Comprehensive Infrastructure Solutions for Electric Vehicle Charging

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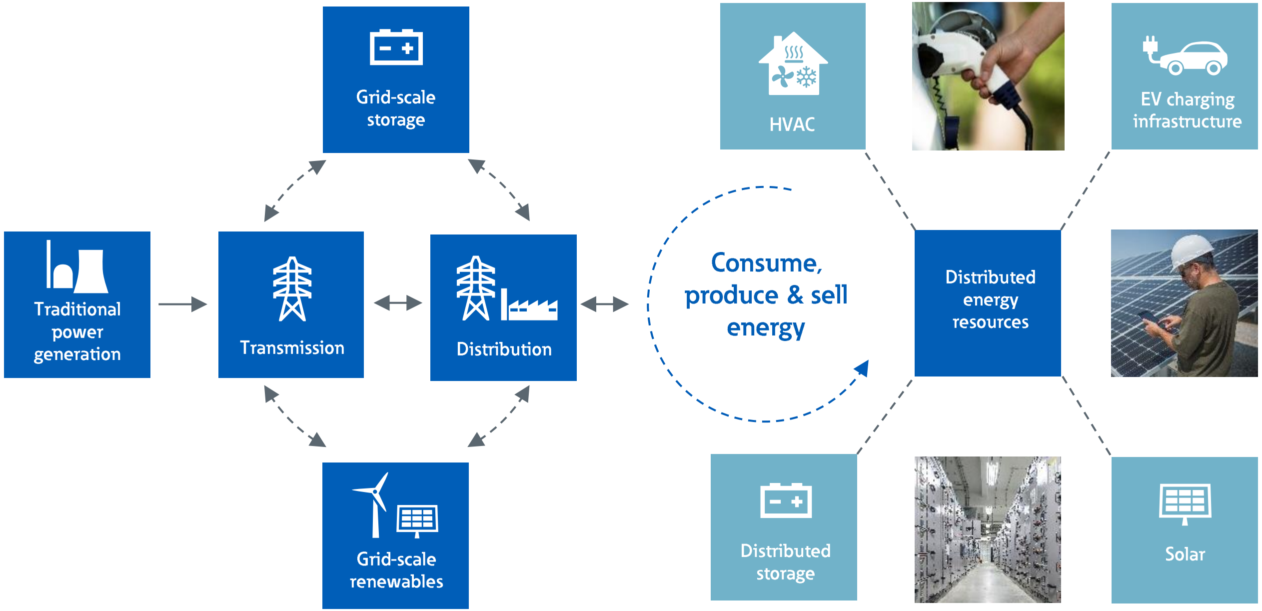
The new power landscape



Enabling customers to safely add more renewables, storage and electrical vehicle infrastructure to their energy mix.

Buildings require a comprehensive infrastructure solution to enable sustainable, resilient and cost-effective performance

Comprehensive EV charging infrastructure offerings include equipment, software and engineering services solutions to meet EV charging project requirements.

EV charging
AC Level 2 and DC level 3 fast chargers for residential, commercial, and fleet operations

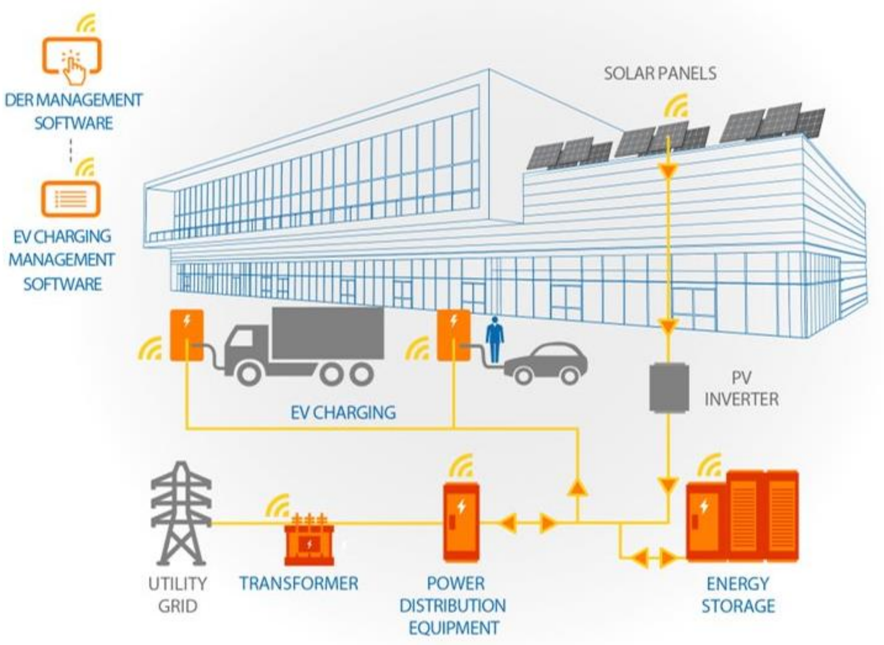
Battery storage
Battery Energy Storage System (BESS) includes batteries, inverters and management software to shave peak demand cost for EV charging applications

EV Charge management software
Enables users to operate a network of charging stations, from charging point management and power management to financial rules

Microgrids and Distributed Energy Resource (DER) integration
Incorporate local solar photovoltaics and other renewables into new or existing infrastructure to maximize charger deployment and help meet sustainability goals

Power distribution equipment and grid connection upgrades
Installation and upgrades of electrical equipment, including transformers, switchgear, switchboards, and panelboards

Electrical engineering services
Includes feasibility analysis of planned EV deployment sites, power systems analysis of electrical infrastructure, electrical system conceptual design and configurations, system protection analysis and recommendations, automation and control solutions and turnkey electrical services



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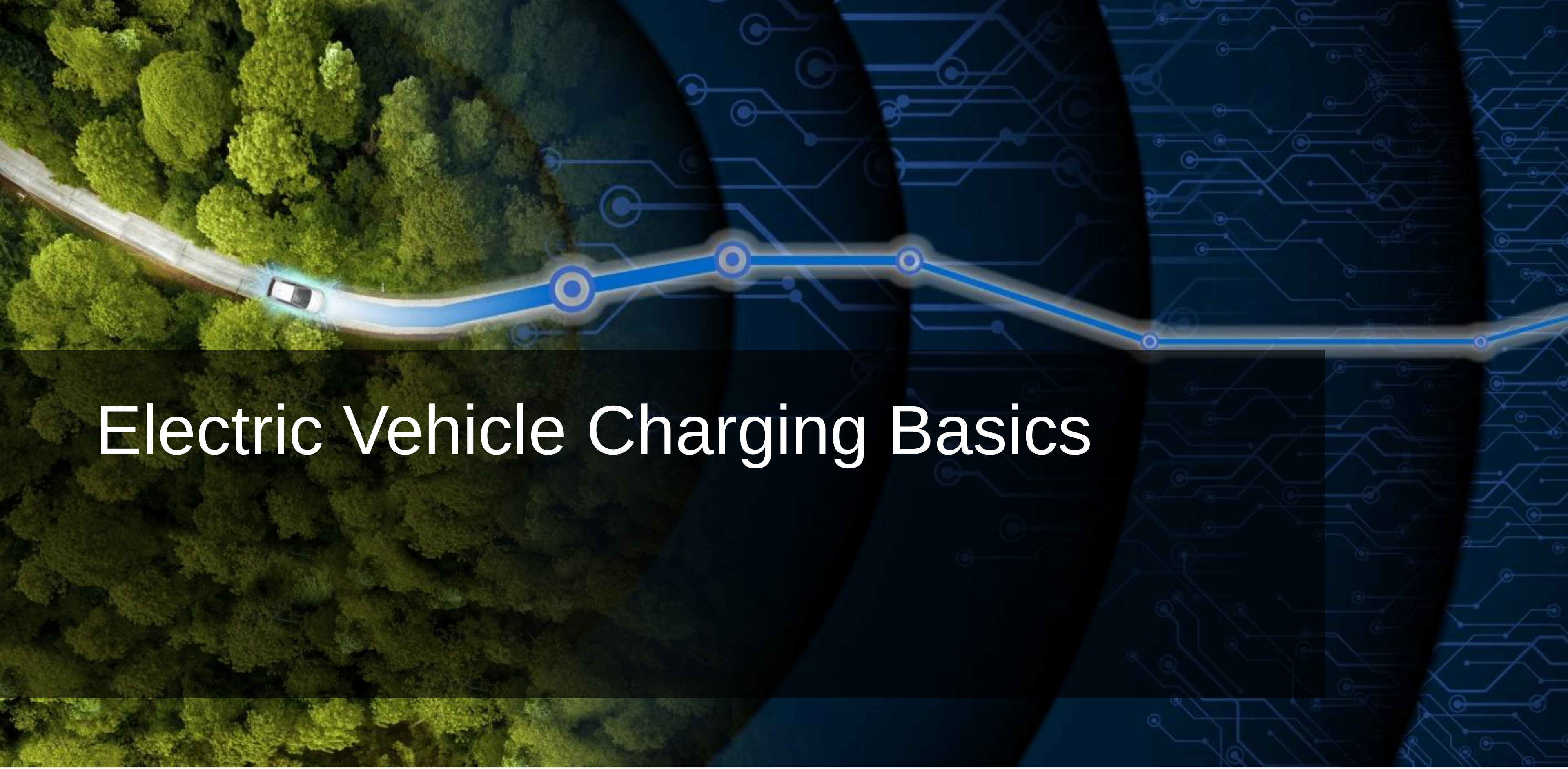

