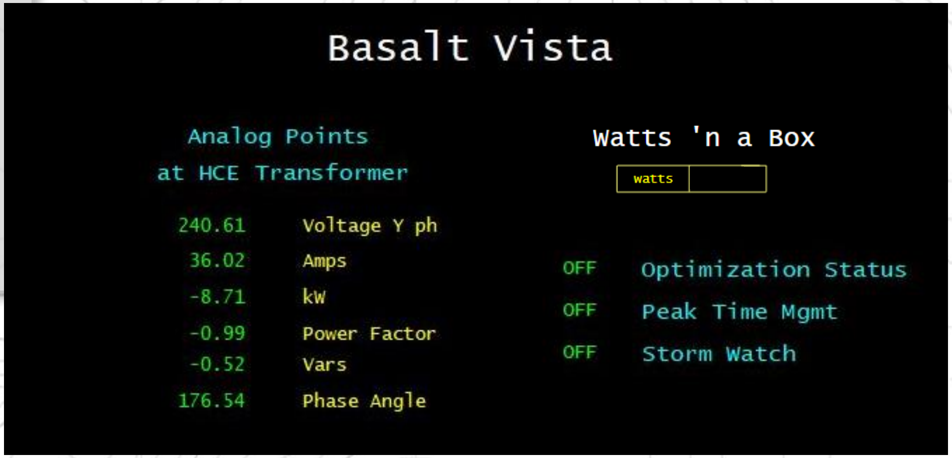
Fully integrated:

- Supervisory Control And Data Acquisition (SCADA)
- Outage Management System (OMS)
- Distribution Energy Resource Management System (DERMS)

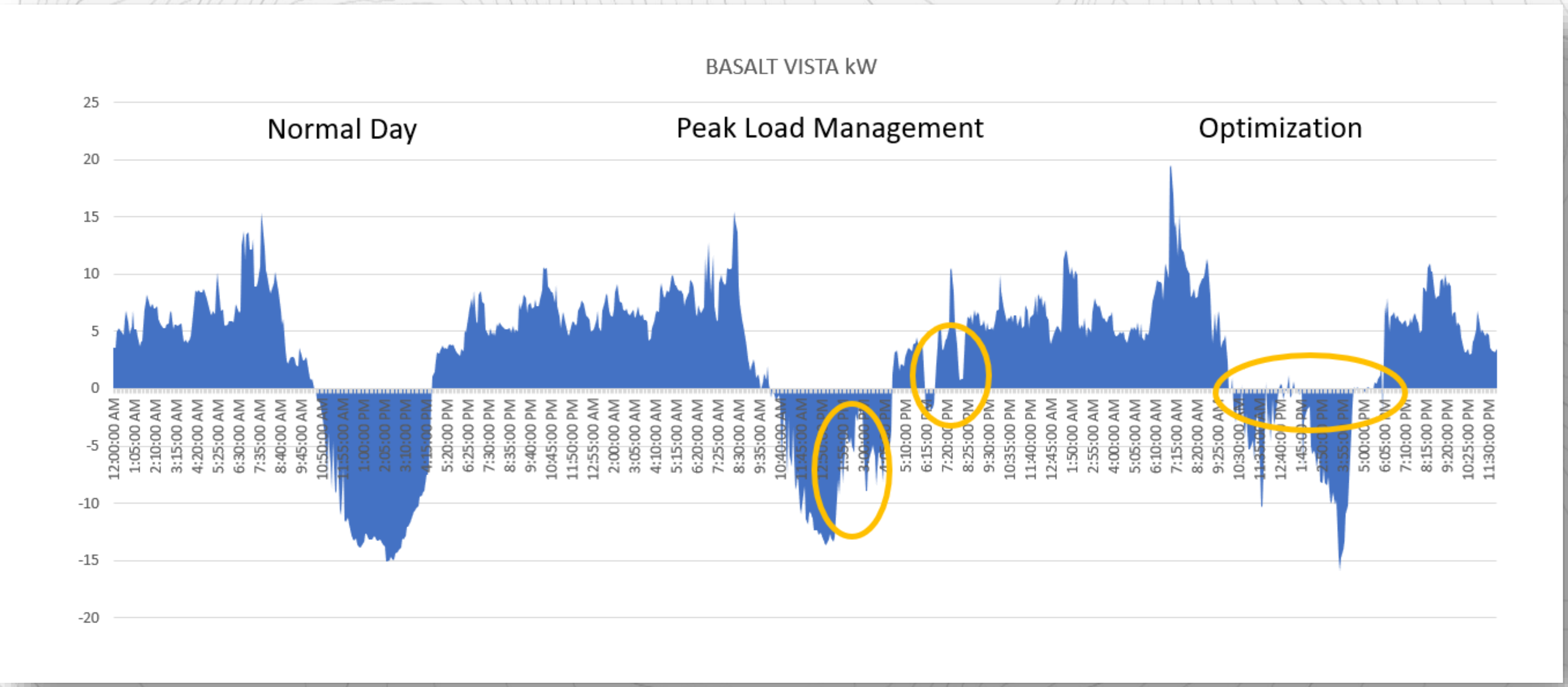
Enhanced Situational Awareness for:

- Load Flow and State Estimation
- Vehicle Location
- Switching Validation
- Outage and Restoration Information from AMI
- Also runs applications, including:
  - CVR – conservation voltage reduction
  - VVO – volt/var optimization
  - FLISR – fault location, isolation and service restoration

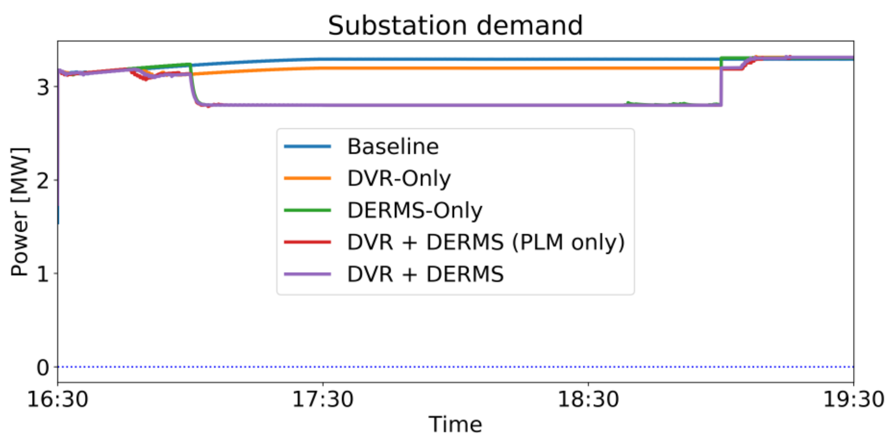
One easy-to-use graphical interface provided by Survalent (existing HCE partner)