Electric Vehicle Charging Basics

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AC vs DC Charging

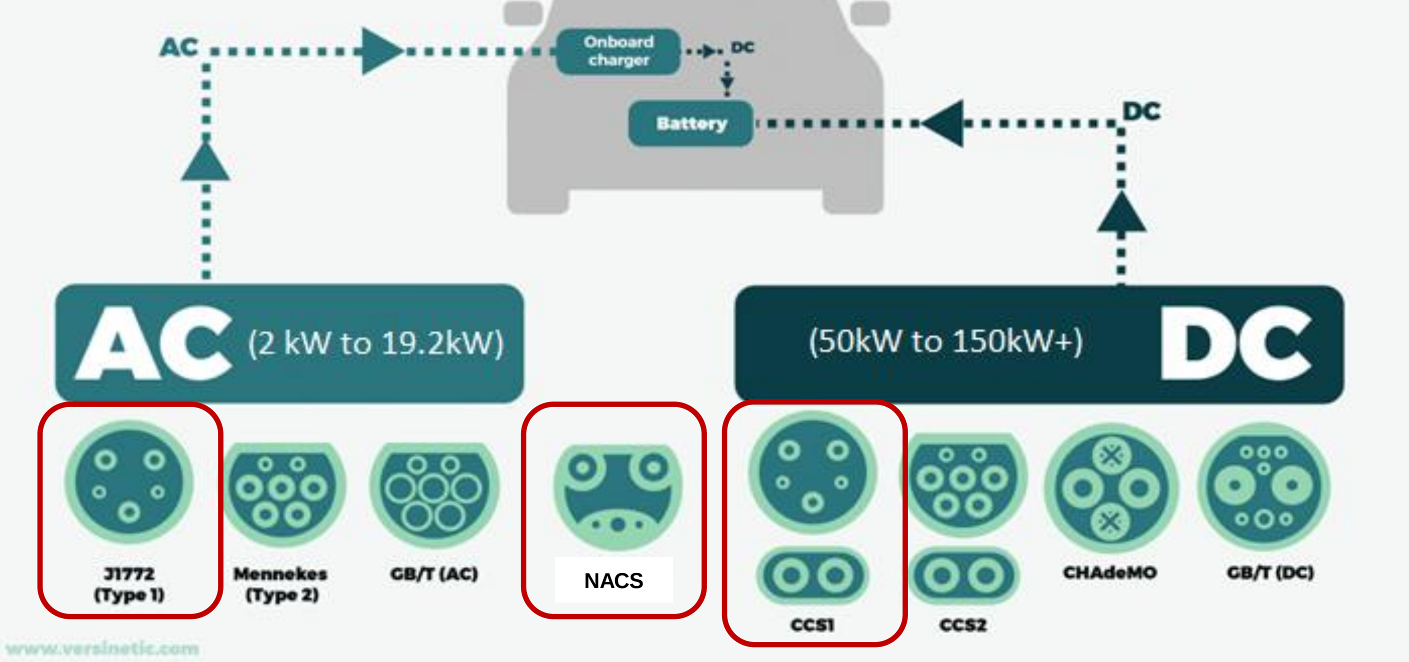
AC Level 1
- 120V
- Home
- Up to 2.4kW

AC Level 2
- 240V
- Home / Public / Fleet
- Up to 19.2kW

Fast DC
- 400-1000V
- Public / Fleet
- 50kW and higher

AC is limited by the lowest of the two components, the onboard charger or the AC charger (208-240V)

DC is limited by the lowest of the two components, the rate the battery can charge or the DC charger (50-1000V)



Note: All but Stellates and Volkswagen will offer a native NACS connector in late 2025, but it is assumed they will adopt.

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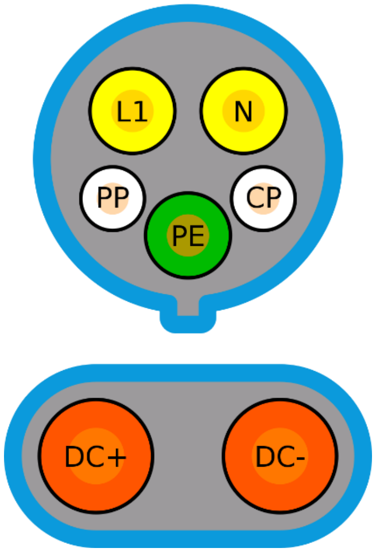
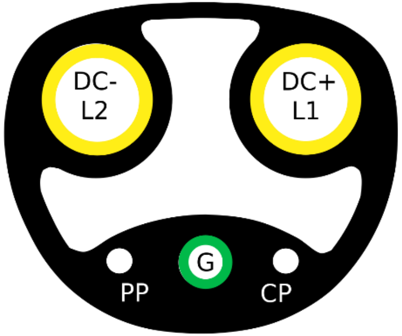
Nozzle Pinout

CCS1



L1	**AC Line 1** (120/240V)
N/L2	**Neutral** (120V) / AC Line 2 (240V)
PE/G	**Ground**
PP	**Proximity Pilot** which disables vehicle when charging and disables charger and or vehicle
CP	**Control Pilot** which is the communication between vehicle and charger
DC+	**DC positive** terminal
DC-	**DC negative** terminal

NACS/J3400



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Charging Stations basics

Charging Level; Description	Typical Power	Input Voltage	Output Voltage	Location	Miles of Range Replenished
AC Level 1; cord comes with car; three-prong outlet or charging station	1 - 1.4kW	120VAC (1ph)	120VAC (1ph)	Home, Work, Public	3–5 miles/hour
AC Level 2; charging station	7.2 - 19.2kW	240VAC (1ph) 208VAC (1ph)	240VAC (1ph) 208VAC (1ph)	Home, Work, Public	8–24 miles/hour, higher on some models
DC Fast; charging station	50kW	480VAC (3ph)	200 - 1000Vdc	Work, Public	2–3 miles/minute; charges 100-mile range car to 80% in 30 minutes
DC Fast; charging station	150kW				6–9 miles/minute; charges 240-mile range car to 80% in 30 minutes
DC Fast; charging station	350kW				12–18 miles/minute; charges 300-mile range car to 80% in 20 minutes

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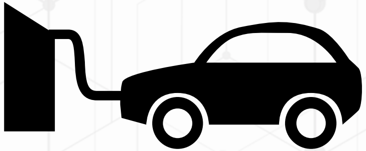
The Charging Stations



Example assumptions:
90 kWh battery (typically charge 20% to 80%)
Time (h) = 0.6 x 90 kWh / (rating of charger)

Rating of charger	Location	Charger Type	Charger Ampacity	Supply Voltage	80% Charge Time	37 Miles Charge Time***
1.4kW	Home	Level 1	12A	120V 1Ph	38.6 hours	8.81 hours
7.7kW	Home	Level 2	32A	240V 1Ph	7.0 hours	1.6 hours
11.5 kW	Work / Public	Level 2	48A	240V 1Ph	4.7 hours	1.07 hours
19.2 kW	Work / Public	Level 2	80A	240V 1Ph	2.8 hours *	0.64 hours *
50 kW	Public	Fast DC	**	480V 3P	1.0 hours	14.8 minutes
150 kW	Public	Fast DC	**	480V 3P	21 minutes	4.9 minutes

* If onboard converter is 11.5 kW then the time will be 4.7 hours
** Varies as charger is rated 400-1000Vdc
*** Assumes EV efficiency of 3 miles / kWh

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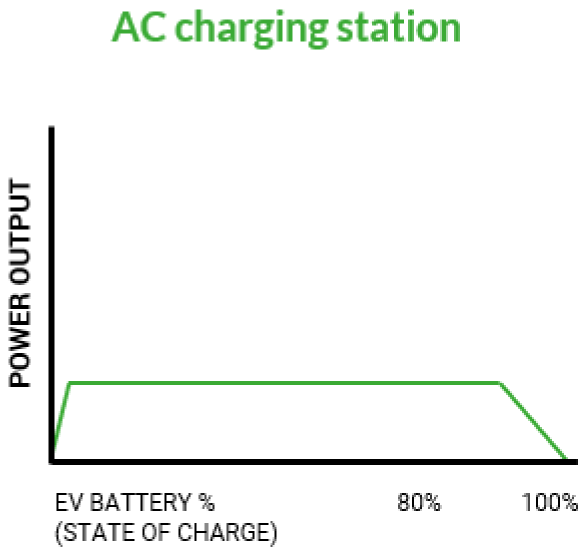
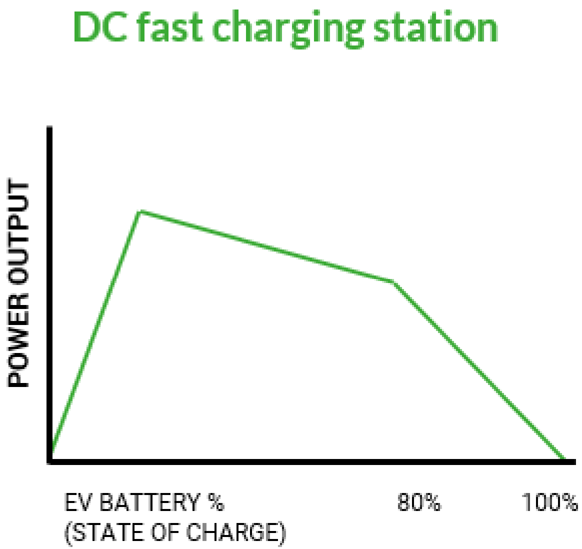
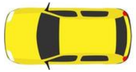
Why Is Charge Time Given as 20% to 80%?



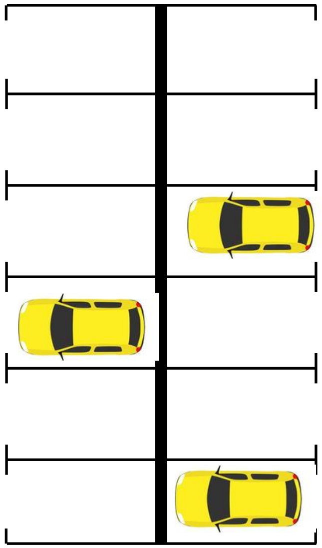


AC charging can use a ratio to determine charge time (kWh to charge / kW of charger) while DC charging does not use that same ratio

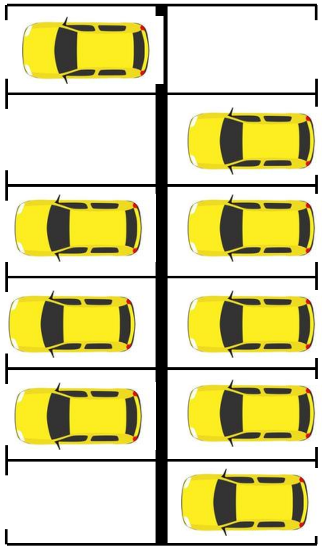
Why Is Charge Time Given as 20% to 80%?

Each car represents an electron (ion)  and each space represents a place for the ion to move to while charging.