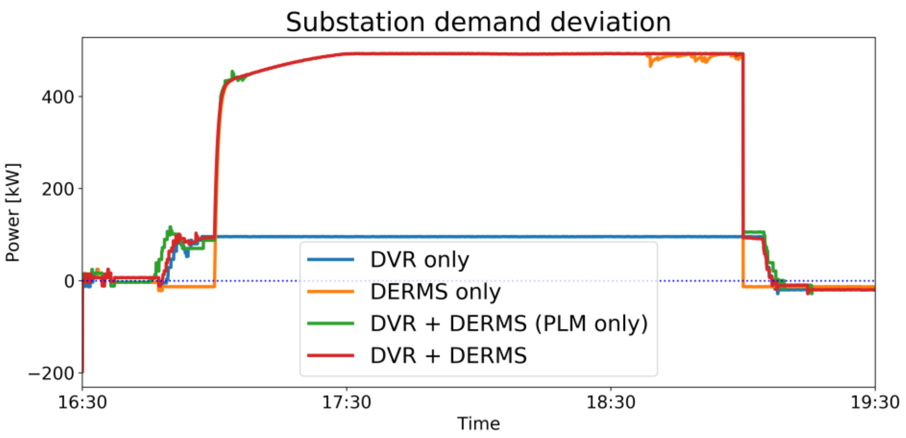


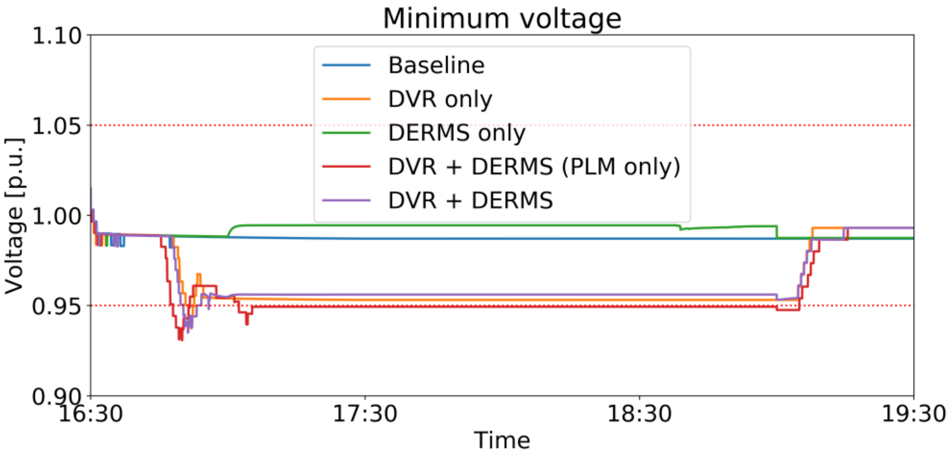
3 Day test at BV (November) – 4 homes



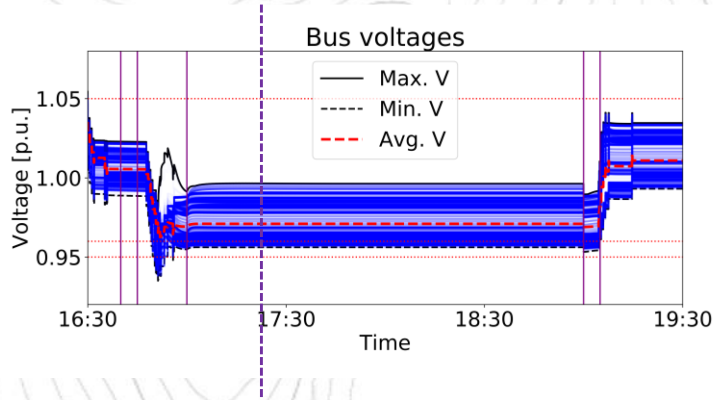
Simulations at NRELs ESIF –ADMS Test Bed