Cathode (+)



Anode (-)

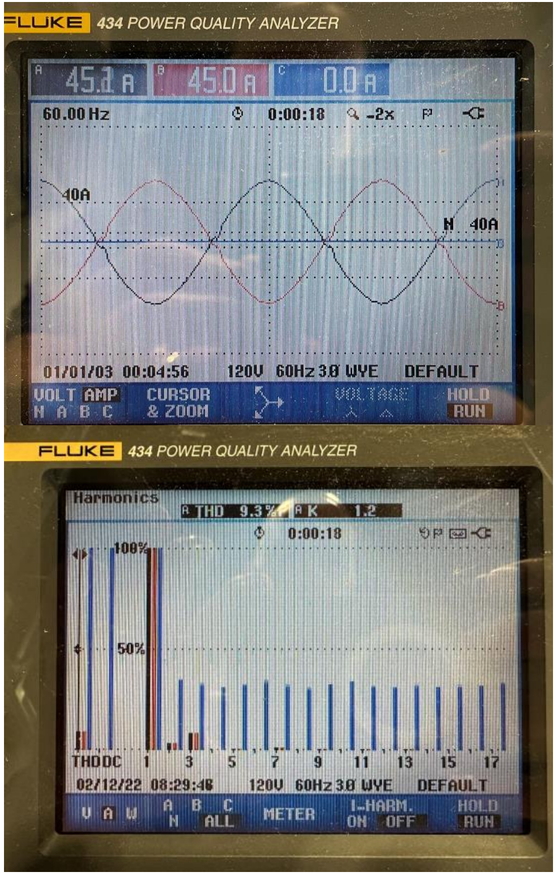


When the parking lot is empty, finding a parking space is easy. Charging an empty battery is fast due to the open places for the ion to attach.

When the parking lot is almost full, finding a parking space is much harder. Charging an almost full battery takes longer as the available spots for the ion to attach are reduced.

Harmonics

- AC chargers are pass through devices
- Vehicle on board charger (OBC) is governed by SAE J2894 (<10% THD)
- Typical passenger vehicles are between 3% and 5% THD (small sampling)
- DC fast chargers follow IEEE 519 as they product harmonics (like a VFD)
- Standard K1 transformers are acceptable, K4 is preferred
  - Oversized for heat generated by any harmonics
  - Electrostatic shield included on K rated
- On a balanced single-phase load, triple harmonics tend to cancel each other out



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Charger Selection: Why Open Charge Point Protocol (OCPP)

- Provides common and open communication protocol
- Offers consistency with how charging stations communicate with charging networks
- Allows for multiple EVSE vendors to work on multiple networks
- Reduces the risk of stranded assets and vendor lock-in
- OCPP version 1.6 is most common, OCPP 2.0 (future)

A Quick Look at Codes

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International Energy Conservation Code (IECC)

Not part of 2021 code release, will likely appear in later releases

Push to have local governments adopt EV infrastructure requirements based off IECC language

State by state adoption

Proposed language

Definitions

- EV-Installed = EV charger installed
- EV-Ready = conduit, wire, (outlet) and circuit for an EV charger
- EV-Capable = Infrastructure sized for the number of chargers

EV installation definitions multi-family (40A circuit)

- EV-Installed (5% of parking spaces)
- EV-Ready (10% of parking spaces, also addresses LEEDS)
- EV-Capable (20% of parking spaces)

Commercial buildings (40A circuit)

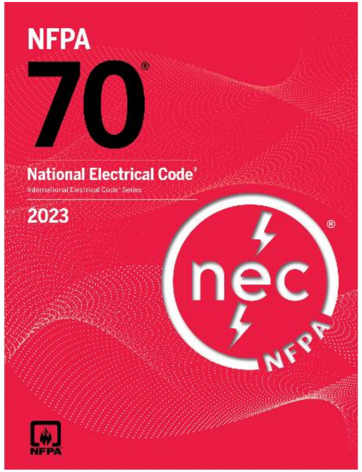
- EV-Ready (2 parking spaces)
- EV-Capable (20% of parking spaces)

Throttling using load management to 8A

NFPA 70 – National Electric Code (NEC)

- Article 625 – Electric Vehicle Power Transfer System

  - Covers the electrical conductors and equipment connecting an electric vehicle to premises wiring for the charging, power export, or bidirectional current flow. (2023 ed.)



NEC 625 – Some Key Points

- **625.17(C)** Charging cords can not be longer than 25 feet unless equipped with a cable management system.

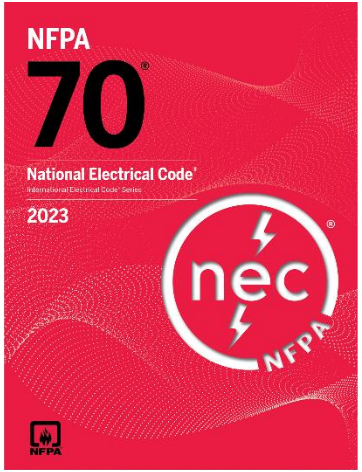
- **625.40** Each outlet for EV shall be dedicated with no other loads on that branch

- **625.42** EV chargers are considered continuous loads and the service and feeder must be sized in accordance with the ratings. An EMS can be used and then the service and feeder can be sized for the rating of the load management system.
    - 625.42 (A) EMS in accordance with 750.30 (load management)
    - 625.42 (B) an EVSE with adjustable settings

- **625.43** When rated more than 60A or 150V to ground a disconnect shall be provided in an easily accessible location and shall be lockable per 110.25.

- **625.48** Special markings apply when bi-directional

- **625.54** GFCI protection required for receptacles installed for the connection of an EV charger



Local Regulations

- Each state is adopting various aspects of the IECC, IBC, IRC, and NEC.
  - Always check the local requirements
- Certain states go beyond the international and national codes and adopt additional policies.
  - California Type Evaluation Program (CTEP)
  - California Air Resource Board (CARB)
  - California Public Utilities Commission – Submetering protocol & EVSE communication protocols
- Other specifications
  - EnergyStar
  - NIST Handbook 44
  - International Organization for Standardization (ISO)

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ADA Requirements

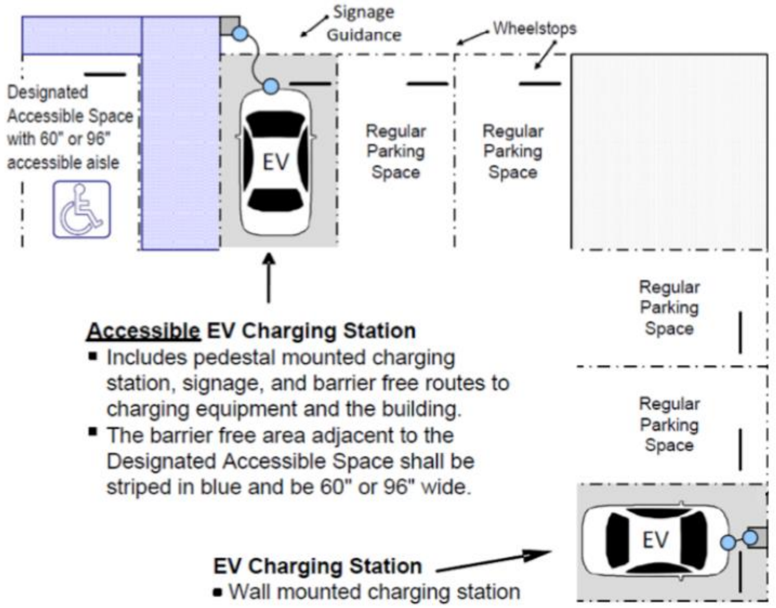
Applies to both workplace and public charging

4% of all spaces designated as assessable

Typically, first charger must adhere to ADA

Height, location, accessibility and other factors as to where the charger can be located

Federally purchased chargers may require voice assistance (section 508).



https://afdc.energy.gov/fuels/electricity_infrastructure_ada_compliance.html

UL listing standards for EVSE

- UL 2202 – Electric Vehicle Charging System Equipment (AC to DC)
- UL 2231-1 – Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements
- UL 2231-2 – Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems
- UL 2251 – Standard for Plugs, Receptacles, and Couplers for Electric Vehicles
- UL 2594 – Standard for Electric Vehicle Supply Equipment (AC to AC)
- UL 9741 – Standard for Bidirectional Electric Vehicle (EV) Charging Systems Equipment

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Dealing with Power Scarcity

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The Electrification Journey

Questions to ask early in the process to plan appropriately

(A) Why are you adding charging

- Corporate EGS goals
- Code or regulation mandates
- Tax or grant benefits
- Demographic change requiring EV charging
- Upgrading existing deployments

(B) What/when are you charging

- Type of vehicle or vehicles which will be charged
- What is the dwell time for the vehicle
- Are there restrictions on when the vehicles can be charged
- How many miles per day will be driven (2-5 m/kWh)
- How many (planned) vehicles will need to be charged
- What charge ports are needed (J1772, CCS, J3400/NACS)
- Are they electrifying all at once or in phases

(C) Let's talk power

- How much power is available (utility, transformer, site…)
- Is there energy usage data for the site if it is a brownfield
- What type of power is available (480, 208…)
- Do you need separate metering (utility programs)
- Does the customer have a single line diagram
- Physical barriers above & below ground

(D) Administration and operation

- Who is going to administer the policies
- Are access control or pricing policies required
- What type of service levels are needed for warranty
- Have they planned for signage and painting
- Are there ADA requirements which must be met
- What is the expected user experience
- Is this going to be in front or behind the gate

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Hierarchy of Dealing with Power Scarcity

Address power constraints in the most cost-effective way!

Various tools have been developed to take the right approach to Electrification. Utilizing some or all of these are necessary to meet expectations of the customer in a constrained environment. Commissioning a study is the first step!