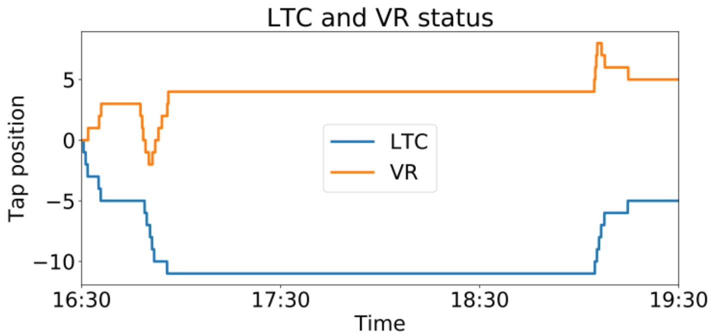


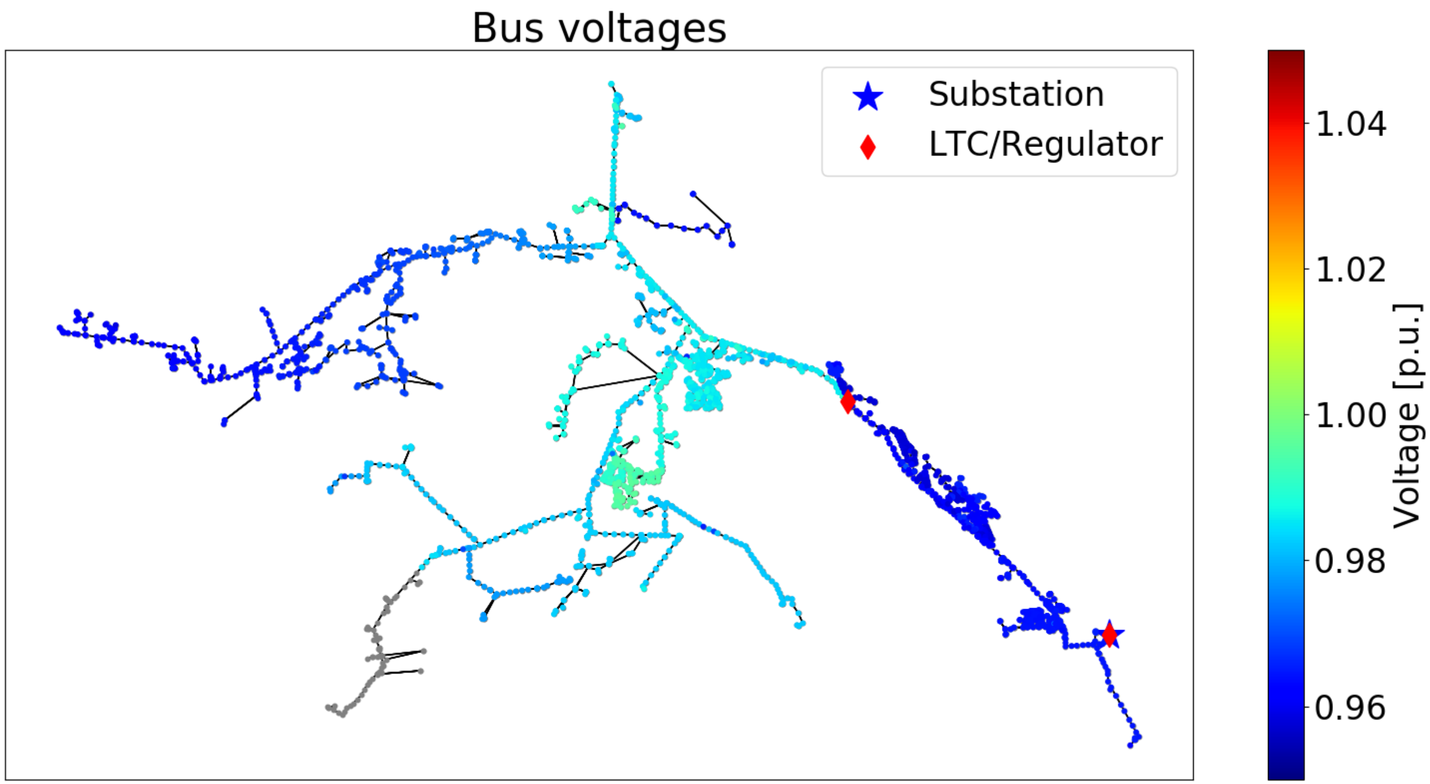




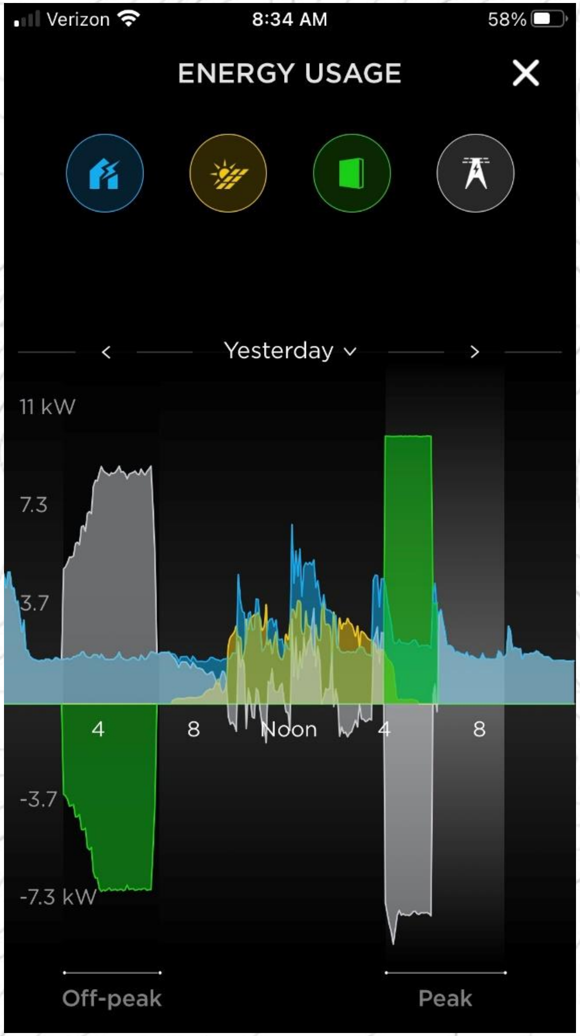
Developing Heatmaps – NRELs ADMS Test Bed







“Power+” Energy Storage Program



Pilot program in 2021 and 2022: 5 MW/15 MWh BTM storage

Combines DER Service Agreement & Distribution Flexibility tariff

Target consumer cost: $30-$60/month for 10 years

Initial install at HCE HQ avoided
12 interruptions/290 SAIDI minutes in Q4 2020 alone!

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Thank You

Tien Duong

U.S. Department of Energy

Energy Efficiency &
Renewable Energy

Lithium-ion Batteries in Electric Drive Vehicles

Tien Q. Duong

Vehicle Technologies Office

EERE, U.S. Department of Energy

Earth Day Special:
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April 22nd, 2021

Battery Requirements & Design

- An automotive battery is considered to reach its end-of-life when it loses either 20% of its capacity or power. In general, most battery chemistries today are power-limited.
- To ensure that the battery lasts the expected life of the vehicle, battery performance requirements are defined at the end-of-life.
- Typical cycle life requirements for Hybrids and EVs are 300,000 and 1,000 cycles, respectively. These correspond to a lifetime requirement of more than100,000 miles/10 years.
- Batteries are generally designed for achieving optimal power/energy ratio (P/E) to meet the load for the specific application at minimum cost.
  - On a per kWh basis, thinner electrodes with larger P/E ratio cost more than thicker electrodes with smaller P/E ratio.