Microgrids
Build resilience on top of your DER assets to operate autonomously from the grid and control your own destiny

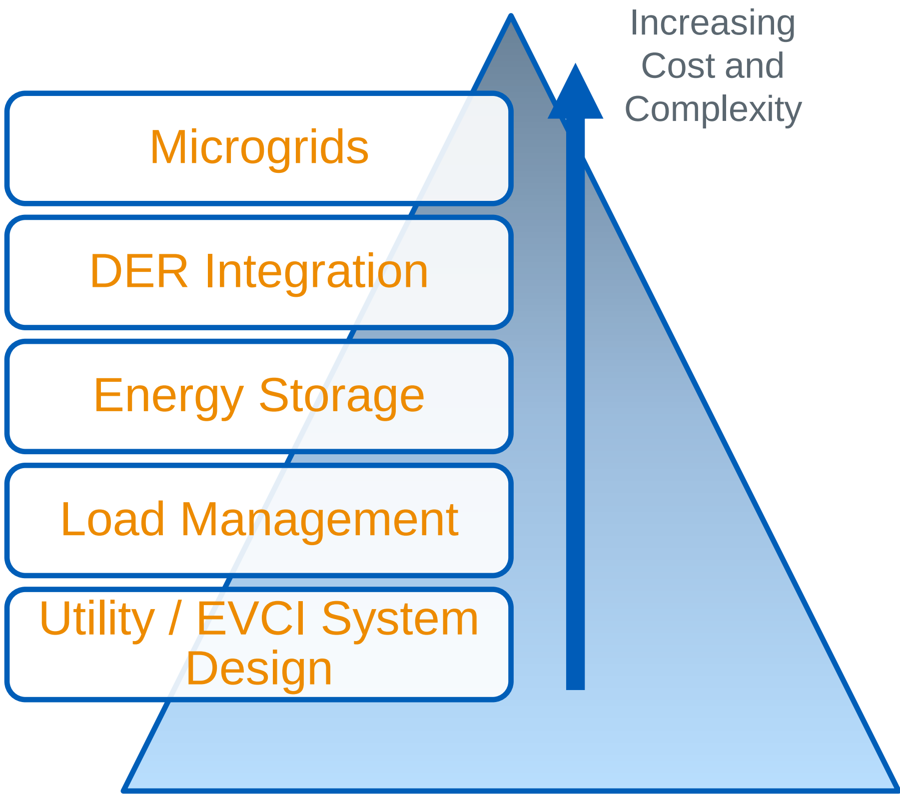
Distributed Energy Resource (DER) integration
Incorporate local solar photovoltaics and other generation assets into new or existing infrastructure to maximize charger deployment and help meet sustainability goals

Battery storage
Eaton xStorage Battery Energy Storage System (BESS) includes batteries, inverters and management software to shave peak demand cost for EV charging applications

EV Charge Network Management software
Enables designers to optimize infrastructure to avoid costly upgrades

Power distribution equipment and grid connection upgrades
Installation and upgrades of electrical equipment, including transformers, switchgear, switchboards, and panelboards

EV charging
Choosing the correct charger for the application:
AC Level 2 and DC level 3 fast chargers for residential, commercial, and fleet operations



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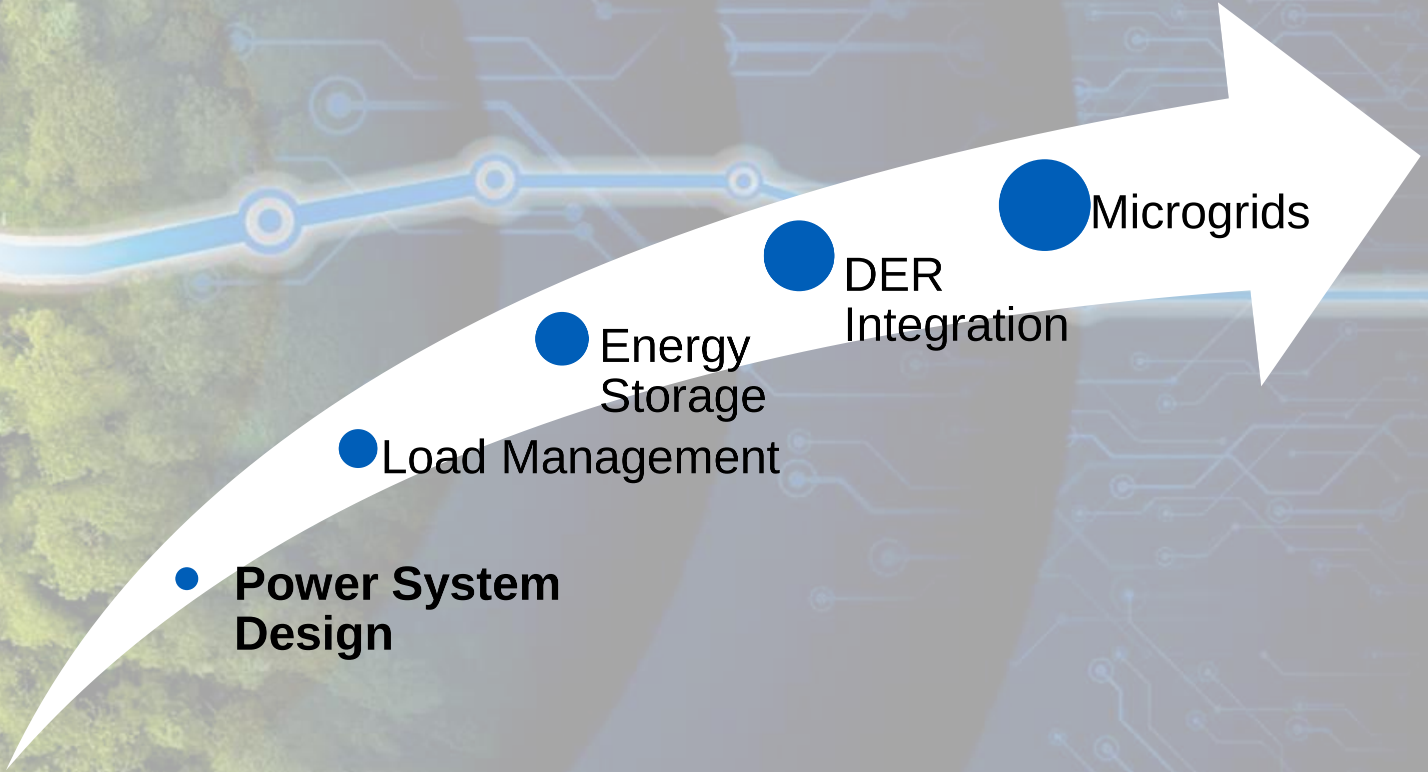
Dealing with Power Scarcity: Power System Design



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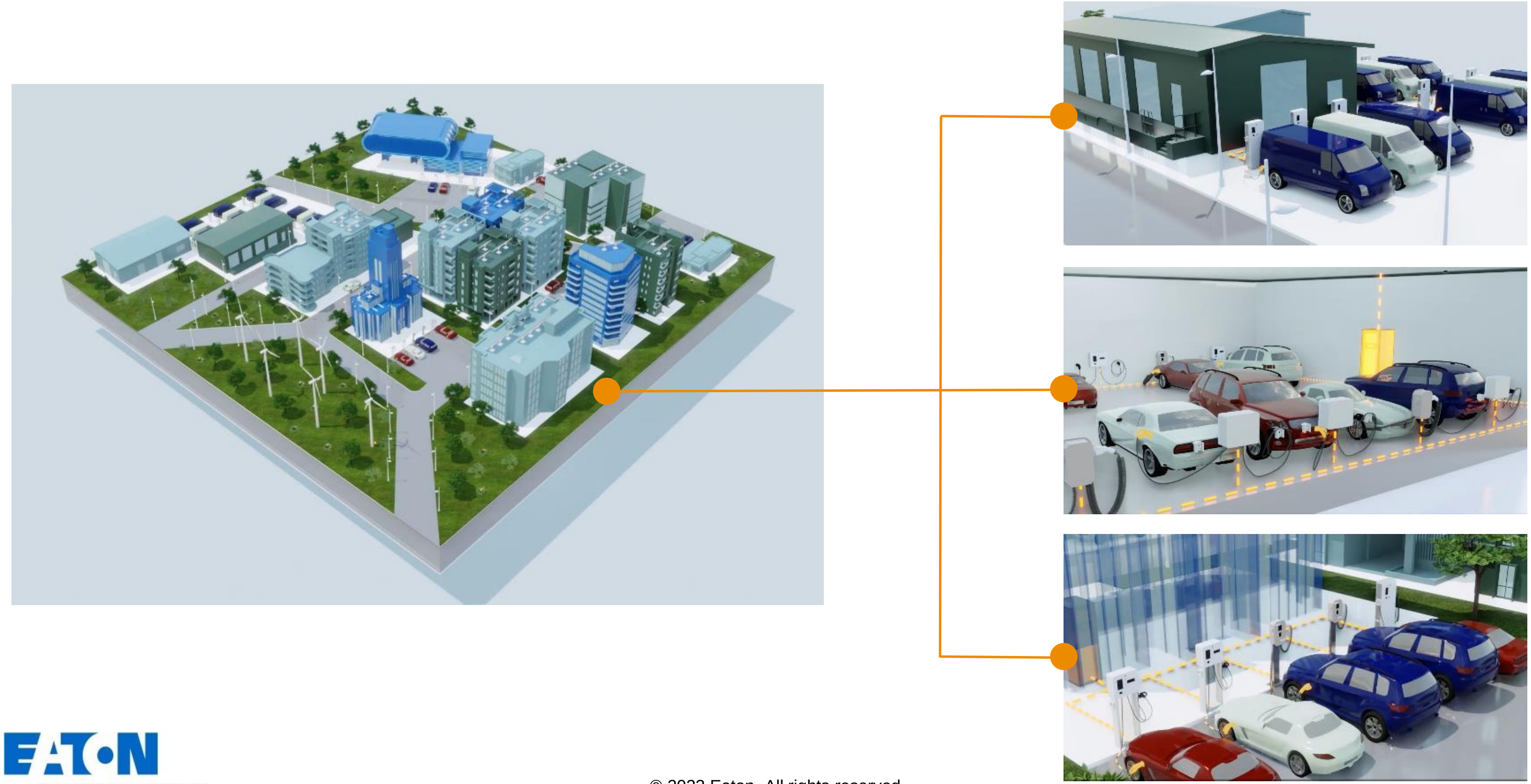
Well-designed power distribution equipment is essential to integrate multiple L2 and L3 chargers with renewable energy and battery storage