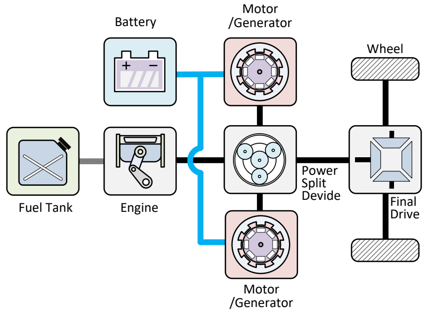
Powertrain Configurations:
HEVs – Two Motor Design

Energy Efficiency & Renewable Energy

Vehicle Specifications

	Unit	Value
Model Year	-	2016
Vehicle type	-	HEV
EPA class	-	Midsize
MSRP	$	32345
EPA FE (city/hwy)	MPG	43/39
0-60mph	s	8.8
Curb weight	kg	1650
Powertrain architecture	-	Power-Split
Featured tech.	-	Atkinson cycle
Engine	-	2L - 4cylinders, 104kW
Engine tech.	-	iVCT, sequential fuel injection, Atkinson cycle, hybrid start- stop system
Battery	-	1.4 kWh
Battery tech.	-	Lithium-ion
Motor	-	Permanent Magnet Synchronous Motor 88kW
Net power	kW	179
Transmission	-	e-CVT
Final drive		2.57
C_d		0.316
Frontal area	m^2	2.2575

HEV – Ford Fusion Hybrid
(2 Motor Design without transmission – most common)

Powertrain Configuration	
Vehicle Components Layout	

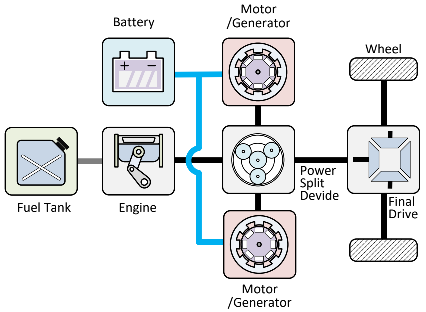
Powertrain Configurations:
PHEVs

Energy Efficiency &
Renewable Energy

Vehicle Specifications

	Unit	Value
Model Year	-	2015
Vehicle type	-	PHEV
EPA class	-	Midsize
MSRP	$	25670
EPA FE (city/hwy)	MPG	38 (combined)
0-60mph	s	8.5
Curb weight	kg	1750
Powertrain architecture	-	Power-Split
Featured tech.	-	Sequential fuel injection, Atkinson cycle, DOHC, hybrid start-stop system
Engine	-	1.999L - 4 cylinders, 105kW
Engine tech.	-	Atkinson cycle
Battery	-	7.6 kWh
Battery tech.	-	Lithium-ion battery pack
Motor	-	Permanent magnet AC synchronous motor, 88kW
Net power	kW	140
Transmission	-	e-CVT
Final drive		2.57
C_d		0.325
Frontal area	m^2	2.553

PHEV – Ford C-MAX Energi Plug-in Hybrid

Powertrain Configuration	
Vehicle Components Layout	

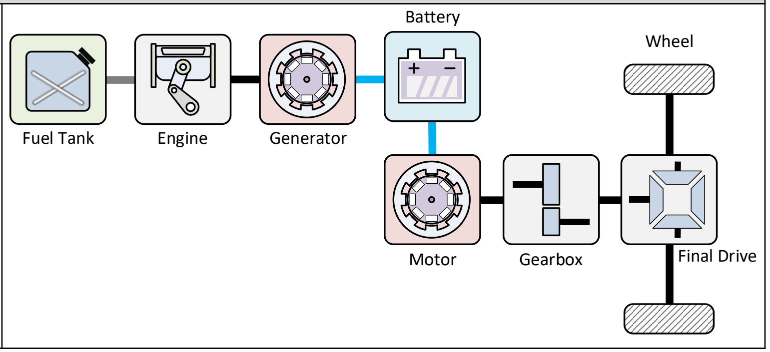
Powertrain Configurations:
PHEVs (Range Extender)

Energy Efficiency & Renewable Energy

Vehicle Specifications

	Unit	Value
Model Year	-	2016
Vehicle type	-	PHEV
EPA class	-	Subcompact
MSRP	$	46250
EPA FE (city/hwy)	MPG	41 / 37
0-60mph	s	7.5
Curb weight	kg	1315
Powertrain architecture	-	Series
Featured tech.	-	–
Engine	kW	25
Engine tech.	-	W2DKD6A
Battery	-	22 kWh
Battery tech.	-	-
Motor	kW	125
Net power	kW	125
Transmission	-	DD
Final drive		9.665
C_d		0.3
Frontal area	m^2	2.3783

PHEV – BMW i3 with Range Extender (2014/2015/2016)

Powertrain Configuration	
Vehicle Components Layout	

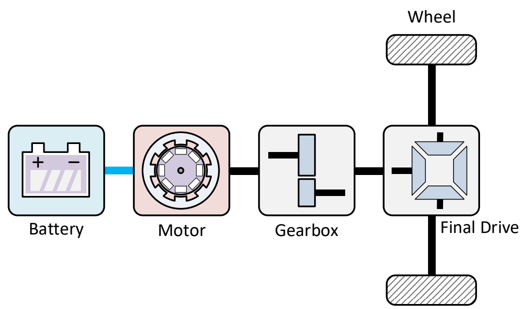
Powertrain Configurations:
EVs

Energy Efficiency & Renewable Energy

Vehicle Specifications

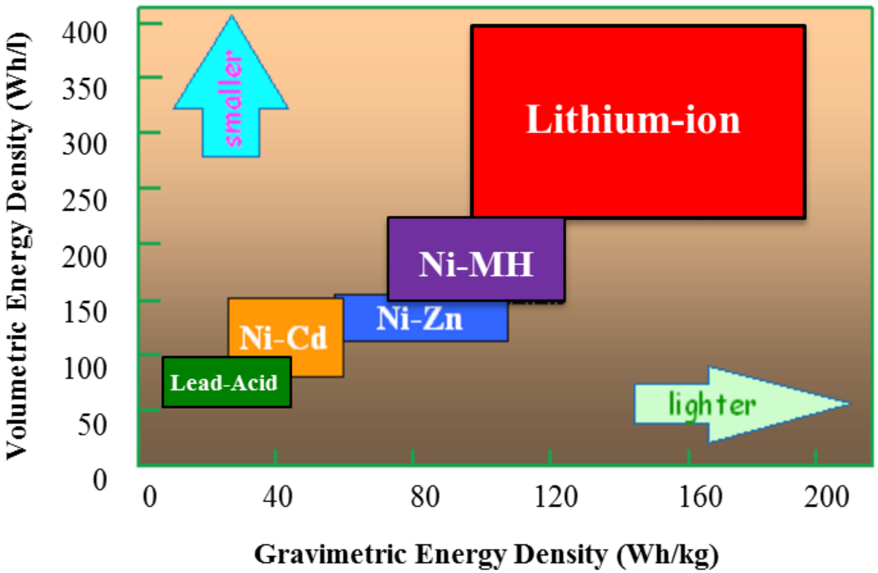
	Unit	Value
Model Year	-	2014/2015/2016
Vehicle type	-	EV
EPA class	-	Large
MSRP	$	
EPA FE (city/hwy)	MPG	88/90
0-60mph	s	5.6
Curb weight	kg	2145
Powertrain architecture	-	Fixed Gear
Featured tech.	-	Rear-Wheel Drive, 3-Phase/4-Pole Electric Motor, Regenerative 4-Wheel Disc Brakes w/4-Wheel ABS, Front And Rear Vented Discs, Brake Assist, Hill Hold Control and Electric Parking Brake
Engine	-	-
Engine tech.	-	-
Battery	-	85 kWh
Battery tech.	-	Lithium Ion Traction Battery
Motor	-	AC induction motor, 285kW
Net power	kW	285
Transmission	-	DD
Final drive		9.73
C_d		0.246
Frontal area	m^2	2.406

EV – Tesla Model S85

Powertrain Configuration	
Vehicle Components Layout	

Lithium-ion Batteries
(Why Li-ion?)

Energy Efficiency & Renewable Energy



After a stable passivation layer (solid electrolyte interphase) on the surface of the graphite electrode is formed.