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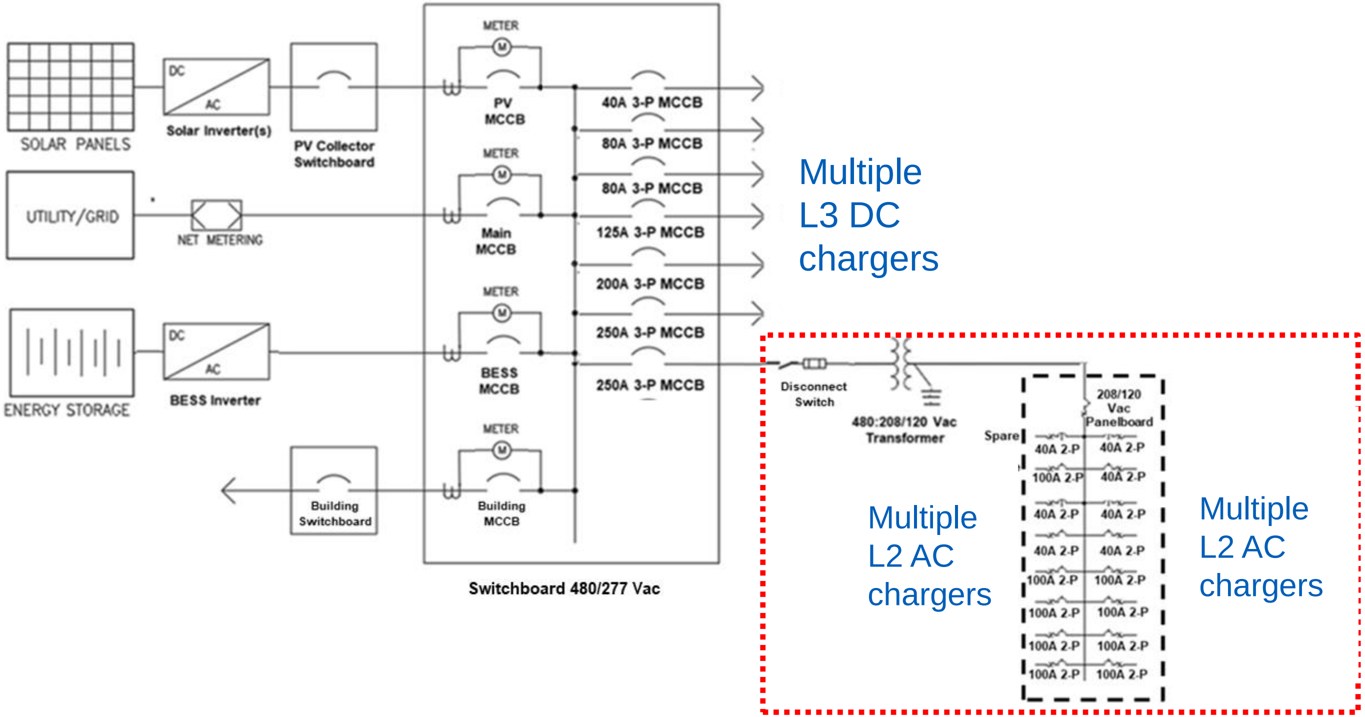

Today's electrical systems must be flexible to optimize bi-directional power flow, energy usage and efficiency

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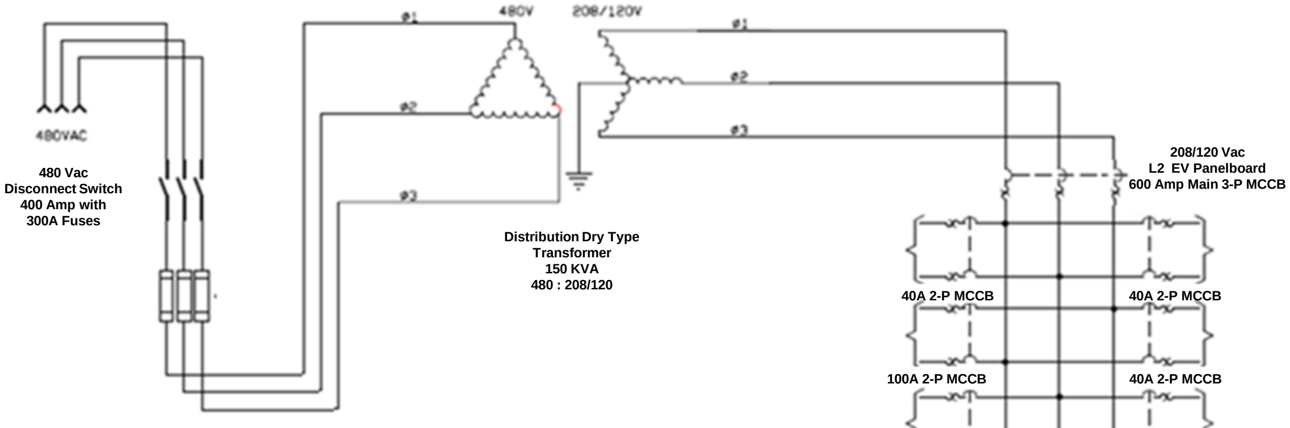
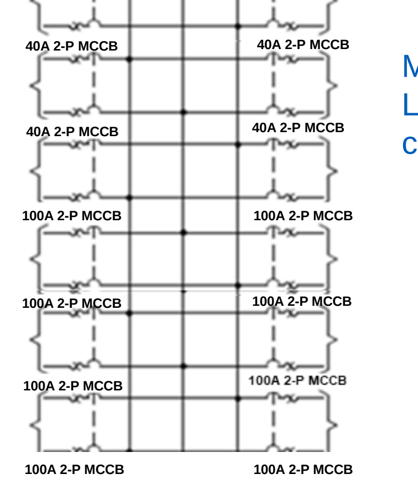
A closer look at AC L2 charging electrical infrastructure

A robust electrical infrastructure is required to support AC L2 charging





Multiple L2 AC chargers

Multiple L2 AC chargers

Disconnect switch

Dry type transformer

Panelboard

7.7 to 19.2 kW L2 AC EV chargers

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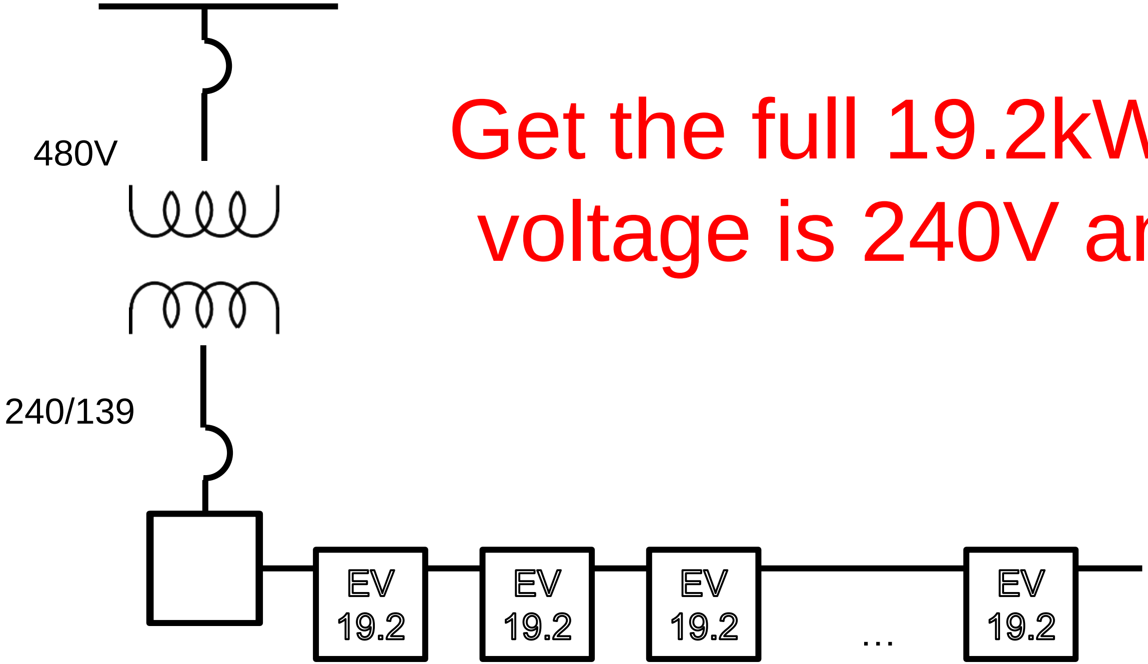
+15% Fleet



Get the full 19.2kW since service voltage is 240V and not 208V!!!

Dealing with Power Scarcity: Load Management

- Power System Design
- **Load Management**
- Energy Storage
- DER Integration
- Microgrids

Dealing with Power Scarcity: **Load Management**

- **625.42** EV chargers are considered continuous loads and the service and feeder must be sized in accordance with the ratings. ***An EMS can be used and then the service and feeder can be sized for the rating of the load management system***.
  - *625.42 (A) EMS in accordance with 750.30 (load management)*
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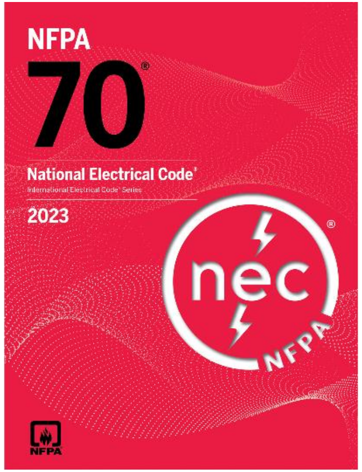

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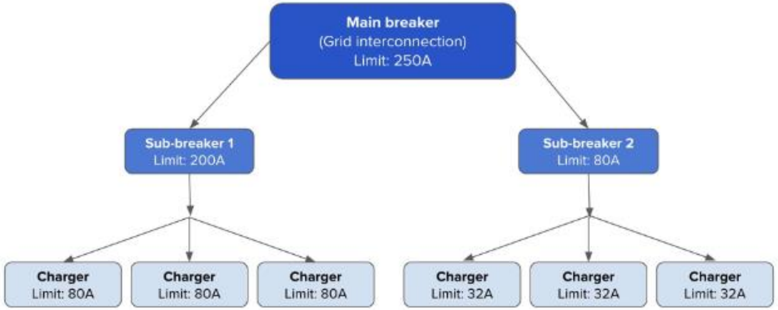
How It Works: Load Management – Network Connected

Scenario:

- Four 32A chargers sharing a breaker with a 100A rating
- 80A limit used for power management (80% maximum continuous load)



1) Four Charge Stations available and online

Charger A	Charger B	Charger C	Charger D
-	-	-	-

2) Two drivers plug in to Chargers A & B; each get full power

Charger A	Charger B	Charger C	Charger D
32A	32A	-	-

Load management control loads to:

- Branch circuits
- Subpanels
- Main panel
- Individual phases
- Unmanaged loads

3) A 3rd driver plugs into Charger C and all throttle to share power.

Charger A	Charger B	Charger C	Charger D
26A	26A	26A	-

4) A 4th driver plugs into Charger D and all throttle to share power.

Charger A	Charger B	Charger C	Charger D
20A	20A	20A	20A

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Load Management – Network Connection Lost

Scenario:

- Four 32A chargers sharing a breaker with a 100A rating
- 80A limit used for power management (80% maximum continuous load)

1) Four Charge Stations available and online

Charger A	Charger B	Charger C	Charger D
-	-	-	-

2) Two drivers plug in to Chargers A & B; each get full power

Charger A	Charger B	Charger C	Charger D
32A	32A	-	-

3) Charger A loses network connectivity. Power is reserved for A.

Charger A	Charger B	Charger C	Charger D
32A	32A	-	-

4) Two more drivers plug into Chargers C & D. Load shared subject to reserved amount for A

Charger A	Charger B	Charger C	Charger D
32A	16A	16A	16A

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How It Works: Load Management – Network Connection Restored

Scenario:

- Four 32A chargers sharing a breaker with a 100A rating
- 80A limit used for power management (80% maximum continuous load)

5a) Charger A reconnects and power is equally distributed.

Charger A	Charger B	Charger C	Charger D
20A	20A	20A	20A

5b) Charger A reconnects and charging on A is complete

Charger A	Charger B	Charger C	Charger D
-	26A	26A	26A

5c) Charger A reconnects and vehicle at A is charging at a lower rate. Charger A is maxed at lower output and remaining power is shared across other stations.

Charger A	Charger B	Charger C	Charger D
10A	23A	23A	23A

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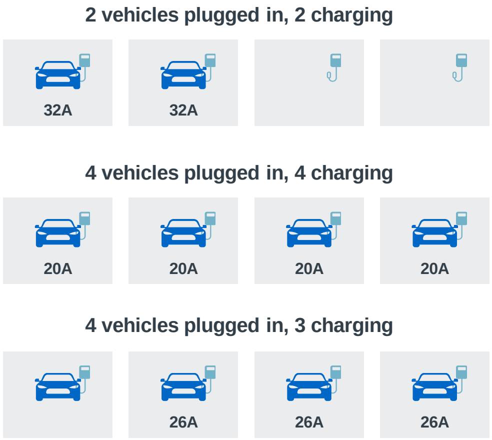
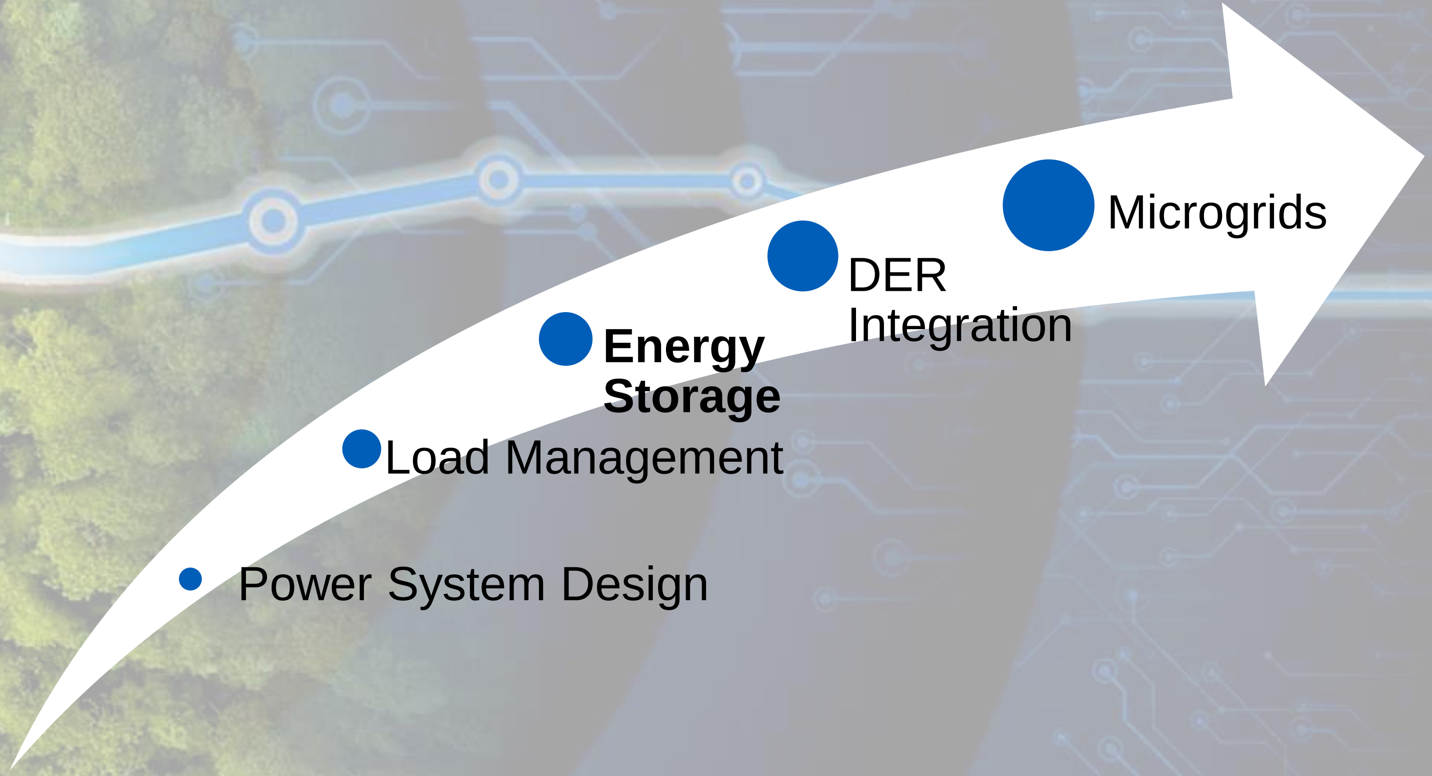
Cut CAPEX spend with power management

Power management is your built-in rebuttal for cost-sensitive customers. Our partners have reported saving up to **$400K** compared to the cost of infrastructure upgrades.

- Active load balancing adjusts output amperage based on the number of vehicles charging and the amount of power they're consuming.
- You can view power allocation and usage and directly in the dashboard.
- Get flexibility as you scale. Save now, and install up to **4X more chargers** on a limited electrical service. Our solution **is guaranteed** not to trip your breaker.



Dealing with Power Scarcity: **Energy Storage**



Battery Energy Storage System (BESS) is the most efficient and effective method to store and release energy into buildings or the grid

A Battery Energy Storage System (BESS) is a system that uses batteries to store electrical energy, which is then released back for self consumption or to the grid as needed

Components of a BESS

Battery System

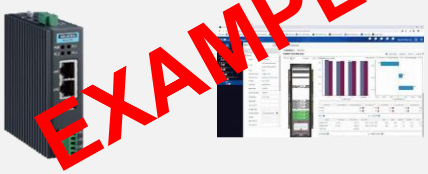
Store/discharge energy

Power Conversion System (PCS)

Power conversion

Controller and EMS software

Manages BESS and interaction with the broader electrical system (including the grid)



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BESS are used to address a variety of needs to supplement the grid during variation in electrical demand

- Utilities have **variations in power generation** based on their infrastructure as well as the use of **more alternative energy** (wind, solar)
- **Variation in the demand for power** continues to increase due to end user loads and **electrification** (machinery, DC charging, AI based chips, etc.)
- A **BESS can store, and supplement power** needs based on supply from utility and demand from end users thereby **keeping utility loads relatively even**
- A BESS can also serve other applications such as **backup power / generator alternatives, demand response and peak shaving** with built in power quality
- In comparison to other forms of energy storage, BESS have become more common because the cost of Lithium is dropping

Key applications and energy services of BESS

Cost Savings	Energy Resiliency	Grid Stabilization
Peak Shaving – avoiding demand charges by intelligent peak shaving capability ***Time-of-use optimization*** – shifting energy consumption to avoid peak energy usage and optimize economic battery charge and discharge times ***Demand response*** – utility company requests reduction in power usage	***Backup power*** – enables islanding capability to protect against utility outage ***Solar self-consumption*** – efficiently utilize on-site generation sources and store excess	**Aggregation services** – enables 3rd party management of BESS as an asset aggregated with other entities