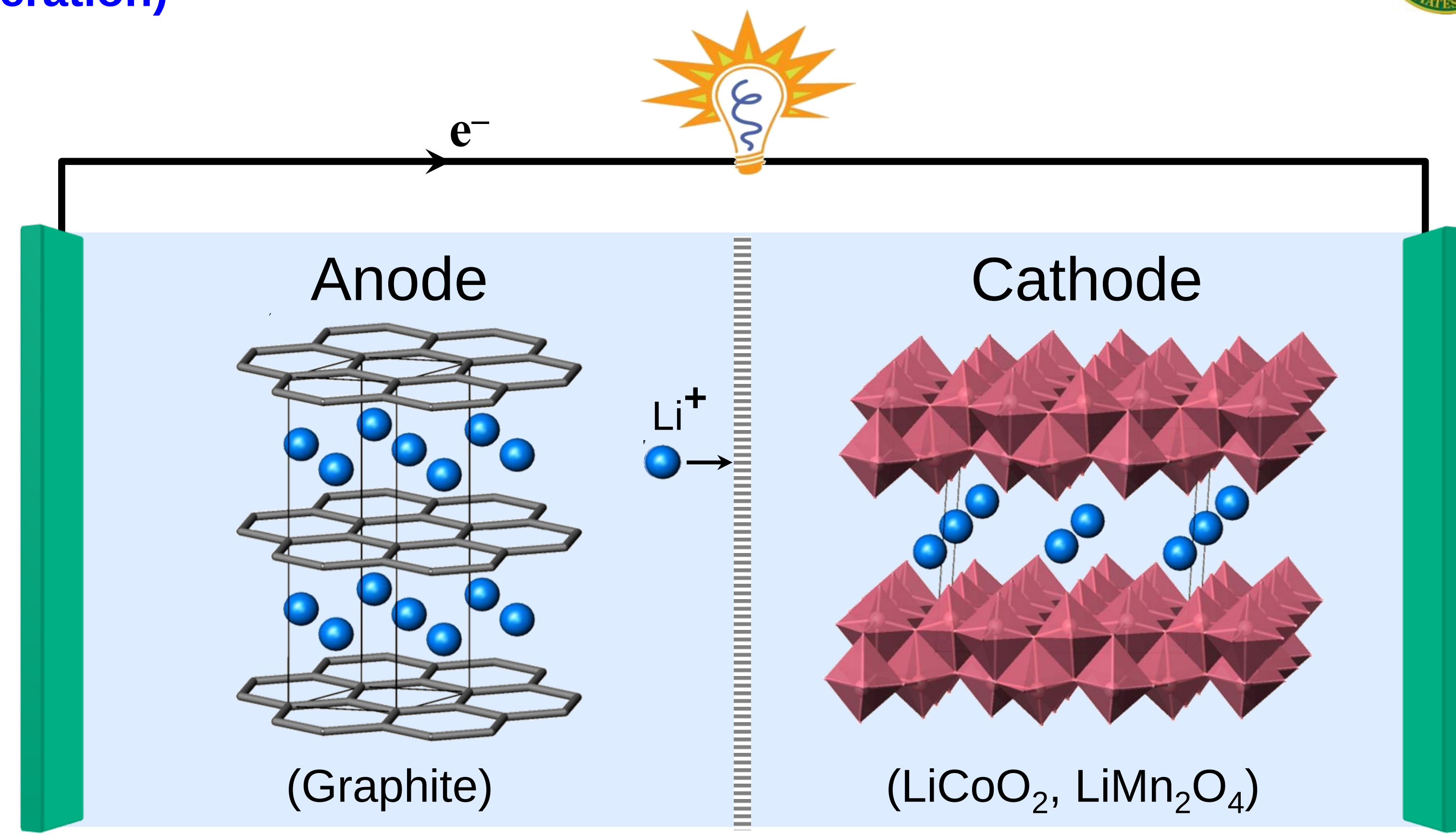
- Intercalation chemistry leads to very long cycle life (>1,000 cycles) due to invariant chemical transformation reaction →
- Example of a chemical transformation reaction →

$$Li_xC + Li_{(1-x)}MO_2 \underset{Charge}{\overset{Discharge}{\rightleftarrows}} C + LiMO_2$$

$$Pb + PbO_2 + 2H_2SO_4 \underset{Charge}{\overset{Discharge}{\rightleftarrows}} 2PbSO_4 + 2H_2O$$

Lithium-ion Batteries
(Operation)

Energy Efficiency & Renewable Energy



$$Li_xC + Li_{(1-x)}MO_2 \underset{Charge}{\overset{Discharge}{\rightleftharpoons}} C + LiMO_2$$

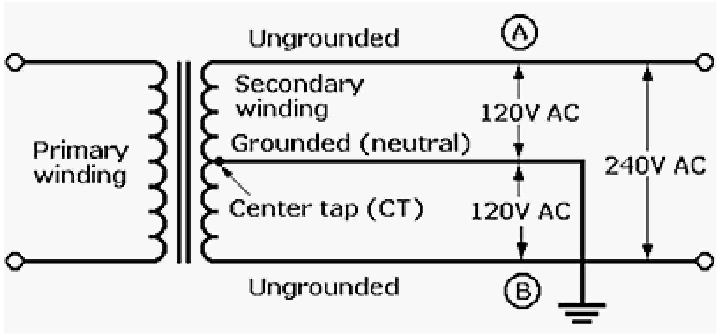
Variations of Lithium-ion Chemistries

- Multiple cathode & anode choices lead to several chemistries, with different open circuit voltages and related performances.
  - In general, systems with high open circuit voltage are preferred, followed by those with high specific capacity (mAh/g) and density (g/cm^3).
  - There is no clear-cut preferred battery chemistry. It is dictated by specific application (a tradeoff between cost, cycle life, safety and total energy output).
- Examples:
  - The state-of-the art battery includes graphite/high nickel NMC (known as 622) battery systems operating at up to 4.4V – now deployed in vehicles.
  - Electric buses prefer a graphite/$LiFePO_4$ system over other chemistries.
  - For applications requiring very fast charges, the lithium titanate/NMC chemistry is preferred, primarily to avoid lithium plating.