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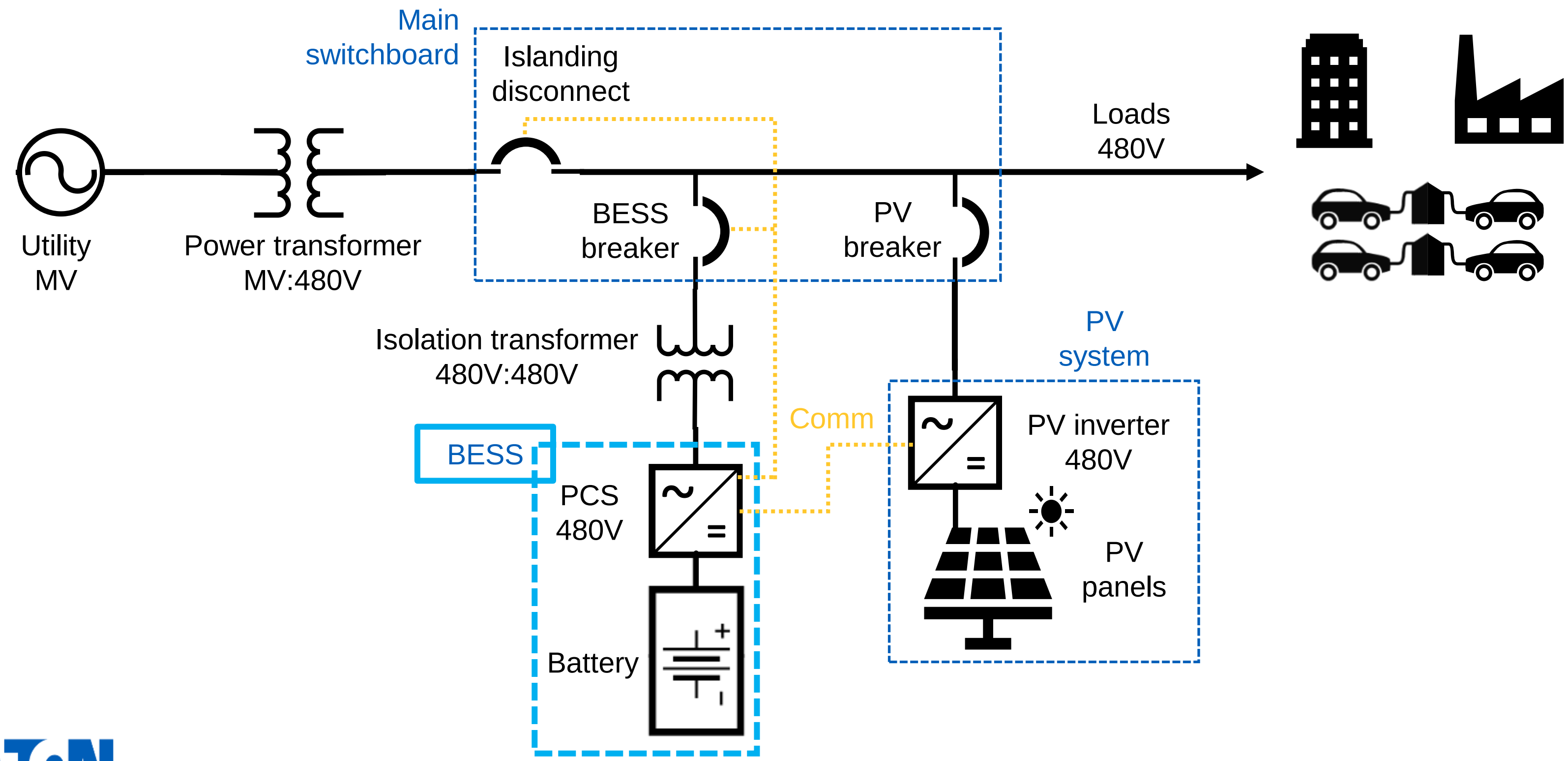
Simple One-Line



EVCI peak shaving

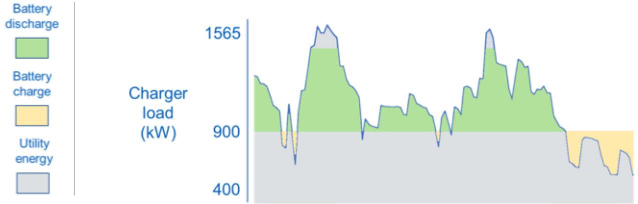
BESS reduces demand charges from utility

Low usage utility power draw
(8am – 4pm)

Increase utility power draw
(4pm – 6pm)

Utilize BESS to minimize utility draw
(Peak Shaving) --- (4pm – 6pm)

Normal draw
Peak
Storage



	No Storage	500kW 1-hr Storage	Savings
Demand charge (monthly)	$20,935	$6,599	$14,336

Payback

Investment:	**500kW/1hr BESS, $365K**
Installation cost:	**~$150K**
IRA rebate:	**30% minimum, ($154.5K)**
Total investment after rebate:	**$360,500**
Reduction in demand charges:	**$172,032/yr.** *($14.3K/month)*

Payback within 2 years

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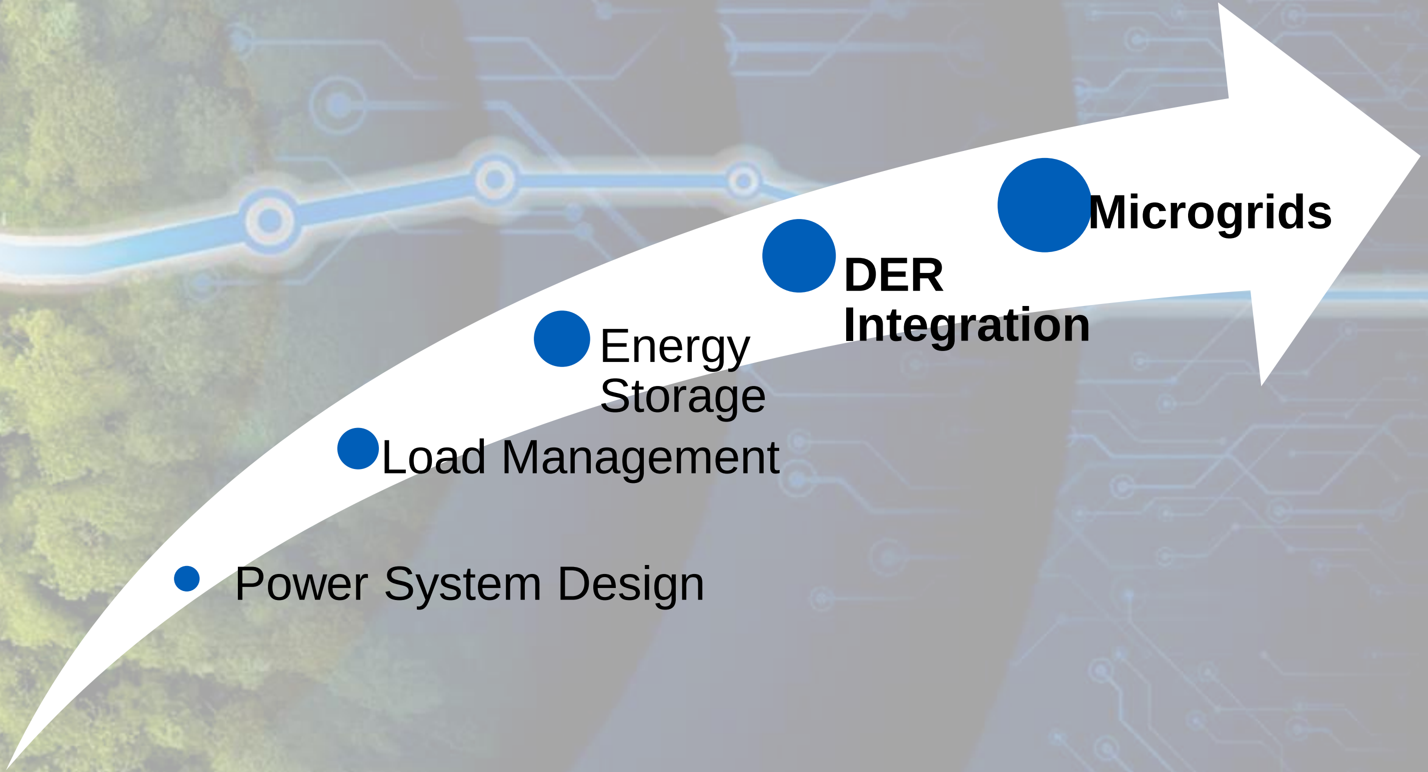
Dealing with Power Scarcity: DER & Microgrids



Microgrids are a grid within the grid

Distributed Energy Resources (DER) System

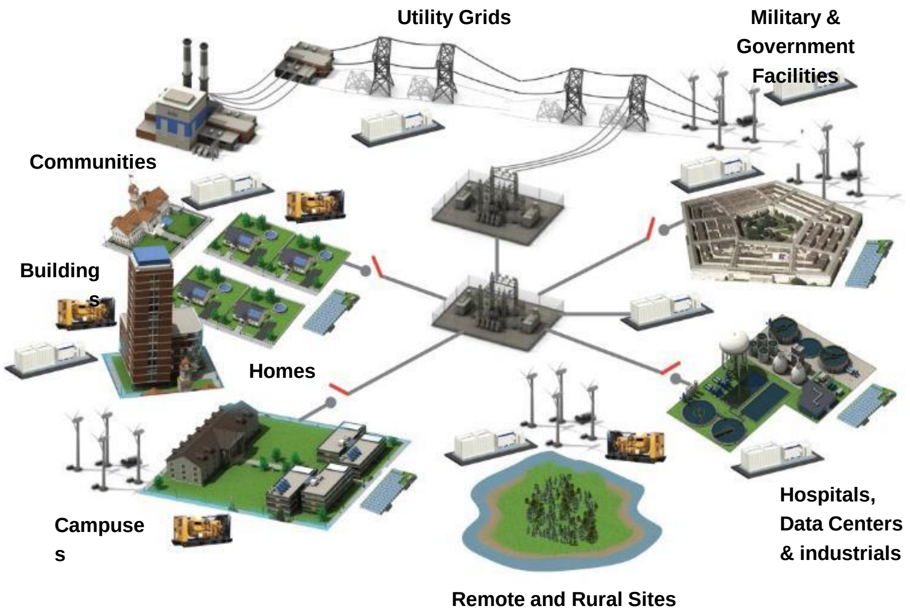
A defined boundary of interconnected electrical loads and decentralized generating assets controlled as an integrated system and operating in parallel with the grid

A **Microgrid** is a DER system than can operate autonomously or “islanded” from the grid for maximum system resiliency

Common system elements

- **Controllable loads**
  Machinery, equipment, EVs, computing, lighting, HVAC, etc.
- **Distributed Energy Resources**
  Solar, energy storage, generators, combined heat & power (CHP)
- **Intelligent Controls**
  Hardware (DER controllers) and software (control algorithms)

DER systems can be | **Community • Campus • Building • Home**



Achieving a more resilient energy infrastructure with microgrids requires an intelligent approach to balancing business goals

Value Propositions of a microgrid system

Sustainability: minimize carbon emissions
- Generate more power from renewable sources
- Reduce greenhouse gas emissions
- Sell clean power back to the grid

Resilience: support for critical operations
- Bolster operations to ensure business continuity
- Operate off-grid in "island" mode
- Protect people, assets and data

Efficiency: reduce energy costs
- Optimize energy consumption to reduce operating costs
- Avoid peak demand charges
- Energy as a Service financing through a partner who owns and operates the microgrid makes it an OpEx vs. CapEx investment

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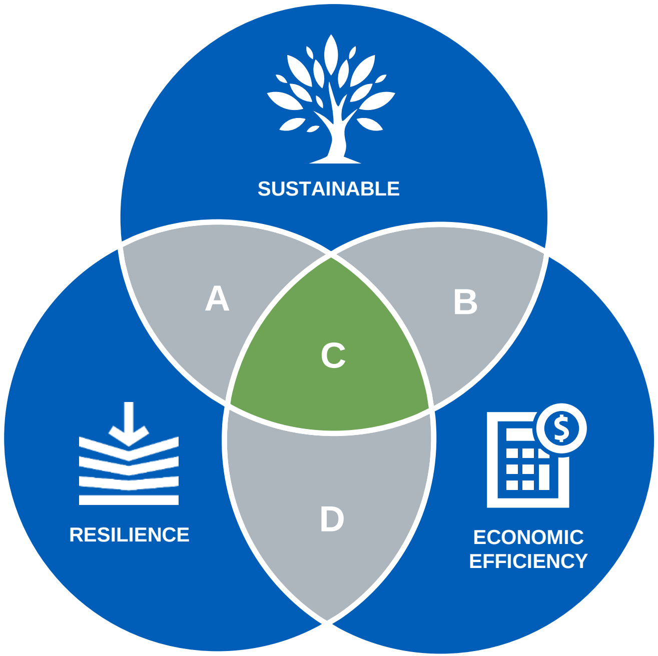
Three primary value propositions of a microgrid often with fundamental trade-offs underlying them



It is often easy to get 2 of 3 but getting 3 of 3 is a challenge:

- **A** **Resilient + Sustainable** but more expensive *microgrid in an area with low cost of power*
- **B** **Sustainable + Economic Efficiency** but lacks resilience *simple storage or PV+storage project - no back up power*
- **C** Achieve trifecta of **Sustainable + Resilient + Efficiency** *microgrid with attractive incentives & DER monetization programs*
- **D** **Economic Efficiency + Resilient** without sustainability benefits *traditional back up diesel generator or co-generation*

Clean energy microgrids aim to address all three benefits of **sustainability, resilience and economic efficiency**

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Basic microgrid functionality

Microgrids are a local grid within the grid delivering power reliability and resilience to the site: **grid-connected**

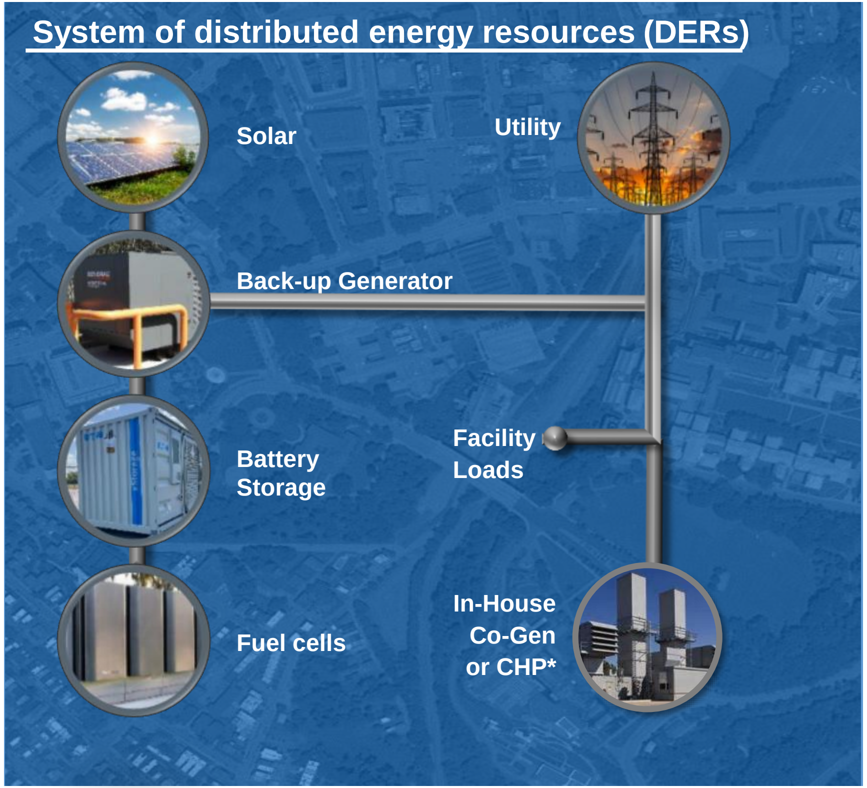
Distributed energy resources (DERs) can be:

- On-site renewables - solar or wind
- Battery energy storage
- Fuel cells
- Backup generators
- Combined Heat and Power (CHP)

Core microgrid applications

- Islanding from the grid & synchronization
- Black start
- Peak shaving
- Generation / Load balance control
- Ancillary services like frequency regulation

Microgrids require an intelligent controller as the "brains" to optimize system performance



* CHP = combined heat and power

Microgrids are a local grid within the grid delivering power reliability and resilience to the site: **islanded microgrid, off-grid**

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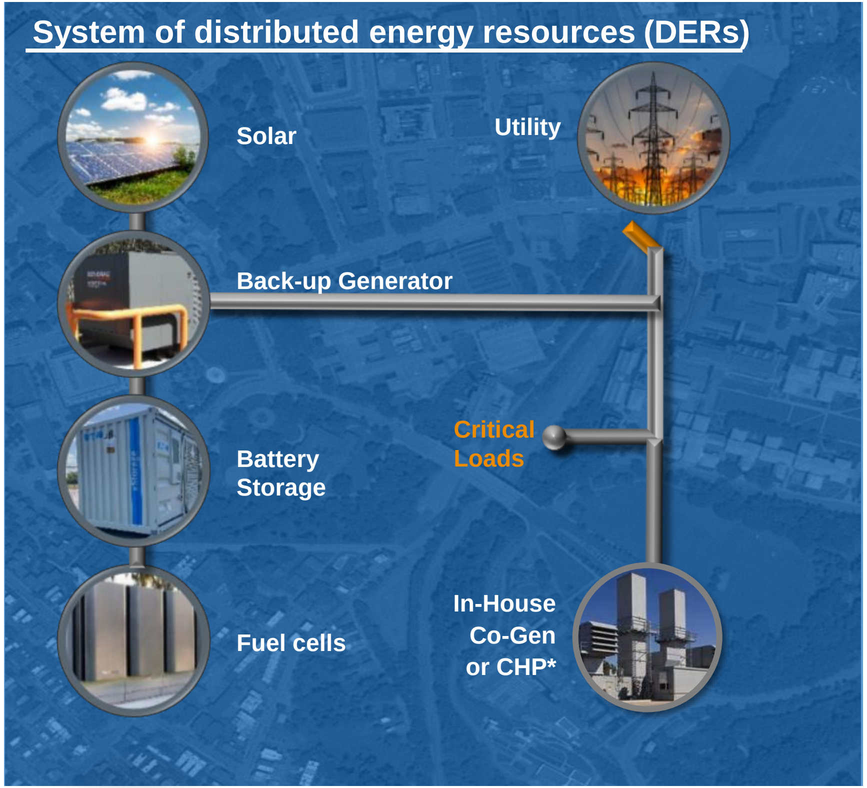

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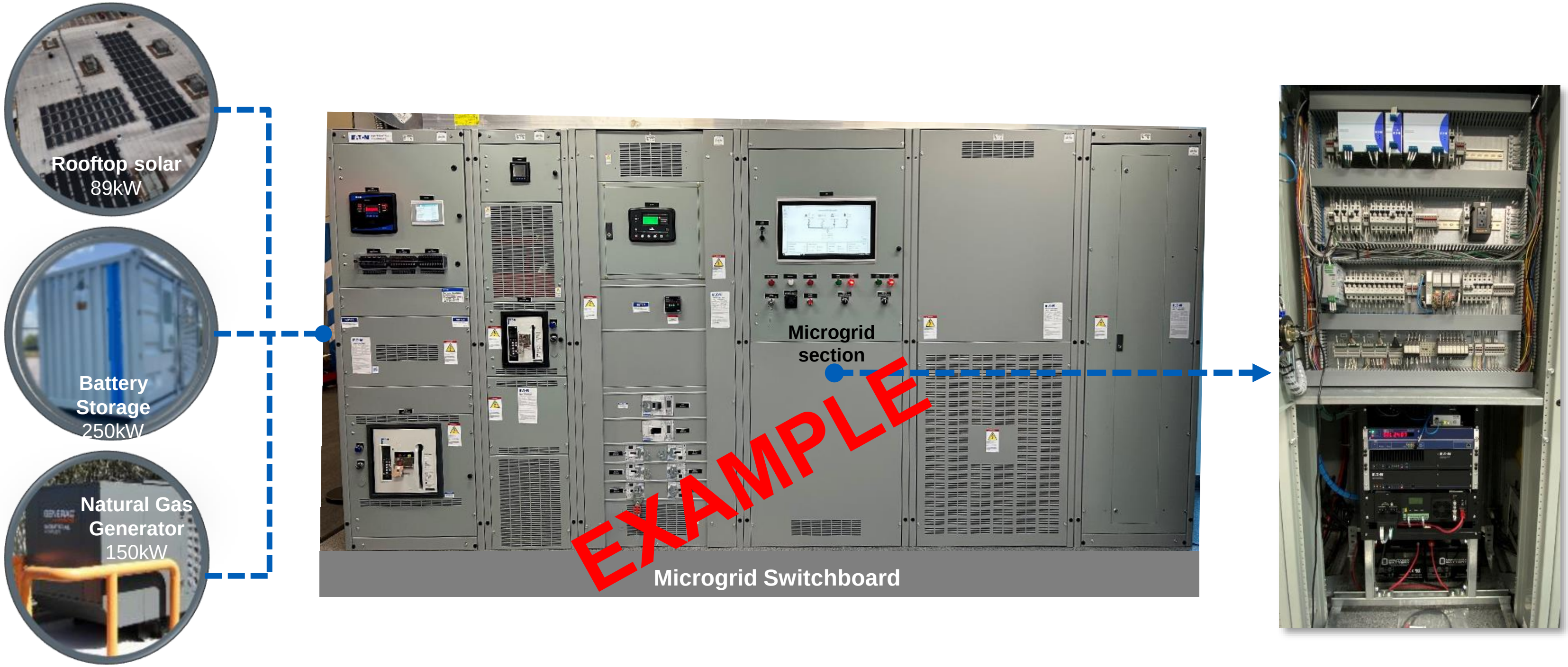
Microgrid Components



Microgrid section components

- Control power
- Digital I/O
- Microgrid / DER controllers
- GPS clock
- Network switch
- Industrial PC
- UPS
- HMI screen

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