Potential Uses: EV Batteries

Energy Efficiency & Renewable Energy

- Electrical distribution in neighborhoods is not flexible
  - Single-phase, three-wire 120/240V distribution, via pole-mounted distribution transformers, limits vehicle-to-grid (V2G) applications.
- EV batteries could be designed to provide back-up power for homes during power outage
  - Typical EV batteries store ~80 kWh (~240+ mile range)
  - Most driving is for < 40 miles/day (using up 12 kWh)
  - The remaining 68 kWh of stored electrical energy could power most typical homes for about 2 days.
- Pair with a Solar System
  - EV batteries can store solar energy during the day and then supply power to the home at night.
- Peak Shaving
  - EV batteries can store energy at low-rate times and then supply power to home at high-rate times.

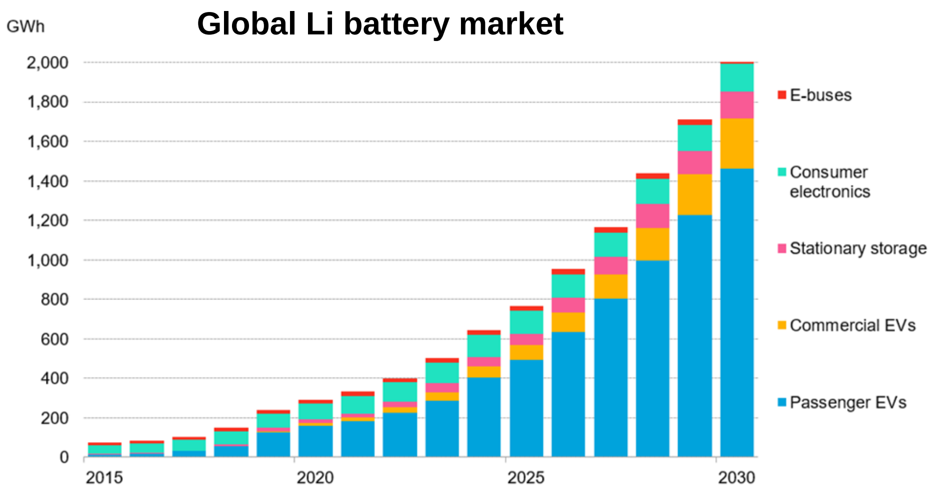


Single-phase, three-wire, 120/240 V Distribution

Pole-mounted Distribution Transformer

Conclusions

EVs would achieve >20 million sales globally by 2030



Worldwide anticipated use applications of Li-ion batteries. Source: BNEF.

- Since its first entry into market (Toyota Prius HEV in 1997), electric drive vehicles have proven to be reliable, offer enjoyable driving experience with great fuel savings.
- Today, there are hundreds of brands and EV models available to choose from.
- With reduction in battery costs, EVs will become more popular.
  - Range anxiety is no longer a concern, with the Chevy Bolt and Tesla Model S achieving a range of 260 and up to 400 miles, respectively.
- Current battery cost is < $170/kWh (battery pack).
  - Cost-parity with the internal combustion engine vehicles can be achieved when the battery cost falls to below $100/kWh.

Thank you for your attention!

For more information, contact:

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Battery R&D
Vehicle Technologies Office
Office of Energy Efficiency & Renewable Energy
U.S. Department of Energy

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(http://bmr.lbl.gov)

Closing Poll

- **After today's call, what will you do?**
  - Consider implementing one or more of the ideas discussed
  - Seek out additional information on one or more of the ideas
  - Make no changes to your current approach
  - Other (please explain)

Upcoming Events

Winning Solar Home - The DOE Solar Decathlon Build Challenge Winners

April 28, 1–2 p.m. E.T.

solardecathlon.gov/virtual_sessions.html

DOE Better Buildings Summit

May 17-20

betterbuildingssolutioncenter.energy.gov/summit


STEM
RISING
U.S. DEPARTMENT OF ENERGY
ENERGY.GOV/STEMRISING

Explore the Residential Program Solution Center

Resources to help improve your program and reach energy efficiency targets:

- Handbooks - explain *why* and *how* to implement specific stages of a program.
- Quick Answers - provide answers and resources for common questions.
- Proven Practices posts - include lessons learned, examples, and helpful tips from successful programs.
- Technology Solutions NEW! - present resources on advanced technologies, **HVAC** & **Heat Pump Water Heaters**, including installation guidance, marketing strategies, & potential savings.

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Thank You!

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